



GOVERNMENT OF INDIA
GEOLOGICAL SURVEY OF INDIA

कर्नाटक राज्य के बेलगावी और गोवा राज्य के उत्तर गोवा और दक्षिण गोवा जिले में
भूआकृति संख्या 48I/01, 48I/02 AND 48I/03 के कुछ हिस्सों में वृहद पैमाने पर (१:
५०,०००) भूस्खलन संवेदनशीलता का मानचित्रण

(कार्य सत्र कोड संख्या: एम4एलएसएसएम/एनसी/एसआर/एसयू-केजी/२०१९/२५१७७)

(कार्यसत्र: २०१९-२०)

REPORT ON MACRO-SCALE (1: 50,000) LANDSLIDE SUSCEPTIBILITY
MAPPING IN PARTS OF TOPOSHEET NO. 48I/01, 48I/02 AND 48I/03, BELAGAVI
DISTRICT, KARNATAKA AND NORTH GOA AND SOUTH GOA DISTRICTS,
GOA

(FSP Code No: FSP CODE NO: M4LSSM/NC/SR/SU-KG/2019/27977)

FIELD SEASON: 2019-20

By

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प्रतिलिपित नहीं किया जाना चाहिए

**MACRO-SCALE (1: 50,000) LANDSLIDE SUSCEPTIBILITY MAPPING IN PARTS
OF TOPOSHEET NO. 48I/01, 48I/02 AND 48I/03, BELAGAVI DISTRICT,
KARNATAKA AND NORTH GOA AND SOUTH GOA DISTRICTS, GOA.**

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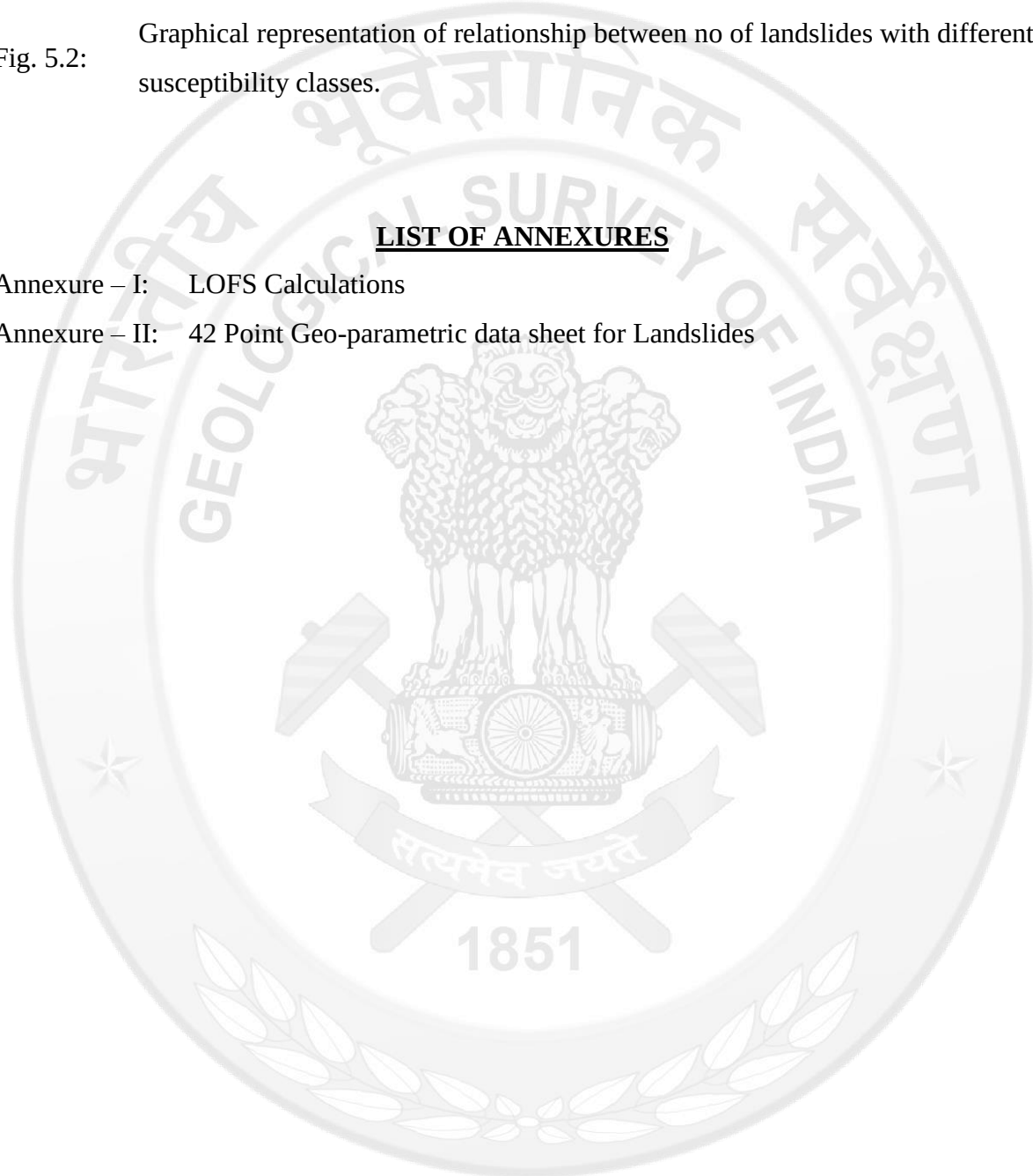
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गोवा राज्य के दक्षिण गोवा और उत्तर गोवा और कर्नाटक राज्य के बेलगाओं जिले में
स्थलाकृतिक मानचित्र संख्या ४८ आई / ०१, ४८ आई / ०२ और ४८ आई / ०३ के आंशिक
हिस्सों में वृहद पैमाने पर (१: ५०, ०००) भूस्खलन संवेदनशीलता का मानचित्रण
(मद कोड सं: एम ४ एल एस एस एम/ एन सी/ एस आर/रा.ई – क. एवं गो./२०१९/२७९७७)
(कार्य सत्र: २०१९-२०२०)

द्वारा

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भारतीय भूवैज्ञानिक सर्वेक्षण के दक्षिण क्षेत्र के कोड सं: एम ४ एल एस एस एम/ एन सी/एस आर/ राई –क. एवं गो./२०१९/२७९७७ वार्षिक कार्यक्रम २०१९-२०२० के अन्तर्गत स्थलाकृतिक मानचित्र संख्या ४८ आई / ०१, ४८ आई / ०२ और ४८ आई / ०३ के गोवा राज्य के दक्षिण गोवा और उत्तर गोवा जिले और कर्नाटक राज्य के बेलगाओं जिले के राष्ट्रीय भूस्खलन संवेदनशीलता मानचित्रण (एनएलएसएम) का कुल १३११ वर्ग किलोमीटर क्षेत्र निष्पादित किया गया राष्ट्रीय भूस्खलन संवेदनशीलता मानचित्रण (एनएलएसएम) एक बहुत महत्वाकांक्षी और साथ ही महत्वपूर्ण योजना है जो भारतीय भूवैज्ञानिक सर्वेक्षण द्वारा २०१४ में संपूर्ण भारत में इस उद्देश्य के साथ प्रारम्भ किया गयी है ; (i)- उच्च समाधानी सुदूर संवेदी आँकड़े और क्षेत्र आगत का उपयोग करते हुए भूस्खलन की विस्तृत सूची का आंकड़ाकोष (ii)- स्थानिक आंकड़े और भू-कारणों को आगत मानचित्र के तौर पर इस्तेमाल करते हुए भूस्थल मानचित्र के आधार पर १:५०,००० पैमाने पर और (iii)- बहु-वर्गीय सूची का उपयोग करते हुए अधोचित्र प्रणाली के जीआईएस स्तर पर भूस्खलन संवेदनशीलता मानचित्रण ।

भौगोलिक दृष्टि से यह क्षेत्र पहाड़ी क्षेत्रों और समतल भूभाग दोनों द्वारा मिश्रित मिश्रित स्थलाकृति को दर्शाता है। यह क्षेत्र पश्चिमी घाट का हिस्सा है, जिसमें घने जंगल से आच्छादित और खड़ी घाटियों की शृंखला है। ऊँचाई का उच्चतम बिंदु कंकुम्बी के पास समुद्र तल से ८३६ मीटर ऊपर है। यह क्षेत्र में लगभग ३५०० मिमी की वार्षिक वर्षा होती है, जो ज्यादातर दक्षिण-पश्चिम मानसून से होती है और कई पश्चिम बहने वाली नदियों से निकलती है। क्षेत्र का जल निकासी पैटर्न प्रकृति उप-ट्रेलिस पैटर्न के उप रेडियल के समान प्रदर्शित करता है।

भूवैज्ञानिक रूप से इस क्षेत्र में प्रायद्वीपीय प्रायद्वीपीय नाइसिक जटिल (पीजीसी) (गोवा), गोवा समूह, धारवाड़ सुपरग्रुप के चित्रदुर्गा समूह के बराबर, मेटा-ज्वालामुखी और मेटा-सेडिमेंट असेंबलिंग (आर्कियन से लोअर प्रोटेरोज़ोइक), माफ़िक अल्ट्रा मैफ़िक जटिल और अंतर्वेधन के दाने शामिल हैं। प्रोटेरोज़ोइक), डेक्कन ट्रैप (अपर क्रीटेशस टू इओसीन), लेटराइट (सेनोज़ोइक) और सगरियो बालू पाया जाता है।

एसओपी के अनुसार, एनएलएसएम कार्यक्रम को तीन अलग-अलग हिस्सों में विभाजित किया जा सकता है, जैसे। (i) पूर्व-क्षेत्रीय अध्ययन, (ii) फील्ड सत्यापन और (iii) पोस्ट फील्ड अध्ययन। पूर्व-क्षेत्रीय अध्ययन के दौरान, पूर्व-क्षेत्र विषयगत मानचित्र गूगल अर्थ छवियों और डीईएम डेटा से तैयार किए जा रहे हैं। फील्ड सत्यापन चरण में क्षेत्र के सभी सुलभ स्थानों पर पूर्व फील्ड मानचित्रों का सत्यापन शामिल है। पोस्ट-फील्ड स्टडीज के दौरान, फील्ड इनपुट के अनुसार पूर्व फील्ड मानचित्र अद्यत किए जाते हैं।

पूर्व-फील्ड विषय गत मानचित्र जैसे कि भू-आकृति मानचित्र, भूमि उपयोग व भूमिआवरणमानचित्र, रेगोलिथ मोटाई मानचित्र, ढलान मोर्फोमेट्रीमानचित्र (ढलान कोण, ढलान वक्रता और ढलान पहलू), अपवाहमानचित्र और भूस्खलन वस्तुसूची मानचित्र गूगल अर्थ मेंडिजिटाइज करकेऔर डीईएम डेटा में कुछ स्थानिक विश्लेषक प्रक्रिया का उपयोग करके तैयार किये गए थे। नियमित अंतराल पर पूर्व-फील्ड विषयगत मानचित्र जैसे कि भूमि उपयोग भूमि आवरण, भू-आकृति,शैल लक्षण,संरचना, उपरिभार प्रकार, रेगोलिथ मोटाई की जांच/ सत्यापन और अद्यतन करने के लिए फील्ड कार्य किया गया था। इसके अतिरिक्त फील्ड कार्य के दौरान दार्जित भूस्खलन के लिए ४२ बिंदु भू-मापदंडों को दर्ज करके अद्यतन भूस्खलन सूची डेटाबेस बनाया गया। अध्ययन क्षेत्र के अंतिम भूस्खलन सूची मानचित्र में कुल 25 भूस्खलन शामिल है।भूस्खलन के भू-वैज्ञानिक कारण सड़क निर्माण के लिए ढलान संशोधन (यानी ढलान काटना) (व्यापक ढलान कटौती) थे, इसलिए सड़कों के आसपास के क्षेत्र में पाए गए।

क्षेत्र सत्यापन पूरा होने के बाद, सभी विषयगत नक्शे और भूस्खलन सूची को क्षेत्र के इनपुट के अनुसार अद्यतन किया गया था। विषयगत मानचित्रों और भूस्खलन सूची के अद्यतन के बाद, भारित मल्टी क्लास इंडेक्स ओवरले पद्धति का उपयोग करके एक गुणात्मक भूस्खलन संवेदनशीलता मानचित्र तैयार किया गया था। अंतिम भूस्खलन संवेदनशीलता मानचित्र के अनुसार,, क्षेत्र का लगभग ६२% कम संवेदनशीलता वर्ग के अंतर्गत आता है, ३३% क्षेत्र मध्यम संवेदनशीलता वर्ग के अंतर्गत आता है, जबकि केवल ५% क्षेत्र उच्च संवेदनशीलता वर्ग के अंतर्गत आता है। अध्ययन क्षेत्र के लगभग सभी प्रमुख इलाके जैसे पोंडा, दरबंदोरा, मोलम, कोल्लम, कुडसीम, शिरोडा, उसगांव, संक्लीम, होंडा, केरी, कंकुम्बी कम अतिसंवेदनशील वर्ग में आते हैं। वालपॉय, चोरला, सुर्ला जैसे इलाके मध्यम संवेदनशीलता वर्ग के अंतर्गत आते हैं। क्षेत्र का कोई भी बड़ा क्षेत्र उच्च संवेदनशीलता वर्ग के अंतर्गत नहीं आता है।

MACRO-SCALE (1: 50,000) LANDSLIDE SUSCEPTIBILITY MAPPING IN PARTS OF TOPOSHEET NO. 48I/01, 48I/02 AND 48I/03, BELAGAVI DISTRICT, KARNATAKA AND NORTH GOA AND SOUTH GOA DISTRICTS, GOA.

FSP CODE NO: M4LSSM/NC/SR/SU-KG/2019/27977

FIELD SEASON: 2019 - 20

By

Sunandan Basu, Geologist

Amar Jyoti Hatiboruah, Geologist

ABSTRACT

Macro scale (1:50,000) landslide susceptibility mapping in parts of Survey of India toposheet no. 48I/01, 48I/02 and 48I/03, covering parts of Belagavi district of Karnataka and North Goa and South Goa districts of Goa for an area of 1311 sq. km, was carried out under the Annual Programme of Geological Survey of India, Southern Region, vide FSP code no: M4LSSM/NC/SR/SU-KG/2019/27977 for the field season 2019 – 20.

The study area covers three Survey of India toposheets, viz. 48I/01, 48I/02 and 48I/03. The National Landslide Susceptibility Mapping (NLSM) programme of Geological Survey of India (GSI) was launched with the following objectives:

- (i) To prepare landslide inventory database using high resolution remote sensing data and field inputs.
- (ii) To prepare toposheets wise 1:50,000 scale spatial database for geo-factors of landslides for use as input maps.
- (iii) To prepare landslide susceptibility map using multi-class index overlay method in a GIS platform.

Physiographically the area shows mixed topography represented by both hilly areas and flat terrain. The area is part of Western Ghats forming series of ridges and steep valleys covered with dense forest. The highest point of elevation is at 836 m above mean sea level near Kankumbi. The state receives an annual rainfall of about 3500 mm, mostly from southwest monsoon and is drained by several west flowing rivers. The drainage pattern exhibits dendritic to sub radial to sub trellis pattern.

Geologically the area comprises rocks belongs to Peninsular Gneissic Complex (PGC) (Archaean), Goa Group, equivalent to Chitradurga Group of Dharwar Supergroup, meta-

volcanics and meta-sedimentary assemblages (Archaean to Lower Proterozoic), mafic ultramafic complexes and intrusive granites (Lower Proterozoic), Deccan traps (Upper Cretaceous to Eocene), laterite (Cenozoic) and beach sands.

National Landslide Susceptibility Mapping (NLSM) includes three components; such as pre-field mapping, field validation and post field updation & landslide susceptibility modelling.

During pre-field mapping, a total of eight factor maps, viz., Slope Morphometry (Slope Angle, Slope Aspect, Slope Curvature), Drainage, Geomorphology, Land use – Land cover, Slope Forming Material and Regolith Thickness were prepared.

During the field validation period, all the pre-field maps were validated in the field by visiting all assessable locations. The pre-field landslide inventory was checked and validated. The final landslide inventory map of the study area contains total 25 landslides. Geoscientific cause of the landslides were slope modification i.e. toe cutting of the slope (extensive slope cut) for road construction hence found in the vicinity of roads.

After the field validations were complete, all the thematic maps and landslide inventory were updated as per the field inputs. Subsequent to the updation of the thematic maps and landslide inventory, a qualitative landslide susceptibility map was prepared by using the weighted multi class index overlay method. In the final landslide susceptibility map, about 62% of the area falls under low susceptibility class, 33% area falls under moderate susceptibility class, whereas only 5% area falls under high susceptibility class. Almost all the major localities of the study area like Ponda, Darbandora, Molen, Kolem, Kudchedem, Shiroda, Usgaon, Sanquelim, Honda, Keri, Kankumbi come under low susceptibility class. Localities like Valpoy, Chorla, Surla come under moderate susceptibility class. No major locality of the area falls in high susceptibility class.

**MACRO-SCALE (1: 50,000) LANDSLIDE SUSCEPTIBILITY MAPPING IN PARTS
OF TOPOSHEET NO. 48I/01, 48I/02 AND 48I/03, BELAGAVI DISTRICT,
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FSP CODE NO: M4LSSM/NC/SR/SU-KG/2019/27977

FIELD SEASON: 2019 - 20

By

Sunandan Basu, Geologist

Amar Jyoti Hatiboruah, Geologist

CHAPTER – 1

INTRODUCTION

1.1 Background Information:

Geological Survey of India (GSI) has been carrying out landslide susceptibility zonation / mapping on macro scale (1:50,000 / 25,000) since last three to four decades. The available landslide-prone areas in India are ~0.42 million sq. km spreading over 1112 toposheets of Survey of India on 1:50000 scale, excluding the permafrost regions. This warrants GSI, being the nodal agency for landslide studies in India, to impart maximum stress towards completion of this basic data generation work on landslides. This matter was deliberated in detail at the Regional Workshop on Landslide Disaster Management at Shillong on 22 – 23 November, 2013 and the Joint Secretary, Ministry of Mines has also advised GSI to revamp and fasten its endeavour of the important task for completing the remaining targets of landslide susceptibility mapping / zonation as early as possible.

Accordingly, since FS 2014 – 15, GSI commenced a national programme on landslide susceptibility mapping: Macro scale (1:50,000) National Landslide Susceptibility Mapping (NLSM) with an aim to cover the targets expeditiously.

Landslides are one of the common natural as well as man-made hazards in India. Out of the 0.42 million sq. km (12.6% of land area) landslide prone areas of the country, 0.034 million sq. km falls in parts of Karnataka & Goa state. Mostly the western parts of Karnataka and Goa districts are vulnerable to landslides.

The National Landslide Susceptibility Mapping (NLSM) programme of Geological Survey of India (GSI) was launched with the following objectives:

- (iv) To prepare landslide inventory database using high resolution remote sensing data and field inputs.
- (v) To prepare toposheets wise 1:50,000 scale spatial database for geo-factors of landslides for use as input maps.
- (vi) To prepare landslide susceptibility map using multi-class index overlay method in a GIS platform.

1.2 Study Area:

Goa is a coastal state with a coast line of 101 km situated in south-western part of the country and is bounded by Karnataka in the southern and eastern sides, whereas, it is bounded by Maharashtra in the northern and north-eastern sides. Karnataka is a state situated in the south western part of India. Karnataka is bounded by Goa in the north-western, Maharashtra in the northern, Telengana in the north-eastern, Andhra Pradesh in the eastern, Tamil Nadu in south-eastern, Kerala in south and south-western and Arabian Sea and Laccadive Sea in the western side. The area under study covers parts of North Goa and South Goa districts of Goa state and Belagavi district of Karnataka, hence the entire area comes under the administrative jurisdiction of South Goa and North Goa districts, Goa and Belagavi district of Karnataka. The study area falls in three Survey of India toposheets i.e. 48I/01, 48I/02 and 48I/03. The study area is bounded by latitude 15°15'00" N to 15°47'20.185" N and longitude 74°00'00" E to 74°15'00" E (refer: Fig. 1.1). The major localities of the study area are Ponda, Molen, Kolem, Usgaon, Honda, Sanquelim, Valpoy, Keri, Kankumbi etc. The area can be accessed by road, rail, sea and air. The majority of the area has good network of roads except the north and north- eastern part which is mostly covered by wildlife sanctuary and reserved forest. The road network comprises National Highways, State Highways and all weathered metal roads. National Highway – 4 (Sanquelim – Kankumbi stretch), National Highway – 4A (Ponda – Anmod stretch), State Highway – 4, State Highway – 8, State Highway – 18 to Ponda and Ponda bypass road. Londa – Vasco Da Gama railway line of South Central Railway passes through the area and nearest major railway station is Madgaon, a major railway terminal of South Western Railway. Nearest international airport is Dabolim airport, Vasco Da Gama and sea port is Marmagoa, Vasco Da Gama.

1.3 Physiography and Drainage:

Physiographically the area shows mixed topography represented by both hilly areas and flat terrain. The area is part of Western Ghats forming series of ridges and steep valleys

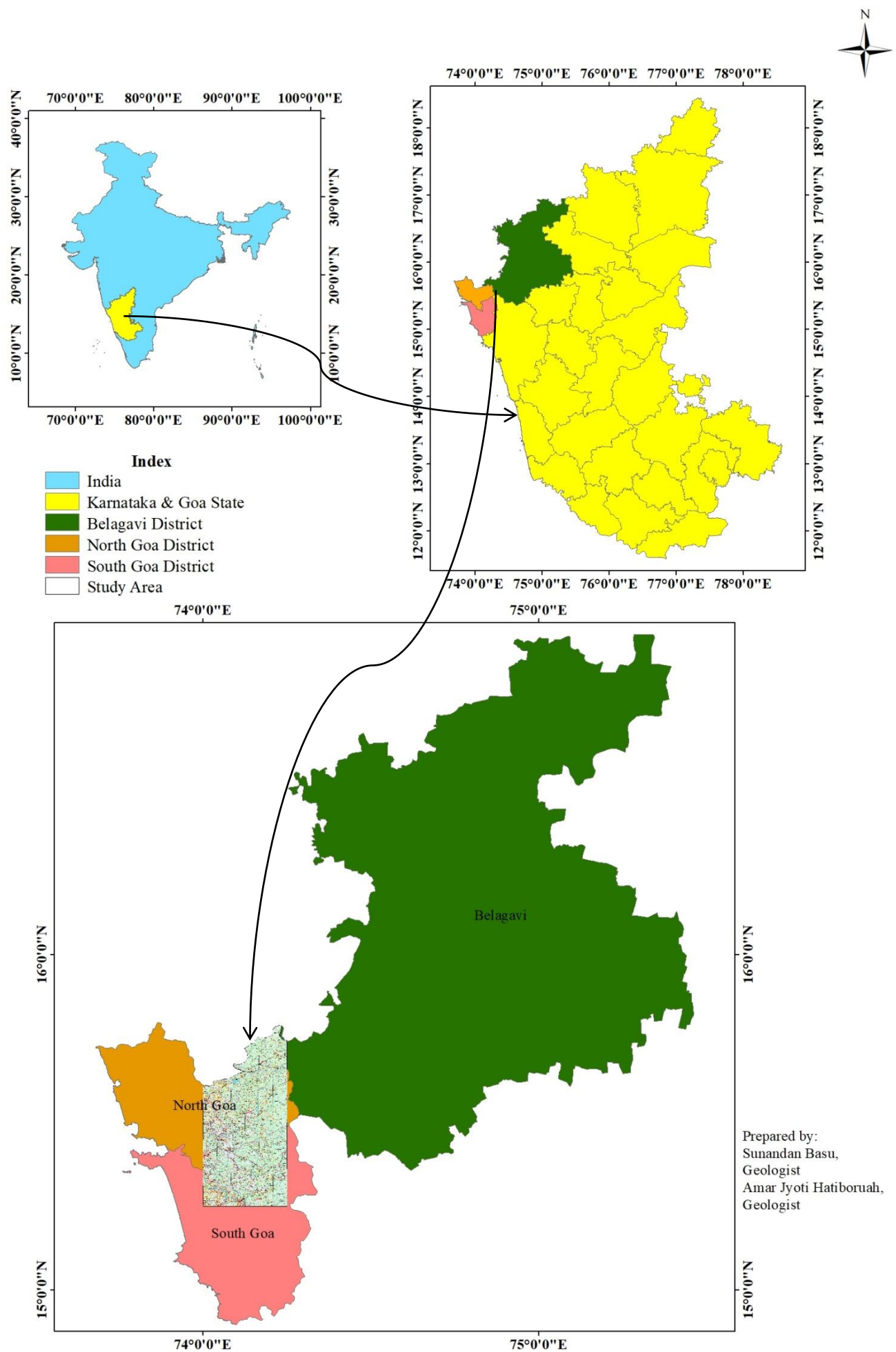


Fig. 1.1: Location Map of the study area

The state receives an annual rainfall of about 3500 mm, mostly from southwest monsoon and is drained by several west flowing rivers. Mandovi river, Zuvari river, Dudhsagar nadi, Malprabha river, Surla nadi, Maderi river, Tilari nadi and their tributaries drains the entire area. The drainage pattern exhibits dendritic to sub radial to sub trellis pattern. The eastern border of the state generally marks the water divide between easterly and westerly flowing rivers.

1.4 Present Work:

National Landslide Susceptibility Mapping (NLSM) of 1311 sq. km area was carried out in parts of South Goa and North Goa districts, Goa and Belagavi district of Karnataka under the Annual Programme of Geological Survey of India, Southern Region, vide FSP code no: M4LSSM/NC/SR/SU-KG/2019/27977 for the field season 2019 – 20. The study area covers three Survey of India toposheet, viz. 48I/01, 48I/02 and 48I/03. The nature and target of work envisaged for Field Season Programme of 2019 – 20 and the achievements are given in Table – 1.1.

Table – 1.1: Nature, quantum of work and achievement

Nature of work	Target for FS 2019 – 20	Achievement for FS 2019 – 20
1. Pre-field preparation		
i. Preparation of Thematic maps (in GIS on scale 1:50,000)		
a) Slope Forming Material map	1311 sq. km	1311 sq. km
b) Geomorphology & Lineament map	1311 sq. km	1311 sq. km
c) Slope Morphometry (slope, aspect & curvature) map	1311 sq. km	1311 sq. km
d) Land use - Land cover map	1311 sq. km	1311 sq. km
e) Drainage map	1311 sq. km	1311 sq. km
f) Regolith thickness map	1311 sq. km	1311 sq. km
ii) Landslide inventory map	1311 sq. km	1311 sq. km
2. Field-based studies		
i) Field checking of all thematic maps	1311 sq. km	1311 sq. km
ii) Field checking and collection of landslide inventory attributes (41 point geo -parametric sheet)	1311 sq. km	1311 sq. km (25 landslides)
3. Post-field studies & modelling		
i) Updation of thematic and landslide inventory maps	1311 sq. km	1311 sq. km
ii) Landslide susceptibility modelling and finalization of landslide susceptibility map in GIS	1311 sq. km	1311 sq. km
4. Collection of Rainfall data	1311 sq. km	1311 sq. km (collected available data)

The fieldwork was carried out from 25th September 2019 to 24th February 2020. Table – 1.2 gives a briefing of total man days spent for the current item. Total 177 man days were spent in the field, which also includes five days of field supervision by Shri. J. Srihari, Director. The post field landslide susceptibility modelling was carried out in SU: K & G, Bengaluru.

Table – 1.2: Details of man days spent for the current item

Name and Designation	2019				2020		Total (Days)
	Sep	Oct	Nov	Dec	Jan	Feb	
Sunandan Basu, Geologist	4	8	21	24	8	20	85
Amar Jyoti Hatiboruah, Geologist	4	8	20	24	12	19	87
J. Srihari, Director	0	0	0	2	0	3	5

1.5 Geology:

1.5.1 Regional Geological Setup:

Geologically the area comprises rocks of Peninsular Gneissic Complex (PGC) (Archaean), Goa Group, equivalent to Chitradurga Group of Dharwar Supergroup, meta-volcanics and meta-sedimentary assemblages (Archaean to Lower Proterozoic), mafic ultramafic complexes and intrusive granites (Lower Proterozoic), Deccan traps (Upper Cretaceous to Eocene), laterite (Cenozoic) and beach sands.

The Peninsular Gneissic Complex (PGC) represented by Tonalite-Trondjemite-Granodiorite suit of rocks and exposed in Anmod Ghats in the eastern part, Quepem in the central part and Chauri in the south. The PGC is unconformably overlain by the Goa Group comprising of Barcem, Sanverdem, Bicholim and Vageri Formations of low grade green schist facies.

The Barcem Formation dominant in South Goa, comprises of Ortho-quartzite, thick piles of meta-basalt, met-acid volcanic (quartz porphyry, meta-dacite and tuffs) and quartz-chlorite-amphibolite schist with bands of agglomerate. The Sanverdem Formation conformably overlies the Barcem Formation and consists mainly of turbidite deposits and comprises of polymict conglomerate, breccia, metagreywacke, quartz-chlorite schist and thin lenses of quartzite. The conglomerate is widely distributed and occurs at different

stratigraphic levels and shares translational contact with the overlying quartz-chlorite-biotite schist of Bicholim Formation. The Bicholim Formation consists of quartz chlorite biotite / amphibolite schist with thin lenses of metabasalt, sills of metagabbros, carbonaceous and manganiferous Chert, quartzite, BIF, quartz sericite schist and magnesian limestone. Rocks of Bicholim Formation occupy a major part of the area with thickness ranging from 250-500m. In south Goa, the lower units of Bicholim Formation are manganiferous.

Layered mafic and ultramafic rocks unit are titaniferous/vanadiferous magnetite, pyroxenite, Gabbroic and anorthosite. All the rocks have been subjected to serpentinisation, subsequently metamorphosed to some extent.

Granite (Chandranath granite) equivalent to Closepet Granite is light grey, coarse grained, consist of quartz and feldspars occurring in the NW quadrant and as plugs and bosses within PGC in the SW corner.

Dolerite represents the youngest phase of igneous activity. These have traversed all the formation. All the rocks have undergone lateritisation. The rocks have undergone metamorphism from green schist facies to lameno-phyllite facies.

Most part of Goa is covered with laterites, reddish in colour and rich in ferric / aluminium oxides. The lateritic weathering profiles exhibits three zones viz. duricrust, underlying clays and bottom saprolite up to 100m depth over schistose rocks, green stones and BIF units, up to 10 m over ultramafics and about 5m over Deccan traps. Variation in mineralogy and texture of the parent rock has resulted in the Formation of ferruginous, manganiferous and aluminous laterite. The Quaternary Formations are represented by beach sands and alluvium. Further inland and along the river banks, the soil is mostly alluvial and loamy. (Abbas and Bhattacharjee, 1994; Babu, 1980; Muthu, 1986; Kariyanna, 1990; Balakrishnan et.al, 1993; Janardan and Manjunatha, 1993).

The regional stratigraphy of the area (after GSI) is given in Table – 1.3 (GSI, Mis. Pub. No.30).

Table 1.3 – Regional Stratigraphy of the area

<i>Litho assemblage</i>	<i>Formation</i>	<i>Group</i>	<i>Supergroup</i>	<i>Age</i>
Beach sands and river alluvium	--	--	--	Quaternary
Laterite and aluminous laterite	--	--	--	Pliocene to Pleistocene
Continental flood basalts- mainly tholeiitic type with dykes	--	Deccan Trap	--	Late Cretaceous to Palaeocene
Alkaline granites mainly; also, variants from monzo granite to granodiorite	Chandranath Granite, Dudsagar Granite, Canacona Granite	Closepet Granite	--	Palaeo Proterozoic to Meso Proterozoic
Peridotite - chromitite, dunite-gabbro - norite, pyroxenite	--	Mafic-ultramafic Layered Complex	--	--
Carbonate-quartz-chlorite schist/greywacke	Vageri	Goa Group (Chitradurga Group)	Dharwar Supergroup	Archean to Palaeo Proterozoic
Dolomitic limestone	Bicholim			
Quartz-sericite schist				
Banded Iron Formation	Bicholim	Goa Group (Chitradurga Group)	Dharwar Supergroup	Archean to Palaeo Proterozoic
Quartz-chlorite-biotite schist inter-layered with chert, iron and Mn oxides, carbonates, meta- basalt and meta-gabbro				
Quartzite/greywacke with conglomerate	Sanvordem			
Quartz-chlorite schist	Barcem			
Meta-acid volcanic (meta-rhyodacite), quartz porphyry, tuff				
Meta-basalt, meta-gabbro and meta-anorthositic gabbro, quartzite				
Migmatite and granites, tonalite - trondjhmite-granodiorite	Ankola Gneiss, Anmod Ghat Gneiss	Peninsular Gneiss - I	Peninsular Gneissic Complex	Achaeon

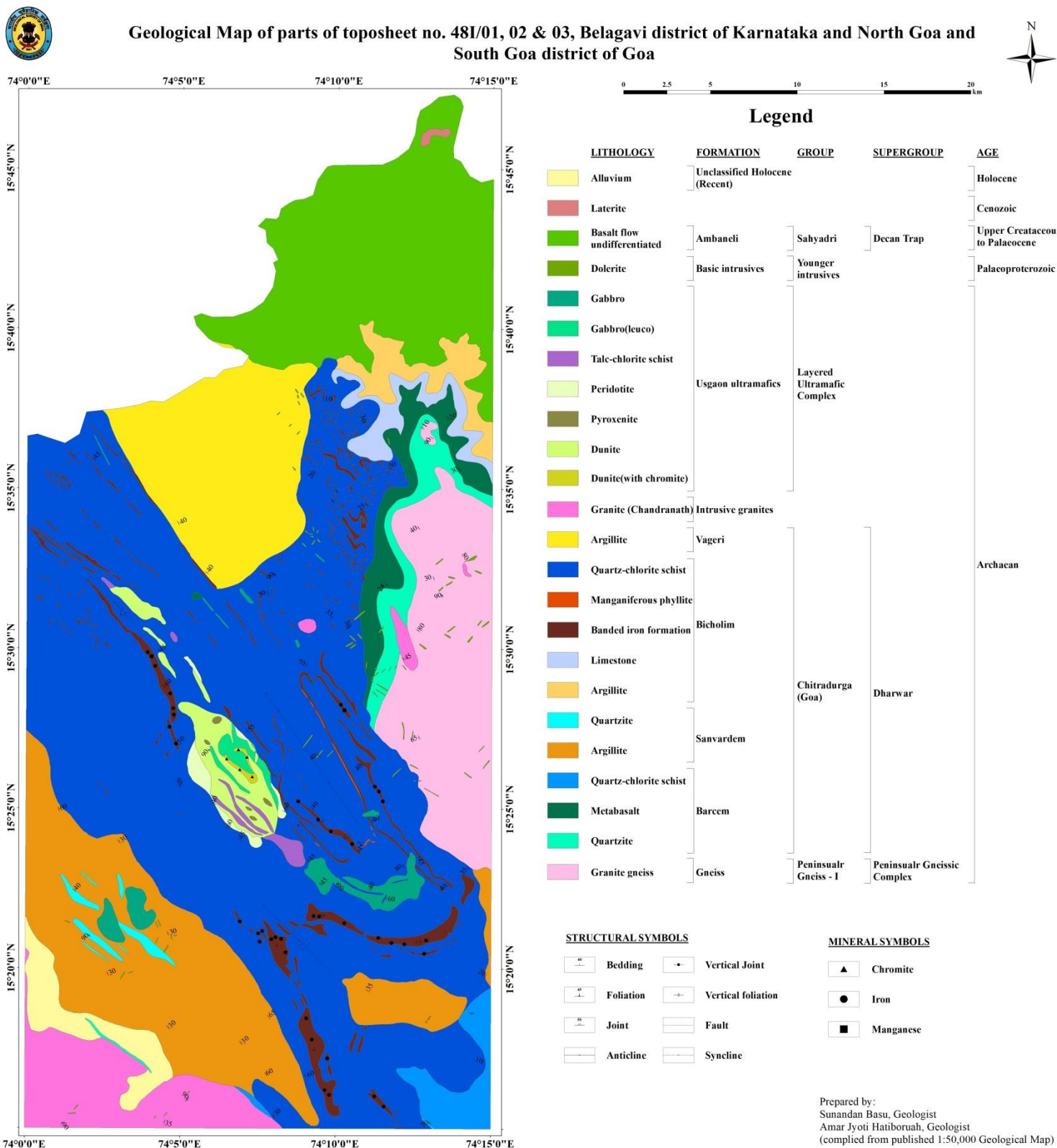


Fig. 1.2: Geological Map of parts of toposheet no. 48I/01, 02 & 03, Belagavi district of Karnataka and North Goa and South Goa districts of Goa

1.5.2 Geology of the study area:

The area comprises rocks belonging to Peninsular Gneiss - I (PG-I) of Peninsular Gneissic Complex (PGC). Goa Group of rocks, Mafic-ultramafic complex of Archaean and acid and basic intrusives of Palaeo-proterozoic age (Fig. 1.2).

1.5.2.1 Peninsular Gneissic Complex – I (PGC – I):

Peninsular Gneiss – I form the basement of overlying volcano-sedimentary rocks. It shows foliation parallel to the trend of volcano-sediments and it is traversed by quartzo-feldspathic veins. Granite gneisses are tonalitic - trondhjemitic in composition which is locally called Anmod Ghat gneisses (Fig. 1.3) and exposed in the eastern part of the study area. The rock is light grey in colour; medium to coarse grained, foliated and shows prominent gneissosity. Enclaves of amphibolite and garnetiferous mica schists are found within the gneiss. Granite Gneiss of PGC is exposed mainly in the Eastern part of the study area in Anmod Ghat.



Fig. 1.3: Granite gneiss exposed along Anmod Ghat section.

1.5.2.2 Quartzite:

Small bands of quartzite exposed which form the base for the Chandranatha granite. The litho unit occurs as boulder and at places shows clear bedding. The quartzite marks as the boundary between the greywacke, conglomerate and phyllite. The quartzite rests unconformably over granitoid / gneisses and occurs as impersistent bands. The rock is white

to greyish white to pale pink in colour consisting of mostly medium to fine grained quartz, hard and compact. Quartzites are exposed near Anmod Ghat and Valpoy area.

1.5.2.2 Meta-basalt:

Meta-basalt in the area is greenish coloured, fine grained, consists of chlorite – actinolite, plagioclase and epidote and occurs along with the quartzite in the eastern part of the area. Metabasalts are exposed near Barajan and Valpoy area.

1.5.2.3 Quartz-Chlorite Schist:

Quartz – chlorite schist in the area overlies the meta-volcanics. The quartz bearing schistose rocks are seen. The rock is grey to greenish in colour, fine grained, schistose and comprises of plagioclase, quartz, biotite, sericite and chlorite. The quartz – chlorite schist is mainly devoid of any clasts. These rocks are exposed in Snquelim, Honda, Pissurle, Ambegal and Darbhandara area.

1.5.2.4 Argillite:

Argillites are extensively exposed in the area. The rock is fine to medium grained, grey to greenish in colour, hard and schistose at places. Argillite consists of rock fragments, quartz, chlorite, sericite and feldspar. Argillite is exposed near Keri and Anjuna Dam area (Fig. 1.4).



Fig. 1.4: Argillite exposed near Anjuna Dam along Chorla Ghat section.

Manganiferous phyllite exposed in the area is soft, medium grained, finely laminated. Iron ore occurring at the top of the phyllitic horizon is represented by haematite and magnetite as lumpy ores.

1.5.2.5 BIF bands:

Banded iron formation with pink ferruginous phyllite is inter bedded with quartz – chlorite schist as linear bands running discontinuously and scattered throughout the area.

1.5.2.6 Usgaon Ultramafic:

Mafic and ultramafic rocks of Usgaon Ultramafic Complex comprises of dunite, pyroxenite, peridotite, talc – chlorite schist and gabbro. The dunite is fine to medium grained, hard and massive, dark green to greyish green and occasionally serpentinitised. Meta-gabbro is dark greenish in colour, medium to coarse grain and is composed of plagioclase and altered pyroxene. The talc schist is schistose, containing mostly talc and is light greenish to yellowish green in colour. Rocks of Usgaon Ultramafics are exposed in and around Usgaon, Valpoy and in the south of Pissurle.

1.5.2.7 Deccan Trap:

The basaltic lava flows of deccan trap are exposed in the north and north eastern part of the area near Chorla (refer: Fig. 1.5). These undifferentiated flows have been lateralized to varying extent and bauxitic at places.



Fig. 1.5: Deccan Basalt exposed near Chorla along Chorla Ghat section.

1.5.2.8 Laterite:

Majority of the present area is covered with laterites, reddish in colour and rich in ferric / aluminium oxides. The lateritic weathering profiles exhibits three zones viz. duricrust, underlying clays and bottom saprolite up to 100m depth over schistose rocks, green stones and BIF units, up to 10 m over ultramafics and about 5m over Deccan traps. Variation in mineralogy and texture of the parent rock has resulted in the Formation of ferruginous, manganiferous and aluminous laterite. Laterite duricrust is well exposed near Kolem (Fig. 1.6) and Ambegal areas.



Fig. 1.6: Laterite duricrust exposed near Kolem.

1.5.2.9 Younger Intrusives:

Dolerite: Dolerite represents the youngest phase of igneous activity and traversed through all the formations. The rocks have undergone metamorphism from green schist facies to lameno-phyllite facies. These rocks are exposed in the northern most part of the study area near Kankumbi and Surla.

Chandranath Granite: Chandranath Granite, equivalent to Closepet Granite is light grey, coarse grained, consist of quartz and feldspars occurring and as plugs and bosses within PGC. These rocks are exposed at the south eastern corner of the study area near Mayna and Asolda.

1.6 Methodology:

For a qualitative landslide susceptibility mapping, the following methodology was adopted, which are shown as flow diagrams in Fig. 1.15 & 1.16. In literature, there are many methods of predictive mapping of landslide susceptibility. However, application of any of the prevalent methods warrants utmost care and prudence by the landslide scientists because landslides are product of interaction of several geo-environmental spatial factors. For modelling, Multi Class Index Overlay Method was adopted using heuristic (knowledge driven) techniques where individual ratings for geofactor classes and weights of geofactor were determined with the prior knowledge of the terrain and after discussion with the local experts. Once the initial ratings were fixed, LOFS (Landslide Occurrence Favourability Score) was determined using Analytical Hierarchy Process (AHP) after preparing the pair wise qualitative comparison matrix of all factors (Saaty, 1977). In NLSM the above methodology was carried out on GIS platform.

National Landslide Susceptibility Mapping (NLSM) includes three components; such as pre-field mapping, field validation and post field updation & landslide susceptibility modelling.

➤ **Pre-field mapping:**

During pre-field period, landslide inventory and different thematic pre-field maps were prepared using different source data. The pre-field maps are as follows:

(i) **Landslide inventory:** Landslide inventory was prepared using old reports, multi temporal google imagery as source data in Arc – GIS software.

(ii) **Slope Morphometry (Slope Angle, Slope Curvature and Slope Aspect):** Slope Morphometry (Slope Angle, Slope Curvature and Slope Aspect) pre-field maps (refer: Fig. 1.7, 1.8 and 1.9) were prepared using Carto DEM (freely downloadable from bhuvan portal; bhuvan.nrsc.gov.in) data as input data source. Though the NLSM is carried out on 1: 50,000 scale, and as the difference of relative relief is relatively lesser in Southern India compared to the Himalayas, to get precise coarse resolution in Slope Angle, Curvature and Aspect map, the slope morphometry maps were prepared from its original 30 m X 30 m resolution.

(iii) **Drainage map:** Drainage pre-field map (Fig. 1.10) was prepared using Carto DEM of 30 m X 30 m resolution.



Slope Angle Map of parts of toposheet no. 48I/01, 02 & 03, Belagavi district of Karnataka and North Goa and South Goa district of Goa

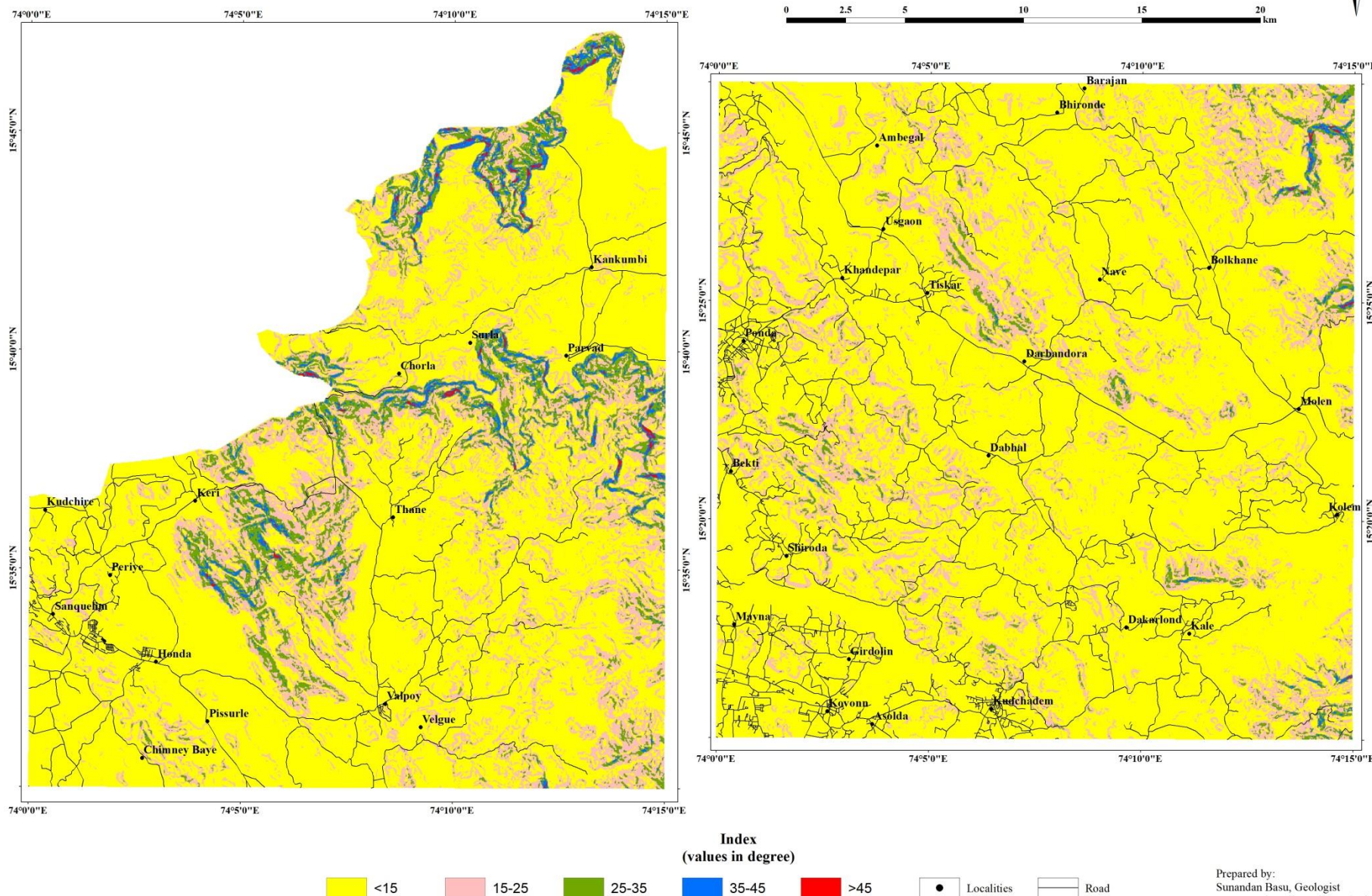


Fig. 1.7: Slope Angle Map of parts of toposheet no. 48I/01, 02 & 03, Belagavi district of Karnataka and North Goa and South Goa districts of Goa



Slope Curvature Map of parts of toposheet no. 48I/01, 02 & 03, Belagavi district of Karnataka and North Goa and South Goa district of Goa

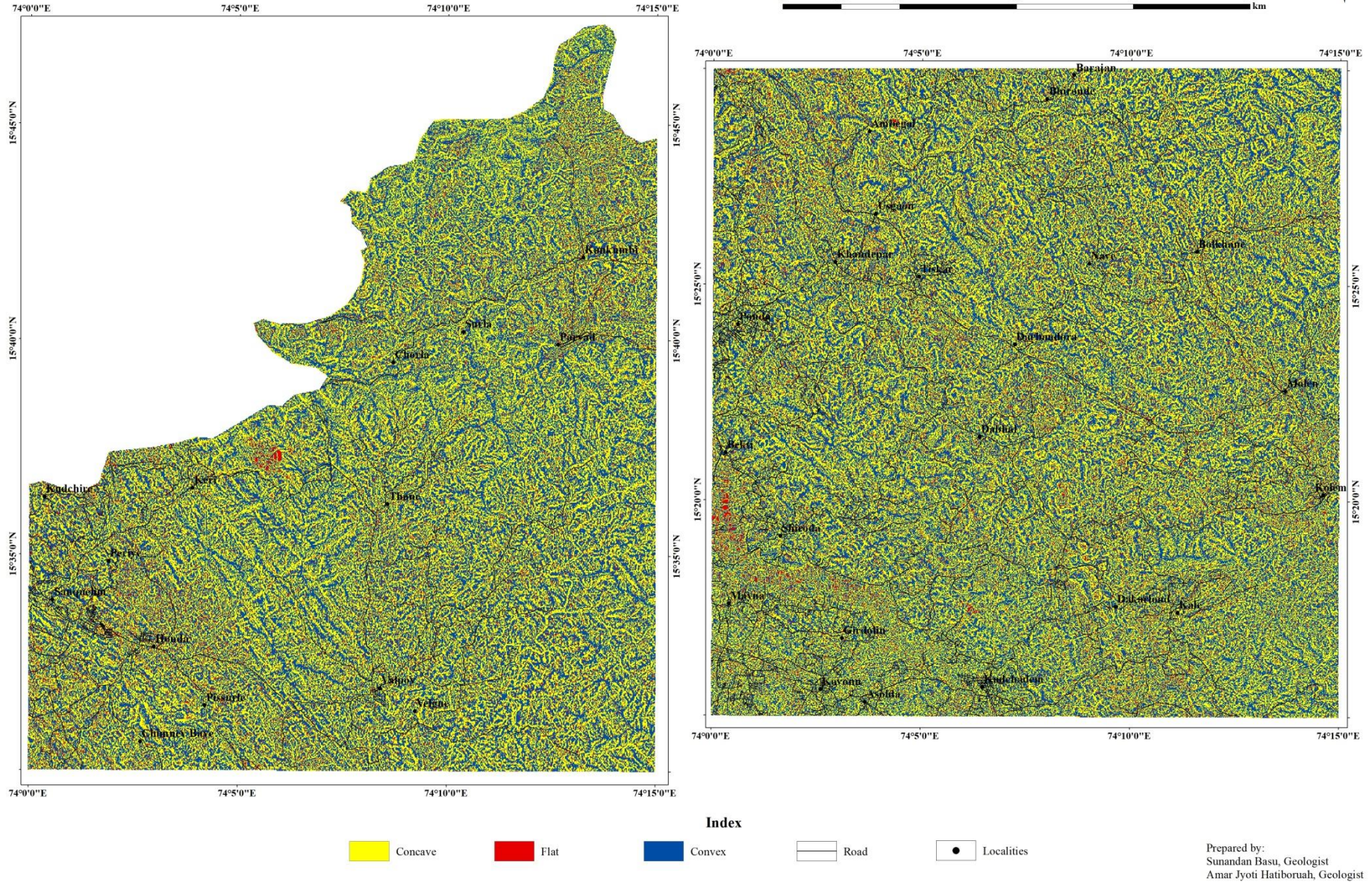


Fig. 1.8: Slope Curvature Map of parts of toposheet no. 48I/01, 02 & 03, Belagavi district of Karnataka and North Goa and South Goa districts of Goa



Slope Aspect Map of parts of toposheet no. 48I/01, 02 & 03, Belagavi district of Karnataka and North Goa and South Goa district of Goa

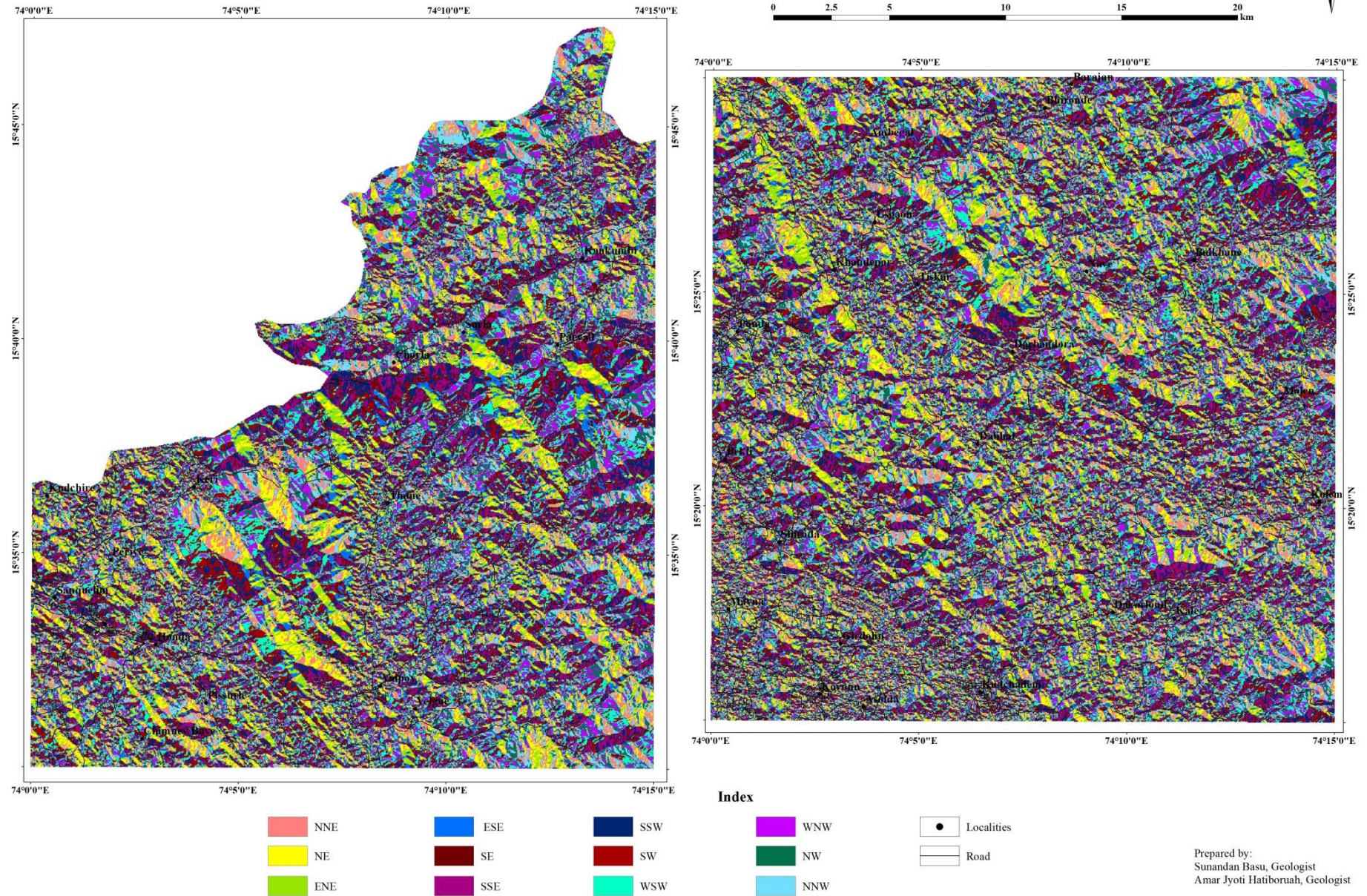


Fig. 1.9: Slope Aspect Map of parts of toposheet no. 48I/01, 02 & 03, Belagavi district of Karnataka and North Goa and South Goa districts of Goa



Drainage Map of parts of toposheet no. 48I/01, 02 & 03, Belagavi district of Karnataka and North Goa and South Goa district of Goa

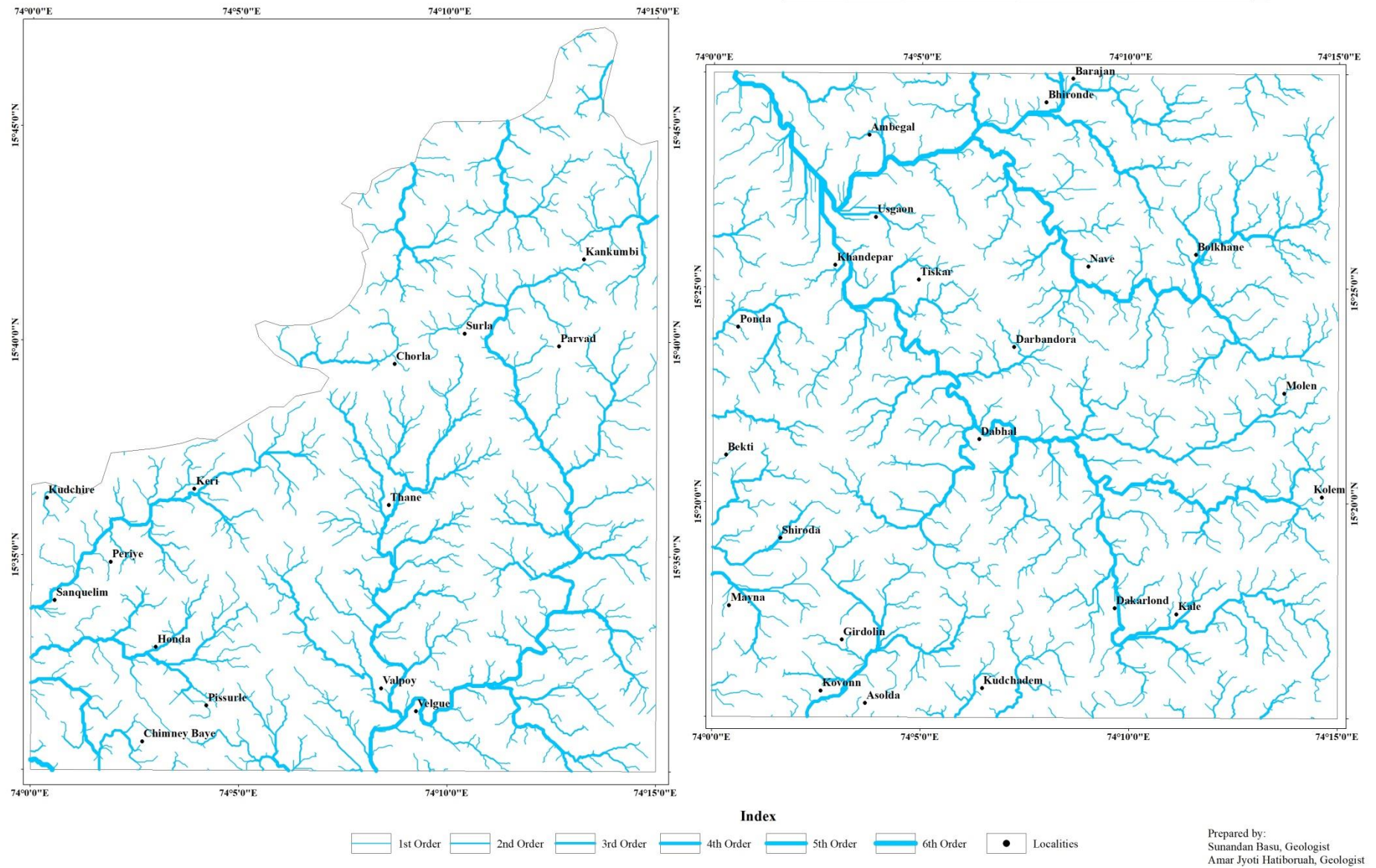


Fig. 1.10: Drainage Map of parts of toposheet no. 48I/01, 02 & 03, Belagavi district of Karnataka and North Goa and South Goa districts of Goa

(iv) **Land Use Land Cover map (LULC):** Land Use Land Cover (LULC) pre-field map was prepared using multi temporal google imagery and Arc – GIS base map (Fig. 1.11).

(v) **Geomorphology map:** Geomorphology pre-field map was prepared using multi temporal google imagery, Arc – GIS base map and 1:50,000 scale NGLM legacy map (Fig. 1.12).

(vi) **Slope Forming Material map (SFM):** Slope Forming Material (SFM) pre-field map was prepared using multi temporal google imagery, Arc – GIS base map, 1:50,000 scale geological legacy map of GSI and proxies from LULC and geomorphology maps (Fig. 1.13).

(vii) **Regolith Thickness map:** Regolith Thickness pre-field map was prepared using multi temporal google imagery, proxies from geomorphology map, contour map and slope map (Fig. 1.14).

➤ **Field validation of thematic maps:**

During the field validation period, all the pre-field maps were validated in the field by visiting all assessable locations and the modifications, wherever required, were recorded. The landslide points from pre-field landslide inventory were checked and validated. Besides, data for new landslides encountered in the field were also collected as per 42 point geo parametric datasheet of GSI. In this way the existing landslide inventory was also updated.

➤ **Post field updation and landslide susceptibility modelling:**

After the field validations were complete, all the thematic maps and landslide inventory were updated as per the field inputs.

Subsequent to the updation of the thematic maps and landslide inventory, heuristic (knowledge driven) techniques were adopted for modelling and generation of final susceptibility map of the area. For modelling using heuristic (knowledge driven) techniques, initial individual ratings for geo-factor classes and weights of geo-factors were fixed with the knowledge of terrain and with discussion with local experts for the entire area. Later the LOFS (Landslide Occurrence Favourability Score) was calculated using Analytical Hierarchy Process (AHP) after preparing the pair wise qualitative comparison matrix of all factors (Saaty, 1977). The steps of landslide susceptibility (refer: Fig. 1.15 & 1.16) using heuristic (knowledge driven) process is as below:



Pre-field Land Use Land Cover Map of parts of toposheet no. 48I/01, 02 & 03, Belagavi district of Karnataka and North Goa and South Goa district of Goa

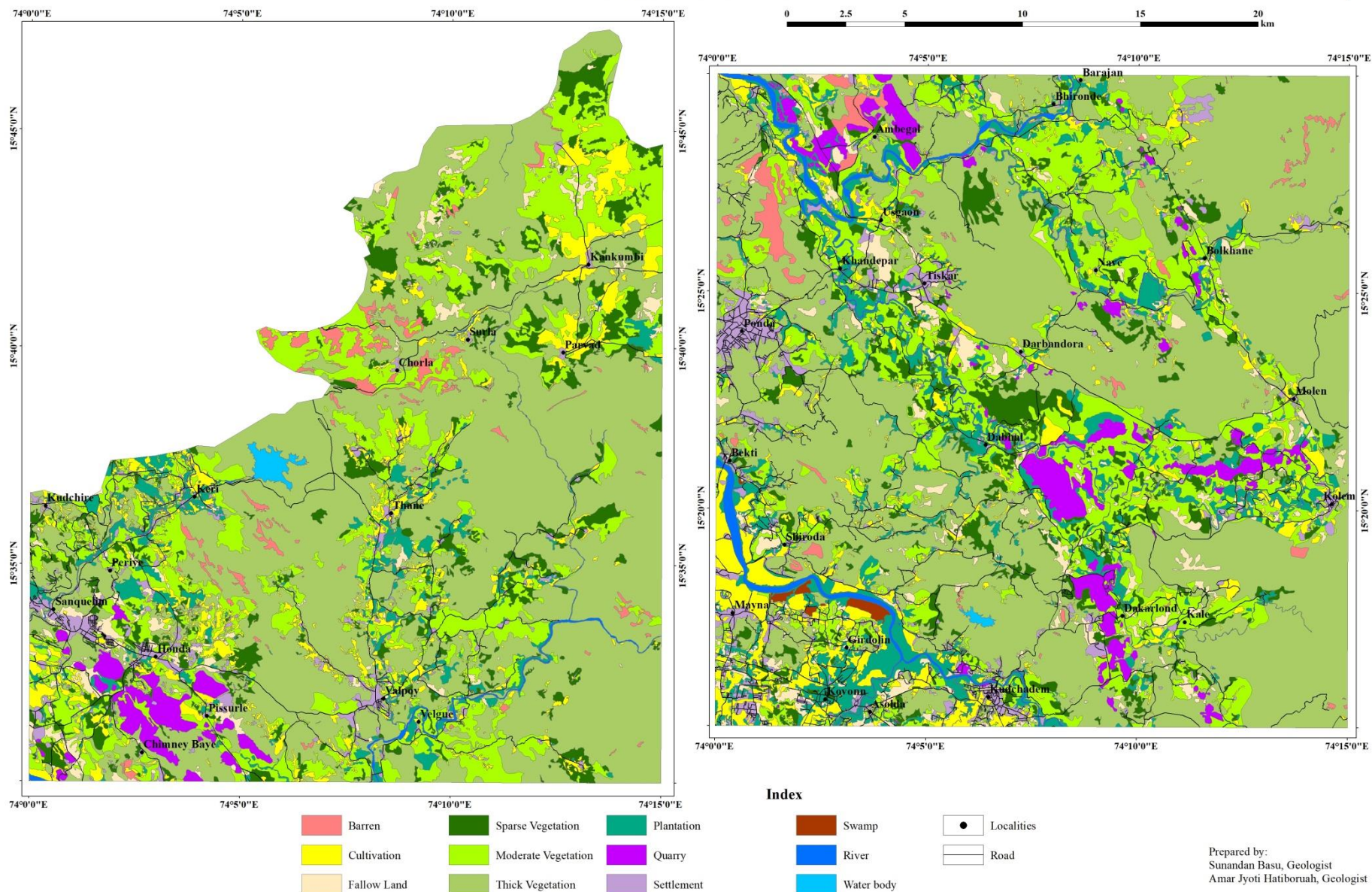


Fig. 1.11: Pre-field Land Use Land Cover Map of parts of toposheet no. 48I/01, 02 & 03, Belagavi district of Karnataka and North Goa and South Goa districts of Goa



Pre-field Geomorphology Map of parts of toposheet no. 48I/01, 02 & 03, Belagavi district of Karnataka and North Goa and South Goa district of Goa

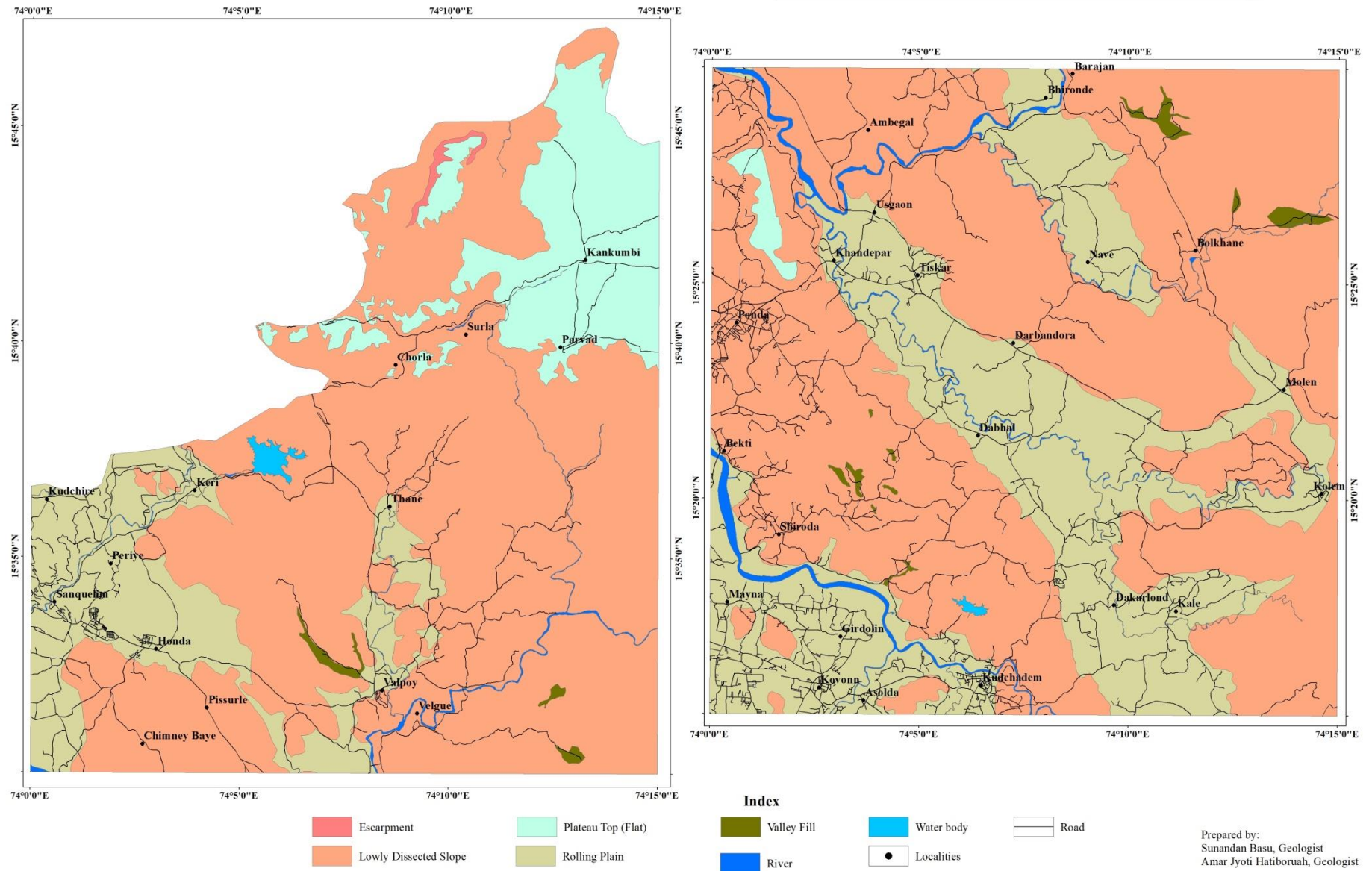


Fig. 1.12: Pre-field Geomorphology Map of parts of toposheet no. 48I/01, 02 & 03, Belagavi district of Karnataka and North Goa and South Goa districts of Goa



Pre-field Slope Forming Material Map of parts of toposheet no. 48I/01, 02 & 03, Belagavi district of Karnataka and North Goa and South Goa district of Goa

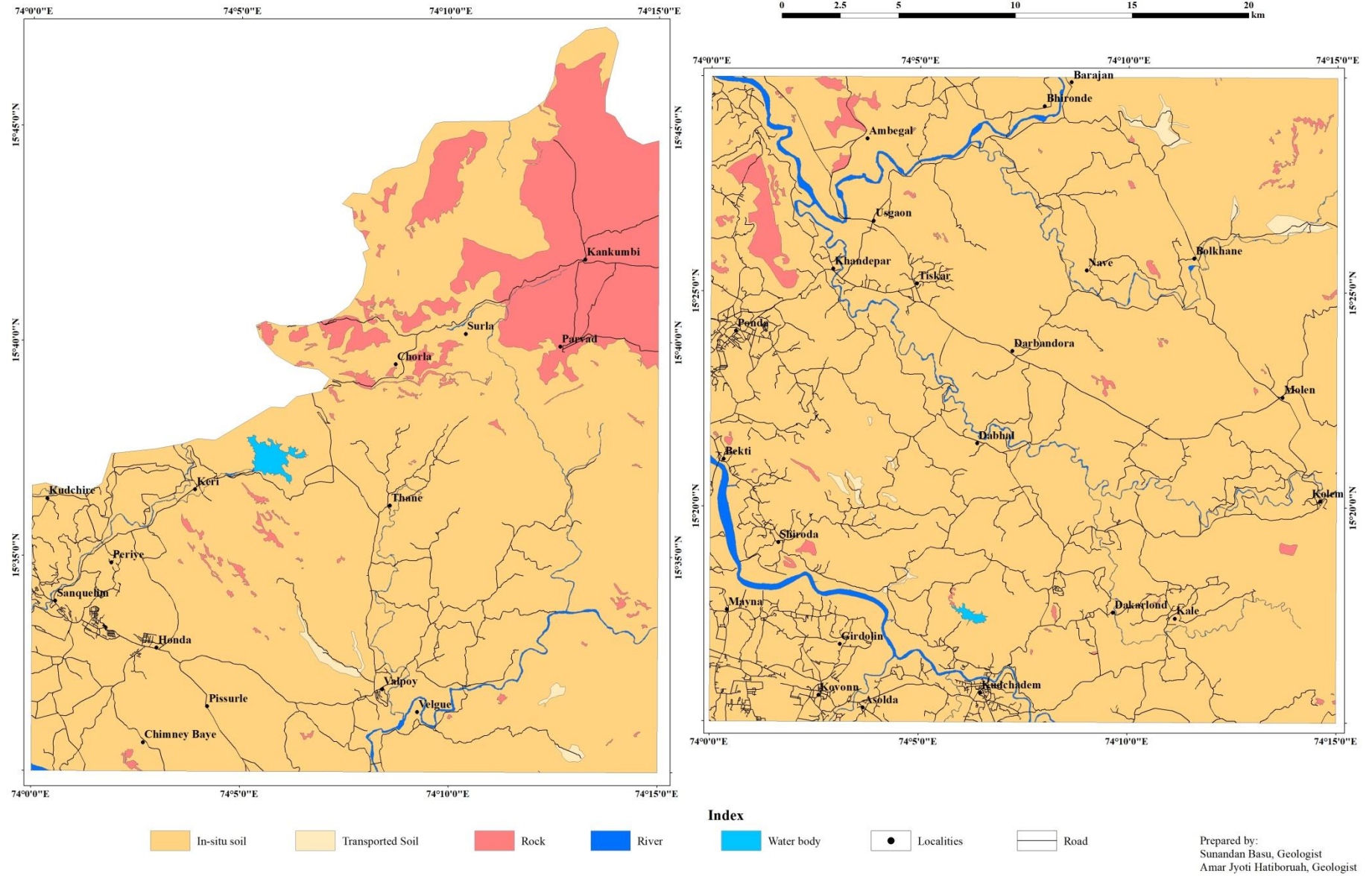


Fig. 1.13: Pre-field Slope Forming Material Map of parts of toposheet no. 48I/01, 02 & 03, Belagavi district of Karnataka and North Goa and South Goa districts of Goa



Pre-field Regolith Thickness Map of parts of toposheet no. 48I/01, 02 & 03, Belagavi district of Karnataka and North Goa and South Goa district of Goa

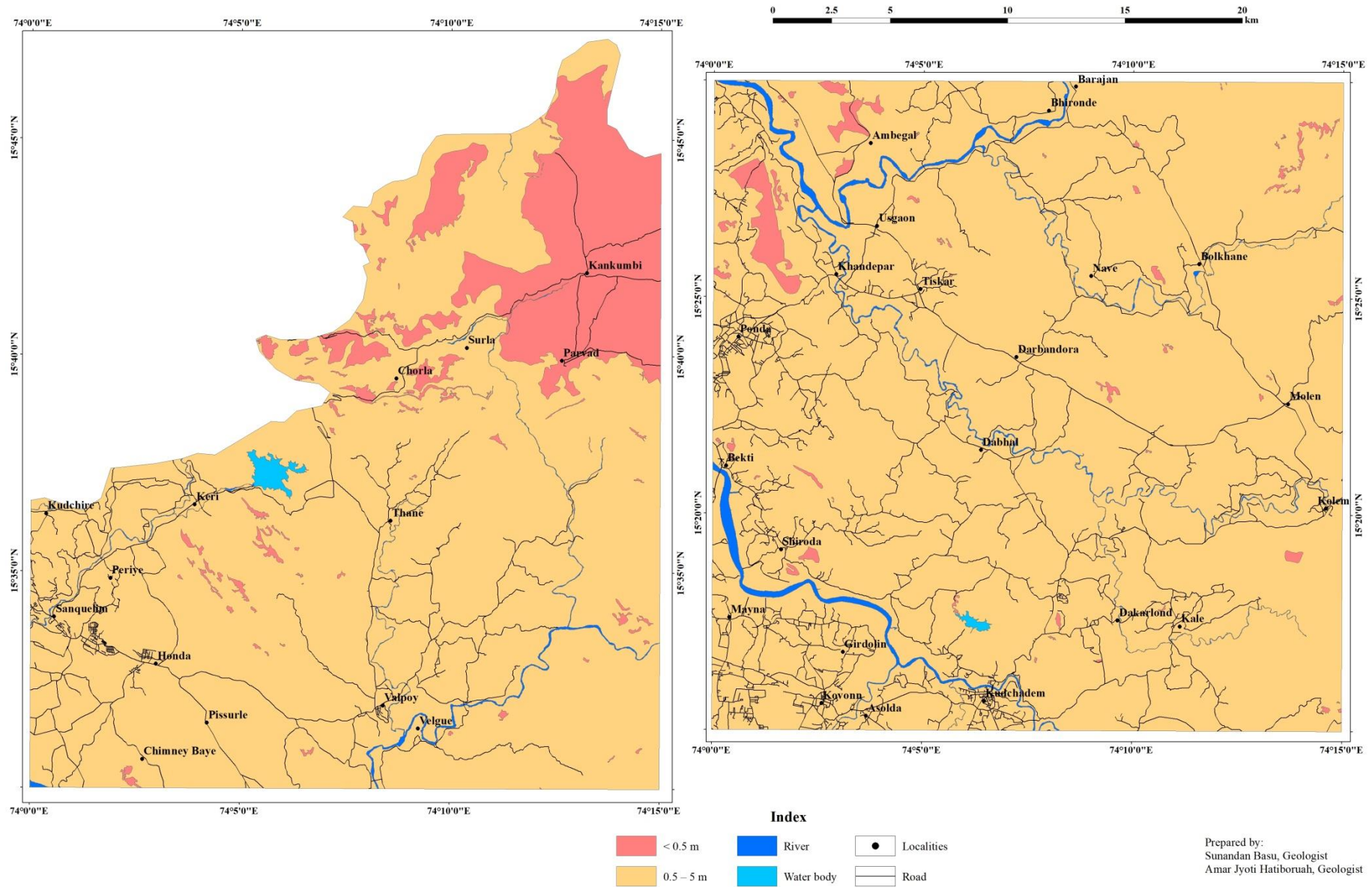


Fig. 1.14: Pre-field Regolith Thickness Map of parts of toposheet no. 48I/01, 02 & 03, Belagavi district of Karnataka and North Goa and South Goa districts of Goa

- A total of eight factor maps, viz., Slope Angle, Slope Aspect, Slope Curvature, Drainage, Land use – Land cover, Geomorphology, Slope Forming Material and Regolith Thickness were prepared for susceptibility analysis. Besides these maps, landslide Inventory map were also prepared.
- All the above eight maps were used for assessment of factor class ratings. However, only six thematic maps (except aspect and drainage) were considered for validation of Landslide Susceptibility Map (LSM) of the study area, due to the absence of identified factor classes in a particular map.
- All the thematic maps were converted to raster keeping field as “class” and output cell size as “50” (as NLSM is a 1:50,000 scale mapping) in GIS.
- Once all the ratings for geo-factor classes and weights of geo-factors were fixed, LOFS was calculated using pair wise comparison matrix and fraction rating.
- After calculation of LOFS for all the geo-factor classes, LOFS maps of the geo-factors were prepared in GIS.
- Once all the LOFS maps were prepared, raw landslide susceptibility score map was prepared using weighted multi class index overlay method in GIS.
- After raw landslide susceptibility score map was prepared classified landslide susceptibility map was generated and determination of break values were carried out by assigning weightages (30% is the boundary between low to moderate susceptibility and 50% is the boundary between moderate to high susceptibility).

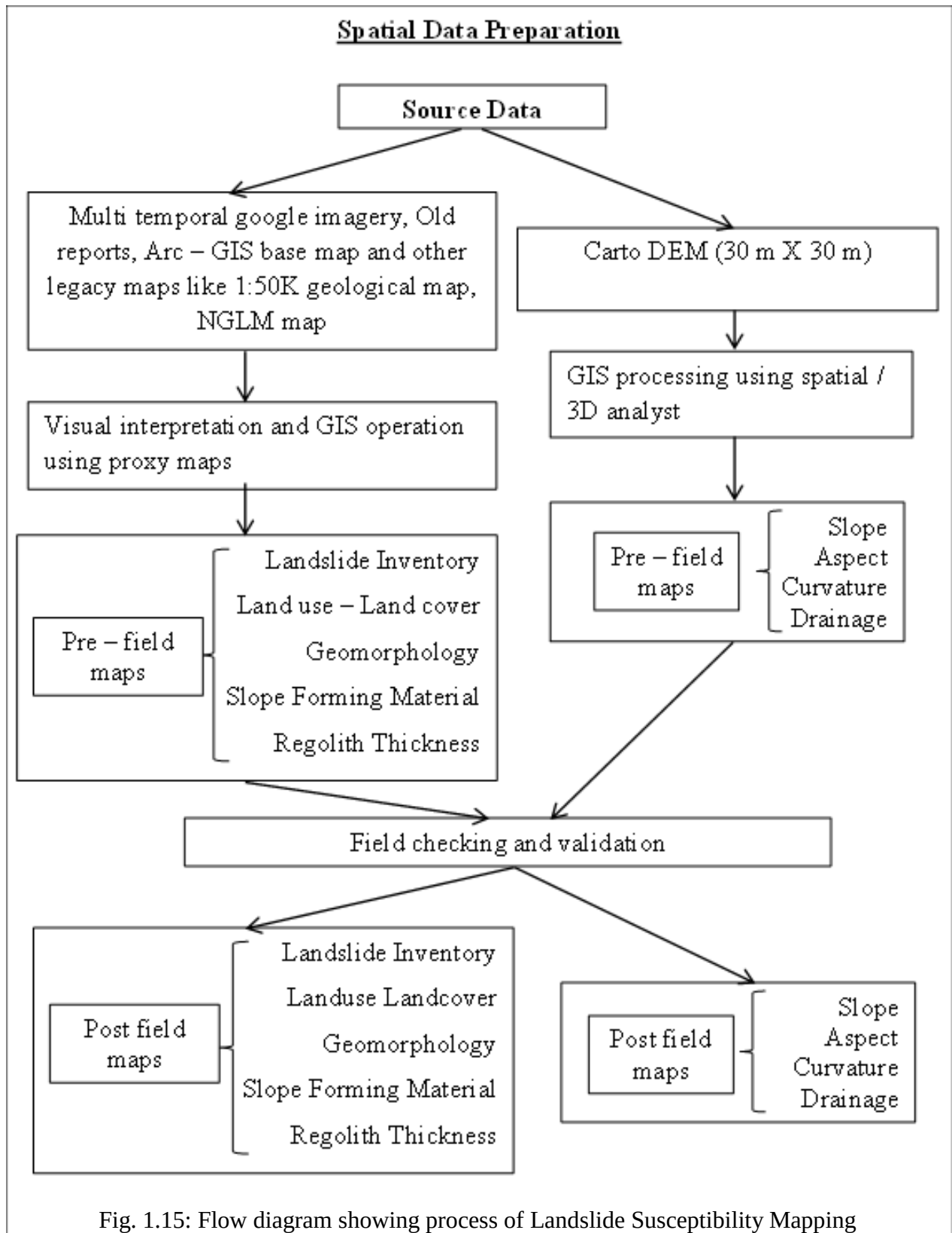


Fig. 1.15: Flow diagram showing process of Landslide Susceptibility Mapping

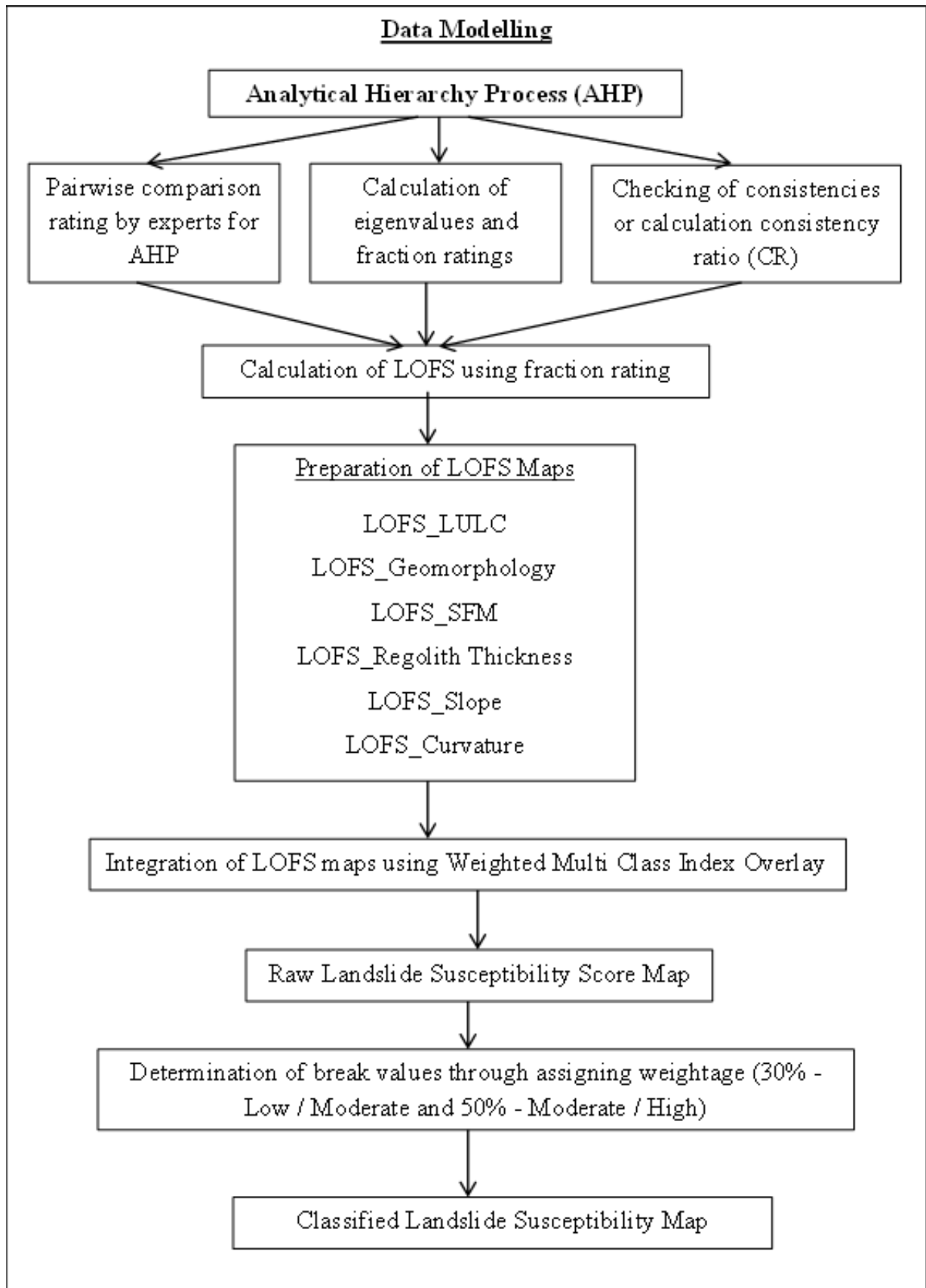


Fig.1.16: Flow diagram showing process of knowledge driven modeling for Landslide Susceptibility Mapping

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CHAPTER – 2

PREVIOUS WORK ON LANDSLIDE STUDIES

2.1 Landslides

Landslides are very common natural as well as man-made hazards in India. Mostly the western part of the Karnataka and eastern part of Goa state is vulnerable to landslides. Our present study area, situated in the north eastern part of Goa and north western part of Karnataka, had also been affected by landslide events rather frequently especially during monsoons. Moreover, Geological Survey of India, being the nodal agency for landslide studies in India, has been working in the area since last few years for preparing landslide inventory.

The present study area covers parts of South Goa and North Goa districts of Goa and Belagavi district of Karnataka. During FS 2012 – 13, Maruthi K.V and Chandran K.V carried out “Landslide Inventory along National Highway & State Highway of Ghat Roads in North Goa and South Goa Districts, Goa”. The authors have reported 17 landslides in parts of TS nos. 48I/02 and 48I/03 along different road sections such as Mapusa – Bicholim, Sattari – Chorla and Sanqielim – Valpoi. Additionally, four landslides were collected from landslide database provided by GHRM center, CHQ, Kolkata. So, in total historical data for 21 landslides were collected from previous reports and landslides database of GSI. Brief descriptions of the landslides are given in Table – 2.1:

Table – 2.1: *Brief Description of the Historical Landslides recorded in the study area*

Sl. No	Landslide No.	Location		Brief Description of the landslide	Causative Factor
		Latitude (N)	Longitude (E)		
1	GA 39	15° 33' 10"	74° 0' 55.4"	The slide is classified as a new debris slump. The debris consists of clay derived from weathering and soil. The slide area has an overburden thickness of nearly 3.0 m. The depth of weathering is > 7.0 m. NH-17 road is “element at risk”, which constitutes the sole land use pattern of the area. Laterite is the exposed rock type in the area. The head and crown parts of the slide are stable and toe part is unstable. The slide has a horizontal extent of 1.0 m and vertical interval of 9.0 m	Effect of human interference and high rainfall with ineffective drainage at toe.
2	GA 46	15° 36' 59.4"	74° 5' 31.2"	The slide is classified as an old and reactivated debris slide. The debris consists of highly weathered meta greywacke particles with size ranging from boulders to pebble, clay derived from weathering and soil. The slide area has an overburden thickness of nearly 2.5 m. The depth of weathering is > 10.0 m. SH-04 Sattari-Chorla road is “element at risk”, which constitutes the sole land use pattern of the area. Meta greywacke is the exposed rock type in the area. The head, crown and toe parts of the slide are unstable. The slide has a horizontal extent of 1.0 m and vertical interval of 11.0 m	Effect of human interference and high rainfall with ineffective drainage coupled with high degree of weathering.

Sl. No	Landslide No.	Location		Brief Description of the landslide	Causative Factor
		Latitude (N)	Longitude (E)		
3	GA 47	15° 36' 57"	74° 5' 34"	The slide is classified as an old and reactivated debris slide. The debris consists of highly weathered meta greywacke particles with size ranging from boulders to pebble, clay derived from weathering and soil. The slide area has an overburden thickness of nearly 3.0 m. The depth of weathering is > 10.0 m. SH-04 Sattari-Chorla road is “element at risk”, which constitutes the sole land use pattern of the area. Meta greywacke is the exposed rock type in the area. The head, crown parts of the slide are stable and toe part of the slide is unstable. The slide has a horizontal extent of 1.0 m and vertical interval of 13.0 m	Effect of human interference and high rainfall with ineffective drainage at toe.
4	GA 48	15° 36' 51"	74° 6' 6.2"	The slide is classified as an old and reactivated debris slump. The debris consists of highly weathered Meta greywacke particles with size ranging from boulders to pebble, clay derived from weathering and soil. The slide area has an overburden thickness of nearly 3.0 m. The depth of weathering is > 5.0 m. SH-04 Sattari-Chorla road is “element at risk”, which constitutes the sole land use pattern of the area. Meta greywacke is the exposed rock type in the area. The head, crown and toe parts of the slide are unstable. The slide has a horizontal extent of 1.0 m and vertical interval of 11.0 m	Effect of human interference and high rainfall with ineffective drainage at toe.

Sl. No	Landslide No.	Location		Brief Description of the landslide	Causative Factor
		Latitude (N)	Longitude (E)		
5	GA 49	15° 36' 33"	74° 6' 15"	The slide is classified as a new earth slump. The debris consists of clay derived from weathering and soil. The slide area has an overburden thickness of nearly 2.0 m. The depth of weathering is > 5.0 m. SH-04 Sattari-Chorla road is “element at risk”, which constitutes the sole land use pattern of the area. Meta greywacke is the exposed rock type in the area. The head, crown and toe parts of the slide are unstable. The slide has a horizontal extent of 1.0 m and vertical interval of 9.0 m	Effect of human interference and high rainfall with ineffective drainage at toe.
6	GA 50	15° 36' 25"	74° 6' 19.3"	The slide is classified as an old and reactivated debris slide. The debris consists of highly weathered meta basalt particles with size ranging from boulders to pebble, clay derived from weathering and soil. The slide area has an overburden thickness of nearly 3.0 m. The depth of weathering is > 10.0 m. SH-04 Sattari-Chorla road is “element at risk”, which constitutes the sole land use pattern of the area. Weathered meta basalt is the exposed rock type in the area. The head, crown and toe parts of the slide are unstable. The slide has a horizontal extent of 2.0 m and vertical interval of 15.0 m.	Effect of human interference and high rainfall with ineffective drainage at toe.

Sl. No	Landslide No.	Location		Brief Description of the landslide	Causative Factor
		Latitude (N)	Longitude (E)		
7	GA 51	15° 36' 22.6"	74° 6' 20.2"	The slide is classified as an old and reactivated debris slide. The debris consists of highly weathered meta basalt particles with size ranging from boulders to pebble, clay derived from weathering and soil. The slide area has an overburden thickness of nearly 2.0 m. The depth of weathering is > 10.0 m. SH-04 Sattari-Chorla road is “element at risk”, which constitutes the sole land use pattern of the area. Weathered meta basalt is the exposed rock type in the area. The head, crown and toe parts of the slide are unstable. The slide has a horizontal extent of 1.0 m and vertical interval of 12.0 m	Effect of human interference and high rainfall with ineffective drainage at toe.
8	GA 52	15° 36' 23.3"	74° 6' 21.2"	The slide is classified as an old and reactivated debris slide. The debris consists of highly weathered meta basalt particles with size ranging from boulders to pebble, clay derived from weathering and soil. The slide area has an overburden thickness of nearly 2.0 m. The depth of weathering is > 10.0 m. SH-04 Sattari-Chorla road is “element at risk”, which constitutes the sole land use pattern of the area. Weathered meta basalt is the exposed rock type in the area. The head, crown and toe parts of the slide are unstable. The slide has a horizontal extent of 2.0 m and vertical interval of 12.0 m	Effect of human interference and high rainfall with ineffective drainage coupled with high degree of weathering.

Sl. No	Landslide No.	Location		Brief Description of the landslide	Causative Factor
		Latitude (N)	Longitude (E)		
9	GA 53	15° 36' 51.2"	74° 7' 14.2"	The slide is classified as an old debris slide. The debris consists of highly weathered meta basalt particles with size ranging from boulders to pebble, clay derived from weathering and soil. The slide area has an overburden thickness of nearly 2.0 m. The depth of weathering is > 10.0 m. SH-04 Sattari-Chorla road is “element at risk”, which constitutes the sole land use pattern of the area. Weathered meta basalt is the exposed rock type in the area. The head, crown parts of the slide are unstable and toe part is stable. The slide has a horizontal extent of 2.0 m and vertical interval of 18.0 m	Effect of human interference and high rainfall with ineffective drainage coupled with high degree of weathering.
10	GA 54	15° 37' 6"	74° 7' 10.8"	The slide is classified as an old and reactivated debris slide. The debris consists of highly weathered meta basalt particles with size ranging from boulders to pebble, clay derived from weathering and soil. The slide area has an overburden thickness of nearly 2.0 m. The depth of weathering is > 10.0 m. SH-04 Sattari-Chorla road is “element at risk”, which constitutes the sole land use pattern of the area. Weathered meta basalt is the exposed rock type in the area. The head, crown and toe parts of the slide are unstable. The slide has a horizontal extent of 1.0 m and vertical interval of 13.0 m	Effect of human interference and high rainfall with ineffective drainage coupled with high degree of weathering.

Sl. No	Landslide No.	Location		Brief Description of the landslide	Causative Factor
		Latitude (N)	Longitude (E)		
11	GA 55	15° 38' 3.2"	74° 6' 51.6"	The slide is classified as a new rock fall. The debris consists of highly weathered greywacke particles with size ranging from boulders to pebble, clay derived from weathering and soil. Two sets of Joints are noticed J1-N490E/670NW with 10.0-20.0 cm spacing and is tight; J2-N500W/ 290NE with 20.0-50.0 cm spacing and is tight. The slide area has an overburden thickness of nearly 2.0 m. The depth of weathering is > 5.0 m. SH-04 Sattari - Chorla road is “element at risk”, which constitutes the sole Land use pattern of the area. Meta greywacke is the exposed rock type in the area. The head, crown and toe parts of the slide are unstable. The slide has a horizontal extent of 1.0 m and vertical interval of 15.0 m	Effect of human interference and high rainfall with ineffective drainage coupled with high degree of weathering.
12	GA 56	15° 38' 5.6"	74° 6' 51.2"	The slide is classified as an old and reactivated debris slide. The debris consists of highly weathered greywacke particles with size ranging from boulders to pebble, clay derived from weathering and soil. The slide area has an overburden thickness of nearly 3.0 m. The depth of weathering is > 10.0 m. SH-04 Sattari-Chorla road is “element at risk”, which constitutes the sole land use pattern of the area. Meta greywacke is the exposed rock type in the area. The head, crown and toe parts of the slide	Effect of human interference and high rainfall with ineffective drainage at toe.

Sl. No	Landslide No.	Location		Brief Description of the landslide	Causative Factor
		Latitude (N)	Longitude (E)		
				is unstable. The slide has a horizontal extent of 1.0 m and vertical interval of 13.0 m	
13	GA 57	15° 38' 11.1"	74° 7' 14"	The slide is classified as a new debris slide. The debris consists of highly weathered greywacke particles with size ranging from boulders to pebble, clay derived from weathering and soil. The slide area has an overburden thickness of nearly 2.0 m. The depth of weathering is > 10.0 m. SH-04 Sattari-Chorla road is “element at risk”, which constitutes the sole land use pattern of the area. Meta greywacke is the exposed rock type in the area. The head, crown and toe parts of the slide are unstable. The slide has a horizontal extent of 1.0 m and vertical interval of 14.5 m	Effect of human interference and high rainfall with ineffective drainage at toe.
14	GA 58	15° 38' 30"	74° 6' 59.7"	The slide is classified as a new rock fall. The debris consists of highly weathered greywacke particles with size ranging from boulders to pebble. Three sets of Joints are noticed J1- N220W/vertical with 10.0-50.0 cm spacing with 1.0 cm opening filled with soil; J2-S510W/ 800NE with 10.0-50.0 cm spacing and is tight and J3- N200E/ 690NW with 20.0 cm spacing and is tight. The slide area has an overburden thickness of nearly 2.0 m. The depth of weathering is > 10.0 m. SH-04 Sattari-Chorla road is	Effect of human interference and high rainfall with ineffective drainage coupled with high degree of weathering.

Sl. No	Landslide No.	Location		Brief Description of the landslide	Causative Factor
		Latitude (N)	Longitude (E)		
				“element at risk”, which constitutes the sole Landuse pattern of the area. Meta greywacke is the exposed rock type in the area. The head, crown and toe parts of the slide are unstable. The slide has a horizontal extent of 1.0 m and vertical interval of 19.0 m.	
15	GA 59	15° 39' 3.1"	74° 7' 41.7"	The slide is classified as an old debris slide. The debris consists of highly weathered meta basalt particles with size ranging from boulders to pebble, clay derived from weathering and soil. The slide area has an overburden thickness of nearly 2.0 m. The depth of weathering is > 6.0 m. SH-04 Sattari-Chorla road is “element at risk”, which constitutes the sole land use pattern of the area. Meta basalt is the exposed rock type in the area. The head, crown and toe parts of the slide are stable. The slide has a horizontal extent of 2.0 m and vertical interval of 50.0 m	Effect of human interference and high rainfall with ineffective drainage at toe.
16	GA 60	15° 38' 58.3"	74° 7' 57.3"	The slide is classified as an old debris slide. The debris consists of highly weathered meta basalt particles with size ranging from boulders to pebble, clay derived from weathering and soil. The slide area has an overburden thickness of nearly 2.0 m. The depth of weathering is > 6.0 m. SH-04 Sattari-Chorla road is “element at risk”, which constitutes the sole land use pattern of the area. Meta basalt is the exposed rock type in the area. The head, crown	Effect of human interference and high rainfall with ineffective drainage coupled with high degree of weathering.

Sl. No	Landslide No.	Location		Brief Description of the landslide	Causative Factor
		Latitude (N)	Longitude (E)		
				and toe parts of the slide are unstable. The slide has a horizontal extent of 2.0 m and vertical interval of 50.0 m	
17	GA 61	15° 31' 36"	74° 6' 25.2"	The slide is classified as an old and reactivated debris slide. The debris consists of highly weathered meta basalt particles with size ranging from boulders to pebble, clay derived from weathering and soil. The slide area has an overburden thickness of nearly 3.0 m. The depth of weathering is > 6.0 m. SH-01 Sanqulim-Valpoi road is “element at risk”, which constitutes the sole land use pattern of the area. Meta basalt is the exposed rock type in the area. The head, crown and toe parts of the slide are unstable. The slide has a horizontal extent of 2.0 m and vertical interval of 13.0 m	Effect of human interference and high rainfall with ineffective drainage coupled with high degree of weathering.
18	NH4A	15° 24' 35"	74° 14' 25"	Data not available	Data not available
19	Charvade m	15° 37' 26"	74° 8' 1"	Data not available	Data not available
20	SH8	15° 18' 54"	74° 1' 50"	Data not available	Data not available
21	Chorlem	15° 39' 0"	74° 7' 30"	Data not available	Data not available

2.2 Landslide Susceptibility

In the present study area no landslide susceptibility studies had been taken up previously. Only preparation of landslide inventory along national highway and state highway was carried out during FS 2012 - 13.



CHAPTER – 3

LANDSLIDE INVENTORY

The generation of a landslide inventory is a tedious work as landslides occur individually and have to be identified, mapped and inventoried. Landslide inventories contain basic information about landslides such as location, classification, morphology, volume, run-out distance, activity and date of occurrence / activity, etc. Landslide inventory can be prepared through various methods such as detailed geomorphologic studies, mapping from remote sensing data and topographic maps, historical archive studies and interviews. In this study, satellite images and previous reports of Geological Survey of India are used as the main source for obtaining a multi-temporal landslide inventory.

3.1 Data Source

Landslides leave discernible signs on slopes, most of which can be recognized, classified and mapped in the field or from photo-interpretation (Varnes, 1978; Hansen, 1984). These signatures are mostly visible as morphological changes such as changes in slope type, break in slopes, hummocky surfaces, etc. These morphological signs are interpreted here to determine important landslide information such as type of failure, the surface area, cause and the run-out distance. Detailed and systematic field work was carried out to generate the 42-point attribute data for landslides.

Preparation of the landslide inventory commenced with the search of archival data sources, particularly published and unpublished reports of GSI. Besides, high resolution google imageries of different time periods (from 2002 to 2019) were used as the main sources for generating the multi-temporal landslide inventory.

3.2 Inventory Mapping

The following steps were used for mapping a landslide and building its inventory attribute.

- In google earth, every segment of the study area was viewed for all available time frames. As the study area falls under thick forest cover of Western Ghats, it is very difficult to identify landslides in Google imagery or Arc – GIS base map. Most of the slides are smaller in dimensions and should ideally be represented as a point on 1:50,000 scale. But for better representation, the slides were represented as polygons and in the process; few

slide dimensions were a little bit exaggerated. Once a landslide was identified, the same was digitized as a polygon.

- The mapped polygons were then saved as .kml file and later imported to Arc GIS, wherein they were stored as polygon shapefile or geodatabase with WGS 1984 UTM projection (43N).
- The landslide polygons were then corrected with the help of the ESRI base map. Any shift in the spatial location of the polygon, due to shift in the multi-temporal images of google earth data, were adjusted manually.
- For each landslide polygon, the attributes such as name, state, district, taluk, toposheet number, initiation and reactivation year based on dates of Google Earth images, slide type, slide material, length, width, surface area, cause, land use and element at risk was attached. Archival data were used for naming and defining the causes of the landslides.
- A systematic and detailed field check was carried out to validate the pre-field map at all the accessible locations. The morphological signatures left by landslides on slopes were used to identify the shape of landslides.
- After identifying the landslides in the field, the morphological parameters (landslide scar length, width and depth) were noted carefully after measuring them in the field using a meter tape. Additional data such as landslide type, run out distance, present land use – land cover, geology, regolith thickness, probable cause and damage details were also added to the inventory as per the 42 point geo parametric data sheets for landslides. The volume of mapped landslides was recalculated by multiplying the morphological parameters. Any new landslides identified were plotted in the topographic maps and were digitized as polygons and added in the existing geo-database of Arc GIS.

3.3 Spatial Distribution of Landslides 1851

In total, 21 landslides were identified during the pre-field mapping from previous GSI report inputs. But during the field work, four new landslides were observed in the field and the data were recorded as a part of the landslide inventory. All these landslides were present along different road sections in the study area. Landslides were classified as either “debris/earth slide”, “debris flows”, “rock slide” or “rock flows” following the classification proposed by Varnes (1978).

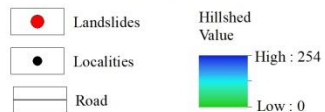
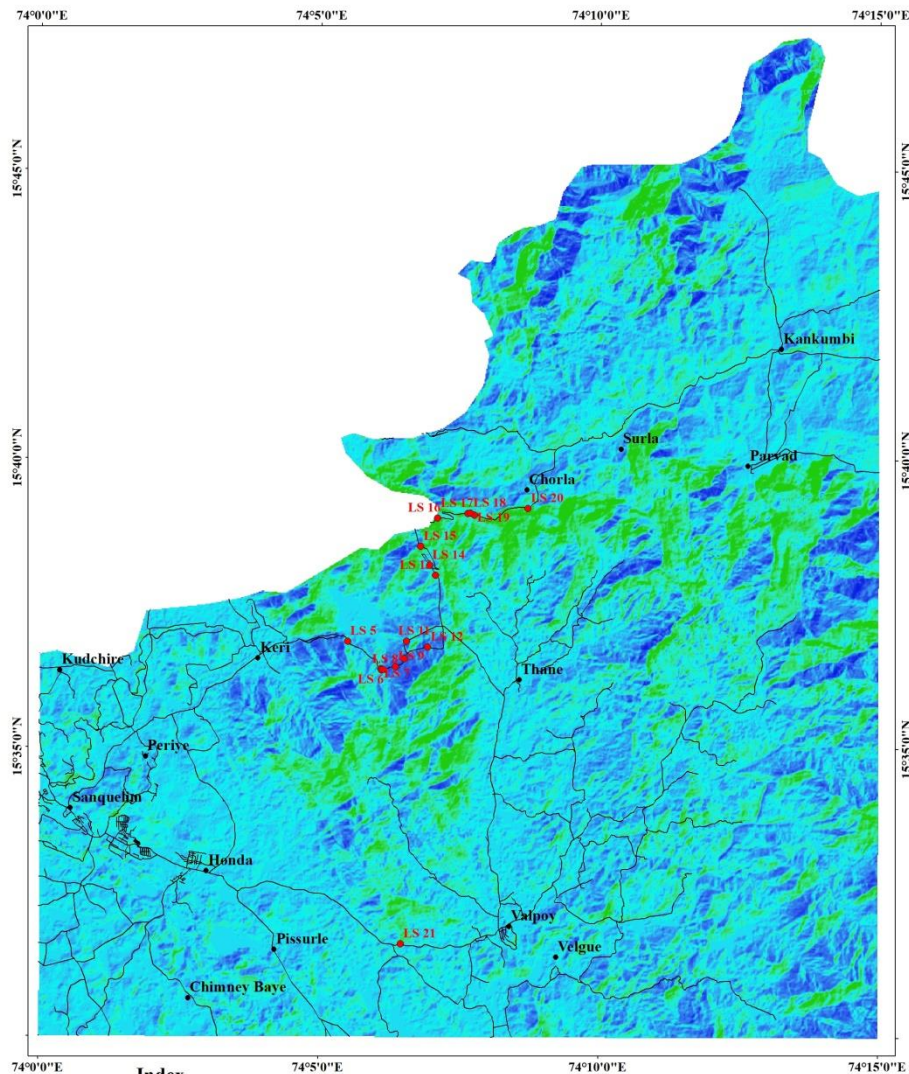
During the field work, 25 confirmed landslides were identified (refer: Fig 3.1. Majority of these landslides were located along the road and resulted as a combination of



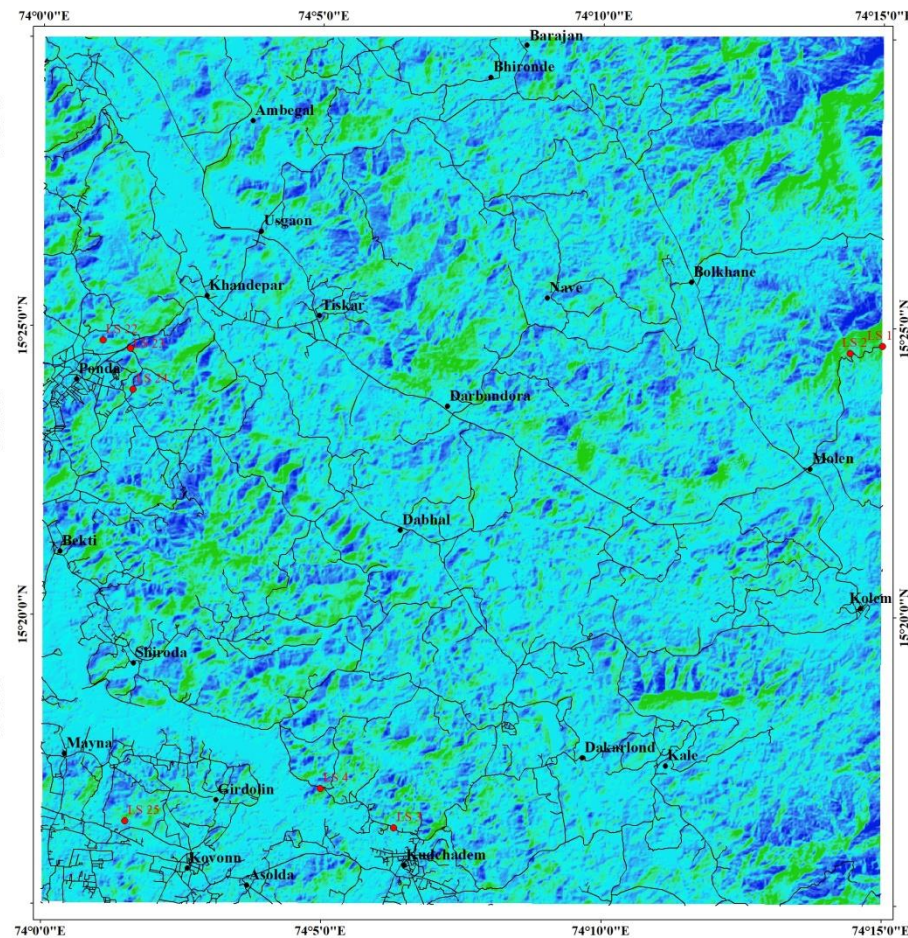
Landslide Inventory Map of parts of toposheet no. 48I/01, 02 & 03, Belagavi district of Karnataka and North Goa and South Goa district of Goa



0 2.5 5 10 15 20 km



Landslide No	Landslide Full Name	Landslide No	Landslide Full Name	Landslide No	Landslide Full Name
LS 1	GOA/SG/48I03/2019/01	LS 5	GOA/NG/48I02/2019/05	LS 9	GOA/NG/48I02/2019/09
LS 2	GOA/SG/48I03/2019/02	LS 6	GOA/NG/48I02/2019/06	LS 10	GOA/NG/48I02/2019/10
LS 3	GOA/SG/48I03/2019/03	LS 7	GOA/NG/48I02/2019/07	LS 11	GOA/NG/48I02/2019/11
LS 4	GOA/SG/48I03/2019/04	LS 8	GOA/NG/48I02/2019/08	LS 12	GOA/NG/48I02/2019/12



Landslide No	Landslide Full Name	Landslide No	Landslide Full Name	Landslide No	Landslide Full Name
LS 13	GOA/NG/48I02/2019/13	LS 17	GOA/NG/48I02/2019/17	LS 21	GOA/NG/48I02/2020/21
LS 14	GOA/NG/48I02/2019/14	LS 18	GOA/NG/48I02/2019/18	LS 22	GOA/SG/48I03/2020/22
LS 15	GOA/NG/48I02/2019/15	LS 19	GOA/NG/48I02/2019/19	LS 23	GOA/SG/48I03/2020/23
LS 16	GOA/NG/48I02/2019/16	LS 20	KAR/BEL/48I02/2019/20	LS 24	GOA/SG/48I03/2020/24
LS 25	GOA/SG/48I03/2020/25				

Prepared by:
Sunandan Basu, Geologist
Amar Jyoti Hatiboruah, Geologist

Fig. 3.1: Slope Angle Map of parts of toposheet no. 48I/01, 02 & 03, Belagavi district of Karnataka and North Goa and South Goa districts of Goa

removal of toe material for the construction of road and super saturation of overburden material during monsoons. Landslides caused under natural conditions are very rare. Most of the landslides are smaller in dimensions, initiated due to the slope cuts and were found to have no or very less run-out as the road provided a horizontal base for accumulation of the slide material (debris / rock).

The spatial distributions of mapped landslides are shown in Fig. 3.1. Table – 3.1 shows spatial distribution of the landslides, whereas detailed inventory of 25 landslides as per 42 point geo parametric data sheet are given as Annexure – II.

Table – 3.1: Spatial distribution of landslides

Sl. No	Landslide No	Latitude (N)	Longitude (E)	Locality
1	GOA/SG/48I03/2019/01	15° 24' 41.781"	74° 14' 59.304"	4.5 km north east of Molen
2	GOA/SG/48I03/2019/02	15° 24' 34.443"	74° 14' 24.362"	3.9 km north east of Molen
3	GOA/SG/48I03/2019/03	15° 16' 19.600"	74° 6' 17.500"	1.2 km north of Kudchedem
4	GOA/SG/48I03/2019/04	15° 17' 0.400"	74° 4' 58.900"	3.6 km north west of Kudchedem
5	GOA/NG/48I02/2019/05	15° 36' 51.019"	74° 5' 30.171"	2.9 km east of Keri
6	GOA/NG/48I02/2019/06	15° 36' 22.758"	74° 6' 5.865"	3.9 km east of Keri
7	GOA/NG/48I02/2019/07	15° 36' 21.252"	74° 6' 6.274"	3.9 km east of Keri
8	GOA/NG/48I02/2019/08	15° 36' 21.908"	74° 6' 8.024"	4 km east of Keri
9	GOA/NG/48I02/2019/09	15° 36' 24.978"	74° 6' 21.639"	4.4 km east of Keri
10	GOA/NG/48I02/2019/10	15° 36' 32.911"	74° 6' 31.085"	4.7 km east of Keri
11	GOA/NG/48I02/2019/11	15° 36' 51.149"	74° 6' 33.228"	4.8 km east of Keri
12	GOA/NG/48I02/2019/12	15° 36' 45.047"	74° 6' 56.090"	5.4 km east of Keri
13	GOA/NG/48I02/2019/13	15° 37' 59.598"	74° 7' 4.044"	4 km south west of Chorla
14	GOA/NG/48I02/2019/14	15° 38' 10.034"	74° 6' 57.804"	3.9 km south west of Chorla
15	GOA/NG/48I02/2019/15	15° 38' 29.730"	74° 6' 48.159"	3.8 km south west of Chorla
16	GOA/NG/48I02/2019/16	15° 38' 59.204"	74° 7' 6.323" E	2.9 km west of Chorla
17	GOA/NG/48I02/2019/17	15° 39' 4.215"	74° 7' 38.571"	2 km west of Chorla
18	GOA/NG/48I02/2019/18	15° 39' 4.397"	74° 7' 41.470"	1.9 km west of Chorla
19	GOA/NG/48I02/2019/19	15° 39' 2.204"	74° 7' 45.557"	1.8 km west of Chorla
20	KAR/BEL/48I02/2019/20	15° 39' 9.464"	74° 8' 43.013"	570 m south of Chorla
21	GOA/NG/48I02/2020/21	15° 31' 37.089"	74° 6' 28.117"	3.5 km west of Valpoi
22	GOA/SG/48I03/2020/22	15° 24' 45.463"	74° 1' 3.972"	1.5 km north east of Ponda

Sl. No	Landslide No	Latitude (N)	Longitude (E)	Locality
23	GOA/SG/48I03/2020/23	15° 24' 36.941"	74° 1' 33.252"	2 km north east of Ponda
24	GOA/SG/48I03/2020/24	15° 23' 54.166"	74° 1' 36.542"	1.8 km east of Ponda
25	GOA/SG/48I03/2020/25	15° 16' 25.863"	74° 1' 29.746"	2.9 km southeast of Mayna

3.3.1 Landslide along road sections

In the study area, 24 were identified along different road sections only. The root causes for these landslides were toe cutting of the slope, vertical or near vertical slope cuts which were left unsupported and became prone to failure during monsoons. Table – 3.2 shows the no. of landslides recorded along different road sections in the study area.

Table – 3.2: No. of landslides along different road sections

Sl. No	Road Section	No. of landslides	%
1.	Mollem - Anmod road (Anmod Ghat Section)	2	8.33
2.	Keri - Chorla road (Chorla Ghat Section)	16	66.67
3.	Sanverdam - Siroda road	2	8.33
4.	Honda - Valpoi road	1	4.17
5.	Borim - Ponda road (Ponda by pass road)	2	8.33
6.	Khandepar - Opa road	1	4.17

Keri - Chorla road (Chorla Ghat section) has encountered 16 landslides within approx. 22 km stretch. This road section is the worst effected by landslides among all the road sections in the study area.

Fig. 3.2: Pie diagram showing distribution of landslides along different road sections

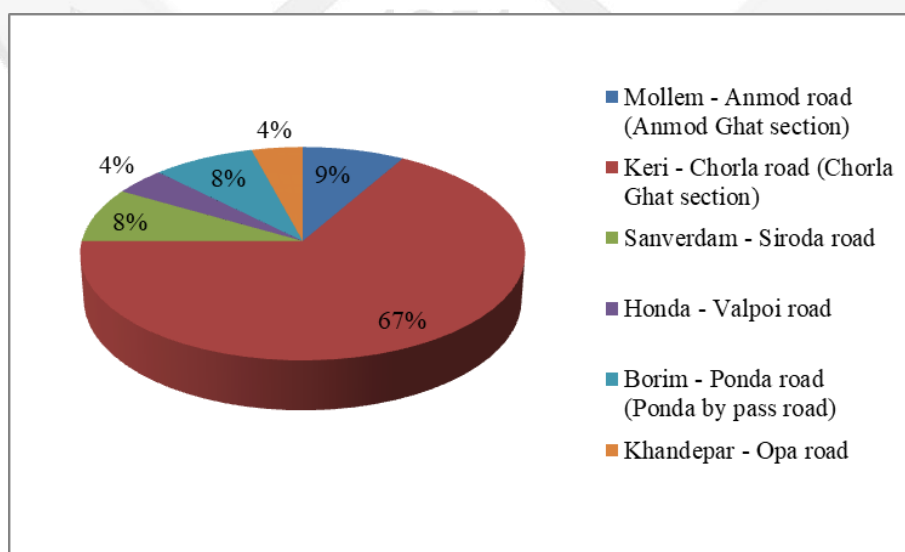




Fig. 3.3: Active debris slide along Sanverdam - Siroda road (slide Name: GOA/SG/48I03/2019/03).



Fig. 3.4: Reactivated debris slide along Chorla Ghat road (slide Name: GOA/NG/48I02/2019/13).



Fig. 3.5: Active debris slide along Chorla Ghat road (slide Name: GOA/NG/48I02/2019/15).



Fig. 3.6: Reactivated debris slide along Chorla Ghat road (slide Name: GOA/NG/48I02/2019/18).



Fig. 3.7: Active debris slide along Khandepar - Opa road near Opa water tank (slide Name: GOA/SG/48I03/2020/22).



Fig. 3.8: Reactivated debris slide along Borim - Ponda bypass road (slide Name: GOA/SG/48I03/2020/23).



Fig. 3.9: Active debris slide along Borim - Ponda bypass road (slide Name: GOA/SG/48I03/2020/23).

During field work, few places were observed along Keri - Chorla road (Chorla Ghat section) where Argillite is exposed along road section. Three prominent joint sets are present in the rock. The intersection of the joints along with the slope is forming wedge (refer: Fig. 3.10) in the rock mass and the plunge of the wedge is towards the road side. So, chances of rock fall due to wedge formation in the road cannot be ruled out. Table – 3.3 and Table – 3.4 shows the structural data of Argillite of these areas and location of tentative rock fall areas respectively.

Table – 3.3: *Structural data of Argillite in the probable rock fall areas*

Sl. No	Joint Set	Dip		Strike
		Amount	Direction	
1.	J1	24°	NW	075°
2.	J2	85°	NW	060°
3.	J3	Vertical	-	135°

Table – 3.4: Location of probable rock fall areas

Sl. No	Latitude (N)	Longitude (E)	Locality	Road Section
1.	15°38'32.26"	74°06'46.40"	North-east of Anjune Dam	Chorla Ghat
2.	15°38'58.15"	74°07'58.06"	South-west of Chorla	Chorla Ghat
3.	15°38'57.59"	74°08'02.98"	South-west of Chorla	Chorla Ghat

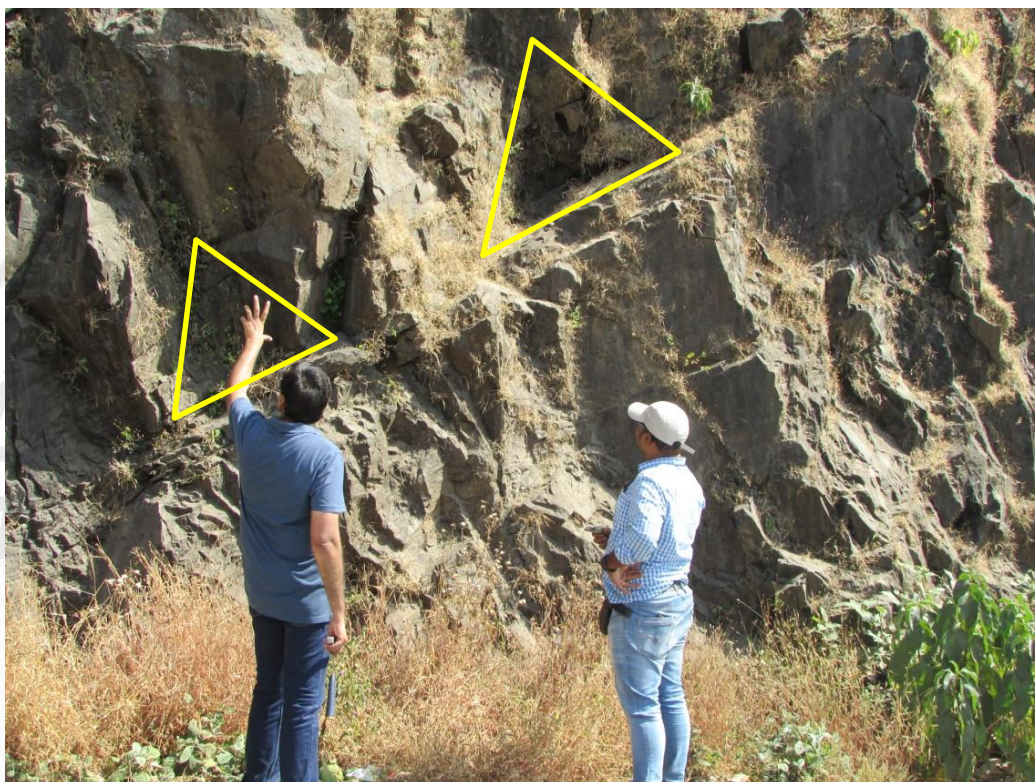


Fig. 3.10: Development of wedge structures in Argillite along Chorla Ghat section.

3.3.2 Landslide on natural slopes

In the study area, one landslide (GOA/SG/48I03/2020/25) was recorded along the natural slope near Mayna, South Goa district (refer: Fig. 3.11). The landslide was active earth slide, deep translational in nature. The geo-scientific cause of the landslide was super situation of the overburden material and higher regolith thickness.



Fig. 3.11: Active earth slide near Mayna (slide Name: GOA/SG/48I03/2020/25).

3.4 Classification of the landslides based of different parameters

The landslides were sub divided based on different parameters. The tables and figures below show brief classification of landslides.

Table – 3.5: Classification of landslides based on “Activity”

Sl. No	Type of Activity	No. of landslides	Percentage (%)
1.	Active	15	60
2.	Reactivated	6	24
3.	Dormant	4	16

Fig. 3.12: Pie diagram showing landslide classification based on “Activity”

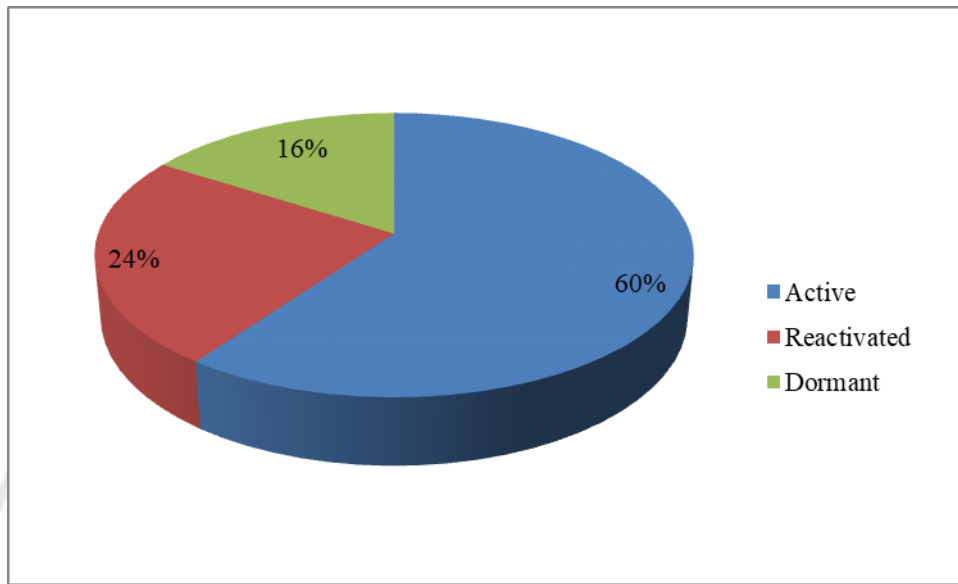
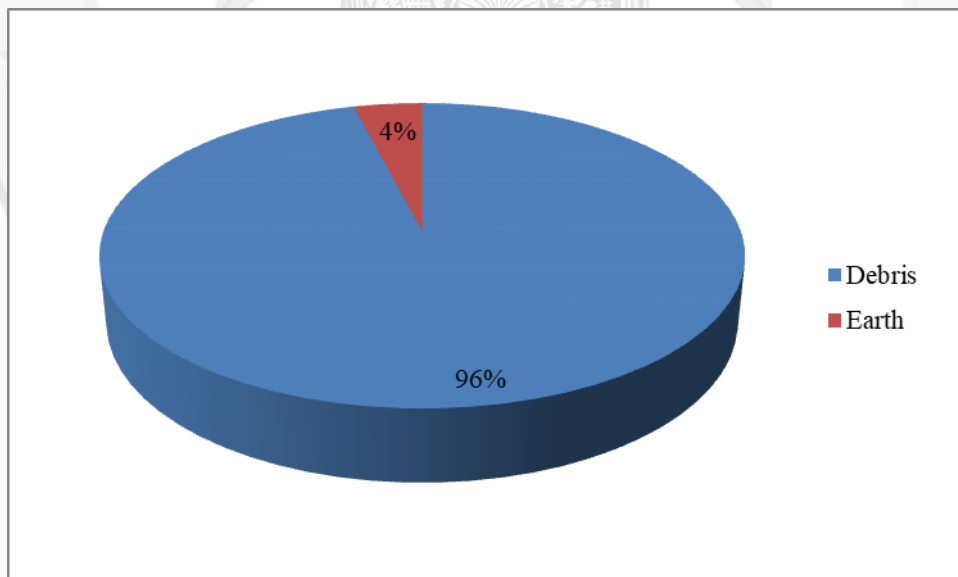


Table – 3.6: Classification of landslides based on “Material”

Sl. No	Type of Martial	No. of landslides	Percentage (%)
1.	Debris	24	96
2.	Earth	1	4

Fig. 3.13: Pie diagram showing landslide classification based on “Material”



Sl. No	Failure Depth	No. of landslides	Percentage (%)
1.	Shallow (<5m)	24	96
2.	Deep (>5m)	1	4

Fig. 3.14: Pie diagram showing landslide classification based on “Failure Depth”

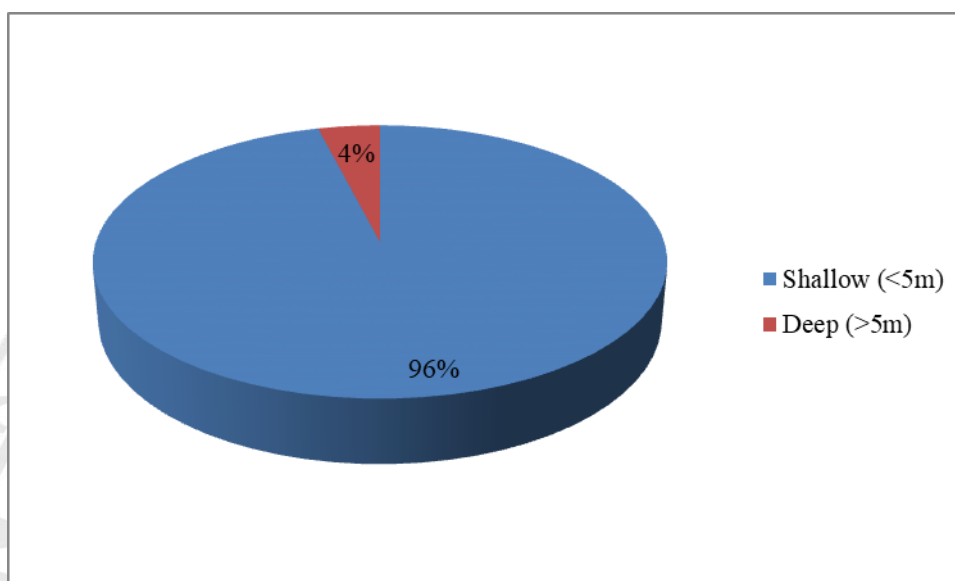


Table – 3.8: Classification of landslides based on “Movement Type”

Sl. No	Movement Type	No. of landslides	Percentage (%)
1.	Slide	25	100

CHAPTER – 4

LANDSLIDE SUSCEPTIBILITY ANALYSIS

This chapter deals with the material and methods of landslide susceptibility analysis using the Weighted Multiclass Index Overlay method, as recommended in the Standard Operating Procedure (SOP) of NLSM.

4.1 Background

Landslide susceptibility is a qualitative estimate of the spatial distribution of landslides, which exist or potentially may occur in an area. Although it is expected that landslides will occur more frequently in the most susceptible areas, however, in the susceptibility analysis, no time frame and magnitude of event are explicitly taken into account. A susceptibility map therefore gives only the qualitative estimation that the mapping unit (e.g., a pixel, slope unit or facet) will be affected by a future landslide source. Therefore, using the term “landslide hazard analysis” instead of “landslide susceptibility analysis”, for methods of spatial prediction of landslide-prone areas may not be correct.

In GIS based knowledge - driven methods such as Weighted Multiclass Index Overlay, individual ratings for geofactor classes and weights of geofactor were determined with the knowledge of the terrain and after discussion with the local experts. Once the initial ratings were fixed, LOFS was determined using Analytical Hierarchy Process (AHP) after preparing the pair wise qualitative comparison matrix of all factors (Saaty, 1977).

4.2 Selection of Preparatory Factors

For susceptibility mapping, the selection of preparatory factors for landslides depends on the scale of analysis, the characteristics of the study area, the landslide type, the failure mechanisms and prior knowledge of the main causes of landslides (Guzzetti et al., 1999; Glade and Crozier, 2005). A systematic overview of the important preparatory factors required for susceptibility mapping in different scales is given in van Westen et al. (2008). A prior knowledge of the main causes of landslides in the area of interest is essential in selecting the most relevant factor out of the many known preparatory factors that can “theoretically” cause landslides (Ghosh and Carranza, 2010).

In the study area, landslides were mostly debris slides along road corridors and the landslides were relatively smaller in dimension. Out of the six thematic maps, two were related to terrain morphometry derived from DEM and four were field based maps prepared

from remote sensing data. A brief description of the significance and mapping techniques for each factor is given below.

4.3 Thematic Layers

Landslides occur when the shearing stress along the failure plane exceeds the shearing strength of rock/debris mass (Varnes, 1978). This can be affected by the changes in various parameters such as i) physical state of slope such as slope angle and slope curvature, ii) lithology or physical characteristics of slope forming mass, iii) spatial variation in thickness of regolith, iv) geomorphological forms and processes, v) land use/cover including road and other physical features mappable on 1:50,000 scale. Based on the estimation of above pre-disposing geo-factors, the following factors and their possible factor classes are considered for preparation of geo-factor databases for the GIS-based analysis of landslide susceptibility. As per the data model, some of the geo-factor themes are categorical (e.g., geomorphology, land use - land cover etc.) and others represent continuous data (e.g., slope, curvature etc.). These spatial factor maps were prepared using various source data and employing different mapping techniques as detailed below.

4.3.1 Slope Morphometry

➤ Slope Angle

Slope Angle geofactor map had highest importance for NLSM modelling performed using Analytical Hierarchy Process (AHP). In the scale of 0 to 9, within the geofactors, this particular geofactor was given 9 weightage by the experts. A geofactor map having weightage 9 create very high impact on the final susceptibility map.

The slope angle map of the study area was derived from Carto DEM of 30 m resolution using Arc GIS platform. For depiction purpose, the slope map is finally reclassified into 5 classes (refer: Fig. 1.7).

The Slope angle of this area varies between 0° and 62° . 76.96% of the area were covered by gentle slope ($<15^{\circ}$), 17.10% of the were covered by slope between 15° to 25° , 4.68% of the area are covered by slope between 25° to 35° , high slope like 35° to 45° covers 1.11% area and only 0.14% area is covered by slope $>45^{\circ}$. The areas having slope between 25° to 35° were found to be most prone to slope failures. The slope angle classes, area coverage, rankings and LOFS (refer: Annexure - I) shown in Table – 4.1.

Table – 4.1: Slope angle classes with individual ranking and LOFS ratings

Sl. No	Slope Angle Class	No. of Pixels	Area (sq. km)	% Coverage	Ranking	LOFS
1.	> 15°	1121800	1009.62	76.96	4	0.16
2.	15° - 25°	249182	224.26	17.10	6	0.46
3.	25° - 35°	68256	61.43	4.68	8	1.00
4.	35° - 45°	16250	14.63	1.11	5	0.28
5.	> 45°	2071	1.86	0.14	4	0.16

➤ **Slope Curvature**

Slope Curvature geofactor map was of lowest importance for NLSM modelling performed using Analytical Hierarchy Process (AHP). In the scale of 0 to 9, within the geofactors, this particular geofactor was given 2 weightage by the expert. A geofactor map having weightage 2 create very low impact on the final susceptibility map.

Slope curvature was also derived from Carto DEM of 30 m resolution using Arc GIS platform. A positive curvature represents upwardly convex surface, while a negative curvature indicates that the surface is upwardly concave at a given pixel. The concave hill slopes are areas having high soil moisture content and receive more surface run-off but the overburden material is less or absent. Whereas most of the convex hill slope are having good amount of overburden material. So failures can be expected to occur more frequently in those convex hill slope areas than the slopes that are concave along the contour. The curvature maps were finally reclassified into three classes viz, concave, flat and convex (refer: Fig. 1.8). A total of 47.42 % of the map area is falling under concave and 45.36 % area comes under convex curvature slopes respectively, while only 7.22 % area falls under flat category. The slope curvature classes, area coverage, ranking and LOFS are shown in Table – 4.2.

Table – 4.2: Slope curvature classes with individual ranking and LOFS ratings

Sl. No	Slope Curvature Class	No. of Pixels	Area (sq. km)	% Coverage	Ranking	LOFS
1.	Concave	678896	611.01	46.58	4	0.41
2.	Flat	105076	94.57	7.21	2	0.17
3.	Convex	673587	606.23	46.21	6	1.00

4.3.2 Land use - Land cover (LULC)

Land use – Land cover (LULC) geofactor map had 2nd highest importance for NLSM modelling performed using Analytical Hierarchy Process (AHP). In the scale of 0 to 9, this particular geofactor was given 8 weightage by the experts.

A geofactor map having weightage 8, creates major impact on the final susceptibility map. So stepwise methodology was followed and necessary modifications were attended with utmost care before finalization of this map. The pre-field land use - land cover map was prepared from the multi temporal google earth imageries for periods ranging from 2014 to 2016, following the normal digitizing procedure in google earth. The scale level around 300 m was maintained for demarcating the boundaries of different classes.

The obtained pre-field LULC map was validated in the field at all accessible locations and all necessary corrections and modifications were carried out in the boundary and nomenclature of the LULC classes. During field work, total 25 landslides were mapped in the area and for 24 landslides; modifications of the slopes (extensive slope cut) were found to be the causative factor. Hence, it was very clear that land use - land cover geofactor had a major impact on the landslides of the area. Dimensions of the extensive slope cuts, at many places, were not mappable in a 1:50,000 scale. But as these extensive slope cut areas had major impact in the occurrences of landslides in this area, leaving these areas from the map due to scale constrains were not possible. Hence, the areas covered under extensive slope cut were mapped during the field work and the dimensions were exaggerated to represent these in a 1:50,000 scale map. This had at places resulted in inclusion of Moderate Vegetation / Thick Vegetation areas in extensive slope cut polygons. Knowingly this discrepancy has been ignored in order to highlight the importance of extensive slope cut polygon in localising landslides.

During post field stage, all the modifications / updations recorded during the field work were attended and the post field LULC map of the study area was prepared. Fig. 4.1 shows the final LULC map of the study area. The LULC classes, area of coverage for pre-field as well as post field maps, rankings and LOFS are shown in Table – 4.3.



Land Use Land Cover Map of parts of toposheet no. 48I/01, 02 & 03, Belagavi district of Karnataka and North Goa and South Goa district of Goa

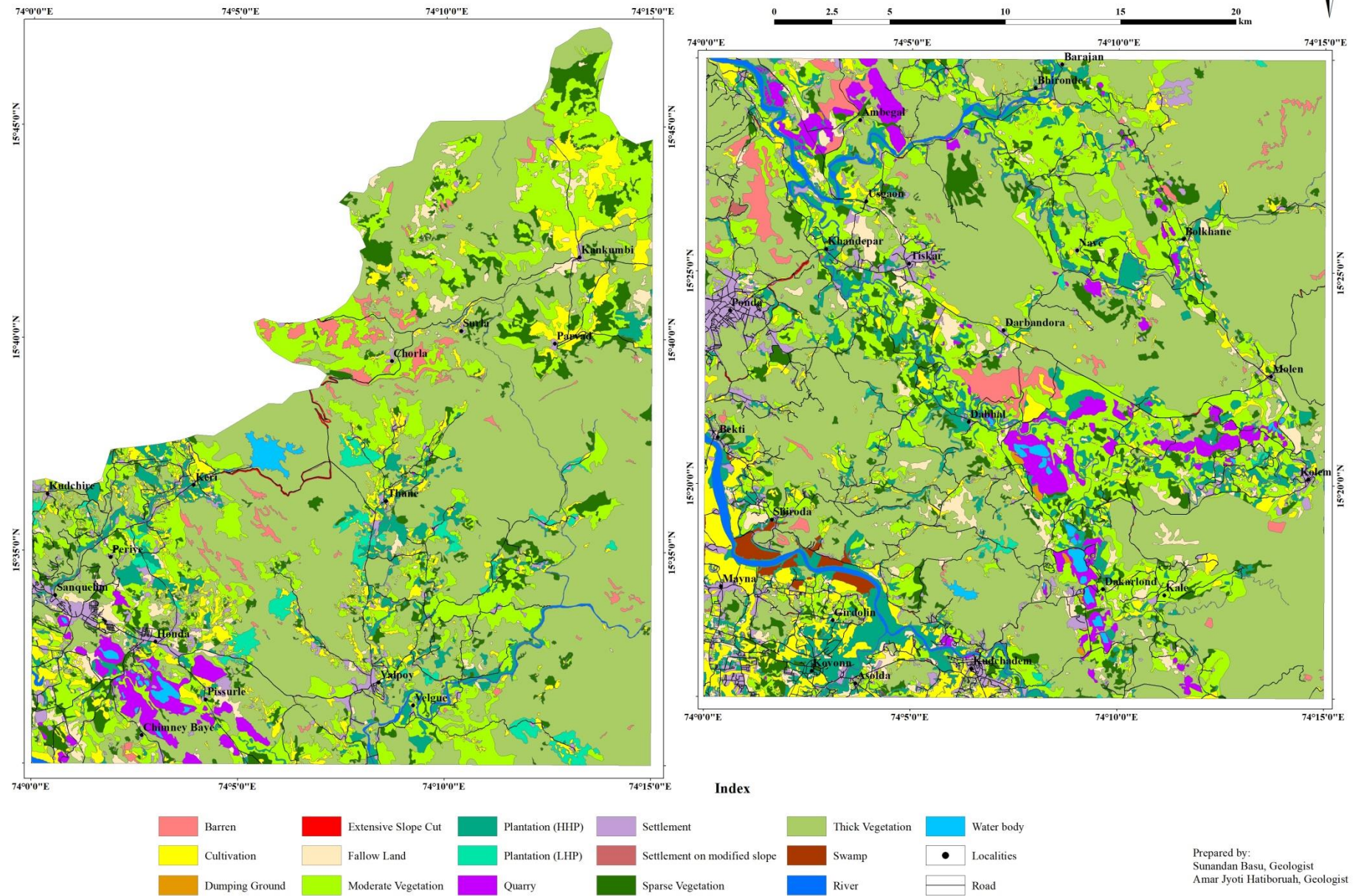


Fig. 4.1: Land Use Land Cover Map of parts of toposheet no. 48I/01, 02 & 03, Belagavi district of Karnataka and North Goa and South Goa districts of Goa

Table – 4.3: *LULC classes with individual ranking and LOFS ratings*

Sl. No	LULC Class	Pre-field map		Post field map		Ranking	LOFS
		Area (sq. km)	% Coverage	Area (sq. km)	% Coverage		
1.	Barren	19.31	1.47	24.06	1.83	1	0.06
2.	Cultivation	78.40	5.98	75.60	5.77	1	0.06
3.	Dumping Ground	0.00	0.00	0.63	0.05	6	0.36
4.	Extensive Slope Cut	0.00	0.00	1.47	0.11	9	1.00
5.	Fallow Land	39.82	3.04	40.96	3.12	1	0.06
6.	Moderate Vegetation	241.23	18.40	237.48	18.11	5	0.24
7.	Plantation (HHP)	77.68	5.92	77.52	5.91	4	0.17
8.	Plantation (LHP)	0.00	0.00	11.77	0.90	3	0.11
9.	Quarry	34.76	2.65	30.60	2.33	5	0.24
10.	River	14.92	1.14	15.09	1.15	0	0.00
11.	Settlement	40.36	3.08	40.65	3.10	1	0.06
12.	Settlement on modified slope	0.00	0.00	0.34	0.03	7	0.52
13.	Sparse Vegetation	83.91	6.40	70.43	5.37	7	0.52
14.	Swamp	1.57	0.12	3.76	0.29	0	0.00
15.	Thick Vegetation	676.83	51.61	674.62	51.45	4	0.17
16.	Water body	2.54	0.19	6.33	0.48	0	0.00

Brief description of the different land use land cover classes present in the study area are given below:

- **Barren:** The barren class in the study area refers to barren slopes with rock exposers (Fig. 4.2).
- **Cultivation:** Cultivation in the study area refers to agricultural lands. The different agricultural verities are rice, wheat and different vegetables.
- **Dumping Ground:** Dumping ground in the area refers to the waste dump areas of the iron manganese mines (Fig. 4.3).
- **Extensive Slope Cut:** Extensive Slope Cut in the study area refers to vertical to near vertical slope cuts along road sections (Fig. 4.4, Fig. 4.5 & Fig. 4.6). In some places, extensive slope cut was also observed adjacent to civil constructed modifying the hill slopes.



Fig. 4.2: Barren rocky slopes present in the north east of Anjune Dam.



Fig. 4.3: Dumping Ground present near Dhabal. The marking shows the loose unconsolidated nature of the mine dump materials.



Fig. 4.4: Extensive Slope Cut along Ponda – Molen road near Ponda. The height of the retaining structures should be increased.



Fig. 4.5: Extensive Slope Cut along Keri – Chorla road near Chorla.



Fig. 4.6: Extensive Slope Cut just behind the Sai Baba Temple at Borim.
Retaining structures should be provided to the unsupported slopes.

- **Fallow Land:** Fallow land in the study area refers to the land which is barren or left empty without any infrastructural development or forest cover or any other land use land cover classes (Fig. 4.7).
- **Plantation (HHP & LHP):** Plantation in the study area is of two types, i.e. high height plantation (HHP) and low height plantation (LHP). The HHP class refers to plantations like coconut, betel nut, acacia, eucalyptus etc. whereas LHP class refers to cashew plantation (Fig. 4.8 & Fig. 4.9).
- **Quarry:** Quarry in the study area refers to places from where mining activities were going on. Both the active and abandoned mining areas were considered under this class (Fig. 4.10).
- **Settlement:** Settlement in the study area refers to the clusters of houses / villages / townships where people live.
- **Settlement on modified slope:** Settlement on modified slope in the study area refers to any houses / cluster of houses that are constructed modifying the natural hill slopes (Fig. 4.11).



Fig. 4.7: Fallow land near Darbandora.



Fig. 4.8: Betel Nut Plantation (HHP) near Thane.



Fig. 4.9: Cashew Nut Plantation (LHP) near Pariye.



Fig. 4.10: Quarry section near Ambegal.



Fig. 4.11: Settlement on modified slope near Mayna.

- **Swamp:** Swamp in the study area refers to low lying uncultivated wetlands where flood waters of river comes into the land (refer: Fig. 4.12).
- **Vegetation (Sparse, Moderate and Thick):** Vegetation in the study area was of three types, i.e. sparse vegetation (Fig. 4.13), moderate vegetation and thick vegetation (Fig. 4.14). This demarcation from sparse to moderate to thick vegetation is based on the density of the vegetation in the increasing order.



Fig. 4.12: Swampy area near Shiroda.



Fig. 4.13: Sparse Vegetation near Kale.



Fig. 4.14: Thick Vegetation near Ponda along Ponda – Borim bypass road.

4.3.3 Geomorphology

Geomorphology geofactor map had moderate importance for NLSM modelling performed using Analytical Hierarchy Process (AHP). In the scale of 0 to 9, within the geofactors, this particular geofactor was given 4 weightage by the experts. A geofactor map having weightage 4 create a moderate impact on the final susceptibility map.

The pre-field geomorphology map was prepared from google earth imagery following normal digitizing procedure in google earth. The scale level of around 900 m was maintained for demarcating the boundaries of different classes. Different geomorphological landforms observed in the present study area are structural hill situated mostly in the northern, north eastern and eastern part of the study area as Lowly Dissected Slope and Highly Dissected Slope. Apart from the hilly areas, central, western and southern part of the study area is mostly Rolling Plain, i.e. slightly undulating surface and hence do not have direct impact on occurrences of landslides. Within the geomorphology classes, the areas with highly dissected slope were found to be most prone to landslides.

The obtained pre-field geomorphology map was validated in the field at all accessible locations and all necessary correction and modifications were carried out in the boundary and nomenclature of the geomorphology class. In this way the post field geomorphology map of



Geomorphology Map of parts of toposheet no. 48I/01, 02 & 03, Belagavi district of Karnataka and North Goa and South Goa district of Goa

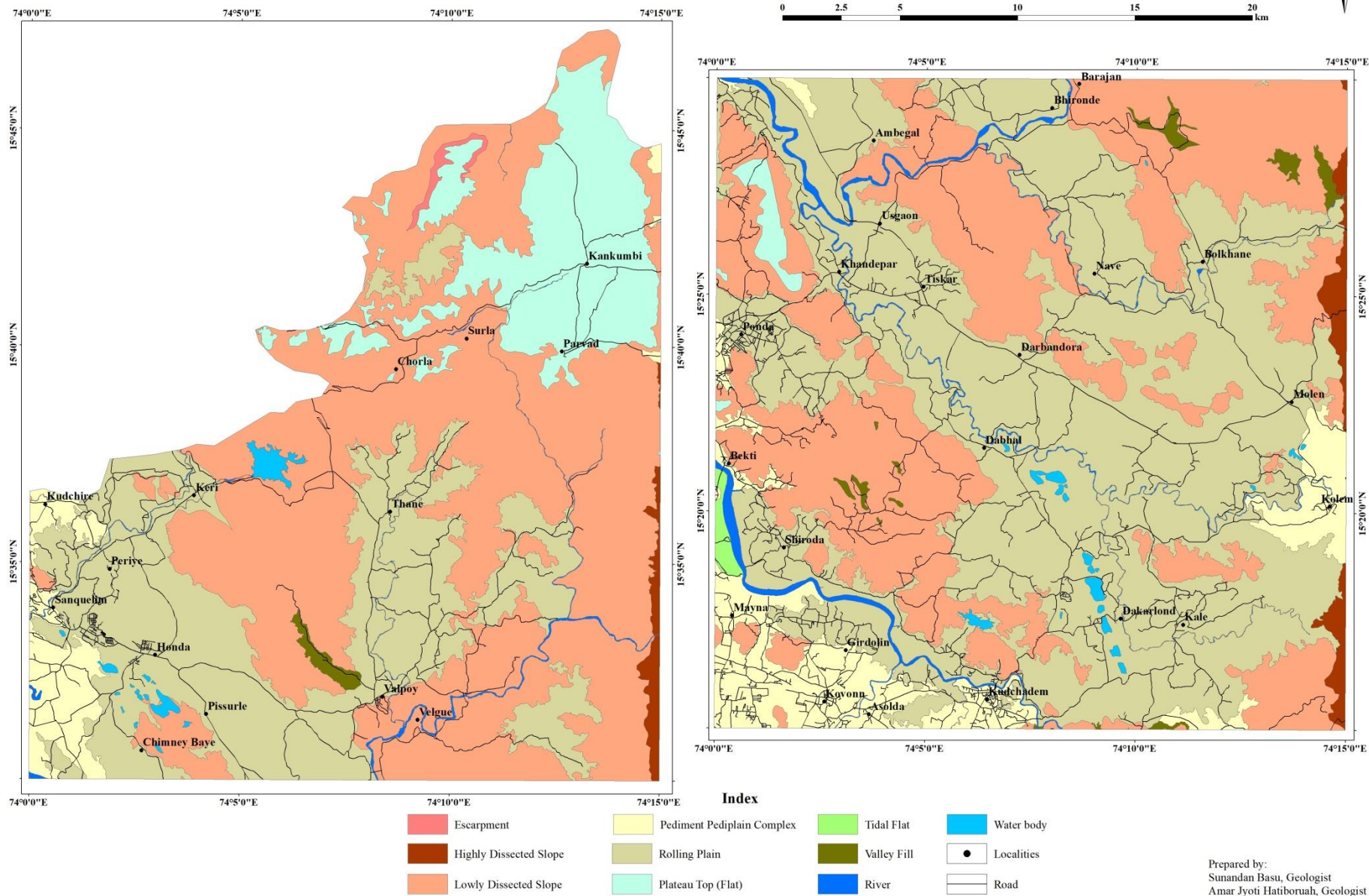


Fig. 4.15: Geomorphology Map of parts of toposheet no. 48I/01, 02 & 03, Belagavi district of Karnataka and North Goa and South Goa districts of Goa

the study area was updated and finalized. Fig. 4.15 shows the final geomorphology map of the study area. The geomorphology classes, area of coverage for pre-field as well as post field maps, rankings and LOFS are shown in Table – 4.4.

Table – 4.4: Geomorphology classes with LOFS ratings

Sl. No	Geomorphology Class	Pre-field map		Post field map		Ranking	LOFS
		Area (sq. km)	% Coverage	Area (sq. km)	% Coverage		
1.	Escarpment	1.84	0.14	1.95	0.15	2	0.11
2.	Highly Dissected Slope	0.00	0.00	14.42	1.10	8	1
3.	Lowly Dissected Slope	872.75	66.56	537.71	41.01	4	0.27
4.	Pediment Pediplain Complex	0.00	0.00	82.94	6.32	0	0.00
5.	Plateau Top (Flat)	81.62	6.22	79.72	6.08	0	0.00
6.	River	14.92	1.14	15.09	1.15	0	0.00
7.	Rolling Plain	330.92	25.24	563.30	42.96	0	0.00
8.	Tidal Flat	0.00	0.00	2.38	0.18	0	0.00
9.	Valley Fill	6.73	0.51	7.47	0.57	0	0.00
10.	Water body	2.54	0.19	6.33	0.48	0	0.00

Brief description of different geomorphology classes present in the study area are given below:

Escarpment: Escarpment in the study area refers to high angle hill slopes ($>45^\circ$) which are most of the cases barren rock slopes in nature.

Dissected Slope (Lowly and Highly): The dissected hill slopes in the study area are of two types i.e. lowly dissected slope (Fig. 4.16) and highly dissected slope. This demarcation from low to high is based on the intensity dissections on hill slope in the increasing order.

Rolling Plain: Rolling plain in the study area refers to undulating plains / cluster of small mounds which cannot be mapped separately in 1:50000 scale (Fig. 4.17).

Pediment Pediplain Complex: Pediment pediplain complex (refer: Fig. 4.18) in the study area refers to combination of very gently sloping ($5^\circ - 7^\circ$) bedrock surfaces near the foothill area (pediments) and an extensive plain formed by the coalescence of pediments (pediplain).

Plateau Top (Flat): Plateau Top (Flat) in the area refers to high plains or tablelands usually consisting of relatively flat terrain and raised significantly above the surrounding area (Fig. 4.19).



Fig. 4.16: Lowly Dissected Slope near Anjune Dam.



Fig. 4.17: Rolling Plain near Tiskar.



Fig. 4.18: Pediment Pediplain Complex near Kavonn.



Fig. 4.19: Plateau Top (Flat) near north of Ponda.

Tidal Flat: Tidal flats are coastal wetlands that form in intertidal areas where sediments have been deposited by tides or rivers.

Valley Fill: Valley fill in the study area refers to the valley areas surrounded by hills from different sides and filled by the materials came down from the upslope of the hills.

4.3.4 Slope Forming Material (SFM)

Slope Forming Material (SFM) geofactor map has 3rd highest importance for NLSM modelling performed using Analytical Hierarchy Process (AHP). In the scale of 0 to 9, within the geofactors, this particular geofactor is given 6 weightage by the experts. A geofactor map having weightage 6 creates a relatively high impact on the final susceptibility map.

The pre-field SFM map was prepared from proxies from LULC, Geomorphology, Geological map and few inputs from google earth imagery and Arc-GIS base map.

The obtained pre-field SFM map was validated in the field at all accessible locations and all necessary correction and modifications were carried out in the boundary and nomenclature of the SFM class. In this way the final SFM map of the study area was prepared. Fig. 4.21 shows the final SFM map of the study area. The SFM classes, area of coverage for pre-field as well as post field maps, rankings and LOFS are shown in Table – 4.5.

Table – 4.5: SFM classes with LOFS ratings

Sl. No	SFM Class	Pre-field map		Post field map		Ranking	LOFS
		Area (sq. km)	% Coverage	Area (sq. km)	% Coverage		
1.	In-situ soil	1191.61	90.87	1129.47	86.133	4	0.41
2.	Transported Soil	6.73	0.51	12.17	0.928	3	0.25
3.	Weathered Rock	0.00	0.00	1.02	0.078	6	1.00
4.	Argillite	95.52 (Mapped as “Rock”)	7.28 (Mapped as “Rock”)	4.66	0.356	4	0.41
5.	Banded iron formation			9.04	0.689	1	0.11
6.	Basalt flow-undifferentiated			3.83	0.292	4	0.41
7.	Dolerite			0.05	0.004	1	0.11
8.	Dunite			1.10	0.084	4	0.41
9.	Gabbro			0.25	0.019	1	0.11
10.	Granite gneiss			10.03	0.765	1	0.11
11.	Granite(Chandranath)			0.28	0.021	1	0.11
12.	Laterite			80.11	6.109	4	0.41
13.	Limestone			0.15	0.011	1	0.11

Sl. No	SFM Class	Pre-field map		Post field map		Ranking	LOFS
		Area (sq. km)	% Coverage	Area (sq. km)	% Coverage		
14.	Manganiferous phyllite	95.52 (Mapped as “Rock”)	7.28 (Mapped as “Rock”)	0.01	0.001	4	0.41
15.	Metabasalt			0.36	0.027	1	0.11
16.	Peridotite			0.07	0.005	4	0.41
17.	Quartz-chlorite schist			32.52	2.480	4	0.41
18.	Quartzite			0.43	0.033	1	0.11
19.	Talc-chlorite schist			0.17	0.013	4	0.41
20.	Tidal Mud	0.00	0.00	4.17	0.318	0	0.00
21.	River	14.92	1.14	15.09	1.151	0	0.00
22.	Water body	2.54	0.19	6.33	0.482	0	0.00



Fig. 4.20: In-situ soil present as slope forming material near Ponda.



Slope Forming Material Map of parts of toposheet no. 48I/01, 02 & 03, Belagavi district of Karnataka and North Goa and South Goa district of Goa

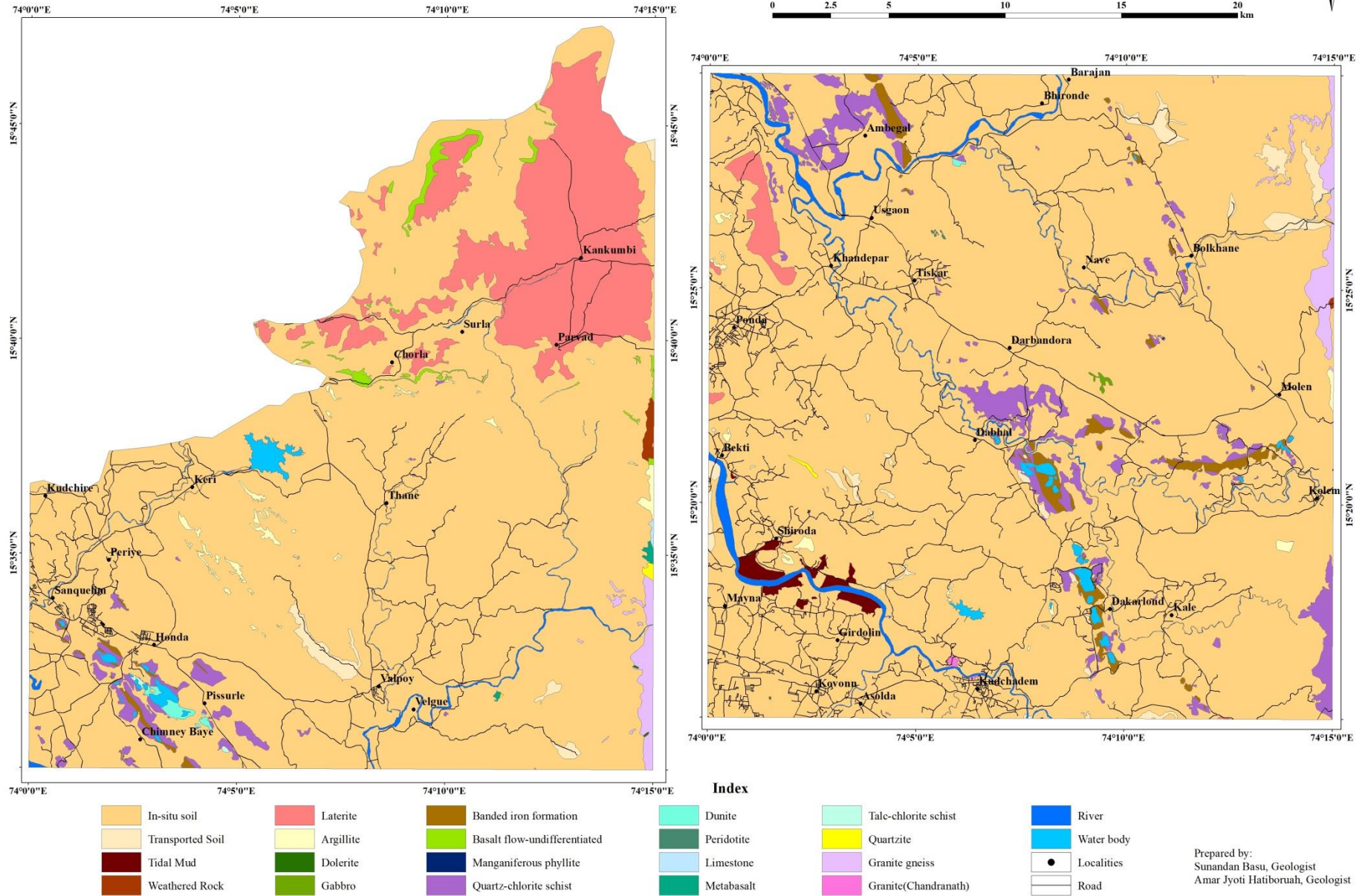


Fig. 4.21: Slope Forming Material Map of parts of toposheet no. 48I/01, 02 & 03, Belagavi district of Karnataka and North Goa and South Goa districts of Goa

4.3.5 Regolith Thickness

Regolith Thickness geofactor map is of moderate importance for NLSM modelling performed using Analytical Hierarchy Process (AHP). In the scale of 0 to 9, within the geofactors, this particular geofactor is given 4 weightage by the expert. A geofactor map having weightage 4, creates a moderate impact on the final susceptibility map.

The pre- field Regolith Thickness map was prepared from proxies from LULC, Geomorphology, Contour, Slope map and few inputs were also taken from google earth imagery.

The obtained pre- field Regolith Thickness map was validated in the field in all accessible locations and all necessary corrections and modifications were carried out in the boundary and nomenclature of the Regolith Thickness class. In this way the post field Regolith Thickness map of the study area was prepared. Fig. 4.22 shows the final Regolith Thickness map of the study area. The Regolith Thickness classes, area of coverage for pre-field as well as post field maps, rankings and LOFS are shown in Table – 4.6.

Table – 4.6: *Regolith Thickness classes with LOFS ratings*

Sl. No	Regolith Thickness Class	Pre-field map		Post field map		Ranking	LOFS
		Area (sq. km)	% Coverage	Area (sq. km)	% Coverage		
1.	< 0.5 m	95.52	7.28	143.18	10.92	0	0.00
2.	0.5 – 5 m	1198.34	91.38	1113.30	84.90	7	1.00
3.	5 – 10 m	0.00	0.00	27.49	2.10	4	0.32
4.	> 10 m	0.00	0.00	5.93	0.45	2	0.14
5.	River	14.92	1.14	15.09	1.15	0	0.00
6.	Water body	2.54	0.19	6.33	0.48	0	0.00



Regolith Thickness Map of parts of toposheet no. 48I/01, 02 & 03, Belagavi district of Karnataka and North Goa and South Goa district of Goa

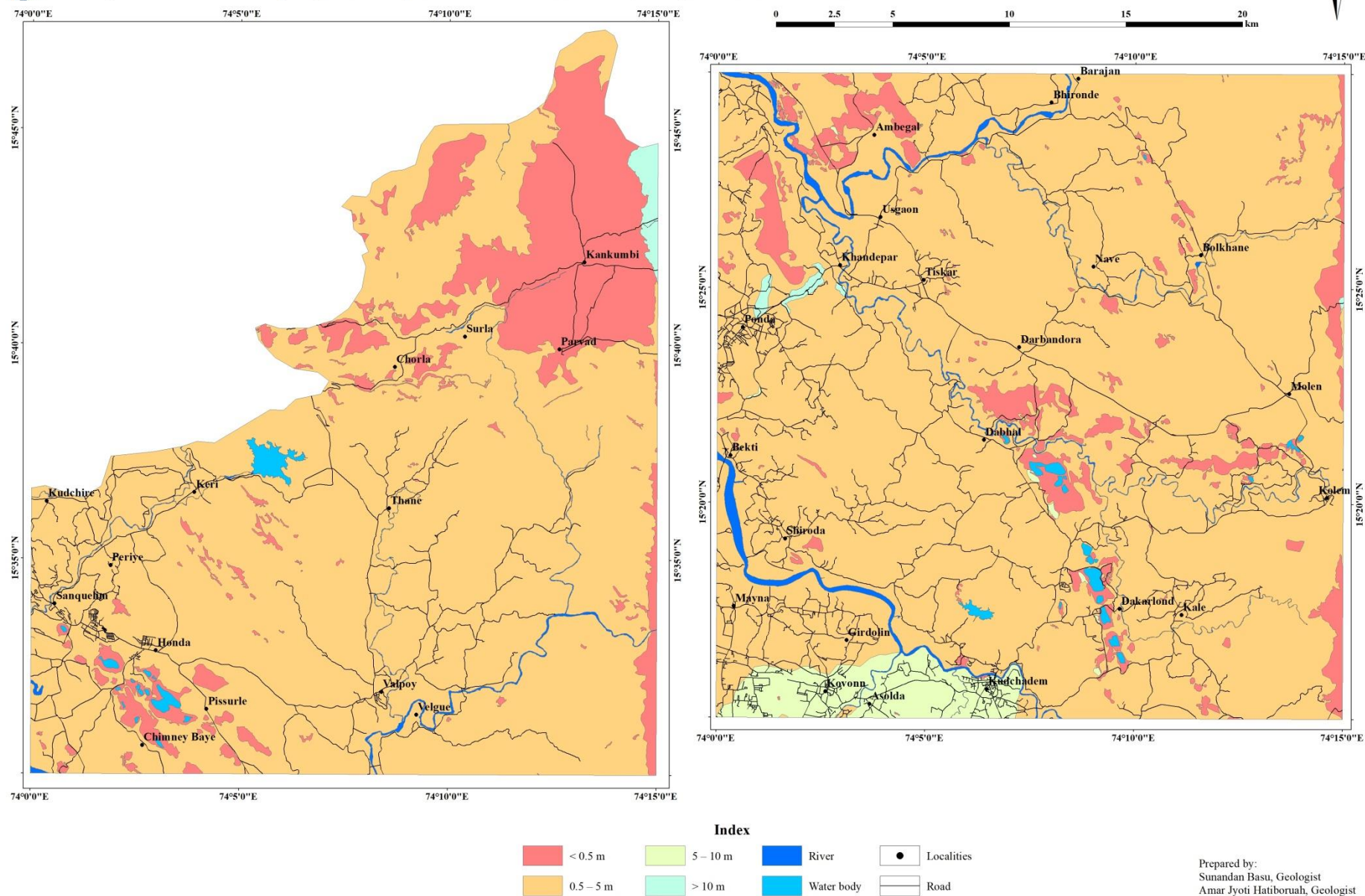


Fig. 4.22: Regolith Thickness Map of parts of toposheet no. 48I/01, 02 & 03, Belagavi district of Karnataka and North Goa and South Goa districts of Goa



Fig. 4.23: Regolith Thickness $<0.5\text{m}$ in north east of Molen along Anmod Ghat section.



Fig. 4.24: Regolith Thickness $0.5 - 5\text{ m}$ near Chorla along Chorla Ghat section.



Fig. 4.25: Regolith Thickness >10 m near Ponda.

4.4 Landslide Susceptibility Analysis

4.4.1 Procedure

Susceptibility is the propensity of an area to generate landslides. In mathematical form, landslide susceptibility is the probability of spatial occurrence of known slope failures, given a set of geo-environmental conditions (Guzzetti et al., 2005). In this study, a qualitative landslide susceptibility map was prepared by using the Weighted Multi-class Index Overlay method, as recommended in the SOP of NLSM.

The landslide susceptibility modelling can be divided into the following main themes:

- Preparation of landslide inventory and geofactor maps and preparation of GIS-based database of the geofactor maps.
- All the thematic maps were converted to raster keeping field as “class” and output cell size as “50” (as NLSM is a 1:50,000 scale mapping) in Arc-GIS software.
- Heuristic (knowledge driven) technique modelling requires fixation of individual ratings for geofactor classes and weights of geofactors for the entire area. So, these initial ratings

for geofactor classes and weights of geofactors are fixed with the knowledge of terrain and after discussion with experts.

- Once all the ratings for geofactor classes and weights of geofactors were fixed, LOFS was calculated using pair wise comparison matrix and fraction rating.
- After calculation of LOFS for all the geofactor classes, LOFS maps of the geofactors were prepared using GIS software.
- Once all the LOFS maps were prepared, raw landslide susceptibility score map was prepared using weighted multi class index overlay method in GIS software.
- After raw landslide susceptibility score map was prepared, a classified landslide susceptibility map was prepared and determination of break values were carried out by assigning weightage (30% is the boundary between low to moderate susceptibility and 50% is the boundary between moderate to high susceptibility).

4.4.2 Selection of Mapping Unit

After the selection of appropriate preparatory factors, the next step was selection of mapping units for the GIS based susceptibility analysis and for selecting a mapping unit importance must be given to the type of landslides in the area, mapping scale and scope of the work.

In this study, the mapping scale is 1:50,000 and preparing slope-units at this scale often do not match with the local geo-environmental setting related to slope instability. One way to overcome this is to resize the slope-units according to the present landslide size by partitioning a river basin into nested subdivisions, coarser for larger landslides and finer for smaller failures (Guzzetti et al., 1999). But, for application purposes this approach is not suitable for small and shallow landslides (Montgomery and Dietrich, 1994). Furthermore, even with GIS it is still difficult to manually digitize irregular mapping units of a very small size e.g., the slope unit of area < 1000 sq. m.

Therefore, in this work, a *pixel* was selected as the basic mapping unit for the susceptibility modelling so that the smallest landslide can be represented by a single pixel. Further, it will support the minimum resolution of Carto DEM which is also of 30 m resolution. As an additional advantage, a pixel based mapping unit can facilitate very fast computation and processing of the raster data set in GIS and it is also the commonly used unit in the raster based analysis (Carrara et al., 1992). Hence, the 1500 sq. km study area was converted into an equal-area grid by rasterizing the polygon map using a 50 m X 50 m pixel size. But as the slope angle difference is relatively lesser in Southern India compared to the Himalayas, to get

precise coarse resolution in Slope Angle and Slope Curvature map, the slope morphometry maps were prepared from its original 30 m X 30 m pixel resolution.

4.4.3 Landslide Occurrence Favourability Score (LOFS)

Landslides on a particular place depend on interaction between various geofactors. In the present study area, for a qualitative landslide susceptibility analysis, for modelling, Multi Class Index Overlay Method was adopted using heuristic (knowledge driven) techniques. In heuristic (knowledge driven) technique, individual ratings for geofactor classes and weights of geofactors were determined with the knowledge of the terrain and after discussion with the local experts. Once the initial ratings were fixed, Landslide Occurrence Favourability Score (LOFS) was determined using Analytical Hierarchy Process (AHP) after preparing the pair wise qualitative comparison matrix of all factors (Saaty, 1977).

For determination of LOFS using AHP, for each geofactor one comparison matrix was calculated for the pair wise qualitative comparison of all the geofactor sub classes. In the comparison matrix, fraction rating was calculated for all the geofactor sub classes. Once all the fraction ratings were determined, maximum value within the fraction ratings was identified. Then all the fraction rating values were divided with the maximum fraction rating value to determine the LOFS for the geofactor sub classes. In this way, as the fraction ratings were divided with the maximum fraction rating value, the LOFS values were arranged in ascending order (refer: Annexure – I).

4.4.4 Integration of Data

Fig. 1.16 shows the steps followed in this analysis for calculating the factor class ratings and inter predictor weights of factor maps using AHP.

- Following the methodological process shown in Fig. 1.15, all the maps such as LULC, Geomorphology, SFM and Regolith Thickness were digitized as a polygon shape file and converted into raster maps keeping output cell size as 50m × 50m.
- The Carto DEM derivatives such as slope angle and slope curvature were reclassified into categorical variables. Slope angle map was reclassified into five classes (<15°, 15° to 25°, 25° to 35°, 35° to 45° and >45°), whereas slope curvature map was reclassified into three classes (concave, flat and convex).
- For each geofactor class, Landslide Occurrence Favourability Score (LOFS) was determined using a pair wise comparison matrix.

- Once the LOFS values for geofactor sub classes were determined, all the LOFS values against the sub classes were compiled. Then the LOFS attributes were joined in the raster map attribute table. Finally LOFS map of the geofactor was prepared in GIS, using raster map of the geofactor as “input raster” and “geofactor_LOFS\$.LOFS” as lookup field.
- For determination of Predictor Weight for the geofactor, one comparison matrix was calculated for the pair wise qualitative comparison of all the geofactors. In the comparison matrix, fraction weights were calculated for all the geofactors. Once all the fraction weights were determined, minimum value within the fraction ratings was identified. Then all the fraction weight values were divided with the minimum fraction weight value to determine the Predictor Weight or weight of geofactors. In this way, as the fraction weights were divided with the minimum fraction weight value, the Predictor Weight or weight values will be one or more than one. For each geofactor, consider the nearest whole number as its Predictor Weight or weight.
- Raw Landslide Susceptibility Score Map in GIS, was generated using the formula -

$$\text{Susc Score} = (\text{LOFS_Factor1} * \text{weight of Factor1} + \text{LOFS_Factor2} * \text{weight of Factor2} + \text{LOFS_Factor3} * \text{weight of Factor3} + \dots + \text{LOFS_Factor}_n * \text{weight of Factor}_n) / \text{Sum of inter - predictor weight}.$$
- In this type of knowledge-driven models, classification break values can be determined on the basis of the logic applied while giving mutual comparison expert driven ranking. It is always thought by any expert that rank value for any factor class is ≥ 5 , and it was considered that the particular factor class had higher likelihood in influencing the landslides. This rank value of “5” in a scale of “0” to “9” comes after 50% of the absolute difference values ($9-0 = 9$; 50% of 9 is 4.5). That is why this 50% cut-off margin or weightage was used to determine the break raster value between “Moderate” and “High” susceptibility classes (*BrMH*). Similarly, when rank value for any factor class is ≤ 3 (lower than 30% of the absolute difference value of 9), and it was considered that the particular geofactor class had lesser likelihood in influencing any landslides. Accordingly, 30% cut-off margin or weightage was used to determine the break values between “Low” and “Moderate” susceptibility classes (*BrLM*).

Using the above logic the required break values were determined by solving the following formula:

BrMH = [(Abs Diff LOFS Factor1*50)*weight of Fcator1 + (Abs Diff LOFS Factor2*50)*weight of Fcator2 + (Abs Diff LOFS Factor3*50)*weight of Fcator3 + + (Abs Diff LOFS Factor_n*50)*weight of Fcator_n] / Sum of inter – predictor weight

BrLM = [(Abs Diff LOFS Factor1*30)*weight of Fcator1 + (Abs Diff LOFS Factor2*30)*weight of Fcator2 + (Abs Diff LOFS Factor3*30)*weight of Fcator3 + + (Abs Diff LOFS Factor_n*30)*weight of Fcator_n] / Sum of inter – predictor weight

- Once break values (BrMH and BrLM) were calculated, Classified Landslide Susceptibility Map was prepared by reclassifying the Raw Landslide Susceptibility Score Map. For reclassification, three classes were chosen and in break values, 2nd topmost value was given as the first value (Class 1), 1st topmost value was given as the second value (Class 2) and third value (Class 3) was given as one. Now the Raw Landslide Susceptibility Score Map was classified into the following categories: Class 1 stands for “Low Susceptibility”, Class 2 stands for “Moderate Susceptibility” and Class 3 stands for “High Susceptibility”.

CHAPTER – 5

LANDSLIDE SUSCEPTIBILITY MAP

5.1 Landslide Susceptibility Map

The landslide susceptibility map (refer: Fig. 5.1) of parts of toposheet nos. 48I/01, 48I/02 and 48I/03 was prepared using weighted multiclass index overlay method. The susceptibility is expressed in terms of the relative proneness to initiation of a landslide in a pixel (the mapping unit) under the given geo-environmental conditions. Table – 5.1 shows the area coverage (pixel and sq. km) with percentage of different susceptibility classes for the area.

Table – 5.1: Landslide Susceptibility classes with area coverage (pixel and sq. km)

Sl. No	Landslide Susceptibility Class	No. of Pixels	Area (sq. km)	% Coverage
1.	Low	326264	816	62.23 (~62)
2.	Moderate	171292	428	32.67 (~33)
3.	High	26733	67	5.10 (~5)

In the area, 62 % area falls under low susceptibility class, 33 % area falls under moderate susceptibility class whereas only 5 % area falls under high susceptibility class.

The majority of the areas situated in the north eastern, western and southern parts fall under low susceptibility class with small patches of areas with moderate and high susceptibility classes within it. On the other hand, areas situated in the northern, eastern, central and south western parts fall under moderate susceptibility class with considerable patches of areas having high susceptibility class within it. Almost all the major localities of the area like Ponda, Darbandora, Molen, Kolem, Kudchedem, Shiroda, Usgaon, Sanquelim, Honda, Keri, Kankumbi comes under low susceptibility class. Localities like Valpoy, Chorla, Surla comes under moderate susceptibility class. No major locality of the area falls under high susceptibility class. One important road corridor i.e. Keri – Chorla stretch (National Highway – 4) (Chorla Ghat) road section falls mostly under moderate to high susceptibility class.

The spatial distribution of the susceptibility classes in the area provides a very clear indication. In the landslide susceptibility modelling, the slope angle, land use – land cover and geomorphology map had major role in generation of the final landslide susceptibility map. The north eastern, western and southern part of the area is having relatively gentle topography and falls under dominantly low susceptibility class. Slope angle wise majority of



Landslide Susceptibility Map of parts of toposheet no. 48I/01, 02 & 03, Belagavi district of Karnataka and North Goa and South Goa district of Goa

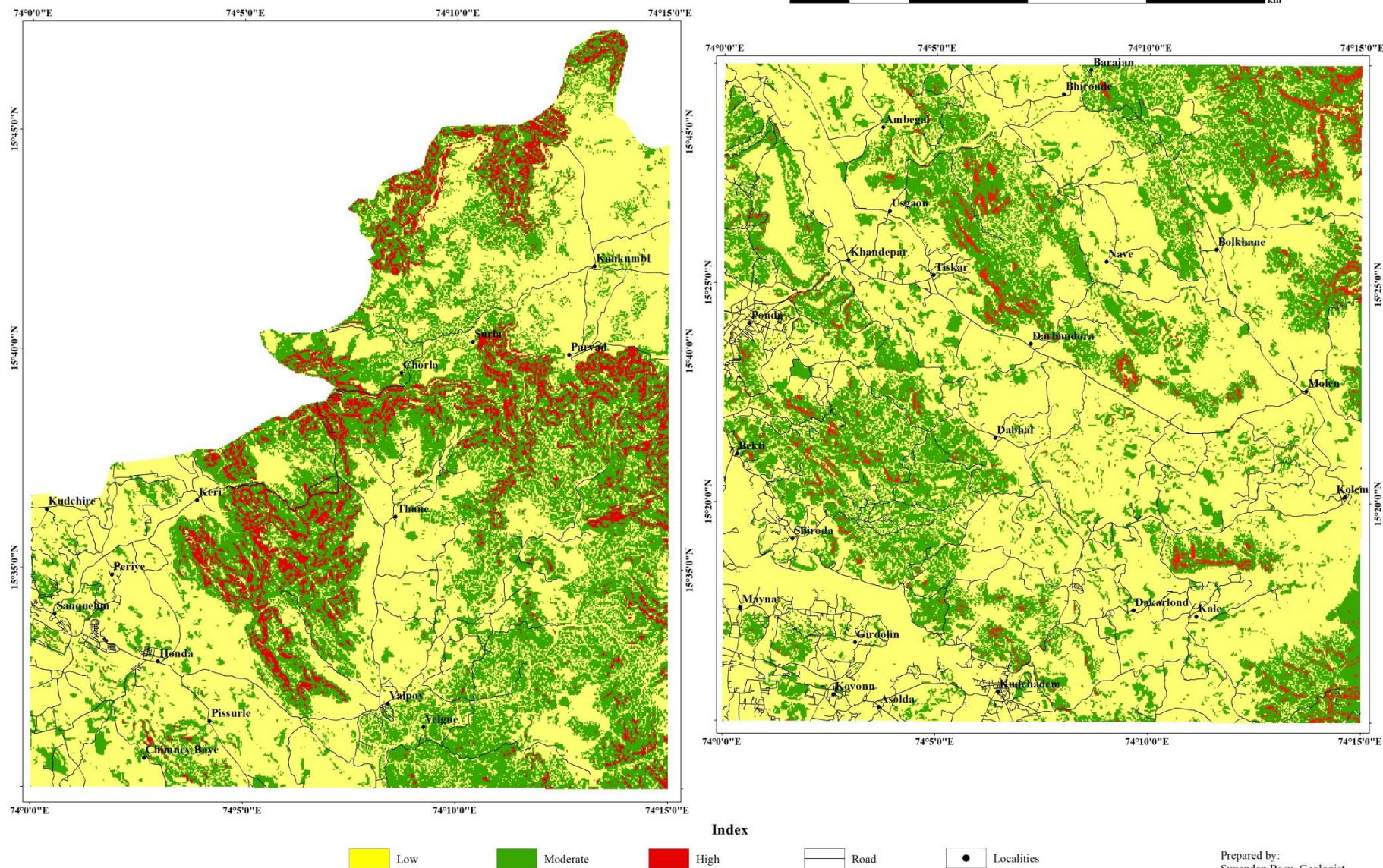


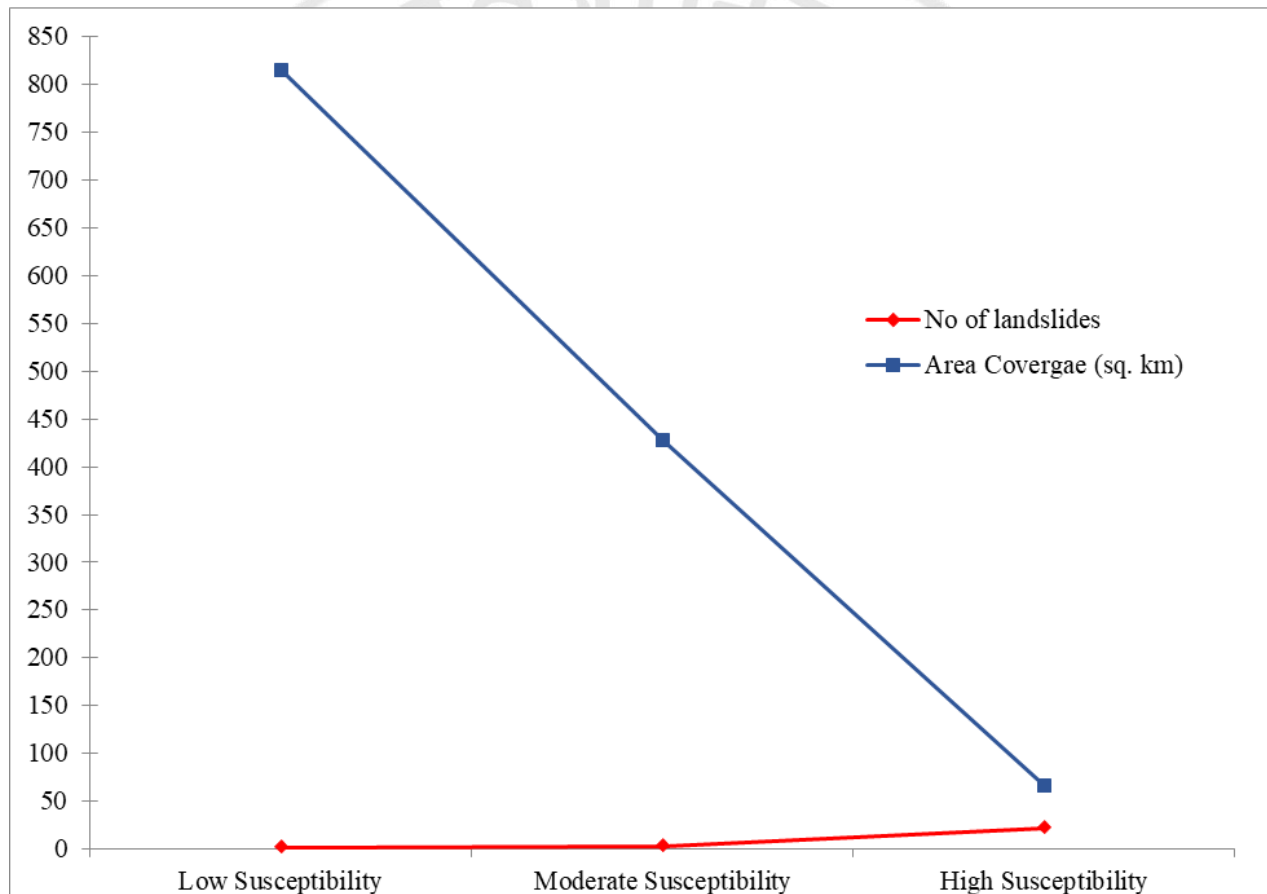
Fig. 5.1: Landslide Susceptibility Map of parts of toposheet no. 48I/01, 02 & 03, Belagavi district of Karnataka and North Goa and South Goa districts of Goa

the areas fall under $<15^\circ$ slope angle class while Geomorphologically come under rolling plain class. Land use – land cover wise the study shows classes like Plantation (both HHP & LHP), cultivation, settlement, fallow land etc. All these geofactor classes have relatively lower ratings within the individual geofactor map, thus the LOFS values of these geofactor classes are towards lower side. So, in the landslide susceptibility modelling, during data integration, these lower LOFS values contribute for the overall low susceptibility class of the area. On the contrary, northern, eastern, central and south western part of the area shows rugged topography and higher slope angle (mostly falls under $25^\circ - 35^\circ$ and $35^\circ - 45^\circ$ with small patches of $> 45^\circ$ slope angle class). Geomorphologically, majority of these areas come under lowly dissected slope with patches of escarpment and highly dissected slope class. Lowly dissected slope has moderate rating, escarpment has low rating but highly dissected slope has higher rating within geomorphology class. In land use – land cover map the dominant classes are thick vegetation, barren along with extensive slope cut. Thick vegetation has moderate rating and barren has low rating but extensive slope cut is having the highest rating within land use – land cover geofactor. Dominant slope angle classes ($25^\circ - 35^\circ$ and $35^\circ - 45^\circ$) of these areas have higher ratings within slope angle geofactor. Moreover, within the geofactor classes, slope angle and land use – land cover has highest and 2nd highest weightage. So, these higher ratings of the geofactor classes contribute to the higher LOFS values for these geofactor classes within the individual geofactor. Similarly, the higher weightage of the geofactors contribute to the higher predictor weight or weight of the particular geofactor within the all the geofactors. So, in the landslide susceptibility modelling, during data integration, these higher LOFS and predictor weight of geofactor classes and geofactors respectively, contribute to the overall moderate and high susceptibility class of the area.

Although there is no provision of direct validation of the pre-field map in the field, an attempt was made to determine the success rate of the landslide susceptibility map by overlapping the landslide points on the landslide susceptibility map in GIS software. In this exercise, it was observed that out of total 25 landslides, 21 landslides (84%) falls within the high susceptibility class followed by three landslides (12%) under moderate susceptibility class and only one landslide (4%) under low susceptibility class. So, overall 96% of the landslides fall under high and moderate susceptibility class which clearly indicates that the landslide

susceptibility model fits well in the area. Fig. 5.2 shows graphical representation of relationship between no of landslides with different susceptibility classes.

Fig. 5.2: Graphical representation of relationship between no of landslides with different susceptibility classes.



CHAPTER – 6

DISCUSSION AND RECOMMENDATIONS

Macro scale (1:50,000) landslide susceptibility mapping in parts of Survey of India toposheet no. 48I/01, 48I/02 and 48I/03, covering parts of North Goa and South Goa districts of Goa and Belagavi district of Karnataka for an area of 1311 sq. km, was carried out during field season 2019 – 20. In this study, a qualitative landslide susceptibility map was prepared by using the weighted multi class index overlay method, as recommended in the SOP of NLSM. The mapping unit used is a pixel of 50 m x 50 m. The outcome of the study is enumerated below:

- A multi – temporal landslide inventory map of the study area was prepared using old reports data, multi temporal google earth imagery from 2002 to 2019 and field inputs. Geo-scientific cause of the landslides were slope modification i.e. toe cutting of the slope (extensive slope cut) for road construction hence found in the vicinity of roads.
- The landslide inventory map of the study area contains total 25 landslides.
- The landslides in the study area are smaller in dimension, hence, ideally can not to be taken into consideration for a 1:50,000 scale map. Though in google earth using higher zoom level the landslides were mapped as polygon but when representing in 1:50,000 scale landslide inventory map (refer: Fig. 5.1) the landslides are represented as point only, as polygons are not visible in 1:50,000 scale.

Heuristic (knowledge driven) technique modelling requires fixation of individual ratings for geofactor classes and weights of geofactors for the entire area. So, these initial ratings were fixed with the knowledge of terrain and with discussion with local experts for Analytical Hierarchy Process (AHP).

Once all the ratings for geofactor classes and weights of geofactors were fixed, LOFS was calculated for all classes using pair wise comparison matrix and fraction rating and LOFS maps of the geofactors are prepared using GIS software.

Based on the landslide characteristics, a total of eight factor maps, viz., Slope Morphometry (Slope Angle, Slope Aspect, Slope Curvature), Drainage, Geomorphology, Land use – Land cover, Slope Forming Material and Regolith Thickness were prepared for

susceptibility analysis. All the above eight maps were used for assessment of factor class ratings. However, only six thematic maps (except aspect and drainage) were considered for validation of Landslide Susceptibility Analysis (LSA) of the study area due to the absence of identified factor classes in a particular map. The detail study of the thematic map and landslide inventory map shows the following:

- In the Slope Morphometry maps, in case of slope angle, approx. 77% area is occupied by $<15^\circ$ slope angle class followed by $15^\circ - 25^\circ$ slope class which occupies approx. 17% area. In case of slope curvature, Concave and Convex classes occupy almost equal area with area coverage of 47% and 46% respectively.
- In the Land use – Land cover map, thick vegetation occupies approx. 51% area followed by moderate vegetation which occupies 18% area.
- In the Geomorphology map, rolling plain occupies 43% area followed by lowly dissected slope that occupies 41% area.
- In Slope Forming Material map, 86% area is occupied by in-situ soil class.
- In Regolith Thickness map, 85% area is covered by 0.5 m – 5 m regolith thickness class.

For understanding the relative importance of every geofactor inter-predictor weights were calculated for the six geofactors. Analysis of the inter-predictor weights has shown that:

- Slope Angle class has the maximum importance amongst all the geofactors.
- Land use – Land cover class has the 2nd most importance followed by Slope Forming Material, Geomorphology and Regolith Thickness classes in descending order amongst all the geofactors.
- Slope Curvature class has the least importance amongst all the geofactors.

Using these six geofactor classes, the final Landslide Susceptibility Map (LSM) was generated. Analysis of the LSM has shown that:

- About 62% of the area falls under low susceptibility class, 33% area falls under moderate susceptibility class, whereas only 5% area falls under high susceptibility class.

- The majority of the areas situated in the north eastern, western and southern part of the study area falls under low susceptibility class with small patches of areas with moderate and high susceptibility class within it.
- Areas situated in the northern, eastern, central and south western part of the study area falls under moderate susceptibility class with considerable patches of areas having high susceptibility class within it.
- Almost all the major localities of the study area like Ponda, Darbandora, Molen, Kolem, Kudchedem, Shiroda, Usgaon, Sanquelim, Honda, Keri, Kankumbi come under low susceptibility class. Localities like Valpoy, Chorla, Surla come under moderate susceptibility class. No major locality of the area falls under high susceptibility class.
- One important road corridor i.e. Keri – Chorla stretch (National highway – 4) (Chorla Ghat) road section falls mostly under moderate to high susceptibility class in the area.

Usability of the output map

The final landslide susceptibility map is useful for:

- Perspective planning for future developmental activities (like construction of new projects) in the classified low susceptibility zones.
- Identification and delineation of target areas for meso - scale (1:5,000/10,000) or detailed site specific studies.
- The landslide inventory database along with the landslide susceptibility map can meaningfully serve as a contributing parameter for the geo-hazard assessment and evaluation of the area.
- The landslide susceptibility map when combined with temporal data can be effectively used for assessing the landslide hazard and risk scenario of the area.

Limitations

Every methodology tends to have its own limitations and constraints. Similarly, during the study, a few constraints in terms of the methodology adopted for this study were also identified which are enumerated below:

- The mapping of the nature and extent of the slope forming material based on observations at accessible stretches may not depict the true picture on all hill slopes. Subsequently, the regolith thickness map was very subjective since the regolith thickness along a slope was visually estimated on the basis of its exposure in a section and extrapolated to adjacent areas considering the terrain morphology.
- The assumption of the methodology that the relations between spatial factors and past / present landslides are relevant to the occurrence of future landslides may not always hold true in nature.
- The Landslide Susceptibility Map (LSM) was prepared considering the slope conditions prevalent at the time of study. However, the dynamicity of the studied hill slopes is greatly increased by the rapidly changing land use – land cover pattern through the augmentation of new settlements, deforestation, alignment of new roads and widening of the existing ones, etc. Therefore, the generated LSM will require periodic updation and reevaluation.
- The susceptibility map is only valid under the given set of geo-environmental conditions taken as input in the susceptibility modelling. Any changes in the spatial distribution of the geo-environmental factors may affect the susceptibility of the area.
- Limitations in understanding the terrain and its landslide characteristics thereby affecting the selection of preparatory factors are also probable.

In spite of the above, the generated landslide susceptibility map of the area is the first level spatial database on regional scale that can form the basis of landslide hazard and risk evaluation indicating the vulnerability and the elements at risk.

General Recommendations

- Landslide Susceptibility Mapping (LSM) studies are very important and user friendly in order to identify landslide susceptible zones. Potential landslide zones / areas can be further studied with more details on meso scale such as 1:10000 or 1:5000 scales. Keeping in view of the severity of the problem, the studies can be taken up on meso scale.
- The landslide susceptibility map (LSM) is generally meant for regional application because the information shown is on 1:50,000 scale; however they are still of considerable significance from the point of specific land use and urban planning. Nevertheless, it is

recommended that a detailed site-specific study may duly be conducted before planning and execution of the civil construction works. Areas falling under high susceptibility class should be given due attention while executing civil constructions.

- The recommendations suggested in this report should be conveyed to concerned agencies such as civil work departments, national highway and state highway authorities.
- As already mentioned, most of the landslides had developed due to human interferences such as construction of roads, building etc. disturbing the natural slope without proper understanding to the slope cutting. If large vertical to sub vertical slopes without proper benching will be left as such for long time, they would tend to fail especially during monsoons. So, this kind of vertical to sub vertical slope cutting should be avoided.
- In upslope of landslide prone zone, drainage lines / rain water should be diverted to other area through catch water drain (CWD) and toe drain leaving no space for stagnation. Drainage holes should be driven in the slope to remove percolating water.
- To suggest remedial / mitigation measures are of utmost importance because it is worthwhile to put forward suitable and adequate preventive measures once we diagnosed the problems. In general, Geo jute / Geo textile may be used to protect the slopes. Besides, retaining wall / gabion wire mesh wall should be constructed to protect the slope as well.
- The assessment of the landslide susceptibility is extremely important for such high vulnerable areas because it gives basic construction standards for new roads or buildings, helps to assess the impact of future landslides and can also be used to locate key facilities like hospitals, fire stations, etc. As a general recommendation, if end users intend to use only the susceptibility map for land use planning, then no public or personal utility projects should be considered in high susceptible areas, strict building safety regulations should be followed in moderate susceptible areas and constructions with simple slope stability measures be allowed in low susceptible areas. This is a general recommendation related to the landslide susceptibility based on the present land use condition. However the susceptibility values can be lowered if proper mitigation measures are adopted such that a high susceptible area can be made less vulnerable to landslides. Therefore, it is recommended that the susceptibility map should be interpreted accordingly and the degree of susceptibility or hazard in response of mitigation measures should be worked out judiciously. In this regard cost - benefit analysis may be carried out for better planning.

- Disaster Risk Reduction (DRR) approach should be adopted to minimise the damage caused by such natural calamity like landslide. India is one of the signatory of SENDAI FRAMEWORK (2015 – 2030), hence the findings of the report should be conveyed to concerned agencies for mitigation and remedial works.
- In the event if a disaster strikes, then loss would be immense if buildings are not safely and properly located. The only economical way of reducing “at least” the loss of life is by making people aware of the inherent risk. Therefore, it is recommended that more priority should be given in increasing awareness amongst people through Community Based Disaster Management Programme (CBDMP).
- The awareness should include information about the potential danger, its identification and its communication; the physical significance of hazard and inherent uncertainties; ways to reduce landslide risk and the available local mitigation options.
- The villages or communities located in and around high susceptible areas should be given priority in holding CBDMP.

Detailed Recommendations

Based on the evaluation of the geofactors and understanding their relative importance that are specific to the terrain, as well as considering the scale of the study and the observations made in the field, the following recommendations are suggested:

- Future developmental planning like expansion of township, development of infrastructure, etc., may be carried out in the designated low susceptibility zones, i.e. in and around localities like Ponda, Darbandora, Molen, Kolem, Kudchedem, Shiroda, Usgaon, Sanquelim, Honda, Keri, Kankumbi etc.
- Future construction of any kind of public or personal utility projects should be avoided in the designated moderate to highly susceptible areas. Localities like Valpoy, Chorla, Surla etc comes under moderate susceptibility class thus requiring special attention.
- In the land use – land cover map, few areas have been mapped as “dumping ground” in and around Dakarlond and Dhabal areas. These mine dump areas consist of unconsolidated waste materials of mines. Any kind of construction should be strictly avoided in and around this demarcated “dumping ground” areas.

- One major road corridor of the study area is NH – 4 connecting Panaji to Belagavi passes through the area. An approx. 43 km stretch of this very important communication corridor falls within the study area. A conclusion derived from the generated Landslide Susceptibility Map (LSM) indicates that a stretch of approx. 22 km between Keri and Chorla of the road corridor falls mostly under moderate susceptibility zones along with few stretches of both high and low susceptibility zones. The area is part of Western Ghats of Karnataka and Goa and locally known as Chorla Ghat section. Regular monitoring and proper maintenance of this stretch may be taken up especially during monsoons to avoid future slope failures.
- The 22 km stretch between Keri and Chorla (Chorla Ghat section) has encountered 16 landslides. All the landslides along this road section are result of the toe cutting of the slope for road construction. As this road section is the worst affected by landslides among all the road sections in the study area, a detail meso scale (1:10,000) landslides susceptibility mapping of this road corridor is required to be taken up for future planning and development.
- Three places (refer: Table – 3.4) were observed along Keri - Chorla road (Chorla Ghat section) where intersection of the three prominent joint sets in Argillite with the slope forming wedge in the rock mass and the plunge of the wedge is towards the road side. Rock bolting and anchored wire mesh should be provided to prevent rock fall in the road.
- For landslide wise detailed remedial measures, the 42 point geo-parametric data sheets attached as Annexure – II should be consulted.

LOCALITY INDEX

Sl. No	Locality	Latitude (N)	Longitude (E)
1	Asolda	15° 15' 19.681"	74° 3' 40.348"
2	Barajan	15° 29' 53.253"	74° 8' 36.936"
3	Bekti	15° 21' 5.883"	74° 0' 19.206"
4	Bhironde	15° 29' 19.780"	74° 7' 58.448"
5	Bolkhane	15° 25' 47.514"	74° 11' 34.208"
6	Chimney Baye	15° 30' 40.070"	74° 2' 40.410"
7	Chorla	15° 39' 28.760"	74° 8' 41.830"
8	Dabhal	15° 21' 28.813"	74° 6' 23.286"
9	Dakarlond	15° 17' 33.416"	74° 9' 39.087"
10	Darbandora	15° 23' 37.999"	74° 7' 13.272"
11	Girdolin	15° 16' 48.298"	74° 3' 7.010"
12	Honda	15° 32' 52.081"	74° 2' 59.684"
13	Kale	15° 17' 25.272"	74° 11' 8.115"
14	Kankumbi	15° 41' 55.705"	74° 13' 14.112"
15	Keri	15° 36' 33.070"	74° 3' 54.112"
16	Khandepar	15° 25' 31.822"	74° 2' 55.138"
17	Kolem	15° 20' 9.239"	74° 14' 36.710"
18	Kovonn	15° 15' 36.977"	74° 2' 36.623"
19	Kudchadem	15° 15' 41.085"	74° 6' 28.743"
20	Kudchire	15° 36' 19.964"	74° 0' 21.988"
21	Mayna	15° 17' 35.640"	74° 0' 24.458"
22	Molen	15° 22' 34.144"	74° 13' 42.051"
23	Nave	15° 25' 30.793"	74° 8' 59.727"
24	Parvad	15° 39' 54.092"	74° 12' 38.789"
25	Periye	15° 34' 50.876"	74° 1' 54.113"
26	Pissurle	15° 31' 30.647"	74° 4' 12.933"
27	Ponda	15° 24' 4.673"	74° 0' 35.993"
28	Sanquelim	15° 33' 57.048"	74° 0' 33.623"
29	Shiroda	15° 19' 9.990"	74° 1' 38.006"
30	Surla	15° 40' 11.554"	74° 10' 22.789"
31	Thane	15° 36' 11.586"	74° 8' 34.314"
32	Tiskar	15° 25' 11.694"	74° 4' 55.603"
33	Usgaon	15° 26' 38.966"	74° 3' 53.317"
34	Valpoy	15° 31' 55.585"	74° 8' 24.215"
35	Velgue	15° 31' 23.594"	74° 9' 14.530"

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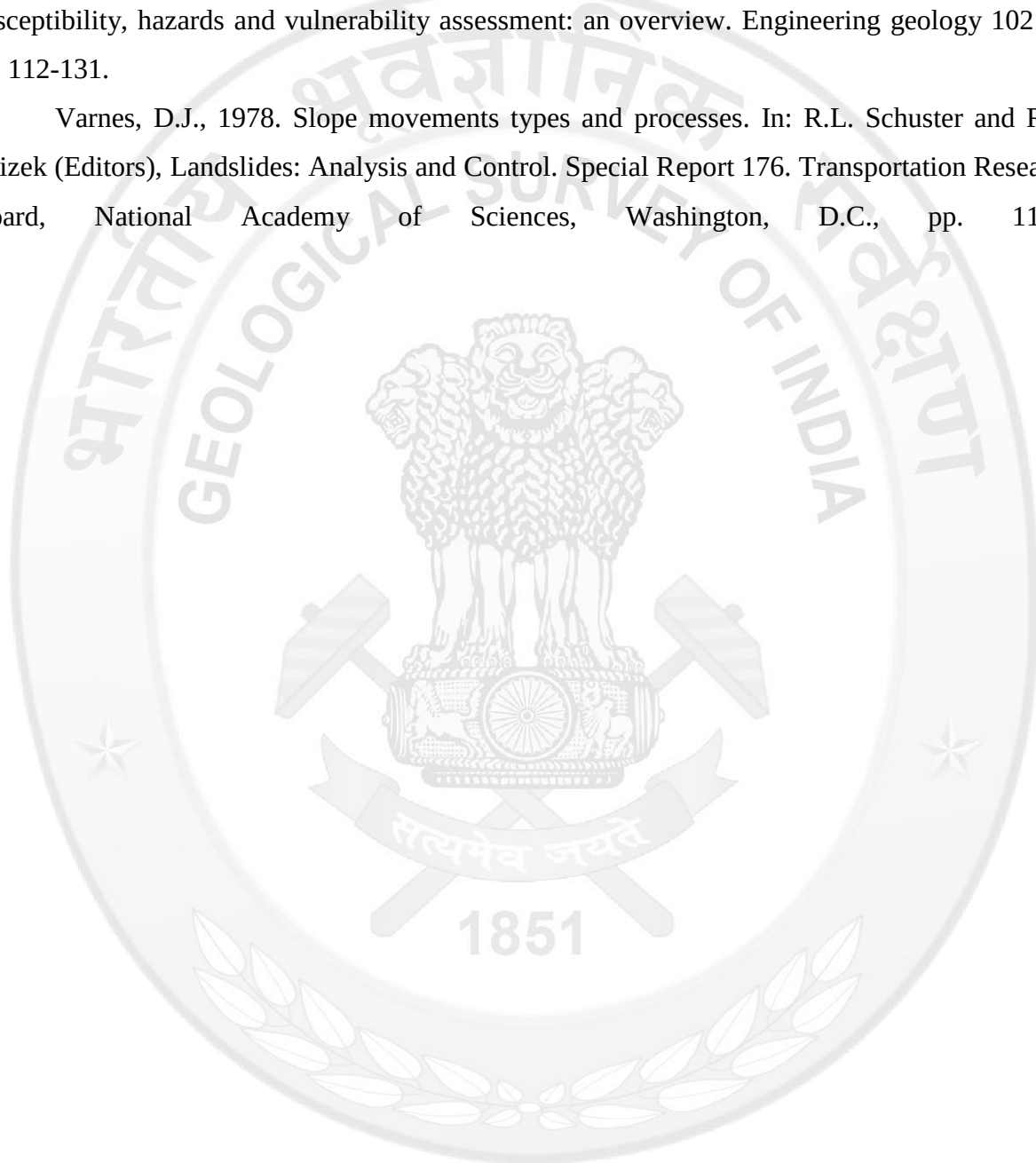
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ANNEXURE-1

Geofactor: Land Use Land Cover (LULC)

Rank of Land Use Land Cover Classes

Sl. No	LULC Class	LULC Code	Rank
1	Barren	B	1
2	Cultivation	CL	1
3	Settlement	SET	1
4	Fallow Land	FL	1
5	Plantation (LHP)	LHP	3
6	Plantation (HHP)	HHP	4
7	Thick Vegetation	TV	4
8	Moderate Vegetation	MV	5
9	Quarry	QR	5
10	Dumping Ground	DG	6
11	Settlement on modified slope	SMS	7
12	Sparse Vegetation	SV	7
13	Extensive Slope Cut	ESC	9
14	Swamp	SW	0
15	Water body	WB	0
16	River	R	0

Pairwise comparison matrix of LULC Classes

LULC	B/CL/SET/FL	LHP	HHP/TV	MV/QR	DG	SMS/SV	ESC
B/CL/SET/FL	1	0.33	0.25	0.2	0.17	0.14	0.11
LHP	3	1	0.5	0.33	0.25	0.2	0.14
HHP/TV	4	2	1	0.5	0.33	0.25	0.17
MV/QR	5	3	2	1	0.5	0.33	0.2
DG	6	4	3	2	1	0.5	0.25
SMS/SV	7	5	4	3	2	1	0.33
ESC	9	7	6	5	4	3	1
Sum Column	35	22.33	16.75	12.03	8.25	5.42	2.2

Estimated Eigen values, fraction rate and LOFS for LULC classes

LULC	B/CL/SE T/FL	LHP	HHP/ TV	MV/ QR	DG	SMS/ SV	ESC	SUM Row's	Fraction rate	LO FS
B/CL/SE T/FL	0.028571 429	0.014 778	0.014 925	0.016 625	0.020 606	0.025 83	0.05	0.17133 655	0.02447 665	0.06
LHP	0.085714 286	0.044 783	0.029 851	0.027 431	0.030 303	0.036 9	0.063 636	0.31861 902	0.04551 7003	0.11
HHP/TV	0.114285 714	0.089 566	0.059 701	0.041 563	0.04 0.04	0.046 125	0.077 273	0.46851 3762	0.06693 0537	0.17
MV/QR	0.142857 143	0.134 348	0.119 403	0.083 126	0.060 606	0.060 886	0.090 909	0.69213 4818	0.09887 6403	0.24
DG	0.171428 571	0.179 131	0.179 104	0.166 251	0.121 212	0.092 251	0.113 636	1.02301 4709	0.14614 4958	0.36

SMS/SV	0.2	0.223 914	0.238 806	0.249 377	0.242 424	0.184 502	0.15	1.48902 2633	0.21271 7519	0.52
ESC	0.257142 857	0.313 48	0.358 209	0.415 628	0.484 848	0.553 506	0.454 545	2.83735 8508	0.40533 693	1.00
						Maximum Fraction rate			0.40533 693	

**Estimation of consistency vector (CV), consistency index (CI) and consistency ratio (CR)
for LULC classes**

LULC	B/CL/SET /FL	LHP	HHP/ TV	MV/Q R	DG	SMS/ SV	ESC	SUM Row's	CV
B/CL/SET /FL	0.0244766 5	0.0150 21	0.0167 33	0.0197 75	0.0248 45	0.0297 8	0.0445 87	0.175217 334	7.158550 455
LHP	0.0734299 5	0.0455 17	0.0334 65	0.0326 29	0.0365 36	0.0425 44	0.0567 47	0.320868 348	7.049417 314
HHP/TV	0.0979066 5	0.0910 34	0.0669 31	0.0494 38	0.0482 28	0.0531 79	0.0689 07	0.475623 838	7.106230 677
MV/QR	0.1223832 5	0.1365 51	0.1338 61	0.0988 76	0.0730 72	0.0701 97	0.0810 67	0.716008 382	7.241448 55
DG	0.1468599 5	0.1820 68	0.2007 92	0.1977 53	0.1461 45	0.1063 59	0.1013 34	1.081310 279	7.398888 681
SMS/SV	0.1713365 5	0.2275 85	0.2677 22	0.2966 29	0.2922 9	0.2127 18	0.1337 61	1.602041 544	7.531309 839
ESC	0.2202898 5	0.3186 19	0.4015 83	0.4943 82	0.5845 8	0.6381 53	0.4053 37	3.062943 427	7.556536 803
Sum CV									51.04238 232
Mean Consistency Vector (Mean CV) = Sum CV/ Nos. Of factor class									7.291768 903
Consistency Index (CI) = (Mean CV - No. Of criteria/ factor class) / (No. Of factor class - 1)									0.048628
Consistency Ratio (CR) = CI/ RI (1.32)									0.03684
CR should never be more than 0.1									

Geofactor: Geomorphology (GEOM)

Rank of Geomorphology Classes

Sl. No	Geom Class	Geom Code	Rank
1	Highly Dissected Slope	HDS	8
2	Lowly Dissected Slope	LDS	4
3	Escarpment	ESC	2
4	Plateau Top (Flat)	PT	0
5	Tidal Flat	TF	0
6	Valley Fill	VF	0
7	Rolling Plain	RP	0
8	Pediment Pediplain Complex	PPC	0

9	Water body	WB	0
10	River	R	0

Pairwise comparison matrix of Geom Classes

GEOM	HDS	LDS	ESC
HDS	1	5	7
LDS	0.2	1	3
ESC	0.14	0.33	1
Sum Column	1.34	6.33	11

Estimated Eigen values, fraction rate and LOFS for Geom classes

GEOM	HDS	LDS	ESC	Sum Rows	Fraction rate	LOFS
HDS	0.746269	0.789889	0.636364	2.17252171	0.724174	1
LDS	0.149254	0.157978	0.272727	0.57995889	0.19332	0.266952
ESC	0.104478	0.052133	0.090909	0.2475194	0.082506	0.113932
			Maximum Fraction rate		0.724174	

Estimation of consistency vector (CV), consistency index (CI) and consistency ratio (CR) for Geom classes

GEOM	HDS	LDS	ESC	Sum Rows	CV
HDS	0.724174	0.966598	0.577545	2.26831732	3.132283
LDS	0.144835	0.19332	0.247519	0.58567381	3.029562
ESC	0.101384	0.063795	0.082506	0.24768629	3.002023
Sum CV					9.163867
Mean Consistency Vector (Mean CV) = Sum CV/ Nos. Of factor class					3.054622
Consistency Index (CI) = (Mean CV - No. Of criteria/ factor class) / (No. Of factor class - 1)					0.027311
Consistency Ratio (CR) = CI/ RI (0.58)					0.047088
CR should never be more than 0.1					

Geofactor: Slope Forming Material (SFM)

Rank of Slope Forming Material Classes

Sl. No	SFM Class	SFM Code	Rank
1	Banded iron formation	Rock Type 1	1
2	Dolerite	Rock Type 1	1
3	Gabbro	Rock Type 1	1

4	Granite Gneiss	Rock Type 1	1
5	Granite (Chandranath)	Rock Type 1	1
6	Limestone	Rock Type 1	1
7	Metabasalt	Rock Type 1	1
8	Quartzite	Rock Type 1	1
9	Argillite	Rock Type 3	4
10	Basalt Flow - undifferentiated	Rock Type 3	4
11	Dunite	Rock Type 3	4
12	Manganiferous phyllite	Rock Type 3	4
13	Laterite	Rock Type 3	4
14	Peridotite	Rock Type 3	4
15	Quartz-chlorite schist	Rock Type 3	4
16	Talc - chlorite schist	Rock Type 3	4
17	Weathered Rock	WR	6
18	In-situ soil	IS	4
19	Transported Soil	TS	3
20	Tidal Mud	TM	0
21	River	R	0
22	Water body	WB	0

Pairwise comparison matrix of SFM Classes

SFM	Rock Type 1	Rock Type 3	WR	IS	TS
Rock Type 1	1	0.25	0.17	0.25	0.33
Rock Type 3	4	1	0.33	1	2
WR	6	3	1	3	4
IS	4	1	0.33	1	2
TS	3	0.5	0.25	0.5	1
Sum Column	18	5.75	2.08	5.75	9.33

Estimated Eigen values, fraction rate and LOFS for SFM classes

SF M	Rock Type 1	Rock Type 3	WR	IS	TS	Sum Rows	Fraction rate	LOFS
Rock Type 1	0.05555556	0.043478261	0.081731	0.043478	0.03537	0.25961262	0.051923	0.113551
Rock Type 3	0.22222222	0.173913043	0.158654	0.173913	0.214362	0.94306443	0.188613	0.412484
WR	0.33333333	0.52173913	0.480769	0.521739	0.428725	2.28630537	0.457261	1
IS	0.22222222	0.173913043	0.158654	0.173913	0.214362	0.94306443	0.188613	0.412484
TS	0.16666667	0.086956522	0.120192	0.086957	0.107181	0.56795315	0.113591	0.248415

					Maximum Fraction rate	0.457261	
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Estimation of consistency vector (CV), consistency index (CI) and consistency ratio (CR) for SFM classes

SFM	Rock Type 1	Rock Type 3	WR	IS	TS	Sum Rows	CV
Rock Type 1	0.05192252	0.047153221	0.077734	0.047153	0.037485	0.26144826	5.035353
Rock Type 3	0.2076901	0.188612886	0.150896	0.188613	0.227181	0.96299328	5.10566
WR	0.31153515	0.565838657	0.457261	0.565839	0.454363	2.35483606	5.149872
IS	0.2076901	0.188612886	0.150896	0.188613	0.227181	0.96299328	5.10566
TS	0.15576757	0.094306443	0.114315	0.094306	0.113591	0.57228636	5.038148
Sum CV							25.43469
Mean Consistency Vector (Mean CV) = Sum CV/ Nos. Of factor class							5.086939
Consistency Index (CI) = (Mean CV - No. Of criteria/ factor class) / (No. Of factor class - 1)							0.021735
Consistency Ratio (CR) = CI/ RI (1.12)							0.019406
<i>CR should never be more than 0.1</i>							

Geofactor: Regolith Thickness (RT)

Rank of Regolith Thickness Classes

Sl. No	RT Class	Rank
1	< 0.5 m	0
2	0.5 – 5 m	7
3	5 – 10 m	4
4	> 10 m	2
5	River	0
6	Water body	0

Pairwise comparison matrix of RT Classes

RT	0.5 – 5 m	5 – 10 m	> 10 m
0.5 – 5 m	1	4	6
5 – 10 m	0.25	1	3
> 10 m	0.17	0.33	1
Sum Column	1.42	5.33	10

Estimated Eigen values, fraction rate and LOFS for RT classes

RT	0.5 – 5 m	5 – 10 m	> 10 m	Sum Rows	Fraction rate	LOFS
0.5 – 5 m	0.704225	0.750469	0.6	2.054694395	0.684898	1
5 – 10 m	0.176056	0.187617	0.3	0.663673599	0.221225	0.323004
> 10 m	0.119718	0.061914	0.1	0.281632006	0.093877	0.137068
			Maximum Fraction rate		0.684898	

Estimation of consistency vector (CV), consistency index (CI) and consistency ratio (CR) for RT classes

RT	0.5 – 5 m	5 – 10 m	> 10 m	Sum Rows	CV
0.5 – 5 m	0.684898	0.884898	0.563264	2.133060275	3.11442
5 – 10 m	0.171225	0.221225	0.281632	0.674081072	3.047045
> 10 m	0.116433	0.073004	0.093877	0.283314114	3.017918
Sum CV					9.179383
Mean Consistency Vector (Mean CV) = Sum CV/ Nos. Of factor class					3.059794
Consistency Index (CI) = (Mean CV - No. Of criteria/ factor class) / (No. Of factor class - 1)					0.029897
Consistency Ratio (CR) = CI/ RI (0.58)					0.051547
<i>CR should never be more than 0.1</i>					

Geofactor: Slope Angle (SA)

Rank of Slope Angle Classes

Sl. No	SA Class	Rank
1	<15	4
2	15-25	6
3	25-35	8
4	35-45	5
5	>45	4

Pairwise comparison matrix of SA Classes

SA	<15	15-25	25-35	35-45	>45
<15	1	0.33	0.2	0.5	1
15-25	3	1	0.33	2	3
25-35	5	3	1	4	5
35-45	2	0.5	0.25	1	2
>45	1	0.33	0.2	0.5	1
Sum column	12	5.16	1.98	8	12

Estimated Eigen values, fraction rate and LOFS for SA classes

SA	<15	15-25	25-35	35-45	>45	Sum Rows	Fraction rate	LOFS
<15	0.083333	0.063953	0.10101	0.0625	0.083333	0.394130256	0.07882605	0.162879
15-25	0.25	0.193798	0.166667	0.25	0.25	1.110465116	0.22209302	0.458912
25-35	0.416667	0.581395	0.505051	0.5	0.416667	2.419779187	0.48395584	1
35-45	0.166667	0.096899	0.126263	0.125	0.166667	0.681495184	0.13629904	0.281635
>45	0.083333	0.063953	0.10101	0.0625	0.083333	0.394130256	0.07882605	0.162879
					Maximum Fraction rate		0.48395584	

Estimation of consistency vector (CV), consistency index (CI) and consistency ratio (CR) for SA classes

SA	<15	15-25	25-35	35-45	>45	Sum Rows	CV
<15	0.078826	0.073291	0.096791	0.06815	0.078826	0.395883486	5.02224176
15-25	0.236478	0.222093	0.159705	0.272598	0.236478	1.127352831	5.07603892
25-35	0.39413	0.666279	0.483956	0.545196	0.39413	2.483691567	5.13206242
35-45	0.157652	0.111047	0.120989	0.136299	0.157652	0.683638713	5.01572666
>45	0.078826	0.073291	0.096791	0.06815	0.078826	0.395883486	5.02224176
Sum CV							25.2683115
Mean Consistency Vector (Mean CV) = Sum CV/ Nos. Of factor class							5.0536623
Consistency Index (CI) = (Mean CV - No. Of criteria/ factor class) / (No. Of factor class - 1)							0.013416
Consistency Ratio (CR) = CI/ RI (1.12)							0.011978
CR should never be more than 0.1							

Geofactor: Slope Curvature (SC)

Rank of Slope Curvature Classes

Sl. No	SC Class	Rank
1	Concave (upto -0.1)	4
2	Flat (-0.1 to 0.1)	2
3	Convex (>0.1)	6

Pairwise comparison matrix of SC Classes

SC	Concave	Flat	Convex
Concave	1	3	0.33

Flat	0.33	1	0.2
Convex	3	5	1
Sum Column	4.33	9	1.53

Estimated Eigen values, fraction rate and LOFS for SC classes

SC	Concave	Flat	Convex	Sum Rows	Fraction rate	LOFS
Concave	0.230947	0.333333	0.215686	0.77996649	0.259989	0.410079
Flat	0.076212	0.111111	0.130719	0.318042536	0.106014	0.167216
Convex	0.692841	0.555556	0.653595	1.901990973	0.633997	1
			Maximum Fraction rate		0.633997	

Estimation of consistency vector (CV), consistency index (CI) and consistency ratio (CR) for SC classes

SC	Concave	Flat	Convex	Sum Rows	CV
Concave	0.259989	0.318043	0.209219	0.787250374	3.028016
Flat	0.085796	0.106014	0.126799	0.318609891	3.005352
Convex	0.779966	0.530071	0.633997	1.944034375	3.066315
Sum CV					9.099683
Mean Consistency Vector (Mean CV) = Sum CV/ Nos. Of factor class					3.033228
Consistency Index (CI) = (Mean CV - No. Of criteria/ factor class) / (No. Of factor class - 1)					0.016614
Consistency Ratio (CR) = CI/ RI (0.58)					0.028644
CR should never be more than 0.1					

Geofactors

Weight of Geofactor Classes

Sl. No	Geofactor Class	Code	Weight
1	Slope Angle	SA	9
2	Slope Curvature	SC	2
3	Slope Forming Material	SFM	6
4	Land Use Land Cover	LULC	8
5	Geomorphology	GEOM	6
6	Regolith Thickness	RT	4

Pairwise comparison matrix of Geofactor Classes

Geofactor	SA	SC	SFM	LULC	GEOM	RT
SA	1	8	4	2	4	6
SC	0.12	1	0.2	0.14	0.2	0.33
SFM	0.25	5	1	0.33	1	3
LULC	0.5	7	3	1	3	5
GEOM	0.25	5	1	0.33	1	3
RT	0.17	3	0.33	0.2	0.33	1
Sum column	2.29	29	9.53	4	9.53	18.33

Estimated Eigen values, fraction rate and Integer Weight for Geofactor classes

Geofactor	SA	SC	SFM	LULC	GEOM	RT	Sum Rows	Fraction rate	Weight	Integer Weight
SA	0.436681	0.275862	0.419727	0.5	0.419727	0.327332	2.379329889	0.396555	13.08327	13
SC	0.052402	0.034483	0.020986	0.035	0.020986	0.018003	0.181860496	0.03031	1	1
SFM	0.10917	0.172414	0.104932	0.0825	0.104932	0.163666	0.737613809	0.122936	4.055932	4
LULC	0.218341	0.241379	0.314795	0.25	0.314795	0.272777	1.612087556	0.268681	8.864419	9
GEOM	0.10917	0.172414	0.104932	0.0825	0.104932	0.163666	0.737613809	0.122936	4.055932	4
RT	0.074236	0.103448	0.034627	0.05	0.034627	0.054555	0.351494442	0.058582	1.93277	2
					Minimum Fraction rate			0.03031		

Estimation of consistency vector (CV), consistency index (CI) and consistency ratio (CR) for Geofactor classes

Geofactor	SA	SC	SFM	LULC	GEOM	RT	Sum Rows	CV
SA	0.396555	0.242481	0.491743	0.537363	0.491743	0.351494	2.511377682	6.332987
SC	0.047587	0.03031	0.024587	0.037615	0.024587	0.019332	0.184018505	6.071198
SFM	0.099139	0.15155	0.122936	0.088665	0.122936	0.175747	0.760972465	6.190007
LULC	0.198277	0.212171	0.368807	0.268681	0.368807	0.292912	1.709655173	6.363135
GEOM	0.099139	0.15155	0.122936	0.088665	0.122936	0.175747	0.760972465	6.190007
RT	0.067414	0.09093	0.040569	0.053736	0.040569	0.058582	0.351800773	6.005229
Sum CV								37.15256
Mean Consistency Vector (Mean CV) = Sum CV/ Nos. Of factor class								6.192094
Consistency Index (CI) = (Mean CV - No. Of criteria/ factor class) / (No. Of factor class - 1)								0.038419
Consistency Ratio (CR) = CI/ RI (1.24)								0.030983
<i>CR should never be more than 0.1</i>								

ANNEXURE-2

1	Slide No (LS .No.)	GOA/SG/48I03/2019/01
2	State	Goa
3	District	South Goa
4	Toposheet	48I/3
5	Name of the slide	Cut Slope failure along Anmod ghat section
6	NH/SH/Locality	4.5 km north east of Molen
7	Latitude (N)	15.41
8	Longitude (E)	74.25
9	Length (m)	9
10	Width (m)	26
11	Height (m)	6
12	Area (m2)	234
13	Depth (m3)	1
14	Volume	234
15	Run out distance (m)	5
16	Type of Material	Debris
17	Type of movement	Slide
18	Rate of movement	Rapid
19	Activity	Active
20	Distribution	Widening
21	Style	Single
22	Failure mechanism	Shallow translational
23	History	Data not available
24	Geomorphology	Highly Dissected Slope
25	Geology	Granite gneiss
26	Structure	Data not available
27	Land use/ Land cover	Extensive slope Cut
28	Hydrological condition	Dry
29	Triggering Factor	Rainfall
30	Death of persons	Nil
31	People affected	Nil
32	Livestock loss	Nil
33	Communication	Blockage of Anmod ghat road
34	Infrastructure	Nil
35	Agriculture/forest/Barren	Forest
36	Geo-scientific Causes	Reduction of strength of overburden material on super saturation, cutting of slope for road construction
37	Remedial measures	Removal of loose material
38	Remarks, if any	Nil
39	Photos. Sketch of Plan	Photos given in the next page

	& section of the slide	
40	Summary/Abstract	The landslide is located along Anmod ghat road section in 4.5 km north east of Molen. It is an active debris slide, shallow translational in nature. The length of the slide is 9 m, width 26 m, height 6 m and depth 1 m. The geo scientific causes of the landslide are reduction of strength of overburden material on super saturation and cutting of the slope for road construction. This landslide caused temporary blockage of Anmod ghat road.
41	Pdf	Data not available
42	Landslide category	Category - II



Field photograph of landslide no: GOA/SG/48I03/2019/01

1	Slide No (LS .No.)	GOA/SG/48I03/2019/02
2	State	Goa
3	District	South Goa
4	Toposheet	48I/3
5	Name of the slide	Cut Slope failure along Anmod ghat section
6	NH/SH/Locality	3.9 km north east of Molen
7	Latitude (N)	15.41
8	Longitude (E)	74.24
9	Length (m)	35
10	Width (m)	95
11	Height (m)	25
12	Area (m2)	3325
13	Depth (m3)	2
14	Volume	6650
15	Run out distance (m)	2
16	Type of Material	Debris
17	Type of movement	Slide
18	Rate of movement	Rapid
19	Activity	Overall the landslide is dormant but there are signs of reactivation at places within the slide body.
20	Distribution	Widening
21	Style	Multiple
22	Failure mechanism	Shallow translational
23	History	Data not available
24	Geomorphology	Lowly Dissected Slope
25	Geology	Granite gneiss
26	Structure	Data not available
27	Land use/ Land cover	Extensive slope Cut
28	Hydrological condition	Dry
29	Triggering Factor	Rainfall
30	Death of persons	Nil
31	People affected	Nil
32	Livestock loss	Nil
33	Communication	Nil
34	Infrastructure	Nil
35	Agriculture/forest/Barren	Forest
36	Geo-scientific Causes	Reduction of strength of overburden material on super

		saturation, cutting of slope for road construction
37	Remedial measures	Periodic maintenance of existing retaining wall and weep holes
38	Remarks, if any	Nil
39	Photos. Sketch of Plan & section of the slide	Photos given in the next page
40	Summary/Abstract	The landslide is located along Anmod ghat section in 3.9 km north east of Molen. It is a dormant debris slide, shallow translational in nature. The length of the slide is 35m, width 95 m, height 25 m and depth 2 m. The geo scientific causes of the landslide are reduction of strength of overburden material on super saturation and cutting of the slope for road construction.
41	Pdf	Data not available
42	Landslide category	Category - II



Field photograph of landslide no: GOA/SG/48I03/2019/02

1	Slide No (LS .No.)	GOA/SG/48I03/2019/03
2	State	Goa
3	District	South Goa
4	Toposheet	48I/3
5	Name of the slide	Cut Slope failure along Sanverdem – Siroda road
6	NH/SH/Locality	1.2 km north of Kudchedem
7	Latitude (N)	15.27
8	Longitude (E)	74.10
9	Length (m)	6
10	Width (m)	40
11	Height (m)	5
12	Area (m2)	240
13	Depth (m3)	1
14	Volume	240
15	Run out distance (m)	2
16	Type of Material	Debris
17	Type of movement	Slide
18	Rate of movement	Rapid
19	Activity	Active
20	Distribution	Widening
21	Style	Single
22	Failure mechanism	Shallow translational
23	History	Data not available
24	Geomorphology	Rolling Plain
25	Geology	Granite (Chandranath)
26	Structure	Data not available
27	Land use/ Land cover	Extensive slope Cut
28	Hydrological condition	Dry
29	Triggering Factor	Rainfall
30	Death of persons	Nil
31	People affected	Nil
32	Livestock loss	Nil
33	Communication	Blockage of Sanverdem – Siroda road
34	Infrastructure	Nil
35	Agriculture/forest/Barren	Forest
36	Geo-scientific Causes	Reduction of strength of overburden material on super saturation, cutting of slope for road construction
37	Remedial measures	Removal of loose material, construction of retaining wall with weep holes
38	Remarks, if any	Nil

39	Photos. Sketch of Plan & section of the slide	Photos given in the next page
40	Summary/Abstract	The landslide is located along Sanverdem – Siroda road section. It is an active debris slide, shallow translational in nature. The length of the slide is 6 m, width 40 m, height 5 m and depth 1 m. The geo scientific causes of the landslide are reduction of strength of overburden material on super saturation and cutting of the slope for road construction. This landslide caused temporary blockage of Sanverdem – Siroda road
41	Pdf	Data not available
42	Landslide category	Category - II



Field photograph of landslide no: GOA/SG/48I03/2019/03

1	Slide No (LS .No.)	GOA/SG/48I03/2019/04
2	State	Goa
3	District	South Goa
4	Toposheet	48I/3
5	Name of the slide	Cut Slope failure along Sanverdem – Siroda road
6	NH/SH/Locality	3.6 km north west of Kudchedem
7	Latitude (N)	15.28
8	Longitude (E)	74.08
9	Length (m)	10
10	Width (m)	11
11	Height (m)	5
12	Area (m2)	110
13	Depth (m3)	1.5
14	Volume	165
15	Run out distance (m)	2
16	Type of Material	Debris
17	Type of movement	Slide
18	Rate of movement	Rapid
19	Activity	Active
20	Distribution	Retrogressive
21	Style	Single
22	Failure mechanism	Shallow translational
23	History	Data not available
24	Geomorphology	Rolling Plain
25	Geology	Argillite
26	Structure	Data not available
27	Land use/ Land cover	Extensive slope Cut
28	Hydrological condition	Dry
29	Triggering Factor	Rainfall
30	Death of persons	Nil
31	People affected	Nil
32	Livestock loss	Nil
33	Communication	Blockage of Sanverdem – Siroda road
34	Infrastructure	Nil
35	Agriculture/forest/Barren	Forest
36	Geo-scientific Causes	Reduction of strength of overburden material on super saturation, cutting of slope for road construction
37	Remedial measures	Removal of loose material
38	Remarks, if any	Nil
39	Photos. Sketch of Plan	Photos given in the next page

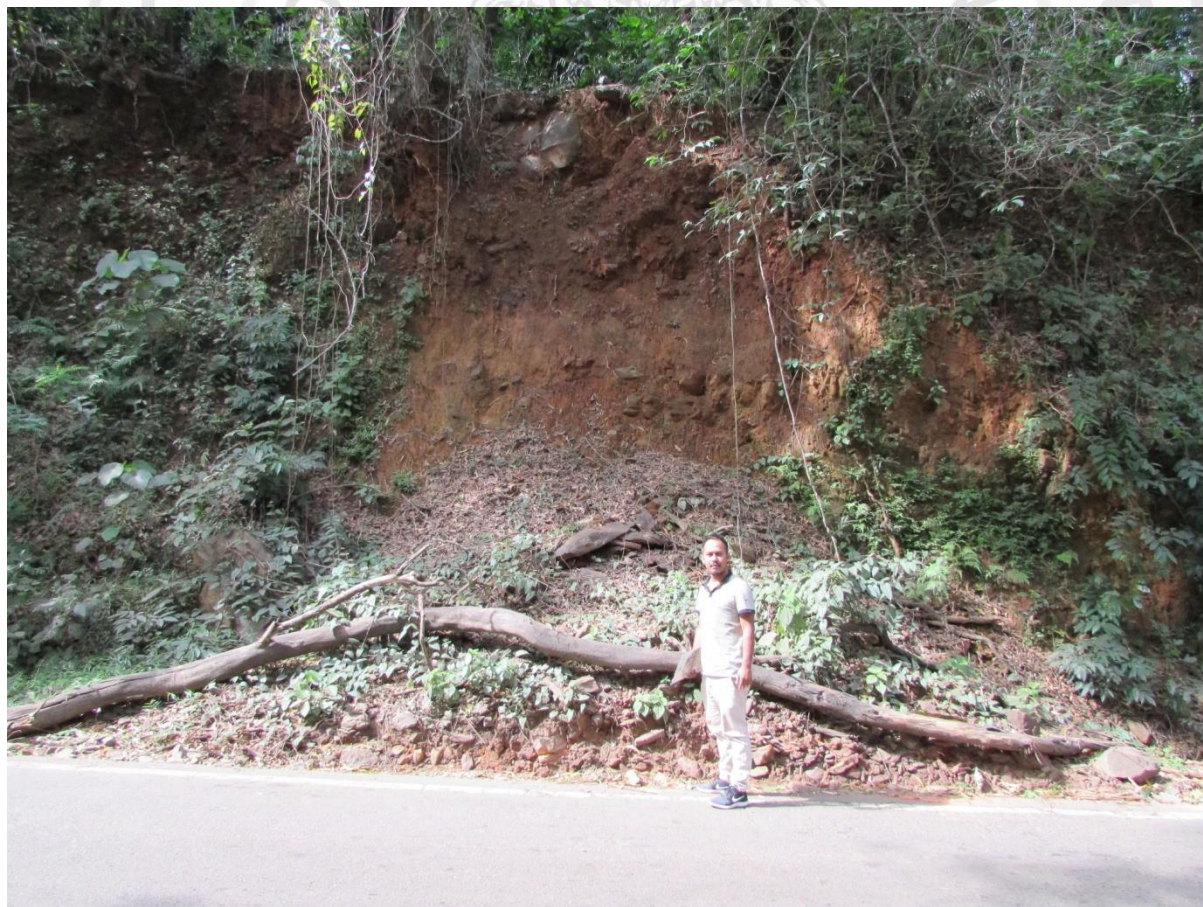
	& section of the slide	
40	Summary/Abstract	The landslide is located along Sanverdem – Siroda road section. It is an active debris slide, shallow translational in nature. The length of the slide is 10 m, width 11 m, height 5 m and depth 1.5 m. The geo scientific causes of the landslide are reduction of strength of overburden material on super saturation and cutting of the slope for road construction. This landslide caused temporary blockage of Sanverdem – Siroda road.
41	Pdf	Data not available
42	Landslide category	Category - II



Field photograph of landslide no: GOA/SG/48I03/2019/04

1	Slide No (LS .No.)	GOA/NG/48I02/2019/05
2	State	Goa
3	District	North Goa
4	Toposheet	48I/2
5	Name of the slide	Cut slope failure along Chorla ghat road, near Anjune Dam
6	NH/SH/Locality	2.9 km east of Keri
7	Latitude (N)	15.61
8	Longitude (E)	74.09
9	Length (m)	10
10	Width (m)	35
11	Height (m)	9
12	Area (m2)	350
13	Depth (m3)	0.5
14	Volume	175
15	Run out distance (m)	2
16	Type of Material	Debris
17	Type of movement	Slide
18	Rate of movement	Rapid
19	Activity	Active
20	Distribution	Widening
21	Style	Single
22	Failure mechanism	Shallow translational
23	History	Data not available
24	Geomorphology	Lowly Dissected Slope
25	Geology	Argillite
26	Structure	Data not available
27	Land use/ Land cover	Extensive slope Cut
28	Hydrological condition	Dry
29	Triggering Factor	Rainfall
30	Death of persons	Nil
31	People affected	Nil
32	Livestock loss	Nil
33	Communication	Blockage of Chorla ghat road
34	Infrastructure	Nil
35	Agriculture/forest/Barren	Forest
36	Geo-scientific Causes	Reduction of strength of overburden material on super saturation, cutting of slope for road construction
37	Remedial measures	Removal of loose material, construction of retaining wall

		with weep holes
38	Remarks, if any	Nil
39	Photos. Sketch of Plan & section of the slide	Photos given in the next page
40	Summary/Abstract	The landslide is located along Chorla ghat road section near Anjume dam at 2.9 km east of Keri. It is an active debris slide, shallow translational in nature. The length of the slide is 10 m, width 35 m, height 9 m and depth 0.5 m. The geo scientific causes of the landslide are reduction of strength of overburden material on super saturation and cutting of the slope for road construction. This landslide caused temporary blockage of Chorla ghat road section.
41	Pdf	Data not available
42	Landslide category	Category - II



Field photograph of landslide no: GOA/NG/48I02/2019/05

1	Slide No (LS .No.)	GOA/NG/48I02/2019/06
2	State	Goa
3	District	North Goa
4	Toposheet	48I/2
5	Name of the slide	Cut Slope failure along Chorla ghat road, near Anjune Dam
6	NH/SH/Locality	3.9 km east of Keri
7	Latitude (N)	15.60
8	Longitude (E)	74.10
9	Length (m)	12
10	Width (m)	30
11	Height (m)	9
12	Area (m2)	360
13	Depth (m3)	1
14	Volume	360
15	Run out distance (m)	2
16	Type of Material	Debris
17	Type of movement	Slide
18	Rate of movement	Rapid
19	Activity	Overall Dormant but signs of activity were observed within the slide body.
20	Distribution	Widening
21	Style	Single
22	Failure mechanism	Shallow translational
23	History	Data not available
24	Geomorphology	Lowly Dissected Slope
25	Geology	Argillite
26	Structure	Data not available
27	Land use/ Land cover	Extensive slope Cut
28	Hydrological condition	Dry
29	Triggering Factor	Rainfall
30	Death of persons	Nil
31	People affected	Nil
32	Livestock loss	Nil
33	Communication	Nil
34	Infrastructure	Nil
35	Agriculture/forest/Barren	Forest
36	Geo-scientific Causes	Reduction of strength of overburden material on super saturation, cutting of slope for road construction
37	Remedial measures	Removal of loose material, Grading of the slope, height of the existing retaining wall should be increase, line

		drainage should be provided
38	Remarks, if any	Retaining wall is already present but the height and width of the retaining wall should be increase.
39	Photos. Sketch of Plan & section of the slide	Photos given in the next page
40	Summary/Abstract	The landslide is located along Chorla ghat section near Anjume dam at 3.9 km east of Keri. It is a dormant debris slide, shallow translational in nature. The length of the slide is 12 m, width 30 m, height 9 m and depth 1 m. The geo scientific causes of the landslide are reduction of strength of overburden material on super saturation and cutting of the slope for road construction.
41	Pdf	Data not available
42	Landslide category	Category - II



Field photograph of landslide no: GOA/NG/48I02/2019/06

1	Slide No (LS .No.)	GOA/NG/48I02/2019/07
2	State	Goa
3	District	North Goa
4	Toposheet	48I/2
5	Name of the slide	Cut Slope failure along Chorla ghat road, near Anjune Dam
6	NH/SH/Locality	3.9 km east of Keri
7	Latitude (N)	15.60
8	Longitude (E)	74.10
9	Length (m)	11
10	Width (m)	35
11	Height (m)	9
12	Area (m2)	385
13	Depth (m3)	1
14	Volume	385
15	Run out distance (m)	2
16	Type of Material	Debris
17	Type of movement	Slide
18	Rate of movement	Rapid
19	Activity	Dormant
20	Distribution	Widening
21	Style	Single
22	Failure mechanism	Shallow translational
23	History	Data not available
24	Geomorphology	Lowly Dissected Slope
25	Geology	Argillite
26	Structure	Data not available
27	Land use/ Land cover	Extensive slope Cut
28	Hydrological condition	Dry
29	Triggering Factor	Rainfall
30	Death of persons	Nil
31	People affected	Nil
32	Livestock loss	Nil
33	Communication	Nil
34	Infrastructure	Nil
35	Agriculture/forest/Barren	Forest
36	Geo-scientific Causes	Reduction of strength of overburden material on super saturation, cutting of slope for road construction
37	Remedial measures	Removal of loose material, construction of concrete retaining wall with weep holes
38	Remarks, if any	Retaining wall is present but not a concrete wall

39	Photos. Sketch of Plan & section of the slide	Photos given in the next page
40	Summary/Abstract	The landslide is located along Chorla ghat road, near Anjune Dam at 3.9 km east of Keri. It is a dormant debris slide, shallow translational in nature. The length of the slide is 11 m, width 356 m, height 9m and depth 1 m. The geo scientific causes of the landslide are reduction of strength of overburden material on super saturation and cutting of the slope for road construction.
41	Pdf	Data not available
42	Landslide category	Category - II



Field photograph of landslide no: GOA/NG/48I02/2019/07

1	Slide No (LS .No.)	GOA/NG/48I02/2019/08
2	State	Goa
3	District	North Goa
4	Toposheet	48I/2
5	Name of the slide	Cut Slope failure along Chorla ghat road, near Anjune Dam
6	NH/SH/Locality	4 km east of Keri
7	Latitude (N)	15.60
8	Longitude (E)	74.10
9	Length (m)	8
10	Width (m)	15
11	Height (m)	7
12	Area (m2)	120
13	Depth (m3)	1
14	Volume	120
15	Run out distance (m)	2
16	Type of Material	Debris
17	Type of movement	Slide
18	Rate of movement	Rapid
19	Activity	Active
20	Distribution	Widening
21	Style	Single
22	Failure mechanism	Shallow translational
23	History	Data not available
24	Geomorphology	Lowly Dissected Slope
25	Geology	Argillite
26	Structure	Data not available
27	Land use/ Land cover	Extensive slope Cut
28	Hydrological condition	Dry
29	Triggering Factor	Rainfall
30	Death of persons	Nil
31	People affected	Nil
32	Livestock loss	Nil
33	Communication	Partial blockage of Chorla ghat road
34	Infrastructure	Nil
35	Agriculture/forest/Barren	Forest
36	Geo-scientific Causes	Reduction of strength of overburden material on super saturation, cutting of slope for road construction
37	Remedial measures	Removal of loose material
38	Remarks, if any	Nil

39	Photos. Sketch of Plan & section of the slide	Photos given in the next page
40	Summary/Abstract	The landslide is located along Chorla ghat road, near Anjune Dam at 4 km east of Keri. It is an active debris slide, shallow translational in nature. The length of the slide is 8 m, width 15 m, height 7 m and depth 1 m. The geo scientific causes of the landslide are reduction of strength of overburden material on super saturation and cutting of the slope for road construction. This landslide caused temporary blockage of Chorla ghat road
41	Pdf	Data not available
42	Landslide category	Category - II



Field photograph of landslide no: GOA/NG/48I02/2019/08

1	Slide No (LS .No.)	GOA/NG/48I02/2019/09
2	State	Goa
3	District	North Goa
4	Toposheet	48I/2
5	Name of the slide	Cut Slope failure along Chorla ghat road
6	NH/SH/Locality	4.4 km east of Keri
7	Latitude (N)	15.60
8	Longitude (E)	74.11
9	Length (m)	9
10	Width (m)	6
11	Height (m)	8
12	Area (m2)	54
13	Depth (m3)	0.5
14	Volume	27
15	Run out distance (m)	2
16	Type of Material	Debris
17	Type of movement	Slide
18	Rate of movement	Rapid
19	Activity	Active
20	Distribution	Widening
21	Style	Single
22	Failure mechanism	Shallow translational
23	History	Data not available
24	Geomorphology	Lowly Dissected Slope
25	Geology	Argillite
26	Structure	Data not available
27	Land use/ Land cover	Extensive slope Cut
28	Hydrological condition	Dry
29	Triggering Factor	Rainfall
30	Death of persons	Nil
31	People affected	Nil
32	Livestock loss	Nil
33	Communication	Partial blockage of Chorla ghat road
34	Infrastructure	Nil
35	Agriculture/forest/Barren	Forest
36	Geo-scientific Causes	Reduction of strength of overburden material on super saturation, cutting of slope for road construction
37	Remedial measures	Removal of loose material
38	Remarks, if any	Nil
39	Photos. Sketch of Plan	Photos given in the next page

	& section of the slide	
40	Summary/Abstract	The landslide is located along Chorla ghat road at 4.4 km east of Keri. It is an active debris slide, shallow translational in nature. The length of the slide is 9 m, width 6 m, height 8 m and depth .5 m. The geo scientific causes of the landslide are reduction of strength of overburden material on super saturation and cutting of the slope for road construction. This landslide caused temporary blockage of Chorla ghat road.
41	Pdf	Data not available
42	Landslide category	Category - II



Field photograph of landslide no: GOA/NG/48I02/2019/09

1	Slide No (LS .No.)	GOA/NG/48I02/2019/10
2	State	Goa
3	District	North Goa
4	Toposheet	48I/2
5	Name of the slide	Cut Slope failure along Chorla ghat road
6	NH/SH/Locality	4.7 km east of Keri
7	Latitude (N)	15.61
8	Longitude (E)	74.11
9	Length (m)	15
10	Width (m)	22
11	Height (m)	11
12	Area (m2)	330
13	Depth (m3)	1
14	Volume	330
15	Run out distance (m)	2
16	Type of Material	Debris
17	Type of movement	Slide
18	Rate of movement	Rapid
19	Activity	Reactivated
20	Distribution	Widening
21	Style	Single
22	Failure mechanism	Shallow translational
23	History	August 2019
24	Geomorphology	Lowly Dissected Slope
25	Geology	Argillite
26	Structure	Data not available
27	Land use/ Land cover	Extensive slope Cut
28	Hydrological condition	Dry
29	Triggering Factor	Rainfall
30	Death of persons	Nil
31	People affected	Nil
32	Livestock loss	Nil
33	Communication	Blockage of Chorla ghat road
34	Infrastructure	Nil
35	Agriculture/forest/Barren	Forest
36	Geo-scientific Causes	Reduction of strength of overburden material on super saturation, cutting of slope for road construction
37	Remedial measures	Removal of loose material, construction of concrete retaining wall with weep holes.

38	Remarks, if any	The existing retaining wall is not a concrete one and is partially damaged.
39	Photos. Sketch of Plan & section of the slide	Photos given in the next page
40	Summary/Abstract	The landslide is located along Chorla ghat road at 4.7 km east of Keri. It is an reactivated debris slide, shallow translational in nature. The length of the slide is 15 m, width 22 m, height 11 m and depth 1 m. The geo scientific causes of the landslide are reduction of strength of overburden material on super saturation and cutting of the slope for road construction. This landslide caused temporary blockage of Chorla ghat.
41	Pdf	Data not available
42	Landslide category	Category - II



Field photograph of landslide no: GOA/NG/48I02/2019/10

1	Slide No (LS .No.)	GOA/NG/48I02/2019/11
2	State	Goa
3	District	North Goa
4	Toposheet	48I/2
5	Name of the slide	Cut Slope failure along Chorla ghat road
6	NH/SH/Locality	4.8 km east of Keri
7	Latitude (N)	15.61
8	Longitude (E)	74.11
9	Length (m)	9
10	Width (m)	20
11	Height (m)	8
12	Area (m2)	180
13	Depth (m3)	0.5
14	Volume	90
15	Run out distance (m)	2
16	Type of Material	Debris
17	Type of movement	Slide
18	Rate of movement	Rapid
19	Activity	Reactivated
20	Distribution	Widening
21	Style	Single
22	Failure mechanism	Shallow translational
23	History	August 2019
24	Geomorphology	Lowly Dissected Slope
25	Geology	Argillite
26	Structure	Data not available
27	Land use/ Land cover	Extensive slope Cut
28	Hydrological condition	Dry
29	Triggering Factor	Rainfall
30	Death of persons	Nil
31	People affected	Nil
32	Livestock loss	Nil
33	Communication	Temporary blockage of Chorla ghat road
34	Infrastructure	Nil
35	Agriculture/forest/Barren	Forest
36	Geo-scientific Causes	Reduction of strength of overburden material on super saturation, cutting of slope for road construction
37	Remedial measures	Removal of loose material, increase of height of the existing retaining wall
38	Remarks, if any	One retaining wall is already constructed

39	Photos. Sketch of Plan & section of the slide	Photos given in the next page
40	Summary/Abstract	The landslide is located along Chorla ghat road, at 4.8 km east of Keri. It is a reactivated debris slide, shallow translational in nature. The length of the slide is 9 m, width 20m, height 8 m and depth 0.5 m. The geo scientific causes of the landslide are reduction of strength of overburden material on super saturation and cutting of the slope for road construction. This landslide caused temporary blockage of Chorla ghat road.
41	Pdf	Data not available
42	Landslide category	Category - II



Field photograph of landslide no: GOA/NG/48I02/2019/11

1	Slide No (LS .No.)	GOA/NG/48I02/2019/12
2	State	Goa
3	District	North Goa
4	Toposheet	48I/2
5	Name of the slide	Cut Slope failure along Chorla ghat road
6	NH/SH/Locality	5.4 km east of Keri
7	Latitude (N)	15.61
8	Longitude (E)	74.11
9	Length (m)	12
10	Width (m)	30
11	Height (m)	8
12	Area (m2)	360
13	Depth (m3)	1
14	Volume	360
15	Run out distance (m)	0
16	Type of Material	Debris
17	Type of movement	Slide
18	Rate of movement	Rapid
19	Activity	Dormant
20	Distribution	Widening
21	Style	Single
22	Failure mechanism	Shallow translational
23	History	Data not available
24	Geomorphology	Lowly Dissected Slope
25	Geology	Argillite
26	Structure	Data not available
27	Land use/ Land cover	Extensive slope Cut
28	Hydrological condition	Dry
29	Triggering Factor	Rainfall
30	Death of persons	Nil
31	People affected	Nil
32	Livestock loss	Nil
33	Communication	Nil
34	Infrastructure	Nil
35	Agriculture/forest/Barren	Forest
36	Geo-scientific Causes	Reduction of strength of overburden material on super saturation, cutting of slope for road construction
37	Remedial measures	Nil
38	Remarks, if any	A retaining wall is already provided
39	Photos. Sketch of Plan	Photos given in the next page

	& section of the slide	
40	Summary/Abstract	The landslide is located along Chorla ghat road at 5.4 km east of Keri. It is a dormant debris slide, shallow translational in nature. The length of the slide is 12 m, width 30 m, height 8 m and depth 1 m. The geo scientific causes of the landslide are reduction of strength of overburden material on super saturation and cutting of the slope for road construction.
41	Pdf	Data not available
42	Landslide category	Category - III



Field photograph of landslide no: GOA/NG/48I02/2019/12

1	Slide No (LS .No.)	GOA/NG/48I02/2019/13
2	State	Goa
3	District	North Goa
4	Toposheet	48I/2
5	Name of the slide	Cut Slope failure along Chorla ghat road
6	NH/SH/Locality	4 km south west of Chorla
7	Latitude (N)	15.63
8	Longitude (E)	74.12
9	Length (m)	40
10	Width (m)	35
11	Height (m)	30
12	Area (m2)	1400
13	Depth (m3)	2
14	Volume	2800
15	Run out distance (m)	2
16	Type of Material	Debris
17	Type of movement	Slide
18	Rate of movement	Rapid
19	Activity	Reactivated
20	Distribution	Retrogressive
21	Style	Single
22	Failure mechanism	Shallow translational
23	History	Data not available
24	Geomorphology	Lowly Dissected Slope
25	Geology	Argillite
26	Structure	Data not available
27	Land use/ Land cover	Extensive slope Cut
28	Hydrological condition	Dry
29	Triggering Factor	Rainfall
30	Death of persons	Nil
31	People affected	Nil
32	Livestock loss	Nil
33	Communication	Blockage of Chorla ghat road
34	Infrastructure	Nil
35	Agriculture/forest/Barren	Forest
36	Geo-scientific Causes	Reduction of strength of overburden material on super saturation, cutting of slope for road construction
37	Remedial measures	Removal of loose material, slope grading, height of existing retaining wall should be increased.
38	Remarks, if any	A retaining wall is already provided

39	Photos. Sketch of Plan & section of the slide	Photos given in the next page
40	Summary/Abstract	The landslide is located along Chorla ghat road at 4 km south west of Chorla. It is a reactivated debris slide, shallow translational in nature. The length of the slide is 40m, width 35 m, height 30 m and depth 2 m. The geo scientific causes of the landslide are reduction of strength of overburden material on super saturation and cutting of the slope for road construction. This landslide caused temporary blockage of Chorla ghat road
41	Pdf	Data not available
42	Landslide category	Category - II



Field photograph of landslide no: GOA/NG/48I02/2019/13

1	Slide No (LS .No.)	GOA/NG/48I02/2019/14
2	State	Goa
3	District	North Goa
4	Toposheet	48I/2
5	Name of the slide	Cut Slope failure along Chorla ghat road
6	NH/SH/Locality	3.9 km south west of Chorla
7	Latitude (N)	15.64
8	Longitude (E)	74.12
9	Length (m)	14
10	Width (m)	16
11	Height (m)	12
12	Area (m2)	224
13	Depth (m3)	1
14	Volume	224
15	Run out distance (m)	5
16	Type of Material	Debris
17	Type of movement	Slide
18	Rate of movement	Rapid
19	Activity	Active
20	Distribution	Widening
21	Style	Single
22	Failure mechanism	Shallow translational
23	History	August 2019
24	Geomorphology	Lowly Dissected Slope
25	Geology	Argillite
26	Structure	Data not available
27	Land use/ Land cover	Extensive slope Cut
28	Hydrological condition	Dry
29	Triggering Factor	Rainfall
30	Death of persons	Nil
31	People affected	Nil
32	Livestock loss	Nil
33	Communication	Blockage of Chorla ghat road
34	Infrastructure	Nil
35	Agriculture/forest/Barren	Forest
36	Geo-scientific Causes	Reduction of strength of overburden material on super saturation, cutting of slope for road construction
37	Remedial measures	Removal of loose material, construction of retaining wall with weep holes
38	Remarks, if any	Nil

39	Photos. Sketch of Plan & section of the slide	Photos given in the next page
40	Summary/Abstract	The landslide is located along Chorla ghat road section, at 3.9 km south west of Chorla. It is an active debris slide, shallow translational in nature. The length of the slide is 14 m, width 16 m, height 12 m and depth 1 m. The geo scientific causes of the landslide are reduction of strength of overburden material on super saturation and cutting of the slope for road construction. This landslide caused temporary blockage of Chorla ghat road.
41	Pdf	Data not available
42	Landslide category	Category - II



Field photograph of landslide no: GOA/NG/48I02/2019/14

1	Slide No (LS .No.)	GOA/NG/48I02/2019/15
2	State	Goa
3	District	North Goa
4	Toposheet	48I/2
5	Name of the slide	Cut Slope failure along Chorla ghat road
6	NH/SH/Locality	3.8 km south west of Chorla
7	Latitude (N)	15.64
8	Longitude (E)	74.11
9	Length (m)	20
10	Width (m)	10
11	Height (m)	15
12	Area (m2)	200
13	Depth (m3)	1
14	Volume	200
15	Run out distance (m)	2
16	Type of Material	Debris
17	Type of movement	Slide
18	Rate of movement	Rapid
19	Activity	Active
20	Distribution	Retrogressive
21	Style	Single
22	Failure mechanism	Shallow translational
23	History	August 2019
24	Geomorphology	Lowly Dissected Slope
25	Geology	Argillite
26	Structure	Data not available
27	Land use/ Land cover	Extensive slope Cut
28	Hydrological condition	Dry
29	Triggering Factor	Rainfall
30	Death of persons	Nil
31	People affected	Nil
32	Livestock loss	Nil
33	Communication	Blockage of Chorla ghat road
34	Infrastructure	Nil
35	Agriculture/forest/Barren	Forest
36	Geo-scientific Causes	Reduction of strength of overburden material on super saturation, cutting of slope for road construction
37	Remedial measures	Removal of loose material, construction of retaining wall with weep holes
38	Remarks, if any	Nil

39	Photos. Sketch of Plan & section of the slide	Photos given in the next page
40	Summary/Abstract	The landslide is located along Chorla ghat road section at 3.8 km south west of Chorla. It is an active debris slide, shallow translational in nature. The length of the slide is 20m, width 10 m, height 15m and depth 1 m. The geo scientific causes of the landslide are reduction of strength of overburden material on super saturation and cutting of the slope for road construction. This landslide caused temporary blockage of Chorla ghat road.
41	Pdf	Data not available
42	Landslide category	Category - II



Field photograph of landslide no: GOA/NG/48I02/2019/15

1	Slide No (LS .No.)	GOA/NG/48I02/2019/16
2	State	Goa
3	District	North Goa
4	Toposheet	48I/2
5	Name of the slide	Cut Slope failure along Chorla ghat road
6	NH/SH/Locality	2.9 km west of Chorla
7	Latitude (N)	15.65
8	Longitude (E)	74.12
9	Length (m)	9
10	Width (m)	12
11	Height (m)	8
12	Area (m2)	108
13	Depth (m3)	1
14	Volume	108
15	Run out distance (m)	2
16	Type of Material	Debris
17	Type of movement	Slide
18	Rate of movement	Rapid
19	Activity	Active
20	Distribution	Widening
21	Style	Single
22	Failure mechanism	Shallow translational
23	History	August 2019
24	Geomorphology	Lowly Dissected Slope
25	Geology	Basalt flow-undifferentiated
26	Structure	Data not available
27	Land use/ Land cover	Extensive slope Cut
28	Hydrological condition	Dry
29	Triggering Factor	Rainfall
30	Death of persons	Nil
31	People affected	Nil
32	Livestock loss	Nil
33	Communication	Blockage of Chorla ghat road
34	Infrastructure	Nil
35	Agriculture/forest/Barren	Forest
36	Geo-scientific Causes	Reduction of strength of overburden material on super saturation, cutting of slope for road construction
37	Remedial measures	Removal of loose material
38	Remarks, if any	Nil
39	Photos. Sketch of Plan	Photos given in the next page

	& section of the slide	
40	Summary/Abstract	The landslide is located along Chorla ghat road section at 2.9 km west of Chorla. It is an active debris slide, shallow translational in nature. The length of the slide is 9m, width 12 m, height 8m and depth 1 m. The geo scientific causes of the landslide are reduction of strength of overburden material on super saturation and cutting of the slope for road construction. This landslide caused temporary blockage of Chorla ghat road.
41	Pdf	Data not available
42	Landslide category	Category - II



Field photograph of landslide no: GOA/NG/48I02/2019/16

1	Slide No (LS .No.)	GOA/NG/48I02/2019/17
2	State	Goa
3	District	North Goa
4	Toposheet	48I/2
5	Name of the slide	Cut Slope failure along Chorla ghat road
6	NH/SH/Locality	2 km west of Chorla
7	Latitude (N)	15.65
8	Longitude (E)	74.13
9	Length (m)	23
10	Width (m)	20
11	Height (m)	18
12	Area (m2)	460
13	Depth (m3)	1
14	Volume	460
15	Run out distance (m)	2
16	Type of Material	Debris
17	Type of movement	Slide
18	Rate of movement	Rapid
19	Activity	Active
20	Distribution	Retrogressive
21	Style	Single
22	Failure mechanism	Shallow translational
23	History	August 2019
24	Geomorphology	Lowly Dissected Slope
25	Geology	Basalt flow-undifferentiated
26	Structure	Data not available
27	Land use/ Land cover	Extensive slope Cut
28	Hydrological condition	Dry
29	Triggering Factor	Rainfall
30	Death of persons	Nil
31	People affected	Nil
32	Livestock loss	Nil
33	Communication	Blockage of Chorla ghat road
34	Infrastructure	Nil
35	Agriculture/forest/Barren	Forest
36	Geo-scientific Causes	Reduction of strength of overburden material on super saturation, cutting of slope for road construction
37	Remedial measures	Removal of loose material, slope grading
38	Remarks, if any	Nil
39	Photos. Sketch of Plan	Photos given in the next page

	& section of the slide	
40	Summary/Abstract	The landslide is located along Chorla ghat road section at 2 km west of Chorla. It is an active debris slide, Shallow translational in nature. The length of the slide is 23m, width 20 m, height 18m and depth 1 m. The geo scientific causes of the landslide are reduction of strength of overburden material on super saturation and cutting of the slope for road construction. This landslide caused temporary blockage of Chorla ghat road.
41	Pdf	Data not available
42	Landslide category	Category - II



Field photograph of landslide no: GOA/NG/48I02/2019/17

1	Slide No (LS .No.)	GOA/NG/48I02/2019/18
2	State	Goa
3	District	North Goa
4	Toposheet	48I/2
5	Name of the slide	Cut Slope failure along Chorla ghat road
6	NH/SH/Locality	1.9 km west of Chorla
7	Latitude (N)	15.65
8	Longitude (E)	74.13
9	Length (m)	25
10	Width (m)	120
11	Height (m)	18
12	Area (m2)	3000
13	Depth (m3)	4
14	Volume	12000
15	Run out distance (m)	5
16	Type of Material	Debris
17	Type of movement	Slide
18	Rate of movement	Rapid
19	Activity	Reactivated
20	Distribution	Widening
21	Style	Single
22	Failure mechanism	Shallow translational
23	History	August 2019
24	Geomorphology	Lowly Dissected Slope
25	Geology	Basalt flow-undifferentiated
26	Structure	Data not available
27	Land use/ Land cover	Extensive slope Cut
28	Hydrological condition	Dry
29	Triggering Factor	Rainfall
30	Death of persons	Nil
31	People affected	Nil
32	Livestock loss	Nil
33	Communication	Blockage of Chorla ghat road
34	Infrastructure	Nil
35	Agriculture/forest/Barren	Forest
36	Geo-scientific Causes	Reduction of strength of overburden material on super saturation, cutting of slope for road construction
37	Remedial measures	Removal of loose basalt boulders from the slope. Slope grading, the height of the existing retaining wall should be increased by at least 2.5 m and width of the retaining wall should be increased around 20 m towards both

		flanks.
38	Remarks, if any	Already a retaining wall is provided with lesser height. Big boulders are resting critically just above the exiting retaining wall.
39	Photos. Sketch of Plan & section of the slide	Photos given in the next page
40	Summary/Abstract	The landslide is located along Chorla ghat road section at 1.9 km west of Chorla. It is a reactivated debris slide, shallow translational in nature. The length of the slide is 25m, width 120 m, height 18m and depth 4 m. The geo scientific causes of the landslide are reduction of strength of overburden material on super saturation and cutting of the slope for road construction. This landslide caused temporary blockage of Chorla ghat road.
41	Pdf	Data not available
42	Landslide category	Category - II



Field photograph of landslide no: GOA/NG/48I02/2019/18

1	Slide No (LS .No.)	GOA/NG/48I02/2019/19
2	State	Goa
3	District	North Goa
4	Toposheet	48I/2
5	Name of the slide	Cut Slope failure along Chorla ghat road
6	NH/SH/Locality	1.8 km west of Chorla
7	Latitude (N)	15.65
8	Longitude (E)	74.13
9	Length (m)	18
10	Width (m)	45
11	Height (m)	15
12	Area (m2)	810
13	Depth (m3)	1
14	Volume	810
15	Run out distance (m)	1
16	Type of Material	Debris
17	Type of movement	Slide
18	Rate of movement	Rapid
19	Activity	Active
20	Distribution	Widening
21	Style	Multiple
22	Failure mechanism	Shallow translational
23	History	Data not available
24	Geomorphology	Lowly Dissected Slope
25	Geology	Basalt flow-undifferentiated
26	Structure	Data not available
27	Land use/ Land cover	Extensive slope Cut
28	Hydrological condition	Dry
29	Triggering Factor	Rainfall
30	Death of persons	Nil
31	People affected	Nil
32	Livestock loss	Nil
33	Communication	Blockage of Chorla ghat road
34	Infrastructure	Nil
35	Agriculture/forest/Barren	Nil
36	Geo-scientific Causes	Reduction of strength of overburden material on super saturation, cutting of slope for road construction
37	Remedial measures	Removal of loose materials
38	Remarks, if any	Nil

39	Photos. Sketch of Plan & section of the slide	Photos given in the next page
40	Summary/Abstract	The landslide is located along Chorla ghat road section at 1.8 km west of Chorla. It is an active debris slide, shallow translational in nature. The length of the slide is 18m, width 45 m, height 15m and depth 1 m. The geo scientific causes of the landslide are reduction of strength of overburden material on super saturation and cutting of the slope for road construction. This landslide caused temporary blockage of Chorla ghat road.
41	Pdf	Data not available
42	Landslide category	Category - II



Field photograph of landslide no: GOA/NG/48102/2019/19

1	Slide No (LS .No.)	KAR/BEL/48I02/2019/20
2	State	Karnataka
3	District	Belagavi
4	Toposheet	48I/2
5	Name of the slide	Cut Slope failure along Chorla ghat road
6	NH/SH/Locality	570 m south of Chorla
7	Latitude (N)	15.65
8	Longitude (E)	74.14
9	Length (m)	10
10	Width (m)	15
11	Height (m)	9
12	Area (m2)	150
13	Depth (m3)	1
14	Volume	150
15	Run out distance (m)	1
16	Type of Material	Debris
17	Type of movement	Slide
18	Rate of movement	Rapid
19	Activity	Active
20	Distribution	Widening
21	Style	Single
22	Failure mechanism	Shallow translational
23	History	Data not available
24	Geomorphology	Lowly Dissected Slope
25	Geology	Basalt flow-undifferentiated
26	Structure	Data not available
27	Land use/ Land cover	Extensive slope Cut
28	Hydrological condition	Dry
29	Triggering Factor	Rainfall
30	Death of persons	Nil
31	People affected	Nil
32	Livestock loss	Nil
33	Communication	Partial blockage of Chorla ghat road
34	Infrastructure	Nil
35	Agriculture/forest/Barren	Nil
36	Geo-scientific Causes	Reduction of strength of overburden material on super saturation, cutting of slope for road construction
37	Remedial measures	Removal of loose materials
38	Remarks, if any	Nil

39	Photos. Sketch of Plan & section of the slide	Photos given in the next page
40	Summary/Abstract	The landslide is located along Chorla ghat road at 570 m south of Chorla. It is an active debris slide, shallow translational in nature. The length of the slide is 10m, width 15 m, height 9m and depth 1 m. The geo scientific causes of the landslide are reduction of strength of overburden material on super saturation and cutting of the slope for road construction. This landslide caused temporary blockage of Chorla ghat road.
41	Pdf	Data not available
42	Landslide category	Category - II



Field photograph of landslide no: KAR/BEL/48I02/2019/20

1	Slide No (LS .No.)	GOA/NG/48I02/2020/21
2	State	Goa
3	District	North Goa
4	Toposheet	48I/2
5	Name of the slide	Cut Slope failure along Honda – Valpoi road
6	NH/SH/Locality	3.5 km west of Valpoi
7	Latitude (N)	15.53
8	Longitude (E)	74.11
9	Length (m)	6
10	Width (m)	63
11	Height (m)	5
12	Area (m2)	378
13	Depth (m3)	1
14	Volume	378
15	Run out distance (m)	1
16	Type of Material	Debris
17	Type of movement	Slide
18	Rate of movement	Rapid
19	Activity	Reactivated
20	Distribution	Widening
21	Style	Single
22	Failure mechanism	Shallow translational
23	History	Data not available
24	Geomorphology	Rolling Plain
25	Geology	Quartz-chlorite schist
26	Structure	Data not available
27	Land use/ Land cover	Extensive slope Cut
28	Hydrological condition	Dry
29	Triggering Factor	Rainfall
30	Death of persons	Nil
31	People affected	Nil
32	Livestock loss	Nil
33	Communication	Partial blockage of Honda – Valpoi road
34	Infrastructure	Nil
35	Agriculture/forest/Barren	Nil
36	Geo-scientific Causes	Reduction of strength of overburden material on super saturation, cutting of slope for road construction
37	Remedial measures	Extension of existing retaining wall on both sides. Height of the retaining wall should also be increased with proper weep holes.
38	Remarks, if any	One retaining wall already provided.

39	Photos. Sketch of Plan & section of the slide	Photos given in the next page
40	Summary/Abstract	The landslide is located along Honda – Valpoi road at 3.5 km west of Valpoi. It is an reactivated debris slide, shallow translational in nature. The length of the slide is 6m, width 66 m, height 6m and depth 1 m. The geo scientific causes of the landslide are reduction of strength of overburden material on super saturation and cutting of the slope for road construction. This landslide caused temporary blockage of Honda – Valpoi road.
41	Pdf	Data not available
42	Landslide category	Category - II



Field photograph of landslide no: GOA/NG/48I02/2020/21

1	Slide No (LS .No.)	GOA/SG/48I03/2020/22
2	State	Goa
3	District	South Goa
4	Toposheet	48I/3
5	Name of the slide	Cut Slope failure along Khandepar – Opa road, Near Opa water tank
6	NH/SH/Locality	1.5 km north east of Ponda
7	Latitude (N)	15.41
8	Longitude (E)	74.02
9	Length (m)	18
10	Width (m)	60
11	Height (m)	14
12	Area (m2)	1080
13	Depth (m3)	1
14	Volume	1080
15	Run out distance (m)	5
16	Type of Material	Debris
17	Type of movement	Slide
18	Rate of movement	Rapid
19	Activity	Active
20	Distribution	Retrogressive
21	Style	Single
22	Failure mechanism	Shallow translational
23	History	August 2019
24	Geomorphology	Rolling Plain
25	Geology	Argillite
26	Structure	Data not available
27	Land use/ Land cover	Extensive slope Cut
28	Hydrological condition	Dry
29	Triggering Factor	Rainfall
30	Death of persons	Nil
31	People affected	Nil
32	Livestock loss	Nil
33	Communication	Blockage of Khandepar – Opa road
34	Infrastructure	Nil
35	Agriculture/forest/Barren	Nil
36	Geo-scientific Causes	Reduction of strength of thick overburden material on super saturation, cutting of slope for road construction
37	Remedial measures	Removal of loose materials, extension of retaining wall

		on both sides of the existing retaining wall.
38	Remarks, if any	One good quality concrete retaining wall already provided.
39	Photos. Sketch of Plan & section of the slide	Photos given in the next page
40	Summary/Abstract	The landslide is located along Khandepar – Opa road at 1.5 km north east of Ponda. It is an active debris slide, shallow translational in nature. The length of the slide is 18m, width 60 m, height 14m and depth 1 m. The geo scientific causes of the landslide are reduction of strength of thick overburden material on super saturation and cutting of the slope for road construction. This landslide caused temporary blockage of Khandepar – Opa road.
41	Pdf	Data not available
42	Landslide category	Category - II



Field photograph of landslide no: GOA/SG/48I03/2020/22

1	Slide No (LS .No.)	GOA/SG/48I03/2020/23
2	State	Goa
3	District	South Goa
4	Toposheet	48I/3
5	Name of the slide	Cut Slope failure along Ponda – Borim bypass road
6	NH/SH/Locality	2 km north east of Ponda
7	Latitude (N)	15.41
8	Longitude (E)	74.02
9	Length (m)	30
10	Width (m)	82
11	Height (m)	25
12	Area (m2)	2460
13	Depth (m3)	3
14	Volume	7380
15	Run out distance (m)	30
16	Type of Material	Debris
17	Type of movement	Slide
18	Rate of movement	Rapid
19	Activity	Reactivated
20	Distribution	Widening and Retrogressive
21	Style	Single
22	Failure mechanism	Shallow translational
23	History	August 2019
24	Geomorphology	Lowly Dissected Slope
25	Geology	Argillite
26	Structure	Data not available
27	Land use/ Land cover	Extensive slope Cut
28	Hydrological condition	Dry
29	Triggering Factor	Rainfall
30	Death of persons	Nil
31	People affected	Nil
32	Livestock loss	Nil
33	Communication	Blockage of Ponda – Borim bypass road
34	Infrastructure	Nil
35	Agriculture/forest/Barren	Forest
36	Geo-scientific Causes	Reduction of strength of thick overburden material on super saturation, cutting of slope for road construction
37	Remedial measures	Removal of loose materials, slope grading, construction of retaining wall with weep holes.
38	Remarks, if any	Nil

39	Photos. Sketch of Plan & section of the slide	Photos given in the next page
40	Summary/Abstract	The landslide is located along Ponda – Borim bypass road. It is an active debris slide, shallow translational in nature. The length of the slide is 30m, width 82 m, height 25m and depth 3 m. The geo scientific causes of the landslide are reduction of strength of thick overburden material on super saturation and cutting of the slope for road construction. This landslide caused temporary blockage of Ponda – Borim bypass road.
41	Pdf	Data not available
42	Landslide category	Category - II



Field photograph of landslide no: GOA/SG/48I03/2020/23

1	Slide No (LS .No.)	GOA/SG/48I03/2020/24
2	State	Goa
3	District	South Goa
4	Toposheet	48I/3
5	Name of the slide	Cut Slope failure along Ponda – Borim bypass road
6	NH/SH/Locality	1.8 km east of Ponda
7	Latitude (N)	15.40
8	Longitude (E)	74.03
9	Length (m)	22
10	Width (m)	50
11	Height (m)	20
12	Area (m2)	1100
13	Depth (m3)	1
14	Volume	1100
15	Run out distance (m)	2
16	Type of Material	Debris
17	Type of movement	Slide
18	Rate of movement	Rapid
19	Activity	Active
20	Distribution	Widening
21	Style	Single
22	Failure mechanism	Shallow translational
23	History	August 2019
24	Geomorphology	Rolling Plain
25	Geology	Argillite
26	Structure	Data not available
27	Land use/ Land cover	Extensive slope Cut
28	Hydrological condition	Dry
29	Triggering Factor	Rainfall
30	Death of persons	Nil
31	People affected	Nil
32	Livestock loss	Nil
33	Communication	Blockage of Ponda – Borim bypass road
34	Infrastructure	Nil
35	Agriculture/forest/Barren	Nil
36	Geo-scientific Causes	Reduction of strength of thick overburden material on super saturation, cutting of slope for road construction
37	Remedial measures	Removal of loose materials, slope grading, construction of retaining wall with weep holes.
38	Remarks, if any	Nil

39	Photos. Sketch of Plan & section of the slide	Photos given in the next page
40	Summary/Abstract	The landslide is located along Ponda – Borim bypass road at 1.8 km east of Ponda. It is an active debris slide, shallow translational in nature. The length of the slide is 22m, width 50 m, height 20m and depth 1 m. The geo scientific causes of the landslide are reduction of strength of thick overburden material on super saturation and cutting of the slope for road construction. This landslide caused temporary blockage of along Ponda – Borim bypass road.
41	Pdf	Data not available
42	Landslide category	Category - II



Field photograph of landslide no: GOA/SG/48I03/2020/24

1	Slide No (LS .No.)	GOA/SG/48I03/2020/25
2	State	Goa
3	District	South Goa
4	Toposheet	48I/3
5	Name of the slide	Landslide at Mayna
6	NH/SH/Locality	2.9 km southeast of Mayna
7	Latitude (N)	15.27
8	Longitude (E)	74.02
9	Length (m)	50
10	Width (m)	140
11	Height (m)	40
12	Area (m2)	7000
13	Depth (m3)	6
14	Volume	42000
15	Run out distance (m)	10
16	Type of Material	Earth
17	Type of movement	Slide
18	Rate of movement	Rapid
19	Activity	Active
20	Distribution	Widening and Retrogressive
21	Style	Multiple
22	Failure mechanism	Deep Translational
23	History	Data not available
24	Geomorphology	Lowly Dissected Slope
25	Geology	Granite (Chandranath)
26	Structure	Data not available
27	Land use/ Land cover	Fallow land
28	Hydrological condition	Dry
29	Triggering Factor	Rainfall
30	Death of persons	Nil
31	People affected	Nil
32	Livestock loss	Nil
33	Communication	Nil
34	Infrastructure	Nil
35	Agriculture/forest/Barren	Barren
36	Geo-scientific Causes	Reduction of strength of overburden material on super saturation
37	Remedial measures	Removal of loose materials, construction of retaining wall with weep holes
38	Remarks, if any	Nil

39	Photos. Sketch of Plan & section of the slide	Photos given in the next page
40	Summary/Abstract	The landslide is located near 2.9 km southeast of Mayna. It is an active earth slide, deep translational in nature. The length of the slide is 50m, width 140 m, height 40m and depth 6m. The geo scientific cause of the landslide is reduction of strength of overburden material on super saturation.
41	Pdf	Data not available
42	Landslide category	Category - III



Field photograph of landslide no: GOA/SG/48I03/2020/25