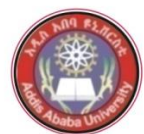


Landslide Hazard Zonation Around The Route From Alemketema Town To Ambat Village, North Shewa, Ethiopia

Birhanu Ermias

**A Thesis Submitted to
School of Earth Sciences**

**Presented in Partial Fullfillment of the requirements for the
Degree of Masters of Science (Engineering Geology)**



ADDIS ABABA UNIVERSITY

Addis Ababa, Ethiopia

May, 2014

SIGNATURE PAGE

Addis Ababa University
School of Graduate Studies

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ABSTRACT

Landslide Hazard Zonation around the route from Alemketema town to Ambat village, North Shewa, Ethiopia

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Addis Ababa University, 2014

In the Present study Landslide Hazard Zonation (LHZ) mapping around the route from Alem ketema town to Ambat village was carried out by applying Slope Stability Susceptibility Evaluation Parameter (SSEP) rating scheme. The main objective of the study was to prepare the LHZ map of the study area and to derive suitable recommendations based on the results of the study. Remote sensing and field survey was conducted to map the distribution of existing landslides and the factors that affect the landslide occurrences. Field measurements on structural discontinuities and observation on field manifestations for landslide and related slope instabilities was carried out. For digitizing, data processing, and analysis purposes, Arc-GIS 9.3 and Global Mapper 12 software were used. In applying SSEP rating scheme, the relative contribution of each of the intrinsic causative and extrinsic triggering factors were evaluated and ratings were assigned for each factor facet wise. The intrinsic parameters considered are; slope geometry, slope material, structural discontinuities, land use/ land cover and groundwater whereas the external triggering factors are; seismicity, rainfall and manmade activities. The sum total of all ratings for causative intrinsic parameters and external triggering parameters are represented as Evaluated Landslide Hazard (ELH) based on which the study area is divided into classes of hazard zones as per the SSEP rating scheme and the LHZ map of the study area was produced in GIS environment. The prepared LHZ map has identified two zones, namely High Hazard (66.9%) and Moderate Hazard (33.1%). Finally, LHZ map was overlaid by past landslide events data out of which 80.3% have fallen in High Hazard zone confirming the validity of the prepared LHZ map. Thus, the satisfactory validation confirms the rationality of considered parameters, the adopted SSEP technique, tools and procedures in developing the LHZ map of the study area.

Key words: Landslide Hazard Zonation (LHZ), Evaluated Landslide Hazard (ELH), Intrinsic, Extrinsic, Alem ketema, Ethiopia.

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Dedicated to my son, Sirak Birhanu, with love.

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CHAPTER I

INTRODUCTION

1.1 Background

Ethiopia is located in the Horn of Africa between latitudes of 3.8°N to 14.5°N and longitudes of 33°E to 48°E with an area of about 1.12 million km². The varied topography of the country shows extreme changes in altitude with its lowest point at about 120 m below sea level (Kobat Sink Afar depression) and its highest point about 4620 m above sea level (Ras dashen) (NMA, 2012). The central highlands with altitudes between 1,500 and 4,000 m are dissected by numerous rivers, including the Blue Nile. The highlands are split by the Rift Valley, which runs from the Danakil depression close to the Red Sea to the Southern part of the country in a southwesterly direction (www.uoguelph.ca/~geology/rocks_for_crops/25ethiopia.PDF).

Ethiopia is a country with great geographic diversity with mountains, high plateaus, deep gorges, river valleys, and lowland plains (Aregay Waktola, 1999). Broadly, the Ethiopian landmass is divided into highlands and lowlands. According to FAO (1986 as cited in Kifle Woldearegay, 2013), the Ethiopian highlands (which include areas with altitude over 1500 m a.s.l) cover about 44% of the Ethiopian landmass. These highlands represent the most densely populated areas; with over 60% of the population living in these areas (Kifle Woldearegay, 2013). These physiographic variations create a large difference in meteorological and hydrological conditions both in time and space (NMA, 2012). Aregay Waktola (1999), stated that the diversity in altitude and resulting climate and ecological variation present both challenges and opportunities in Ethiopia.

Landslides and landslide-generated ground failures are among the common geo-environmental hazards in many of the hilly and mountainous terrains of both the developed and developing world (Kifle Woldearegay, 2013). According to Kifle Woldearegay (2013), the hilly and mountainous terrains of the highlands of Ethiopia are frequently being affected by rainfall-induced landslides of different types and sizes.

Landslides are one of the most destructive phenomena of nature that cause damage to both property and life every year. The study of landslides has drawn global attention mainly due to increasing awareness of its socio-economic impacts and also increasing pressure of urbanization on the mountain environment (Aleotti and Chowdhury, 1999 as cited in Kanungo et al., 2006).

In Ethiopia, according to Lulseged Ayalew and Yamagishi (2005), slope failures occur in broad regions that possess characteristic soil and rock materials, geologic structures and topographic settings. According to them, landslides include deep seated rotational slumps, massive translational slides, and slow progressive creep movements. They stated that rock falls on the other hand exist largely in the form of discernible block toppling and wedge failures all along mountains ranges, valley walls and roadsides. Therefore, according to Kanungo et al. (2006), landslide hazard zonation (LHZ) is necessary for planning future developmental activities in hilly and mountainous terrains of countries like Ethiopia.

1.2 Problem Statement

Eberhardt (2003) stated that, despite improvements in recognition, prediction and mitigation measures, landslides still exert a heavy social, economic and environmental toll in mountainous regions. According to him, this is partly due to the complexity of the processes driving slope failures and our inadequate knowledge of the underlying mechanisms. He added that, ever increasingly, experts are called upon to analyze and predict the stability of a given slope, assessing its risk, potential failure mechanisms and velocities, areas endangered, and possible remedial measures.

According to Terlien (1996 as cited in Batista, 2013), a small percentage of individual landslides are catastrophic, it is essentially the high number which makes the total economic loss due to slope instability (direct damage to agricultural land and infrastructure and indirect damage to economic activity) to be higher than due to other hazardous natural phenomena.

Schuster (1995 as cited in Batista, 2013) indicates that world-wide landslide activities are expected to continue in the 21st century for the following reasons: (a) increased urbanization and development in landslide-prone areas, (b) continued deforestation of landslide-prone areas, and (c) increased precipitation caused by changing climatic conditions.

According to Kifle Woldearegay (2013), the hilly and mountainous terrains of the highlands of Ethiopia which are characterized by variable topographical, geological, hydrological (surface and groundwater) and land-use conditions, are frequently affected by rainfall-triggered slope failures though earthquake triggered landslides are little reported.

In Ethiopia, landslide-generated hazards are becoming serious concerns to the general public and to the planners and decision makers at various levels of the Government. However, so

far, little efforts have been made to reduce losses from such hazards. With the on-going infrastructural development, urbanization, rural development, and with the present land management system, it is foreseeable that the frequency and magnitude of landslides and losses due to such hazards would continue to increase unless appropriate actions are taken in Ethiopia (Kifle Woldearegay, 2013).

Kifle Woldearegay (2013) further indicated that, considering the scale of the landslide problems and the socio-economic development in the country, the on-going research on landslides is negligible. According to him, there is a strong need to initiate research on: (a) landslide hazard mapping and loss assessment, (b) landslide hazard forecasting and monitoring, and (c) cost-effective landslide mitigation (remedial) measures.

The identified project area for the present study covers an area around a route which extends from Alem ketema town to Ambat village. Landslides are the major geological hazards in the gorges of the project area. This phenomenon is mainly associated with the colluvial material making most of the slope faces in the project area. Long, steep, straight mountain and valley sides of the project route are covered by a mantle of colluvial soil (transported slowly by gravity) over weathered rock. Instability is normal in this terrain; shallow translational and planar landslides and gully erosion are the commonest forms. Local landslides up to 15 m deep are observed in colluvial deposits (ERA SMRR, 2010).

Dai et al. (2002) suggested that in order to mitigate landslide hazard effectively, new methodologies are required to develop a better understanding of landslide hazard and to make rational decisions on the allocation of funds for management of landslide risk. A new slope susceptibility evaluation parameter (SSEP) rating scheme was developed by Raghuvanshi et al., (2013) as an approach for landslide hazard zonation by considering both intrinsic and external triggering parameters that are responsible for slope instability. The SSEP technique was successfully applied in the area around Wurgessa Kebelle of North Wollo Zonal Administration, Amhara National Regional State in northern Ethiopia, which is 490 km far from Addis Ababa. The results obtained indicated that all past landslide activities and potential instability areas have fallen within very high and high hazard zone of the landslide hazard zonation map prepared during the study. Thus, according to Raghuvanshi et al. (2013), this satisfactory agreement confirmed the rationality of considered governing parameters, the adopted SSEP technique, tools and procedures in developing the landslide hazard map of the study area.

Hence, in the present study, SSEP is preferred to be used as an approach for landslide hazard zonation mapping of the study area.

1.3 Objectives

1.3.1 General Objectives

The overall objective of the present research study is to assess and examine the slope stability problems associated with the zones extending from Alemketma town to Wanchit and SI - E by classifying the area in to zones of relative susceptibility to landslide hazard.

The general objectives are;

- (i) To prepare landslide hazard zonation map of the study area.
- (ii) To validate the prepared landslide hazard zonation map.
- (iii) To derive the possible suitable recommendations based on the results of the present study.

1.3.2 Specific Objectives

- To identify the types of landslides occurring in the study area,
- To understand processes and factors leading to slope failures in the area,
- To prepare landslide hazard zonation map of the study area by considering Landslide causative factors (both internal preparatory factors and External or triggering factors),
- To check the validity of the prepared landslide hazard zonation map,
- To derive possible suitable recommendations based on the results of the present study.

1.4 An Overview of the study area

1.4.1 Location

The present study area is located about 120 km north of Addis Ababa which is situated in the north-eastern part of Jemma River basin (sub - basin of Abay) in Central Ethiopia. Specifically, it lies in the Northern part of North Showa Zone and Southern part of South Wallo Zonal Administration in Amhara National Regional State. Geographically the study area is bounded from north to south by latitudes 1132955mN (10⁰15'N) and 1105376mN (10⁰00'N) and from East to West by longitudes 527387mE (39⁰15'E) and 500000mE (39⁰00'E). The study area covers an area around a route which extends from Alemketema town (with a geographic coordinates of E 37 0500000, N 1111420 and Elevation of 2249m

amsl) to Wenchit and SI - E area (with a geographic coordinates of E 37 0527392, N 1118529 and Elevation of 2000m amsl). The location map of the area is illustrated in Fig. 1.1(a).

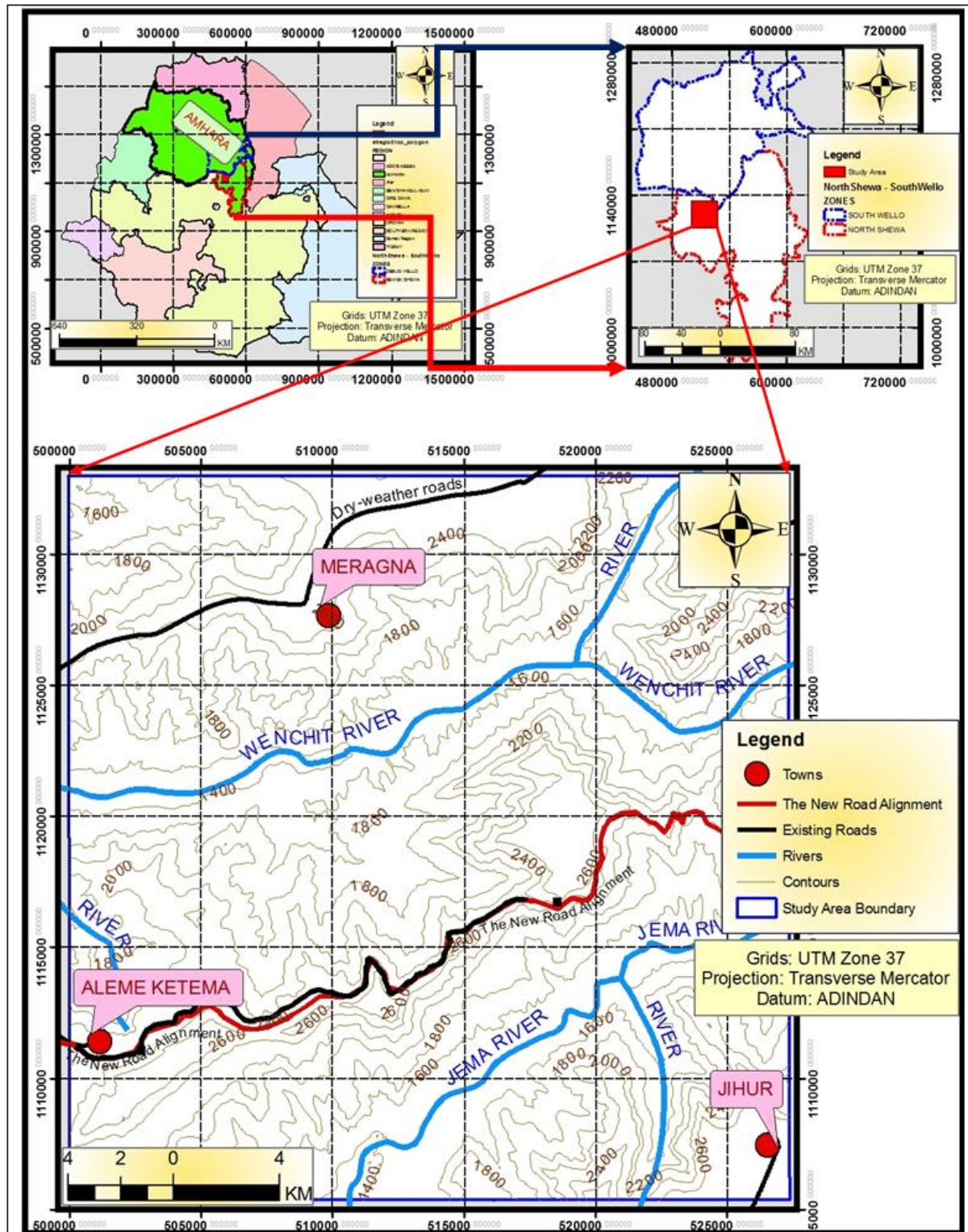


Fig. 1.1 (a) Location Map of the study area

The study area touches five Weredas and two Zonal Administrations in the surrounding area. As shown in Fig.1.1 (b), 16 % of the study area (in its northern and northwestern part) lies in

Weremo Wajituna Mida wereda, 22 % of the study area (in its northeastern part) falls in Jema Wereda, 19 % of the study area (in its central and southwestern part) lies in the Lay Betna Tach Bet Wereda, 29 % of the area (in its eastern part) lies in Gera Midirna Keya Gebriel Wereda, and 14 % of the area (in its southern and southeastern part) lies in the Moretna Jiru Wereda. Generally, 81 % the study area lies in the North Shewa (Semen Shewa) Administration Zone where as the remaining 19% of the study area falls in the South Wallo (Debug Wollo) Administration Zone (Fig. 1.1 (b)).

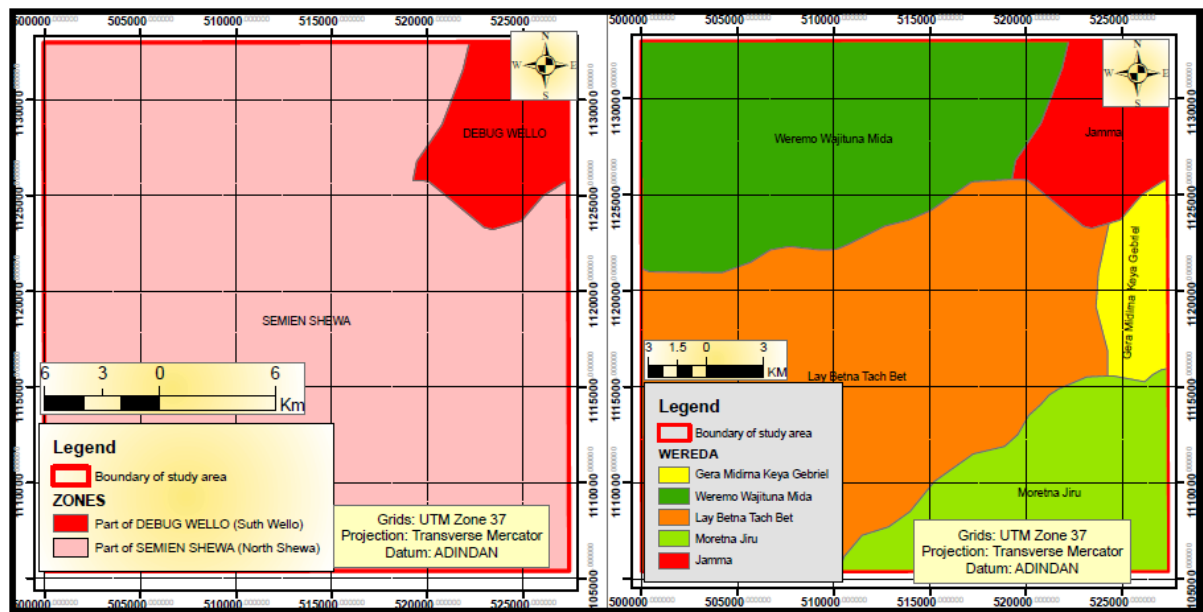


Fig. 1.1 (b) Part of the Zones and Weredas touched by the present study area

1.4.2 Accessibility

Alemketema town, in the study area, can be accessed via Addis Ababa - Bahir Dar main asphalt road up to Mukaturi town which is about 76 km from Addis Ababa. From Mukaturi town to Alemketema the accessibility is via gravel road that reaches about 184 km distance. After Alemketema town is reached, within the project area, there are no motorable access roads. However, currently, there is a new road alignment under construction that extends from Alemketema town through Wanchit and SI - E areas to Mehalmeda town. The present study covers only the area from Alemketema town up to Wanchit and SI - E areas (Fig. 1.1 (a)).

1.4.3 Climate

From meteorological point of view, there are three seasons in Ethiopia; Belg, Kiremt and Bega. Belg (February-May) is the small rainy season in Ethiopia. Much of the northeastern, central, southern, southwestern, eastern and southeastern parts of the country receive

considerable amount of rainfall during this season. Kiremt (June-September) is the main rainfall season for most parts of the country except for the lowlands of southern and southeastern Ethiopia. Bega (October-January) is mostly a dry season for most parts of the country except for southwestern as well as the lowlands of south and southeast Ethiopia (NMA, 2012).

The Amhara National Regional State, like the rest of the country, is located within the tropics where there is no significant variation in day length and the angle of the sun throughout the year. As a result, average annual temperatures in the region are high and variations low. The region has climatic zones ranging from hot dry tropical (800-1830 m above sea level), sub tropical (1830-2440 m above sea level), temperate (2440-3000 m above sea level), and alpine (over 3000 m above sea level). Highlands above an altitude of 1500 m experiences relatively cool temperature conditions in contrast to the lowlands (ANRS BoFED, 2011).

Table 1.1 Climatic zones (after ANRS BoFED, 2011)

Name of the climate zone	Altitude (m.a.s.l.)
Kolla (Tropical zone)	below 1830m
Woina dega (subtropical zone)	1830m - 2440m
Dega (Cool zone)	above 2440m

A climatic zoning map of the study area (Fig. 1.2) was compiled based on the climatic region classification given in Table 1.1 and the elevation of the study area. It was found that 12.1 % of the area lies in the Dega (Cool Zone) zone and covers the plateau areas around Alemketem, Meragna and Jihur; 45.9 % of the area fall in the Weina Dega (sub-tropical) zone and covers a large part of the upper slopes of ridges, mountains and valley sides; 41.9 % lies in the Kolla (tropical) region and covers the deep river gorges and lowland areas in the Wanchit River and Jema Rivers valleys, and also northwestern part of the study area (Fig.1.2).

A total of 3 Meteorological stations are located in the study area that are found in the towns Alem Ketem, Jihur, and Meragna. The basic characteristics of these stations are shown in Table 1.2.

Years with a full set of data were extracted from the review of data obtained from National Meteorological Agency of Ethiopia, from the period of 1990 to 2013 G.C..

Long term temperature data is given in Tab. 1.3 (a), (b), (c) and Fig. 1.3 (a) and (b).

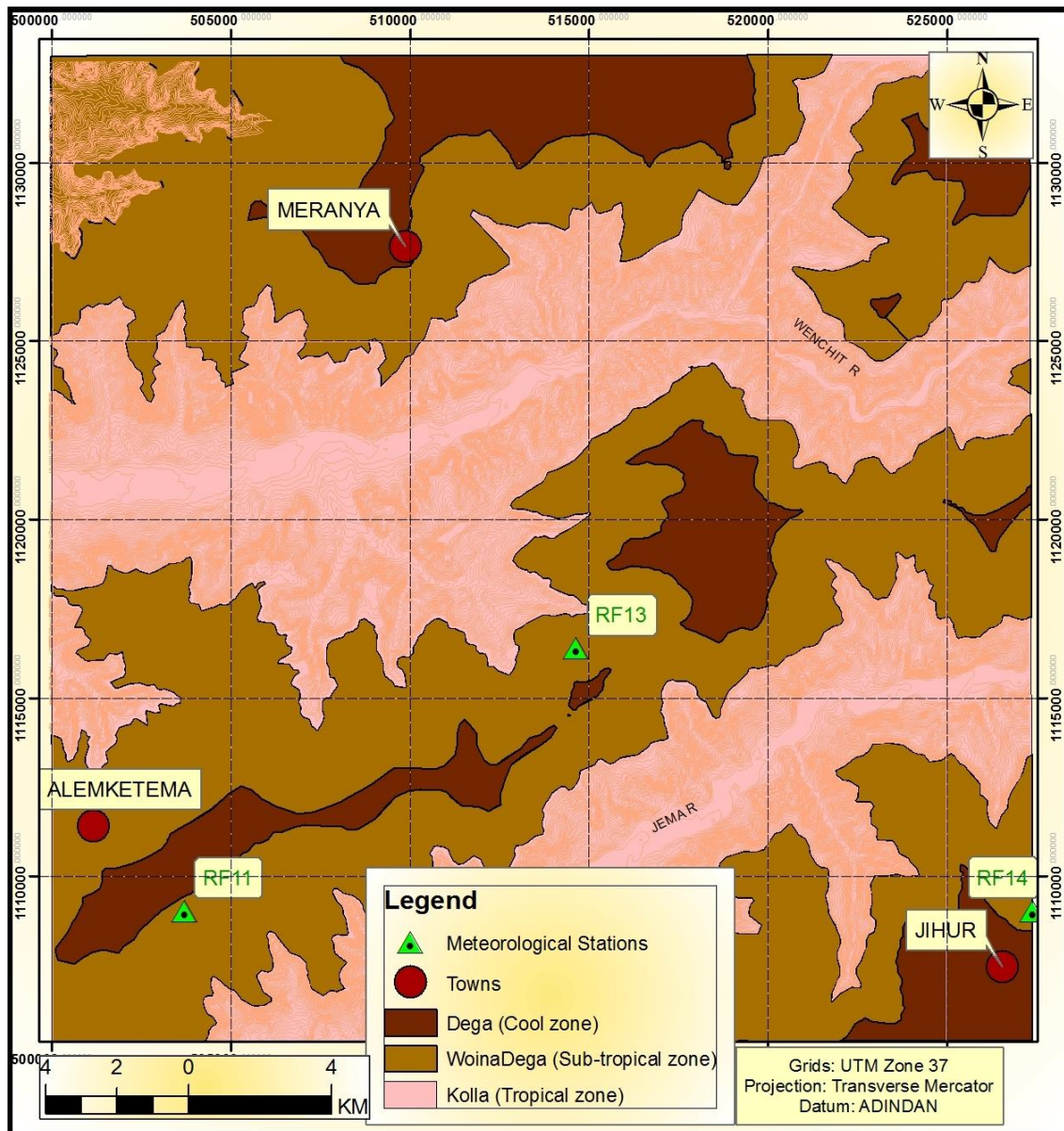


Fig. 1.2 Climatic zoning map of the study area

Table 1.2 Basic characteristics of Alemketema, Meragna, and Jihur meteorological stations

Map ID	Station	Class	Latitude	Longitude	Altitude (m.a.s.l.)	Data types	Sub -basin
RF11	Alemketema	1	10 ⁰ 02'	39 ⁰ 02'	2280	RF, TT, RH, Wind	Jema
RF13	Meragna	3	10 ⁰ 06'	39 ⁰ 08'	-	RF, TT,	Jema
RF14	Jihur	4	10 ⁰ 02'	39 ⁰ 15'	-	RF	Jema

Around Alemketema, the air temperature shows some seasonal changes with an average of 17.8 °C during Kiremt (June to September) season, 19.3 °C during Bega (October-January) season, and 21.2 °C during Belg (February-May) season. The minimum and maximum temperature ranges from 12.5 °C to 28.0 °C (Table 1.3 (a) and Fig. 1.3 (a)). Seasonal changes

in air temperature at Meragna is smaller with minimum and maximum temperatures ranging from 10.6 °C to 25.4 °C (Table 1.3 (b) and Fig. 1.3 (b)).

Table 1.3 (a) Long-term monthly temperature [⁰C] at Alemketema (fully recorded years only)

Temp.	Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
MAX	2001	25.5	27.3	25.7	28.2	27.6	25.4	21.2	20.5	23.3	25.7	25.3	25.7
MIN	2001	13.3	14.4	14.5	16.1	15.9	14.6	13	13.7	13.8	13.9	12.6	13
MAX	2003	26.7	28.1	27.5	27.7	29.5	26.9	21	20.8	22.4	25.7	25.7	25.4
MIN	2003	14.1	15.1	15.2	15.8	18	15.7	13.4	13.7	13.5	13.4	13	12.5
MAX	2005	25.6	27.9	28.3	27.7	26	26.5	21	20.8	23.1	25.3	24.9	24.9
MIN	2005	12.9	14.4	14.9	14.7	15.2	15.2	12.8	13	13.2	12.8	11.9	10.7
MAX	2006	26.4	28	27.2	26.7	28	27.3	22	20.5	22.3	25.6	24.5	25.6
MIN	2006	12.4	14.3	14.8	15.1	16.1	15.4	13.1	12.7	13.3	14.6	13	13.4
MAX	2007	26.4	26.8	28.4	27.9	28.8	25.4	20.8	20.6	22.5	24.6	25.5	25.1
MIN	2007	14.3	14.6	15.4	15.9	16.9	15.2	12.8	12.8	6.7	13.5	12.7	11.9
MAX	2008	26.5	27.3	29.2	27.8	28.1	26.3	22.4	20.9	23.3	25.3	24.3	25.6
MIN	2008	14.1	14.1	15.4	16.2	16.7	14.9	13.1	12.6	13.7	14	12.2	13.1
MAX	2011	26.5	28.6	27	29.1	28.3	27.7	22.6	21.2	23.2	25.9	25.7	26.3
MIN	2011	14.2	14.1	14.7	16	16.1	15.9	13.3	13.1	13.6	13.7	13.3	12.4

Table 1.3 (b) Long-term monthly temperature [⁰C] at Meragna (fully recorded years only)

Temp.	Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
MAX	1999	24.2	24.7	24.4	25.2	25	24.3	17.7	17.8	20	20.3	21.2	22.1
MIN	1999	10.5	11.7	12.6	13.4	14.1	12.1	10.1	10.3	11	10.8	10	10.2
MAX	2001	22.6	24.4	22.7	24.6	24.2	22	18.2	18.1	20.7	22.7	22.3	22.9
MIN	2001	10.6	11.8	11.7	13.3	13	11.5	10.7	11.1	11.5	12	10.6	10.9
MAX	2002	22.4	24.3	23.9	25.3	26.1	24.2	20.9	18.7	20.3	22.6	23.1	22.9
MIN	2002	10.5	12.2	12.3	12.6	14.6	12.4	9.7	10.4	11.1	12.2	10.6	11.8
MAX	2003	23.4	25	24.5	24	25.6	23.5	19	18.2	19.6	22.2	22.7	22.5
MIN	2003	11.5	12.7	12.1	12.4	13.6	12.5	10.8	10.9	11.2	11.3	10.8	10.5
MAX	2005	22.7	25.8	25.2	24.8	22.9	23.2	18.5	18.9	19.9	22.1	22.3	22.7
MIN	2005	10.9	12.5	12.7	13	12.7	13.1	10.8	11.1	11.3	11.4	10.1	9.9
MAX	2006	23.6	25.2	23.8	23.1	24.1	23.8	19	17.9	19.6	22.5	22.5	22.2
MIN	2006	11.6	12.3	12.2	12	13.4	12.5	11	10.9	11	12	10.7	11.1
MAX	2009	22.9	24.3	25.4	25.2	25.5	25.6	17.7	18.7	21.1	22.6	23.1	22.1
MIN	2009	11.6	12.4	12.9	13.5	13.8	13.9	10.9	11.3	12.2	11.6	10.8	11.5
MAX	2010	26.2	26.9	27.7	30.4	23.3	33.9	19.6	29.1	19.8	22.6	22.2	22.2
MIN	2010	12.7	13.8	13.2	15.8	16	15.9	11.2	16.3	11.3	12.1	10.6	10.7
MAX	2013	23.6	25.3	25.3	25.7	24.9	23	17.6	17.6	20.4	21.1	22.4	22
MIN	2013	11.8	12.6	13.3	13.3	13.5	12.3	10.3	10	11.6	11.5	11.1	9.8

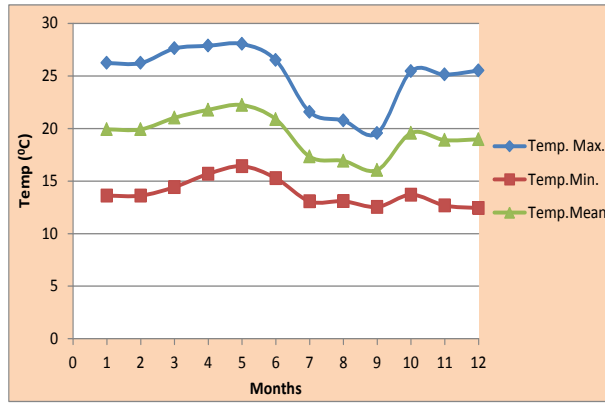


Fig. 1.3. (a) Temperature at Alemketema

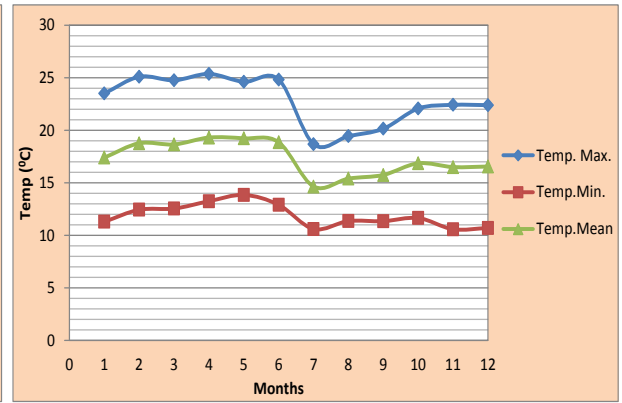


Fig. 1.3. (b) Temperature at Meragna

Long-term precipitation data is given in Table 1.4 (a), (b), (c) and Fig. 1.4 (a), (b), (c), respectively. The long-term average annual precipitation from Alemketema meteorology station is 1038 mm/year for the twenty assessed years. For data from Meragna meteorology station, the average annual precipitation is 1049 mm/year for the eleven years assessed. From Jihur meteorological station complete set of data was available for two years only and the average precipitation for the two years is 778 mm/year.

Table 1.4 (a) Long-term monthly rainfall at Alemketema [mm] (fully recorded years only)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1992	14.1	48.6	33.2	56.1	15.9	24.8	204.4	326.7	133.9	50.1	112.9	0	1020.7
1993	0	23.5	11.7	123.3	111.4	48.3	345.5	256.6	194.6	23.6	0	0	1138.5
1994	0	0	44	26.2	8.3	98.6	290.7	320.5	170.5	0	2.2	0	961
1995	0	3.4	53.9	43.9	50.1	26	229.2	342	83.3	0	0	12.8	844.6
1996	25.9	6.7	101.6	11.5	79	191.1	319.9	338.5	104	0	16	0	1194.2
1997	20.3	0	49.3	37.1	40.3	190	344.2	252.5	85	76	46.3	2.1	1143.1
1998	17.4	17.6	28.3	25	73.4	66.8	247.2	355.5	87.1	113.9	23.15	0	1055.4
1999	7.2	0	0	1.5	10	39.3	297.4	514.6	66.3	151.8	0	1.3	1089.4
2000	0	0	36.1	103.7	88.1	58.6	449.1	311.5	122.1	7.2	32.2	0.4	1209
2001	0	5	45.7	20.5	29.9	96	373.5	266.5	90.9	0.3	0	6.1	934.4
2002	41.6	38.2	44.8	40.8	9.3	39.3	283.9	282.2	121.1	0	0	13.4	914.6
2003	9	54	53.4	61.3	1.5	90.5	308.8	254	139	2.5	0.5	31.2	1005.7
2004	9.2	6.1	21.9	71.5	23.2	96.4	206.8	258.9	142.8	32.6	1.1	0	870.5
2005	18.9	0	53.6	47	97.9	91.1	273.8	328.7	142	15.4	7.4	0	1075.8
2006	12.6	13	96.4	27.8	31.2	103.7	388.9	355.6	166.1	5.4	6.2	0	1206.9
2007	2.4	37	34.5	57.4	24.3	138.7	373.4	299.4	201.7	8	0	0	1176.8
2008	0	0	0	37.8	46.3	96.5	301	313	106.2	13	47.2	0	961
2009	17.7	2.6	25.2	18.1	52	24.6	371.8	285.3	71.6	23.1	1	55.7	948.7
2010	0	37.5	22.1	38.3	57.7	13.5	252.5	369.8	156	1.1	13.2	18.4	980.1
2013	1	0.6	21.7	43.8	30.8	91.1	314.7	325.1	114	82.1	0	3.95	1028.9

Table 1.4 (b) Long-term monthly rainfall at Meragna [mm] (fully recorded years only)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	Total
1999	0	0	28.3	11.7	5.4	33.3	303.9	372.3	44.4	44.9	0	0.3	844.5
2000	0	8.75	13.6	61.5	29.2	50.6	472.2	330.6	134	48.9	1.4	1.3	1152.1
2001	0	17.5	68.2	19.3	57.2	109.9	357.4	236.1	35.7	1	0	17.8	920.1
2002	54.7	27.5	52.7	17.1	16.4	49.1	330.5	311.3	103	0	0	16.2	978.5
2003	7.9	51.3	102.7	84.4	0.4	98.4	374.5	348	89.7	0.6	0.2	13	1171.1
2004	6.3	4	40.1	77.2	46.6	91.75	300.6	288.6	68.9	27	0.3	0	951.35
2005	23.4	0.5	44.5	91.1	120	85.1	226.7	237.9	139.1	7.3	7	0	982.6
2006	10.6	49.2	115.4	71.9	40.3	38.7	398	344.1	153.1	3.3	7.5	14.4	1246.5
2007	12.6	38.2	25.4	48.3	16.6	128.4	276.7	274.3	177.1	1.3	0	7.2	1006.1
2008	4.2	2.1	0	40	24.1	56	294.7	230.8	86.2	9.9	32.9	0	780.9
2009	6.4	9.3	19.9	69.5	47.1	31.4	349.9	335.5	42.7	18.5	2	37.6	969.8
2010	0	49.8	75.4	75.7	148.6	5.2	367.3	546.4	117.7	0	30.3	13.5	1429.9
2013	1.5	0	40.9	45.6	30.6	125.7	389.2	464.6	72.5	35.8	1.4	0	1207.8

Table 1.4 (c) Long-term monthly rainfall at Jihur [mm] (fully recorded years only)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	Total
2010	1.6	55.8	41.4	56.9	59.9	28.8	299.8	334	76.1	0	0	20.7	975.1
2011	2.3	0	94.3	46.2	67.3	33.1	106.9	187.1	90.9	0	3.9	10.3	642.3

According to the results from these stations it's observed that most of the major rainfall in the study area occurs during the summer season mainly from June to September (Fig 1.4 (a), (b) and (c)). Whereas, there is somewhat low rainfall occurrence in November and January. The rainfall peaks in July or August at about 330 to 520 mm per month. On the other hand it is obvious that rainfall during the dry season from October to May, tends to be low.

The long term fluctuation of precipitation at Alemketema is shown in Fig. 1.5. It can be seen that there is some fluctuations of precipitation from 1992 to 2013 G. C. with the minimum annual rainfall of 884.6 mm/year in the year 1995 and the maximum annual rainfall of 1209 mm/year in 2000 G. C.. An average long-term annual rainfall from 1992 to 2013 G. C. is 1038 mm/year.

1.4.4 Physiography

Mohr (1971) states that more perhaps than in any other country of Africa, the physiography of Ethiopia is an intimate expression of the underlying geology. The comparatively late date of the uplift of the Arabo-Ethiopian swell and its subsequent bisection by the Rift System means that the present-day physiography of Ethiopia is broadly determined by these two tectonic phenomena.

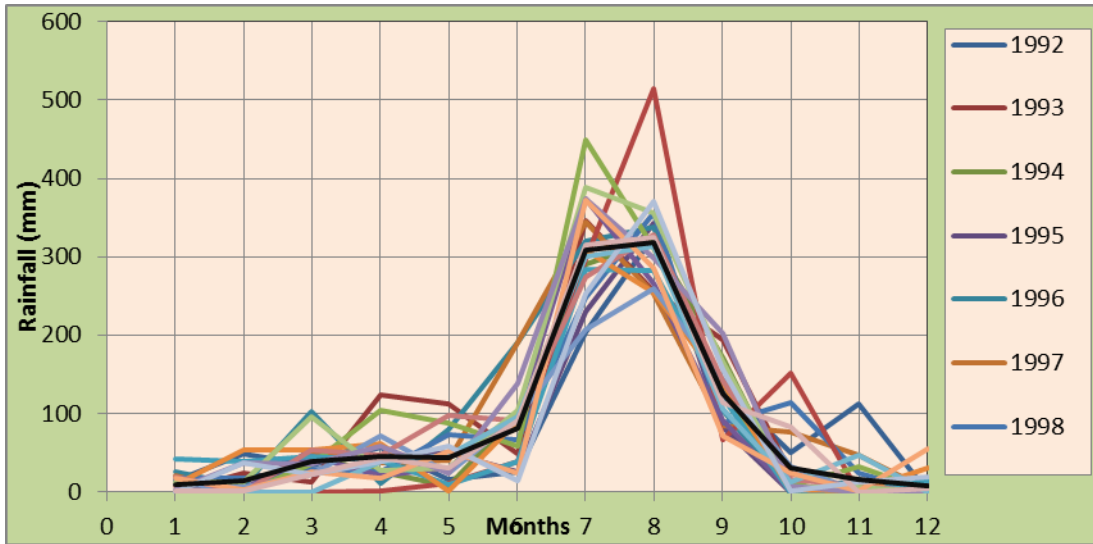


Fig 1.4 (a) Graph showing Rainfall data for Alemketema town

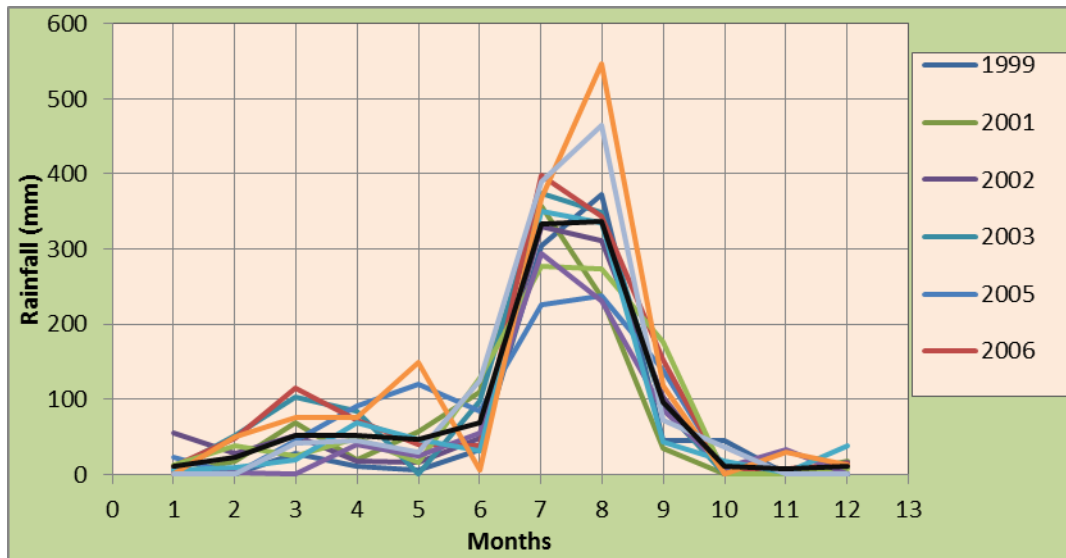


Fig 1.4 (b) Graph showing Rainfall data for Meragna town

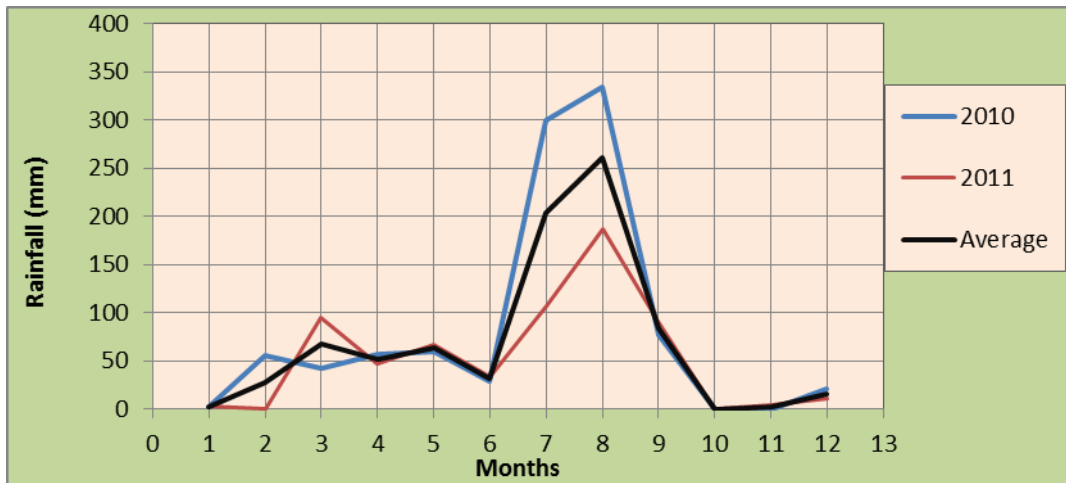


Fig 1.4 (c) Graph showing Rainfall data for Jihur town

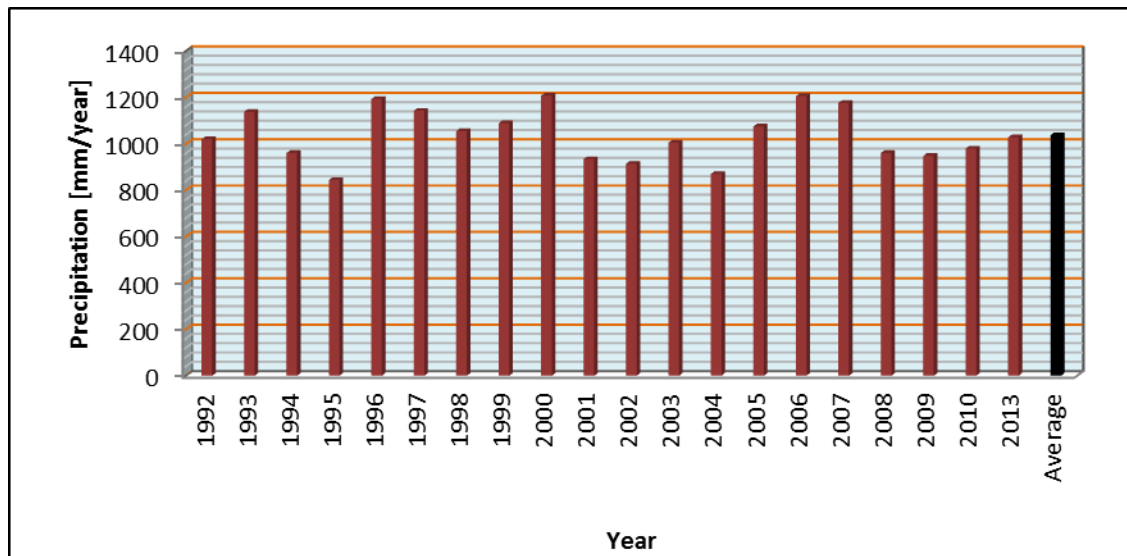


Fig. 1.5 Graph showing long term fluctuation of precipitation at Alemketema

The Rift System in Ethiopia has divided the uplifted swell into two separate units, the Ethiopian Plateau proper, in the west and the Somalian Plateau to the east. The Ethiopian Plateau includes all the highland area lying between the Rift System scarps to the east and the Sudan border scarps to the west. In both these cases erosional recession has occurred from original tectonic scarps (Mohr, 1970).

The present study area is mainly located in the northeastern part of Jema river basin which is the sub-basin of Abay river. The area is characterized by deeply dissected gorges, plateau and high altitude continuous chain of mountains and ridges. It occupies parts of the highlands of the North-central Ethiopian plateau. The general physiographic map of the study area was prepared from DEM of the study area and is shown in Fig. 1.6.

The area has a very high rugged topography with a maximum elevation of 2650 m.a.s.l around the plateau above Ahiya Fej Ridge and around Sertesus Mariyam Church, whereas a minimum elevation value of 1340 m.a.s.l. is found around the confluence of Lam Megbiya stream to Wanchit River. The elevation difference between the maximum and minimum elevations with in this specific area is about 1310 m which indicates the most likely condition for landslides and related movement to happen in the area.

In addition to the uplifting phenomena and its subsequent bisections by the Rift System, the present physiographical setting of the study area is also affected by various processes such as erosion, weathering and mass wasting activities. The drainage network in this area is formed part of the Abay drainage basin where the streams follow the general northeast-southwest direction. Major streams in this physiographic area include Wenchit, Jema and Beto. Parallel,

sub-parallel and dendritic drainage pattern characterize this physiographic region (Tigel Belay et al., 2009) that mainly follows the weakness zones of the valleys (Fig. 1.6. and 1.7).

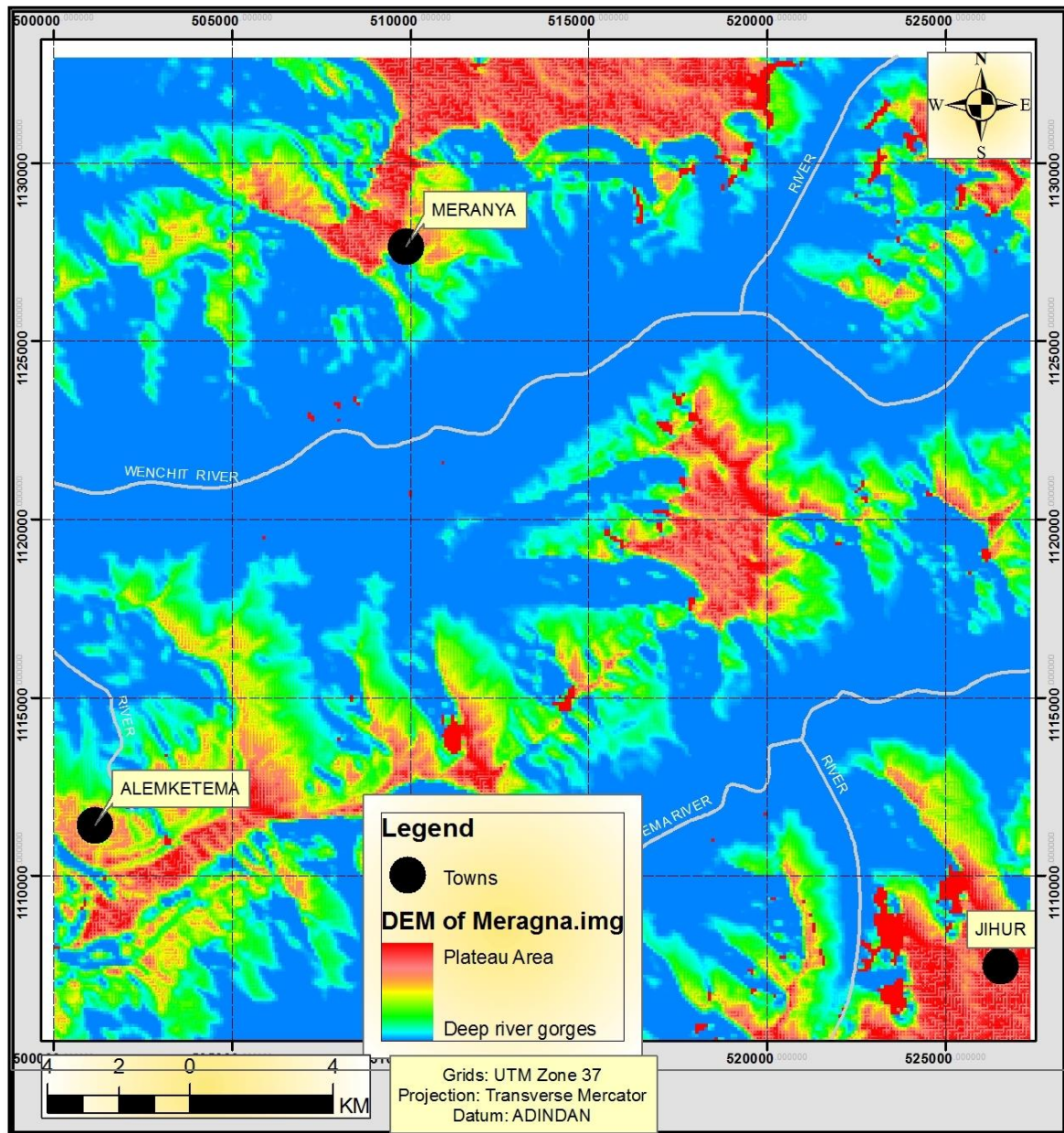


Fig 1.6 General physiographic map of the study area

The Jema river and Wanchit River and their tributaries cut deep into the sedimentary successions to form deep gorges in the study area. Deep river gorges are developed along the Wanchit and Jema Rivers. Both of these rivers drain towards the northeast - southwestern direction in the study area. These river gorges are covered by alluvial deposits with the lowest elevation of 1310 m.a.s.l in the Wanchit River around the confluence of Lam Megbiya stream to Wanchit River (Fig. 7).



Fig 1.7 Drainage pattern of the study area

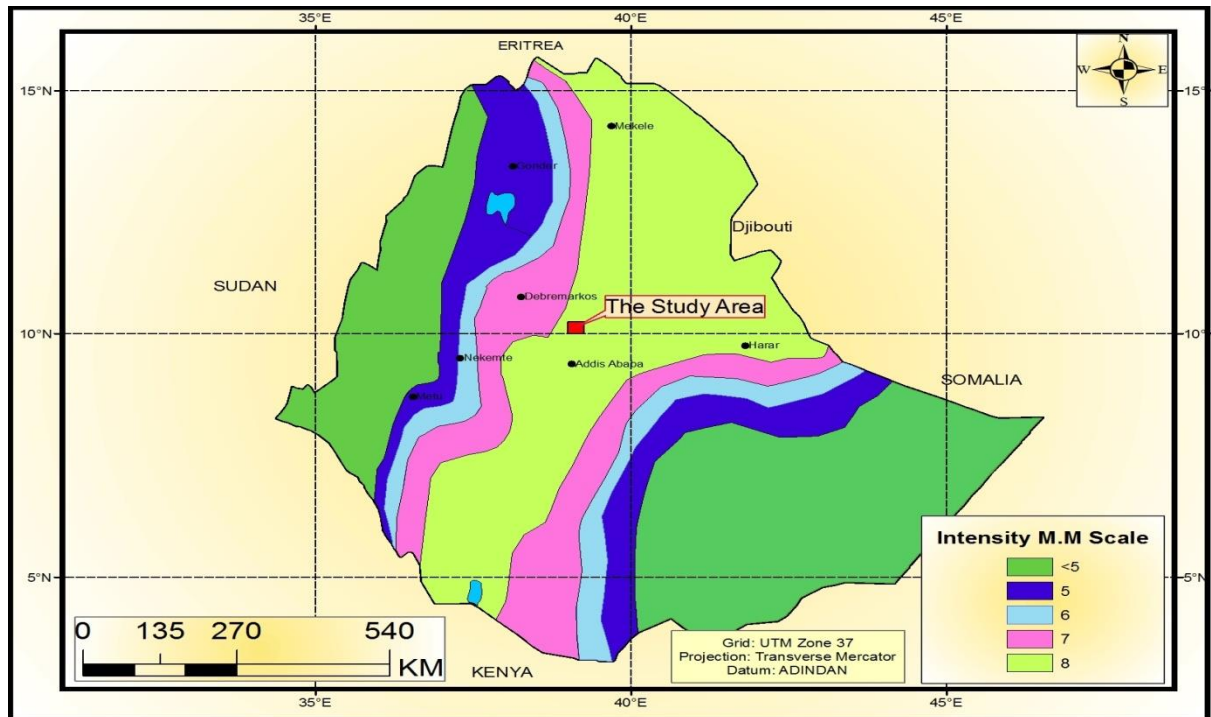
1.4.5 Vegetation cover

In the study area it has been observed that it is only 1.8 % of the area which is covered with thick vegetation of trees. The majority of the area is covered with moderate tree vegetation which amounts to 33% of the study area. 27% of the area is covered with cultivated land; mainly, the upper reaches of the gorge and plateau areas are intensively cultivated. 21% of the study area is covered by sparse trees and grass land whereas the remaining 15% of the study area is covered with bare-land and rock exposures.

1.4.6 Seismicity

The 'Seismic Risk Map' produced by Laike Mariam for a hundred year return period and 0.99 probability shows that the study area falls within 8 M.M scale. Based on the MM scale

intensity the estimated horizontal earthquake acceleration comes out to be 0.1 - 0.2g, as determined from the MM intensity graph (Raghuvanshi *et al.*, 2014). Thus the average value (that is 0.15g) has been utilized for the stability analysis of the slopes in the study area. The map showing the Seismic Risk zones of Ethiopia and location of Project area is presented in Fig. 1.8.



(After Laïke Mariam Asfaw, 1986).

Fig 1.8 Seismic risk map of Ethiopia 100 year return period, 0.99 probability

1.5 Significance of the Study

Ethiopia is currently involved in massive infrastructural development (including roads and railways), urban development and extensive natural resources management. In this whole socio-economic development, landslides and landslide-generated ground failures need to be given due attention in order to reduce losses from such hazards and create safe geo-environment (Kifle Woldearegay, 2013).

Thus, it is important to delineate the area for its susceptibility for landslide hazard. Landslide hazard zonation (LHZ) mapping is useful means to assess the landslide prone areas. According to Ambalagan (1992) the LHZ maps are useful for the following purposes:

- (a) The LHZ maps identify and delineate unstable hazard-prone areas, so that environmental regeneration programmes can be initiated adopting suitable mitigation measures.

(b) These maps help planners to choose favorable locations for sitting development Schemes, such as building and road constructions. Even if the hazardous areas cannot be avoided altogether, their recognition in the initial stages of planning may help to adopt suitable precautionary measures.

The information emanating from this research study is hoped to be of great importance in assisting the improvement of the decision making processes in the project area related to land-use planning and other design options of developmental activities.

All the stakeholders of the road construction activities in the project area such as Ethiopian Roads Agency (ERA) (ERA is a Client), Consultants and Contractors as well as local authorities can benefit from the landslide hazard zonation map produced and the recommendations given. Besides, the primary data that is collected during field visits and the secondary data collected from different sources as well as the analysis results will be an input to the data management system of the region.

1.6 Scope and Limitations of the Study

The scope and limitations of the present study are listed below;

- Since the Physiography of the area is highly rugged and access to the different areas was not easily available,
- Lack of sufficient existing data related to the present study has also effect on the results of the present study,
- Limitations on time and financial constraint have also limited the work of the present study to conduct preparation of the landslide hazard zonation map of the study area without conducting and including laboratory test results. However, despite all these difficulties and limitations, all efforts were made to conduct research in a systematic manner, which were all supported by the actual field observation, measurements and in-situ testing.

1.7 General outcome of the study

The development and exploitation of natural resources requires landslide hazard zonation maps that attempt to divide the terrain into safe and unsafe areas according to the incidence of landslides and other mass movements (Varnes, 1981 as cited in Sarkar et al., 1995).

According to Bhandari (1987 as cited in Sarkar et al., 1995), such maps can serve as a base map for land-use planning and the development of appropriate remedial measures.

Gorsevski et al. (2006), Anbalagan and Singh (1996) pointed out that, identification of such slope instability problems in the initial stage of planning and investigation of engineering structures, particularly the road projects may lead to evolve possible remedial measures which may either be adopted to improve the slope stability or such problematic slopes may be avoided if identified during the initial planning stage.

Thus, as the major outcome of the present study, Landslide Hazard Zonation (LHZ) map of the project area extending from Alemketema town to Wanchit and SI - E area is prepared. The prepared map is validated by overlying past landslide event map on the prepared map. This map can serve as a base map for land-use planning and the development of appropriate remedial measures for slope instability problems in the area.

1.8 Future extensions of the research

The present study area being one of the areas currently facing land slide hazard problems in the country, it is evident that this work must have a continuation in the future. This study covers only about 39 km distance of the new road alignment under construction in the area which is about 32% of the total designed length of the road alignment. Therefore, further effort has to be made to cover the remaining part of the road alignment and the surrounding area. These techniques are rapid evaluation of an area which is prone to landsliding; therefore, in future all possible efforts must be made to make such kinds of maps for those areas of the country where there are expectations of landslide hazards.

1.9 Chapter Schemes

Chapter 1 presents an introduction which includes background to problem, problem statement, description about study area, objectives, significance of study, scope and limitations and general outcome of study.

Chapter 2 presents the literature review conducted in the present study. It gives general overview and a conceptual framework on landslides and landslide classification. It also includes discussions on Landslide Evaluation and Zonation Techniques.

Chapter 3 outlines the previous research studies conducted in and around the study area. It also gives summary on some of the landslide studies conducted in Ethiopia, background and justification for the present study.

Chapter 4 deals with the geological set up of the study area. It gives an overview on general geological setting and brief discussion on local geological setting of the study area.

Chapter 5 shows the methodology followed during the present study. Descriptions are given on the general methodology followed, data procurement, data processing and analysis, landslide evaluation, and Landslide Hazard Zonation.

Chapter 6 presents the landslides and slope instability in the study area. Discussions are also made on; landslide inventory, landslide distribution, types and manifestations of landslides, possible causes and potential slope instabilities in the study area.

Chapter 7 discusses about Landslide Evaluation and Zonation. Evaluations are made on intrinsic causative factors and external triggering factors. It explains the landslide evaluation and zonation conducted and validation of the prepared landslide hazard zonation (LHZ) map.

Chapter 8 presents the conclusion and recommendation forwarded through the present study.

CHAPTER II

LITERATURE REVIEW

2.1 General

Owing to the force of gravity, the materials (rock and soils or regolith) on the slope move from higher elevations to lower elevations. This down slope movement of rock and regolith near the Earth's surface mainly due to the force of gravity is known as Mass Movement. However, the material that has been moved down to the lower elevations will be picked up by transporting agents such as streams and glaciers and then will be moved to even lower elevations. Due to their contribution to the transporting agents, mass movement processes are also considered as an important part of erosion processes.

On the other hand, any perceptible down slope movement of rock or regolith is being described by the general term “landslide” (Nelson, 2012). According to Varnes (1978 as cited in Guzzetti, 2003; 1984), the term “landslide” comprises almost all varieties of mass movements on slopes, such as; rock-falls, topples, and debris flows, that involve little or no true sliding. Nevertheless, many landslides exhibit a combination of two or more of these types of movements.

Landslides are causing damages to roads, buildings and other structures, and disrupting the activities of the local people in most mountainous areas (DFID, 2003). Thus, landslide hazards can be considered as one of the most serious geo-environmental problems in mountainous countries like Ethiopia. According to Kifle Woldearegay (2013), all the studies on landslides carried out in the highlands of Ethiopia indicated that such hazards have economic, social and environmental significance and the issue of landslides and landslide-generated ground failures remain far more than what is actually reported. He also added that landslides still are affecting infrastructures like roads and agricultural lands in different parts of the country.

According to Raghuvanshi *et al.* (2014), the developmental activities in hilly and mountainous terrains, particularly road construction, cover large areas of slopes. Specially, within the humid tropics and subtropics this construction activity is taking place at a rapid rate, and often in areas where existing geological and geotechnical information is insufficient to make informed decisions regarding the choice of alignment and its design (Hearn, 2011).

This indicates that there will be high chances of slope instability problems in these areas accompanied by the road construction activities.

On the other hand, according to ADBG-ESIA (2013), road infrastructure plays a key role in the social and economic well-being of a society. For instance, the road network of Ethiopia provides the dominant mode of freight and passenger transport and thus plays a vital role in growing the economy of the country.

All sectors of the economy, service sectors and people of the country rely on the availability and satisfactory performance of these roads (ERA RSDP, 2009). However, the satisfactory performance of these roads will be secured only when the assessment of risk posed by potential geo-hazards and adverse ground conditions is carried out early on in the planning stage of the project (Ho and Lau, 2010 as cited in Hearn, 2011).

According to Hearn (2011), effective route selection requires the identification of hazard areas within corridor options, including the locations of existing landslides and those slopes that could become problematic during construction and maintenance. Thus, some rapid slope stability analysis techniques has to be applied for the identification of such slope instability problems (Raghuvanshi *et al.*, 2014) and to provide information that will be used for the choice of the alignment and its design.

According to Anbalagan (1992), Landslide Hazard Zonation (LHZ) technique may be employed for rapid assessment of slope stability condition over a large area. Landslide hazard zonation is a technique in which land is divided into zones of varying degree of actual or potential hazard for landslide. The degree of potential hazard in an area can be estimated on the basis of qualitative or semi-qualitative measures of various instability inducing factors (Varnes, 1984).

Hearn (2011) stated that in the humid tropics and sub-tropics heavy seasonal rainfall is responsible for a high incidence of slope instability.

Generally, speaking; slope geometry, slope material (lithology or soil type), structural discontinuities, land use and land cover and groundwater are taken as the major intrinsic parameters whereas excessive rainfall, earthquakes and manmade activities can be considered as the major triggers of Landslides (Varnes, 1984; Wati *et al.*, 2010; Raghuvanshi *et al.*, 2014).

2.2 Landslide Classification

2.2.1 Preamble

Mass wasting is a generic term referring to the down slope movement of soil or rock material under the influence of gravity. Landslides are nearly a synonymous term, implying a surface of failure along which slippage, flow, or fall occurs (Ritter, 2004). For a scientific investigation of landslides, classification is considered as an important first step process, which has the purpose of reducing the multitude of different, but related phenomena to a few easily recognized and meaningful groups on the basis of common attributes (Crozier, 1984 as cited in Msilimba, 2007).

Among the factors that can be used and have been used to classify landslides are: (a) Material: (Rock, Soil Lithology, structure, Geotechnical properties), (b) Geomorphic attributes: (Weathering, Slope form) (c) Landslide geometry: (Depth, Length, Height etc), (d) Type of movement: (Fall, Slide, Flow etc), (e) Climate: (Tropical, Periglacial etc.), (f) Water: (Dry, wet, saturated), (g) Speed of movement: (Very slow, slow etc.), (h) Triggering mechanism: (Earthquake, rainfall etc.) (Van Westen, westen@itc.nl p.14). According to Msilimba (2007), a good classification specifies its classificatory parameters in unambiguous, universal terms to allow for standardized application and reproducibility of results.

However, there is no consensus within the international geotechnical community on which landslide classification system to use (Fell *et al.*, 2008). According to Fell *et al.* (2008), it is recognized that all existing landslide classification systems are seen to have shortcomings, and due to this reason, the Joint Technical Committee (JTC) on Landslides and Engineered Slopes has established a working committee to develop a new classification system on behalf of ISSMGE, IAEG and ISRM.

With an important source of landslide information being the proceedings of the International Symposium on Landslides, the technical literature describing landslides has grown considerably since 1978 (Cruden and Varnes, 1996). According to them, among the other important English language texts and collections of descriptions of landslides have been those by Zaruba and Mencl (1982), Brunsden and Prior (1984), Crozier (1986), and Costa and Wieczorek (1987).

2.2.2 Classification of Landslides and Other Mass movements by NEMCOK *et al.*, (1972)

Nemcok, Pasek and Rybar (1972 as cited in Novotny, 2013), classified landslides and other mass movements in to four types of processes based on geo-mechanical character and velocity of the movement.

These area; 1) Creep, 2) Sliding, 3) Flow, and 4) Fall. According to this classification, in each group elementary phenomena can be further subdivided according to different types determined by regional, morphological, geological or climatic conditions. For this reason it is not possible to consider all possible variations.

1) Creep:

Creeps are geologically long-term movements of non increasing velocity without well-defined sliding surfaces with displacements nearly negligible in contrast to space of rock mass affected by creep. Generally, the velocity of creeping movements ranges from 0.1 mm/year – 1 mm/day. However, if the creep movement achieves a critical acceleration, the creep becomes sliding, flow or fall.

The causes for creeping movements indicated by Nemcok, Pasek and Rybar (1972 as cited in Novotny, 2013) are described as follows

- a. Loosening of the rocks in the valley slope by cracks parallel to the surface
- b. Loosening by opening of tension cracks in upper part of the slope,
- c. Loosening of slope by deep seated creep of high mountain ridges,
- d. Gravitational folding by deep seated creep - deformation of high mountain slopes,
- e. Gravitational folding along basins margins,
- f. Gravitational folding of soft rock in valley bottom,
- g. Block - type movements on plastic underlying rocks,
- h. Block - type movements on pre-existing surface,
- i. Superficial creep

2) Sliding

According to Nemcok, Pasek and Rybar (1972 as cited in Novotny, 2013), sliding can occur in one of the following ways as described in Tab. 2.1.

3) Flow

The movement of rock and soil material along the slope from source area on a terrain surface on a long distance in a similar manner to liquid is known as flow. The velocity of flow movements range from 1 km/day (earth flow) to 1 km/hour (debris flow).

4) Fall

Fall is a sudden movement of slope materials in which moving masses lose their coherence and for a short time also their contact with the underlying rock. The distance moved by rock falls is much higher in contrast to their volume with their velocity ranging from 1 km /hour to 100 km/hour (Nemcok, Pasek and Rybar, 1972 as cited in Novotny, 2013).

Tab. 2.1 Ways of sliding and types of landslides

Ways of sliding	Types of landslide
Sliding on simple rotational shear surface	Rotational landslide
Sliding along a planar sliding surface in soils	Planar landslides in soils, Planar landslides along pre-disposed shear surface
Sliding along a planar sliding surface in rocks	Planar landslides in rocks, Planar landslides along pre-disposed shear surfaces such as bedding, schistosity, jointing, faults...
Sliding along combined sliding surface	Rotational planar landslide
Horizontal translation on a pre-existing sliding surface	lateral landslides, translational landslides

2.2.3 Classification of Landslides by Varnes (1975, 1978)

According to Ritter, 2004, Varnes' (1958, 1975) classification system for landslides is the most widely-used system and is reproduced in Tab 2.2. A summary of the criteria for landslide classification is given by Varnes, (1978 as cited in Msilimba, 2007). An abbreviated version of classification of slope movements (Varnes, 1978 as cited in USGS, 2004) is presented in Tab 2.3.

2.2.3 Classification of Landslides by Hutchinson (1988)

Hutchinson classified landslides in to six classes. Each of these classes are described in Table 2.4

2.2.4 Classification of Landslides by Cruden and Varnes (1996)

The range of landslide processes was reviewed by Cruden and Varnes (1996), and a vocabulary was provided for describing the features of landslides relevant to their classification for avoidance, control, or remediation. However, they followed Varnes's expressed intention of (1978, 12) "developing and attempting to make more precise a useful vocabulary of terms by which ... [landslides] ... may be described." Therefore, they retained the terms Varnes recommended in 1978 unchanged and they added a few useful new terms only.

Table 2.2 Classification of landslide types (Varnes' 1975 as cited in Ritter, 2004).

Type of Movement		Type of Material		
		Bedrock	Unconsolidated Sediment or Soil	
Falls			Coarse	Fine
Slides	Rotational	Rockfall	Debris Fall	Earth Fall
	Translational	rock Slump	Debris Slump	Earth Slump
Flows		Rock Block Glide Rock Slide	Debris Block Glide Debris Slide	Earth Block Glide Earth Slide
Complex		Rock Flow	Debris Flow	Earth Flow

Tab 2.3 Abbreviated version of Varnes' classification of slope movements
(Varnes, 1978 as cited in USGS, 2004)

TYPE OF MOVEMENT		TYPE OF MATERIAL		
		BEDROCK	ENGINEERING SOILS	
			Predominantly Coarse	Predominantly Fine
FALLS		Rock fall	Debris fall	Earth fall
TOPPLES		Rock topple	Debris topple	Earth topple
SLIDES	ROTATIONAL	Rock slide	Debris slide	Earth slide
	TRANSLATIONAL			
LATERAL SPREADS		Rock Block Glide Glide Rock Slide	Debris Block Glide Debris Slide	Earth Block Glide Earth Slide
FLOWS		Rock Flow (deep creep)	Debris Flow	Earth Flow (soil creep)
COMPLEX Combination of two or more principal types of movement				

According to Cruden and Varnes (1996), any landslide can be classified and described by two nouns: the first describes the material and the second describes the type of movement, as shown in Tab 2.5 (e.g., rock fall, debris flow).

The names for the types of materials are unchanged from Varnes's classification (1978 as cited in Cruden and Varnes, 1996): rock, debris, and earth. The movements have again been divided into five types: falls, topples, slides, spreads, and flows (Tab 2.4 and 2.5).

Cruden and Varnes (1996), suggested that the name of a landslide can become more elaborate as more information about the movement becomes available. To build up the complete identification of the movement, descriptors are added in front of the two-noun classification using a preferred sequence of terms.

The sixth type proposed by Varnes (1978, Tab 2.3), as complex landslides, has been dropped from the formal classification, although the term complex has been retained as a description of the style of activity of a landslide.

Tab 2.4 Landslide movement types and corresponding definitions, simplified from Hutchinson (1988 as cited in Van Westen, westen@itc.nl p.14)

Type of Movement	Definition
Rebound	When ground is unloaded, either artificially by excavation or naturally by erosion, the unloaded area responds, initially elastically and subsequently by slow swelling (Peterson, 1958 as cited in Van Westen, westen@itc.nl p.14)
Creep	Any extremely slow movements which are imperceptible except through long-period measurement are known as creep.
Sagging of mountain slopes	Sagging of mountain slopes is a general term for those deep-seated deformations of mountain slopes, which, in their present state of development, do not justify classification as landslides.
Landslide	Relatively rapid down slope movements of soil and rock, which take place characteristically on one or more discrete bounding slip surfaces which divide the moving mass is described by the term landslide.
Debris movement of flow like form	This term covers five types of movement of flow-like form, which differ markedly in mechanism: i) non-periglacial mudslides, ii) periglacial mudslides, iii) flow slides, iv) debris flows, and v) sturzstroms.
Topple.	Topple is a movement that occurs when the vector of resultant applied forces falls through, or outside a pivot point in the base of the affected block.

Tab 2.4 Landslide movement types and corresponding definitions, simplified from Cruden and Varnes (1996)

Type of Movement	Definition
Slide	Down slope movement of soil or rock that occurs on a rupture surface or on thin zones of intense shear strain. A continuum exists between slides and flows.
Flow	Spatially continuous movement in which the shear surfaces are closely spaced and short-lived. Often resembles a viscous liquid.
Fall	Detachment of soil or rock from a steep slope. The detached material then moves down slope by falling, bouncing, or rolling.
Spread	Extension of a cohesive mass (either rock or soil) combined with the general subsidence of that mass into softer underlying material.
Topple	Forward rotation of a mass of soil or rock about a point or axis. Topples are created by freeze - thaw actions, or are driven by gravity.

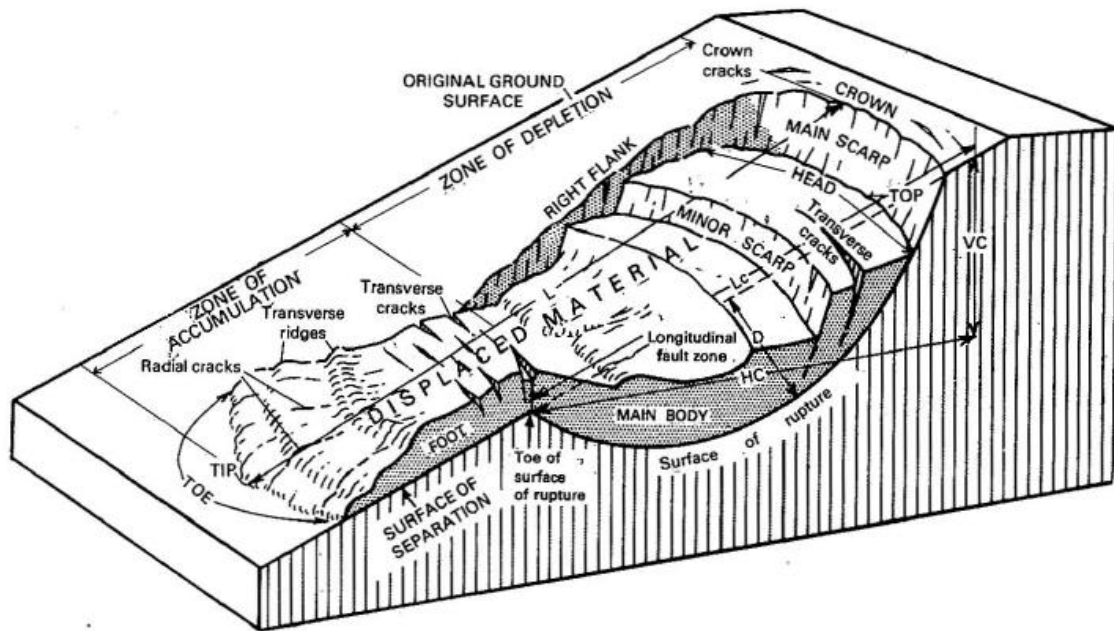
Tab 2.5 Abbreviated classification of slope movements (Cruden and Varnes, 1996)

TYPE OF MOVEMENT	TYPE OF MATERIAL		
	BEDROCK	ENGINEERING SOILS PREDOMINANTLY COARSE	PREDOMINANTLY FINE
Fall	Rock fall	Debris fall	Earth fall
Topple	Rock topple	Debris topple	Earth topple
Slide	Rock slide	Debris slide	Earth slide
Spread	Rock spread	Debris spread	Earth spread
Flow	Rock flow	Debris flow	Earth flow

2.2.4 Landslide features

Varnes (1978 as cited in Cruden and Varnes, 1996) provided an idealized diagram showing the features for a complex earth slide-earth flow, which has been reproduced here as Fig 2.1. More recently, the IAEG Commission on Landslides (1990) produced a new idealized landslide diagram (Fig 2.2) in which the various features are identified by numbers, which are

defined in different languages by referring to the accompanying tables. Tab 2.6 provides the definitions in English.



(Source: Varnes 1978, figure 2.1 t as cited in Cruden and Varnes, 1996)

Fig 2.1 Block diagram of idealized complex earth slide-earth flow

The names of the features are unchanged from Varnes's classification (1978). However, Tab 2.6 contains explicit definitions for the surface of rupture (Fig 2.2, 10), the depletion (16), the depleted mass (17), and the accumulation (18) and expanded definitions for the surface of separation (12) and the flank (19). The sequence of the first nine landslide features has been rearranged to proceed from the crown above the head of the displaced material to the toe at the foot of the displaced material. This sequence may make these features easier to remember.

2.2.5 Landslide velocity scales

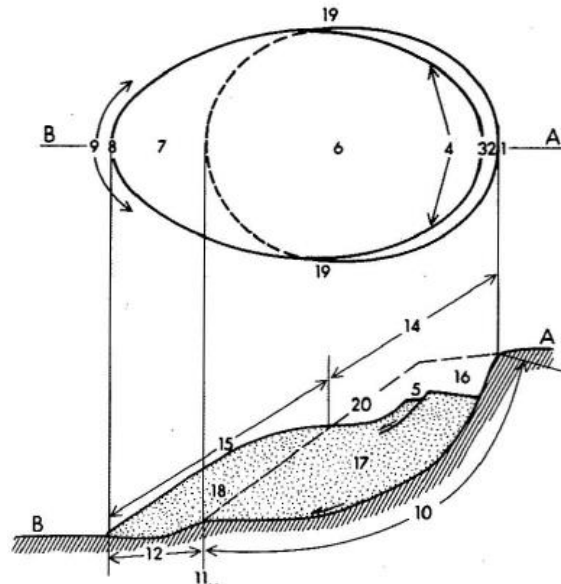
Landslide velocity is a parameter whose destructive significance requires independent definition. Tab 2.7 defines the probable destructive significance of the seven velocity classes on the new landslide velocity scale proposed by Cruden and Varnes (1996) (Fig 2.3b).

Previously, rate-of-movement scale was provided by Varnes (1978, Figure 2.1u as cited in Cruden and Varnes, 1996) which is shown here as Fig 2.3a. However, Cruden and Varnes (1996) modified the landslide velocity scale and presented the new scale as shown in Fig 2.3b.

The divisions of the scale were adjusted to increase in multiples of 100 by a slight increase in its upper limit and a decrease in its lower limit. These two limits now span 10 orders of magnitude. Interpretation of the scale was aided by Morgenstern's (1985 as cited in Cruden and Varnes, 1996) analogy to the Mercalli scale of earthquake intensity.

Fig 2.2 Landslide features: upper portion, plan of typical landslide in which dashed line indicates trace of rupture surface on original ground surface; lower portion, section in which hatching indicates undisturbed ground and stippling shows extent of "displaced material."

Numbers refer to features defined in Tab 2.6 (IAEG Commission on Landslides 1990 as cited in Cruden and Varnes, 1996).



2.3 Landslide Hazard Evaluation and Zonation Techniques

2.3.1 Preamble

According to Brabb and Carrara (1984; 1989 as cited in El Morjani, 2011), for the preparation of landslide hazard maps, either qualitative (direct) or quantitative (indirect) landslide hazard mapping techniques can be followed. However, there is no consensus among researchers on the best appropriate model to be used in order to identify and map mass-wasting-prone areas. This is because each technique and model has a unique set of advantages and disadvantages. Therefore, it is generally preferable to determine the frequency of land sliding in quantitative terms because this will enable the hazard from different sites to be compared, and consequently, the risks to be estimated in quantitative terms also.

Nevertheless, in some situations it may not be practical to assess frequencies sufficiently accurately to use quantitative hazard zoning and a qualitative system of describing hazard classes may be adopted (Fell *et al.*, 2008).

Although there are many methods and techniques proposed for evaluation and zonation of landslide hazards in literature, these techniques can be broadly classified in to three groups:

statistical methods, mechanical approach and expert evaluation methods (Leroi, 1997 as cited in Fall et al., 2006; Guzzetti et al., 1999; Casagli et al., 2004; Van Den Eeckhaut et al, 2009 as cited in Raghuvanshi et al., 2013; Kanungo et al. 2006).

Tab 2.6 Definition of landslide features (Source: Adopted from Cruden and Varnes, 1996)

NUMBER	NAME	DEFINITION
1	Crown	Practically un-displaced material adjacent to highest parts of main scarp
2	Main scarp	Steep surface on undisturbed ground at upper edge of landslide caused by movement of displaced material (13, stippled area) away from undisturbed ground; it is visible part of surface of rupture (10)
3	Top	Highest point of contact between displaced material (13) and main scarp (2)
4	Head	Upper parts of landslide along contact between displaced material and main scarp (2)
5	Minor scarp	Steep surface on displaced material of landslide produced by differential movements within displaced material
6	Main body	Part of displaced material of landslide that overlies surface of rupture between main scarp (2) and toe of surface of rupture (11)
7	Foot	Portion of landslide that has moved beyond toe of surface of rupture (11) and overlies original ground surface (20)
8	Tip	Point on toe (9) farthest from top (3) of landslide
9	Toe	Lower, usually curved margin of displaced material of a landslide, most distant from main scarp (2)
10	Surface of rupture	Surface that forms (or that has formed) lower boundary of displaced material (13) below
11	Toe of surface of rupture	Original ground surface (20); mechanical idealization of surface of rupture is called slip surface
12	Surface of separation	Intersection (usually buried) between lower part of surface of rupture (10) of a landslide and original ground surface (20)
13	Displaced material	Part of original ground surface (20) now overlain by foot (7) of landslide
14	Zone of depletion.	Material displaced from its original position on slope by movement in landslide; forms both depleted mass (17) and accumulation (18); it is stippled in Figure 3-4
15	Zone of accumulation	Area of landslide within which displaced material (13) lies below original ground surface (20)
16	Depletion	Volume bounded by main scarp (2), depleted mass (17), and original ground surface (20)
17	Depleted mass	Volume of displaced material that overlies surface of rupture (10) but underlies original ground surface (20)
18	Accumulation	Volume of displaced material (13) that lies above original ground surface (20)
19	Flank	Un-displaced material adjacent to sides of surface of rupture; compass directions are preferable in describing flanks, but if left and right are used, they refer to flanks as viewed from crown
20	Original ground surface	Surface of slope that existed before landslide took place

Tab 2.7 Definition of Probable Destructive significance of Landslides of Different Velocity Classes
(Source: Cruden and Varnes, 1996)

LANDSLIDE VELOCITY CLASS	PROBABLE DISTRUCTIVE SIGNIFICANCE
7	Catastrophe of major violence; buildings destroyed by impact of displaced material; many deaths; escape unlikely
6	Some lives lost; velocity too great to permit all persons to escape
5	Escape evacuation possible; structures, possessions, and equipment destroyed Some temporary and insensitive structures can be temporarily maintained
4	Remedial construction can be undertaken during movement; insensitive structures can be maintained with frequent maintenance work if total movement is not large during a particular acceleration phase
3	Some permanent structures undamaged by movement
2	Imperceptible without instruments; construction possible with precautions
1	

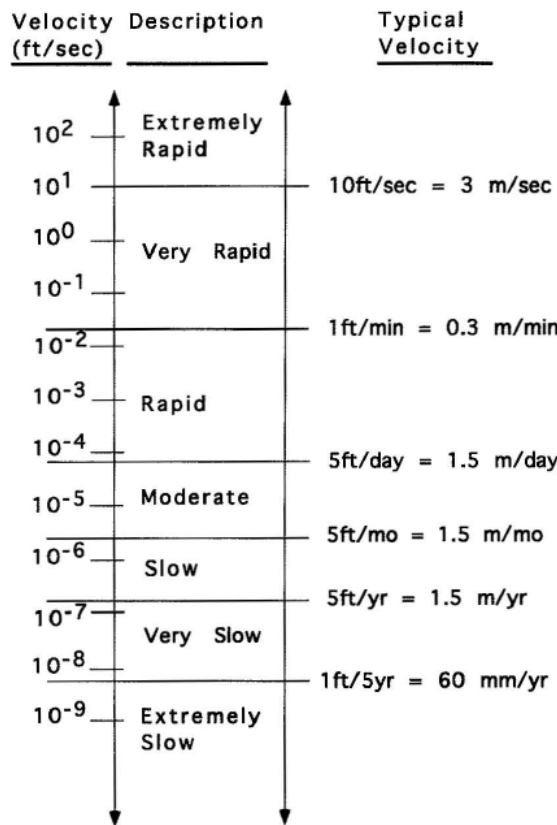


Fig 2.3a. Varnes landslide movement scale (Varnes 1978, Figure 2.1 u as cited in Cruden and Varnes, 1996).

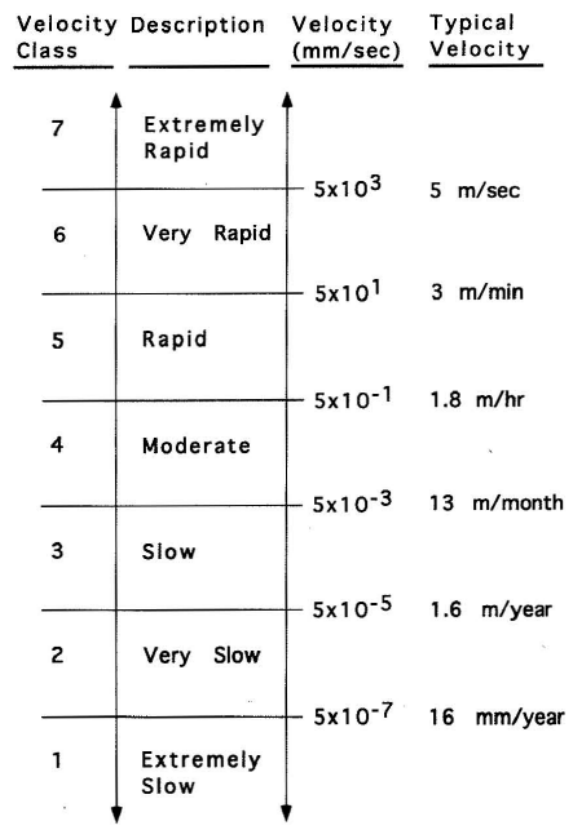


Fig 2.3b. Landslide Velocity scale proposed by Cruden and Varnes (1996).

2.3.2 Statistical Methods

Statistical methods are used to make the statistical determination of the combinations of variables that have led to landslide occurrence in the past in areas currently free of landslides, but where similar conditions exist (Dai *et al.*, 2002). In this method, the observed

relationships between each instability factor and past landslides is used to establish a factor's role in the mass-wasting process and to calculate the likelihood of a future mass-wasting event at a specific location (Gupta and Joshi, 1990; as cited in El Morjani, 2011). In other words, landslide casual factors or parameters are derived and combined with the landslide inventories to predict the future occurrence of landslides (Carrara et al. 1991, Guzzetti *et al.*, 1999 as cited in Adhikari, 2011; Dai *et al.*, 2002).

Statistical analysis approach can be distinguished into bivariate and multivariate methods (Carrara 1983, Carrara et al. 1991, Lee and Min 2001, Süzen and Doyuran 2004a as cited in Adhikari, 2011; Vanwesten et al., 2006; Raghuvanshi *et al.*, 2013).

In bivariate method of landslide susceptibility assessments, the weights are assigned to various factors (such as; geology, slope, land use – land cover, etc) based upon statistical relationships between past landslides and various factors (VanWesten, 1994 as cited in Raghuvanshi et al., 2013). Each factor map (for example, slope, geology, land use) is combined with the landslide distribution map, and weighting values based on landslide densities are calculated for each parameter class (for example, slope class, lithologic unit, land use type) (Soeters and VanWesten, 1996). That means, individual factor maps will be prepared and then are overlaid on past landslide map to workout relative contribution for each factor and subclass in inducing landslide. From this data, weights are developed to be applied to each factor subclass so that landslide hazard can be developed (Raghuvanshi *et al.*, 2014).

Several statistical methods have been applied to calculate weighting values; these have been termed the landslide susceptibility method (Brabb 1984; van Westen 1992, 1993 as cited in Soeters and VanWesten, 1996; Adhikari, 2011), information value method (Yin and Yan 1988; Kobashi and Suzuki 1988 as cited in Soeters and VanWesten, 1996; Adhikari, 2011), and weight-of-evidence modeling method (Spiegelhalter 1986 as cited in Soeters and VanWesten, 1996; Adhikari, 2011). Chung and Fabbri (1993 as cited in Soeters and VanWesten, 1996) described several methods, including Bayesian combination rules, certainty.

In multivariate method, all relevant landslide casual factors or parameters are treated together (Carrara 1983, Carrara et al. 1991, Lee and Min 2001, Süzen and Doyuran 2004a as cited in Adhikari, 2011) by using an equation in which independent variables are the geo-environmental factors and the coefficients are maximizing the predictive capability of the model (Raghuvanshi *et al.*, 2014). In their applications all relevant factors are sampled either

on a large-grid basis or in morphometric units. For each of the sampling units, the presence or absence of landslides is also determined. The resulting matrix is then analyzed using multiple regression or discriminant analysis (Soeters and VanWesten, 1996).

According to Dai *et al.* (2002), logistic regression and determinant analysis are the common types of multivariate statistics used in landslide susceptibility analysis. Artificial neural network (ANN) classifiers are also another type of multivariate method. This type of analysis gives the relative contribution of each of the factors responsible for the slope movement (Nandi and Shakoor, 2006). As a result, interaction effects of multiple factors are displayed by this method.

In statistical methods, there is the tendency to simplify the factors that condition landslides, by taking only those that can be relatively easily mapped in an area or derived from a DEM. There is also a problem related to generalization of the causal factors, assuming that landslides happen under the same combination of conditions throughout the study area and through time, whereas in reality the environmental factors change continuously. The other problem is related to the fact that each landslide type will have its own set of causal factors and should be analyzed individually, whereas, the statistical models generally ignore the temporal aspects of landslides and are not able to predict the impact of changes in the controlling conditions (e.g., water table fluctuations, land use changes, climatic change) (Vanwesten *et al.*, 2006).

According to Vanwesten *et al.* (2006), these methods cannot therefore provide full temporal probability information and are difficult to use in quantitative risk assessments. However, this could be improved if use is made of landslide inventory maps for particular time intervals, or better for events with a particular return period for the generation of the statistical relations.

On the other hand, still, the collection of data over large areas and sometimes over large time periods regarding landslide distribution and factors will be the most drawbacks of these methods again. It could be very problematic to carry out this data gathering at acceptable costs (Westen Van *et al.*, 1997 as cited in Fall *et al.*, 2006). A further potential source of error, which is common to all statistical methods, is the quality and detail of the landslide frequency or factors data on which the correlations are based. Thus, the results are largely dependent on the quality of the data (Fall *et al.*, 2006) such as errors in mapping, incomplete inventory and poor resolution of some data sets as the models are essentially data trained (Fell *et al.*, 2008). For the present study, this method has not been chosen to be employed.

2.2.3 Mechanical Approaches

The analysis and evaluation of the stability state of slopes can be carried out by applying the mechanical approaches. These approaches can be categorized as numerical modeling (e.g. discontinuous modeling) and deterministic methods (e.g. limit equilibrium methods) (Fall *et al.*, 2006).

In order to model the discontinuities and calculate the behavior of a rock mass in detail, discontinuous 'distinct block' numerical calculations can be carried out provided that property data are available. Despite the need to have powerful computers, the main drawback of this approach is, the test data needed for a detailed numerical discontinuous calculation are never available to do the large number of calculations required by the vast quantity of discontinuities. An often-applied practice to avoid these problems is to simplify the discontinuity model and estimate or guess the properties or to use values from the literature (Hack *et al.*, 2003).

Deterministic methods apply classical slope stability theory and principles such as infinite slope, limit equilibrium and finite element techniques. The standard soil parameters such as soil thickness, soil strength, groundwater pressures, slope geometry etc. are required as inputs in these models (Fell *et al.*, 2008). The availability of computers nowadays allows the analysis of complex landslides to be undertaken routinely using state - of - the - art numerical modeling codes on desktop computers. However, in order to maximize the benefits of these methods, the field data collection techniques are required to be more responsive to advances in design capabilities. At the present time, much of the data collection methodologies are aimed towards limit equilibrium analysis and have shown little change over the last decade (Eberhardt, 2003).

According to Eberhardt (2003), limit equilibrium techniques are routinely used in the analysis of landslides where translational or rotational movements occur on distinct failure surfaces. He indicated that, these analyses are undertaken to provide either a factor of safety or, through back-analysis, a range of shear strength parameters at failure. Dai *et al.* (2002) also explained that, for site-specific slopes, the probability of failure is usually considered as simply probability that the factor of safety is less than unity. According to Dai *et al.* (2002), the performance function of slopes is usually formulated using the simplified limit equilibrium method. For instance if we denote the performance function of the slope by $P(X)$

where X is the collection of random input parameters, then, the performance function or $P(X)$ is a function which defines the failure or safety state of a slope. The function is defined in such a way that failure is implied when $P(X) < 0$ and safety is implied by $P(X) > 0$. When $P(X) = 0$, it is called the limit state boundary which separates the safety and failure domains. If we represent the resistance force for sliding as $R(X)$ and the driving force for sliding as $S(X)$ and also the factor of safety as $F(X)$, then, the performance function for a slope, $P(X)$, can generally be expressed as, $P(X) = R(X) - S(X)$ or $P(X) = F(X) - 1$.

Eberhardt (2003) claims that limit equilibrium method still remains the most commonly adopted solution method in rock slope engineering, even though most failures involve complex internal deformation and fracturing which bears little resemblance to the 2-D rigid block assumptions required by most limit equilibrium back-analyses. The factors initiating eventual failure may be complex and not easily allowed for in simple static analysis. Notwithstanding the above comments, according to Eberhardt (2003), limit equilibrium analyses may be highly relevant to simple block failure along discontinuities or rock slopes that are heavily fractured or weathered (i.e. behaving like a soil continuum). The results derived from stability analysis based on deterministic models can be directly used by engineers in the design of infrastructural or remedial works (Westen Van *et al.*, 1997 as cited in Fall *et al.*, 2006). The main problem with these methods is the over simplification of the geological and geotechnical model, and difficulties in predicting groundwater pore pressures and their relationship to rainfall and/or snow melt (Fell *et al.*, 2008). According to Casagli *et al.* (2004) and Clerici (2002), the deterministic slope stability analysis techniques are time consuming and require thorough knowledge on geological and geotechnical considerations with a clear understanding on potential mode of slope failure. Besides, such analysis techniques may be suitably applied to small areas, at the scale of a single slope only.

Moreover, Anbalagan (1992) further indicated that, due to constraints of time and financial limitations systematic deterministic slope stability analysis techniques for road projects are often neglected or carried out too quickly without proper geological or geotechnical inputs. According to him, such inadequate analysis may result in failures affecting the safe performance of the engineering structures.

Likewise, Jiri Sima *et al.* (2009) added that, mapping on a broad regional scale in limited time provides no guarantee that data-driven models will capture all of the important patterns

of the natural conditions. Thus, in the present research study, the deterministic approach has not been employed.

2.3.4 Expert Evaluation Methods

A great deal of research concerning slope instability hazard has been done over the last 30 years. Techniques were developed by engineers for the appropriate design of a planned structure as well as the prevention of slope failure. Therefore, research emphasized site investigation techniques and the development of deterministic and probabilistic models. However, the heterogeneity of the natural environment at the regional scale and the large variability in geotechnical properties such as; cohesion and internal friction are in sharp contrast to the homogeneity required by deterministic models. This contrast, coupled with the costly and time consuming site investigation techniques required to obtain property values, makes the engineering approach unsuitable for application over large areas (Soeters and VanWesten, 1996).

According to Jiri Sima et al. (2009), in Jema River basin including the present study area, there was not enough statistical data found from the direct field documentation and inventory of active risky processes to use data-based models for susceptibility zoning of the Jemma basin. That means it was not possible to find enough statistical data to identify important factors in the processes studied, and to assign them different degrees matching their regional importance. They stated that, because of the insufficient density of 0.0016 point/km² of documented active geo-risk event/km², it was not possible to rigorously derive the main variables controlling the geo-risk occurrence. Hence, according to them, emphasis was placed on the idea-driven approach.

Furthermore, they suggested that, idea-based susceptibility zoning can be used to test the regional reliability of the susceptibility zoning. In addition to this, Eberhardt (2003) stated that, the design of a slope using a limit equilibrium alone may be completely inadequate if the slope fails by complex mechanisms (e.g. progressive creep, internal deformation and brittle fracture, liquefaction of weaker soil layer, etc). Hence, expert evaluation technique was applied in the proposed study area.

Expert evaluation techniques are the most widely used approaches for landslide hazard evaluation (Nash, 1987; Fall *et al.*, 1996; Evans *et al.*, 1997; Leroi, 1997; Atkinson and Massari, 1998; Guzzetti *et al.*, 1999; etc. as cited in Fall *et al.*, 2006; Anbalagan, 1992).

The expert evaluation techniques can include *landslide inventory mapping* and/or *heuristic approaches*.

In landslide inventory mapping, emphasis is given for position and dimension of recorded landslides and hence, this technique can be used as an elementary form of susceptibility mapping (Dai and Lee, 2001 as cited in Fall *et al.*, 2006; Dai *et al.*, 2002). The shortcoming of this method is that it shows susceptibility only for those areas where landslides have been observed; however, it may not provide information on landslide susceptibility for those areas which may have potential for future landslide activities (Casagli *et al.*, 2004).

The heuristic methods are based on the assumption that the relationships between landslide susceptibility and the preparatory variables are known and are specified in the models. Thus, in these methods, expert opinions are used to estimate landslide potential from data on preparatory variables (Dai *et al.*, 2002). In heuristic approaches, the mapping of the landslides will be combined with their geomorphologic setting as the main input factors for assessing the hazard. These methods can also be categorized in to two types: (i) *geomorphic analysis* and (ii) *qualitative map combination*.

In geomorphic analysis, the person carrying out the study uses his individual experience and reasoning by analogy to determine the susceptibility or hazard directly on site. The decision rules are therefore difficult to formulate because they vary from place to place.

In qualitative map combination, the person carrying out the study uses expert knowledge to assign weighting values to a series of input parameters. The weighting values of the series of the input parameters are then summed according to their weights, leading to susceptibility and hazard classes. The main problem in these methods is the difficulty to determine the weighting of the input parameters (Fell *et al.*, 2008). Anbalagan (1992) explained that, the numerical ratings are assigned to various causative factors or input parameters that are responsible for instability of slopes based on logical judgments of a Geoscientist acquired from experience of studies of causative factors and their relative impact on instability of slopes. According to Kanungo *et al.* (2006), the higher the value of the numerical rating, the greater will be its influence on the occurrence of landslide.

However, Carrara *et al.*, (1992 as cited in Fall *et al.*, 2006), indicated that landslide hazard maps produced by different researchers according to expert evaluation method can be very different. This indicates the presence of high degree of subjectivity in the decision making

which can be considered as the main criticism of the methodology of expert evaluation (Westen Van *et al.*, 1997; Leroi, 1997; Fall, 2000 as cited in Fall *et al.*, 2006). Fall *et al.* (2006) argued that, even though improvement is required, the approach based on expert evaluation will remain the most widely used and the most versatile method available. Alternatively, they also indicated that, for integration of data from different parts of the area in to the overall methodology of landslide danger or hazards mapping, it will be necessary to rely on more sophisticated techniques such as: statistical methods, mechanical methods, etc. and on state-of-the-art geographical data management tools.

On the other hand, according to Raghuvanshi *et al.* (2014), application of expert evaluation techniques are more practical, simple in application and provide much more realistic field data well supported by experience of an expert. Furthermore, Vanwesten *et al.* (2006) stated that, qualitative risk assessment procedure based on heuristic approaches have been implemented in many countries in the world.

There are several Expert evaluation techniques available these includes techniques proposed by Anbalagan, 1992; Pachauri and Pant, 1992; Sarkar *et al.*, 1995; Turrini and Visintainer, 1998; Guzzetti *et al.*, 1999; Raghuvanshi *et al.*, 2014 etc.

2.4 Methodology adopted in the present study

As discussed above, each technique for landslide hazard assessment has its own advantages and disadvantages. From the review of various techniques it is well understood that landslide is a complex process and there is no straight forward approach available which individually or in combination may provide realistic results. Each method has some degree of subjectivity in recognizing various parameters responsible for slope instability, collection of data or assigning weight and ratings to various parameters. Thus, a technique is required which is relatively more practical, simple in its application and provide much more realistic field data well supported by experience of an expert.

In 2013, a new slope stability susceptibility evaluation parameter (SSEP) scheme was proposed by Raghuvanshi *et al.*, (2014) by considering both intrinsic (such as: slope geometry, slope material, structural discontinuities, land use and land cover and groundwater) and external (such as, seismicity, rainfall and manmade activities) triggering parameters that are responsible for slope instability.

The main advantage of this technique is that it considers both intrinsic (preparatory or causative) factors and external (triggering) parameters that are responsible for slope instability. Therefore, in the proposed research study, the slope stability susceptibility evaluation parameter (SSEP) has been preferred to be used for rapid assessment of slope stability condition (LHZ) in the study area; because, this technique is more practical, simple in its application and provide much more realistic field data well supported by experience of an expert. A detailed description on this technique is given in Chapter 5.

CHAPTER III

PREVIOUS RESEARCH STUDIES

3.1 Preamble

In order to have a basic understanding for the geological, hydro-geological, engineering geological, and geo-hazard condition of the present study area, a systematic literature review on the previous and existing works conducted in and around the study area was carried out.

The hilly terrains of the Ethiopian landmass have been frequently affected by new as well as reactivated old landslides because of their complex geo-morphological, hydrological, and geological setting. Except for some efforts made by the Ethiopian Geological Survey and Ethiopian Roads Authority, so far no comprehensive inventory of landslides and their significance (economic, social and environmental) has been made in Ethiopia. However, despite multi-faceted challenges in landslide research in the country, several authors have reported on slope instability problems in different parts of country (Kifle Woldearegay, 2013).

Locations of landslide affected areas in relation to the rainfall distribution (mean annual rainfall in mm) and slope instability problems in different parts of Ethiopia are shown in Fig. 3.1 (Batista, 2013; Kifle Woldearegay, 2013).

3.2 Previous studies

From the present study area, no published research study related to landslides (Fig. 3.1) was found. However, general and broad Geological, Hydrogeological, Engineering geological, and Geohazard information of the mapped area was obtained from 1:250,000 scale maps of: *Engineering geological map of Were - Illu map sheet NC 37 - 7* (GHID-GSE, 2012), *Water Resources Management and Environmental Protection Studies of the Jemma River Basin for Improved Food Security* (Jiri Sima et al., 2009) and *Geology of Were - Illu area* (GSE, 2009).

In addition to this, other published and unpublished works available in the area were also reviewed.

The summary of the previous works that were conducted in and around the study area are presented systematically in the following paragraphs.

Classic Consulting Engineers (CCE, 2013a; 2013b), and Ethio Infra (2012), conducted slope stability analysis for four selected slope sections along road section from station 72km (around Ambat village) to 109 km (around Alemketema town) in the study area.

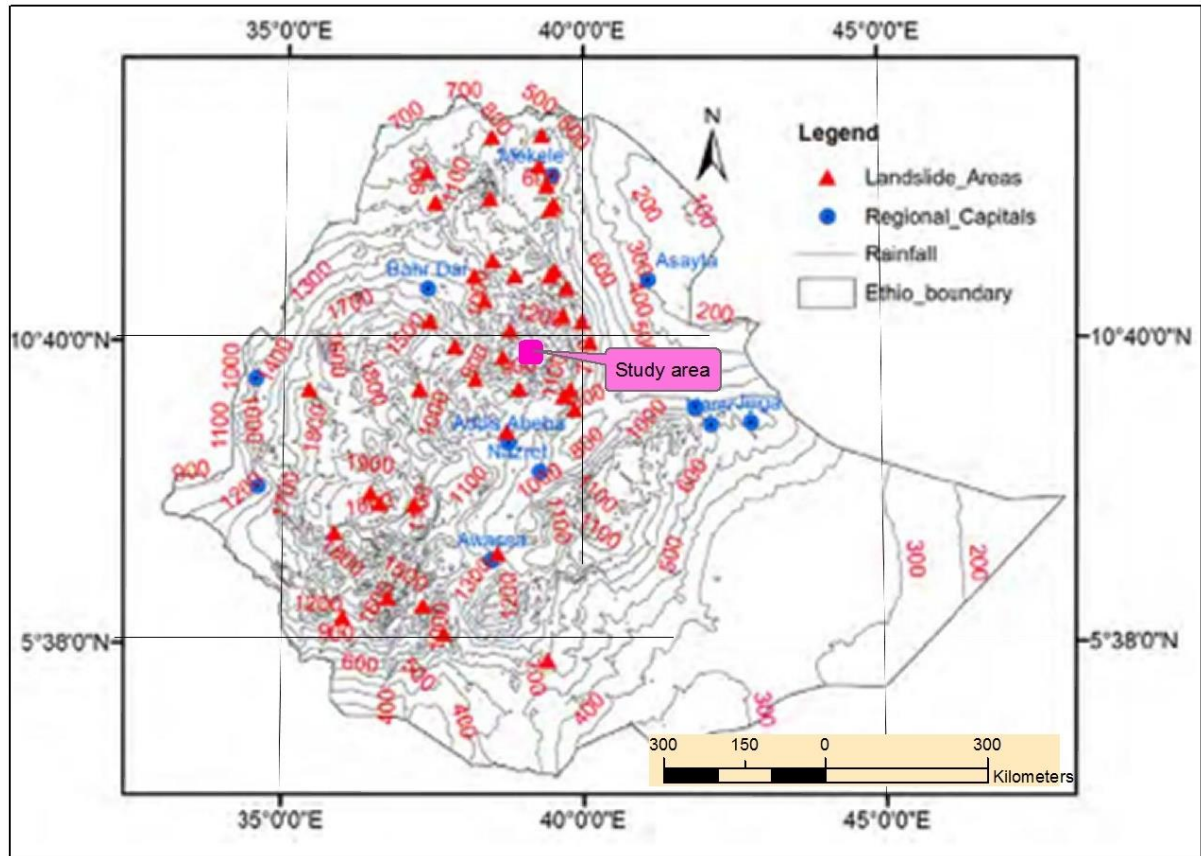


Fig. 3.1 Landslide - affected areas and rainfall distribution in Ethiopia (After Kifle W/Aregay, 2013)

The selected slope sections were analyzed using semi-circular failure surfaces using the Morgenstern-Price method. Two layer models have been utilized to analyze the slope stability in GeoStudio, Slope/W®. Out of the four sites tested for stability, three of them indicate potential for failure or near failure by assumed circular slip surface. Slope Models and stability analysis was carried out for unstable slopes at 111km, 102km, 93.2km chainages and a switch curve between 85.7km and 83.3km chainages. It was intended that the results could give preliminary insight that would have to be carefully revised with more deterministic approach for designing of counter measures during construction. Based on the review of documents such as ERA design manuals (2002), design review consultant coupled with field inspection, CCE (2013b) suggested that slope stability analysis based on ground investigation for safe cut back slope angles is recommended and to be completed within three months of time.

Asmelash Abay and Barbieri (2012) conducted Remote sensing and GIS based mapping and evaluation of landslide at the Debresina area, located on the western Afar Margin of Ethiopia. They applied remote sensing and detailed field survey to map the distribution of existing landslides and the factors that affect the landslide occurrences. They also carried out field measurements on joint characteristics (orientation, dip angle, spacing, opening, and roughness), degree and depth of weathering of the different lithologies. Finally, they produced landslide susceptibility zonation of the study area identifying four classes / zones, namely; very high (0.7%), high (22.7%), moderate (65.0%) and low (11.6%) zones.

In preparation of the Engineering Geological Map of Were-Ilu Map Sheet (NC37-7), GHID-GSE (2012) had conducted the assessment of mass wasting activities in the Were Illu area. In this assessment, relief energy was considered as the major controlling parameter for mass wasting, and also a conceptual model used for integrated Environmental study of Jema Basin (Jiri Sima *et al.*, 2009) (adjacent to the Were-Ilu map sheet) was adopted in the case of Were Illu area to assess distribution of relief energy (Fig. 3.2). Accordingly, the area was considered as being part of any of the three physiographic relief classes with topographic slopes above 27°, between 5° and 27°, and less than 5°. These correspond to the geomorphologic threshold angles of Destructive (high energy) zones, transport (medium energy) zone, and accumulation (low energy) zones, respectively.

Ethiopian Road Authority (ERA SMRR, 2010), conducted detailed investigation on sub - grade material observed along the project rout in the study area, and found that the colluvium which covers the mountains and hills sides of the project route corridor is very poor or unsuitable as roadbed material. Since the source rock of this material is basalt, the finer fraction is dark clay soil which exhibits high expansive property which needs to be replaced.

Jiri Zvelebil *et al.* (2010) published a progress report on conceptual and applied analyses bearing on engineering geological, hydrogeological mapping, and zoning of vulnerability to mass wasting conducted for nearly a 16,000-km² area of the Jema River basin, central Ethiopian highlands. In this study, because of the mapping scale of 1:250,000 and the inadequacy of information by regular field inventory of events and their conditions to enable regular statistical analyses and to identify of the generic types of events and factors affecting their occurrence, an alternative, conceptual energy-process and land unit-oriented method was chosen. The alternative model for compiling of the engineering geological and vulnerability maps was based on assessment of relief energy which, under supposed

regionally quasi-homogeneous conditions of climatic influence, has been considered the main driving force of shaping of relief by exogenic processes. The latter incorporated mainly processes of mass wasting including weathering, landslides, rock-falls, and erosion together with the types of accumulations produced by them (Fig. 3.2).

Fig. 3.2 depicts the graphical scheme of the model for relief energy scoring according to slope angles. This energy is, under assumed regional quasi-homogeneous conditions of climatic influence, considered as the main driving force of relief shaping by exogenic processes incorporating mass wasting.

Jiri Sima *et al.* (2009), produced a map (1:250,000) showing the susceptibility to occurrence of slope instabilities like; rock falls in the Jema river basin considering the energy/force which drives the mass wasting processes of landslides and erosion, and the passive opposition of the geological environment to that force. In the preparation of this map, they followed three steps on two hierarchical levels.

In the first step and on the most general level, they prepared engineering geological map zoning that reflects the main morpho-structural and morphometric features of the mapped area with First Order Units being established with them in mind. In the second step and the second hierarchic level, the Second Order Units of fine division were introduced by merging the bedrock environment (basic geology, rock strength, and erosion susceptibility) with the local level of relief energy (high/destruction, medium/transport, and low/accumulation zones) producing an engineering geological map with basic units.

A conceptual model for energy relief and related processes (which delimits the three zones) used in this study is depicted in Fig. 3.2. In the third step, the Second Order Units were scored in accordance with idea- as well as data-driven models of occurrence of geological risks to produce engineering geology map of Jema river basin showing Susceptibility to occurrence of geo-risks.

Leta Alemayehu (2007) carried out Landslide Susceptibility Modeling Using Logistic Regression and Artificial Neural networks in GIS: a case study in Northern Showa area, Ethiopia. Two landslide susceptibility maps were produced: one by Logistic regression, and the second by Artificial Neural networks. In order to verify the practicality of the results, a comparison was made between the two susceptibility maps and a landslide activity map of the same time period including the major massive landslide that occurred in the area.

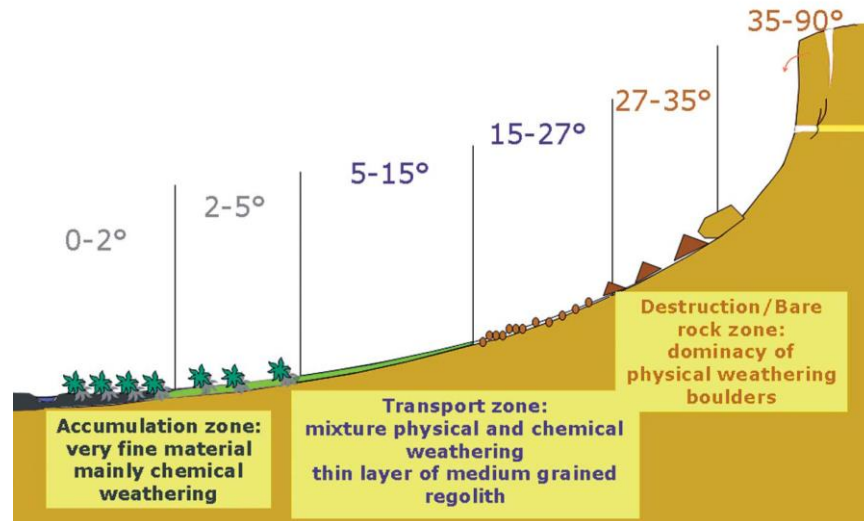


Fig. 3.2 Conceptual model for relief categorization in accordance with relief energy.

Tenalem Ayenew & Barbieri (2005) conducted a comprehensive study of landslide processes in the city of Dessie and its environs in northern Ethiopia by making first, a preliminary zoning by dividing the area into a discrete number of smaller units having similar susceptibility to sliding, followed by semi-quantitative field investigation of the geological, geotechnical, geomorphological, hydrogeological, and anthropogenic factors that contribute to the susceptibility of the units to landslide activity. They accomplished the final landslide susceptibility map by using classical overlay procedures of established maps representing the different influencing factors.

In Ethiopia, in general, various landslide studies have been carried out by various researchers, and some of these landslide studies conducted are summarized as follows;

A team from Addis Ababa University and Italy has studied the landslide occurrences in Ethiopian highlands and Rift margins. The findings of this study revealed that the high relief and the rugged topography induced by a strong Plio-Quaternary uplift, the occurrence of clayey horizons within the sedimentary sequences, the dense network of tectonic fractures and faults, the thick alluvial mantles on volcanic outcrops, and the thick colluvial–alluvial deposits at the foot of steep slopes are the predisposing factors for a large variety of mass movements. Heavy summer rainfall is the main triggering factor for most of the landslides (Bekele Abebe *et al.*, 2009).

Shiferaw Ayele (2009) delineated Landslide Hazard zones in the Gohatsion - Dejen section by utilizing Remote sensing and GIS approach. For the study the causative factors considered

were; slope, structures, aspect, geology, groundwater condition, drainage, and landuse / land cover.

The Landslide hazard zone map prepared was validated with the past landslide activities in the study area and it was found that 67% of the past landslide locations lie within the maximum hazard zone delineated by this study.

Engdawork Mulatu *et al.*, (2009) conducted landslide hazard zonation mapping around Gilgel-Gibe II, Southwestern Ethiopia. In their study they have classified the landslide potential areas into high hazard, Moderate Hazard, and low hazard areas.

Henok Weldegiorgis (2008) conducted Landslide Hazard zonation mapping in Blue Nile Gorge. In his study he has used Anbalagan (1992) LHEF method for zonation and classified the study area into high, moderate and low hazard zones. By utilizing Limit equilibrium method he further made quantitative analysis for critical slopes.

Jemal Saed (2005) presented an inventory of landslides mainly along the road alignment between Gohatsion and Dejen towns. This inventory on landslides showed 17 critical slope sections. He further attempted a detailed slope stability evaluation on critical slope sections to suggest suitable remedial measures.

Lulseged Ayalew and Yamagishi (2003) described slope failures in the Abay Gorge from the point of view of landscape evolution. In their study they attempted to relate topographical characteristics with the process of landslide and rock fall. They concluded that slope instability was part of the mega-forces that shaped the entire Abay river basin and that it also contributed to general landscape evolution.

Berhanu Temesgen *et.al* (2001) has studied the occurrence of landslide in Wondogenet area. In their study they have evaluated the relationship between the landslide occurrences with various controlling parameters using GIS and remote sensing techniques and they have prepared the Hazard and Risk map of Wendogenet area.

Fikre Girma (2010) A Multi Method Approach to Study Landslide Hazard A Case study in Ada Berga Woreda, Western Showa Zone, Oromiya Region, Ethiopia

Samuel Molla (2011) Slope stability analysis on a selected slope section along the road Gohatsion – Dejen

Jemal Ibrahim (2011) Landslide assessment and hazard zonation in Mersa and Wurgessa Area, North Wollo, Ethiopia

Yonathan Tsegaye (2011) Landslide Hazard Zonation Mapping of Tarmaber Area in Northern Ethiopia

Lensa Negassa (2012) Landslide Hazard Zonation Using Remote Sensing and GIS Approach - A Case Study in Meta Robi Wereda, West Showa Zone, Oromiya, Ethiopia

Mulugeta Beyene (2013) Assessment of slope stability using combined probabilistic and deterministic approach for selected sections along Gohatsion – Dejen Route, Blue Nile Gorge, Central Ethiopia.

Similar landslide studies were carried out by Lulseged Ayalew (1999), Kefeyalew Terefe (2001), Gebretsidik Eshete (1982), Mesfin Wubshet et al. (1994), Almaz et al (1994) etc.

3.3 Background and justification (for the Present Research Study)

Among the previous works conducted around the present study area, only three of them, namely; Jiri Sima et al. (2009), Jiri Zvelebil et al. (2010), and GHID-GSE (2012) which has covered the present study area were utilized. However, the mapping scale for these works is small that is 1:250,000 which make it less specific to be used to prepare a base map for the present study area.

The other works conducted by ERA and its stake holder (Classic Consulting Engineers Plc, Ethio Infra Plc and others) are limited to the route alignment corridors only and are mainly focused on remedial works for failed slope sections along the route alignment.

The development and exploitation of natural resources requires landslide hazard zonation maps that attempt to divide the terrain into safe and unsafe areas according to the incidence of landslides and other mass movements (Varnes, 1981 as cited in Sarkar et al., 1995).

As the present study aspires to prepare a landslide hazard zonation map of landslide prone area, the zone extending from Alemketema town to Ambat village was selected because this zone has been experiencing a practical problem of landslide hazard and the road construction is currently underway. However, the present study is not limited to route corridor only; rather, it covers an area of about 756 km² that is a full 1:50,000 topographic map sheet of

Meranya (i.e. 1039 C3 MERANYA) in the north shewa zone of central Ethiopia. Landslide hazards are the major geological hazards in the gorges of this area.

Landslide and related slope instabilities is mainly associated with the colluvial material making most of the slope faces in the project area. Long, steep, straight mountain and valley sides of the project route are covered by a mantle of colluvial soil (transported slowly by gravity) over weathered rock. Instability is normal in this terrain; shallow translational and planar landslides and gully erosion are the commonest forms. Local landslides up to 15m deep are observed in colluvial deposits (ERA SMRR, 2010). According to Bhandari (1987 as cited in Sarkar et al., 1995), landslide hazard zonation maps can serve as a base map for land-use planning and the development of appropriate remedial measures.

Thus, as the major outcome of the present study, Landslide hazard zonation (LHZ) map of the study area is prepared and this map is expected to serve as a base map for land-use planning and the development of appropriate remedial measures for slope instability problems in the present study area.

CHAPTER IV

GEOLOGICAL SETUP

4.1 Regional Geology

The geological makeup of Ethiopia is product of tectonics and accompanying sedimentation and volcanic activities + metamorphism that operated since > 950 million years up to present.

The Precambrian or basement rocks upon which all the younger formations were deposited are exposed in areas where the younger cover rocks have been eroded away (Kazmin, 1975), in the northern, western and southern parts of the country (Tarekegn Tadesse, 2005). Getachew Lemesa (2008) indicated that these rocks cover about 25 % of the country (low grade volcano-sedimentary assemblage and associated plutonic rocks and high grade rocks).

According to Kazmin (1975), any sediments which were deposited during the Palaeozoic interval, which lasted some 375 million years, have been largely removed by erosion, except for shales and deposits partly of glacial origin laid down in northern Ethiopia towards the end of this period. According to Tarekegn Tadesse (2005), as the Paleozoic rocks are overlain by the Mesozoic and Tertiary rocks, their real extent of areal coverage is not known.

The Mesozoic Geology is characterized by thick marine and continental sedimentary sequences. Together with lower Tertiary sedimentary rocks (at the eastern most part of the country) it covers over 24 - 25 % of the landmass of Ethiopia (Tarekegn Tadesse, 2005; Getachew Lemesa, 2008). These sedimentary rocks are only exposed in areas where the Tertiary volcanic rocks did not cover during eruption or eroded afterwards. The major Mesozoic rocks exposures are found in three areas; in the Ogaden Basin, Mekelle Basin and Blue Nile Basin.

The Tertiary to Quaternary Geology comprises rock types of volcanic products including basaltic to felsic flows, tuffs, ignimbrites, rhyolites and scoria together with inter-volcanic, clastic and evaporitic sedimentary rocks, much of which are concentrated along the Main Ethiopian Rift Valley (Mohr 1962, 1983 as cited in Tarekegn Tadesse, 2005).

The road project alignment in the present study area predominantly traverses parts of the Central Canyons where major shield and fissural volcanic activities had taken place. According to Hofmann *et al.* (1997 as cited in Kieffer *et al.*, 2004), most of the Ethiopian

flood basalts erupted 30 Myr ago, during a short 1Myr period, to form a vast volcanic plateau. Immediately after this peak of activity, a number of large shield volcanoes developed on the surface of the volcanic plateau, after which subsequent volcanism was largely confined to regions of rifting (Mohr, 1983a; Mohr & Zanettin, 1988).

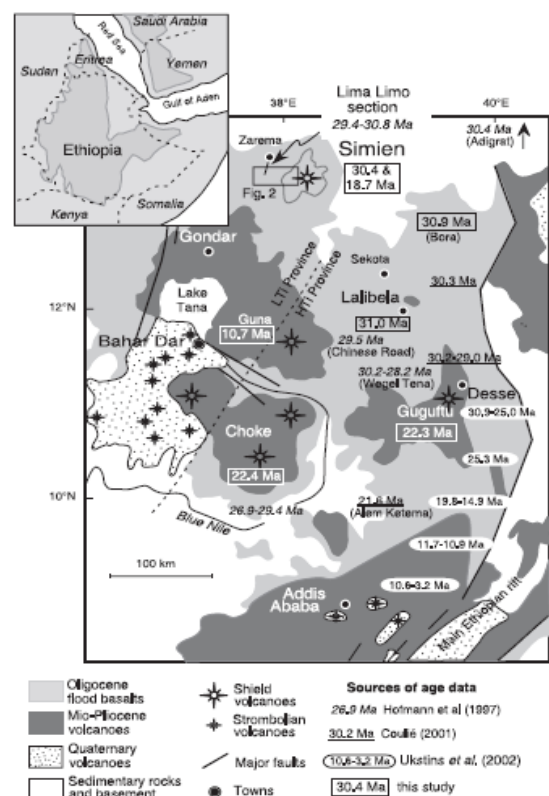
The rift that opened along the Red Sea and Gulf of Aden separated the Arabian and African continents, and isolated a small portion of the volcanic plateau in Yemen and Saudi Arabia (Chazot & Bertrand, 1993; Baker *et al.*, 1996a; Menzies *et al.*, 2001 as cited in Kieffer *et al.*, 2004). Volcanic activity continues to the present day along the Ethiopian and Afar rifts.

The lava flows of the shield volcanoes are thinner and less continuous than the underlying flood basalts. They also are more porphyritic, containing abundant and often large phenocrysts of plagioclase and olivine. Like the flood volcanics, the shield volcanoes are bimodal and contain sequences of alternating basalts, rhyolitic and trachytic lava flows, tuffs and ignimbrites, particularly near their summits (Fig 4.1).

The village of Alem Ketema is situated on the left bank of the Blue Nile, about 120 km north of Addis Ababa (Fig4.1). In this region the flood basalts are far thinner than to the north, being limited to several 50 - 200m thick sequences of relatively thin flows that alternate with felsic volcanics and clastic sedimentary rocks. The flood basalts from Alem Ketema have alkaline compositions and are enriched in incompatible trace elements, very like the alkali basalts of the Choke and Gugufu shields (Kieffer *et al.*, 2004).

4.2 Local Geology

This chapter deals with the description of the various units outcropping in the study area. Field observations, geomorphic features, satellite imagery interpretation, literature review and



(Source: adopted from Kieffer *et al.*, 2004)

Fig 4.1 Map of the northern part of the Ethiopian plateau showing the extent of the flood volcanism and the location and ages of the Major shield volcanoes.

DEM analysis conducted in this study indicates that the study area comprises two litho-stratigraphic units. These are:-

- (i) Mesozoic sedimentary rocks, which account to 15.2 % of the exposures in the mapped area, and
- (ii) Cenozoic volcanic rocks and superficial deposits, which make up 84.8 % of the mapped area (Fig. 4.2).

4.2.1 The Mesozoic Sedimentary Rocks

a) Debrelibanos Sandstone (Msst)

During the field work, the oldest lithologic unit outcropping in the study area is the Debrelibanos or upper sandstone (Msst). This unit is exposed at the deep gorges of Wenchit and Zhema streams, in the study area (Fig.4.2). The unit has unconformable contact with the overlying Ashangi basalt; however, the contact with the underlying unit is not exposed elsewhere in the mapped area. It attains a maximum thickness of 380 m at Beto section and a minimum thickness of 50 m at Zhema (Jema) river section, showing a decrease in thickness from northwest to southeast.

The sandstone is white, pink and light grey, fine to medium grained and cross bedded to cross laminated. At places, the sandstone is laminated to thinly bedded at the lower part and massive at the top. Thin sections study showed that the sandstone is quartz arenite composed of angular to subrounded grains of quartz (up to 86 %) with other constituents include magnetite (5%), tourmaline (3%), muscovite (2%) and epidote (1%). The sandstone is texturally submature and is moderately to well-sorted. The major cementing material is interstitial clay minerals (Tigel Belay *et al.*, 2009). The sandstone is referred to as Debre Libanos sandstone (Assefa, 1991 as cited in Tigel Belay *et al.*, 2009) and Upper sandstone or Amabradom Formation (Mengesha Tefera *et al.*, 1996).

5.4.2 Cenozoic Volcanic Rocks

The Cenozoic volcanic rocks in the study area are represented by varying proportions of basalts and bimodal basalts and silicic rocks spanning from Tertiary to Quaternary (Fig. 4.2). According to Geology of the Were-Illu area (GSE, 2009) and present field observation, the four Tertiary volcanic rock types were identified in the study area (Fig. 4.2) and their descriptions are presented in the following sections.

a) Ashangi Basalt (Tab)

In the mapped area the Ashangi basalt is exposed in the northeastern, central, and southwestern part of the plateau within the deep gorges of Wenchit and Jema rivers, and in the eastern part along the escarpment. It covers about 33.3 % of the study area (Fig.4.2).

It lies unconformably on the sandstone, in which the unconformity is marked by 3-7 m thick nodular laterized soil horizon. It is also un-conformably overlain by Alajae basalt.

The Ashangi basalt is dominantly composed of basalt with minor inter-layering of pyroclastics towards the top part of the succession. It attains a maximum thickness of 560 m at Beto section and a minimum of 114 m at Zhema (Jema) river section (Fig 4.3). Characteristically, the exposures of the Ashangi basalt are strongly weathered, intensely fractured and jointed, friable and rarely vesicular. On vesicular varieties, the vesicles attain 3-4cm in diameter and are usually filled by calcite, silica and zeolites.

In the study area within the dissected valleys and gorges of the plateau, the Ashangi basalt is represented by three flow units (lower, middle and upper), separated from each other by paleosoils or inter-trappean sediments. The lower unit is mainly comprised of spheroidally weathered aphanitic basalt. However, at the Wenchit river and Zhema river sections the basalt flow is associated with scoria. The middle flow is medium grained porphyritic basalt with phenocrysts of pyroxene, plagioclase and olivine. At places minor interlayers of amygdaloidal basalt are seen. The top part is dominated by aphanitic basalt with occasional interlayers of pyroclasts (Fig 4.3).

(b) Alajae basalt (Talb)

The name Alajae basalt is taken from Mengesha Tefera *et al.* (1996) and references therein. The Alajae basalt covers parts of the study area, which accounts to 27.8% of the total mapped area. It forms relatively flat topped topography on the plateau, and cliff along the escarpment (Fig. 4.2). The contact with the underling Ashangi basalt is marked by reddish brown paleosoils.

Lithologically, the Alajae basalt is dominantly represented by association of different basalts, and subordinate pyroclastic rocks. The basalts consist of olivine-pyroxene phyric, olivine-phyric and aphanitic varieties, and the pyroclastics are composed of rhyolitic tuff, rhyolitic obsidian and ignimbrites. The thickness increases from Beto (140 m), to Wenchit (636 m) and Zhema (Jema) river sections (790 m) (Tigel Belay *et al.*, 2009) (Fig 4.3).

The pyroclastic rocks mostly cover plains and few exposures are seen along stream and road sections. Lithologically, the pyroclastic rocks are represented by varying proportions of rhyolitic tuff, ignimbrite, trachytic obsidian and volcanic ash. At Wenchit river section the lower part is dominantly rhyolitic tuff overlain by tuffaceous sediments, whereas the top part occupies alternating layer of plagioclase phyric basalt and rhyolitic tuff.

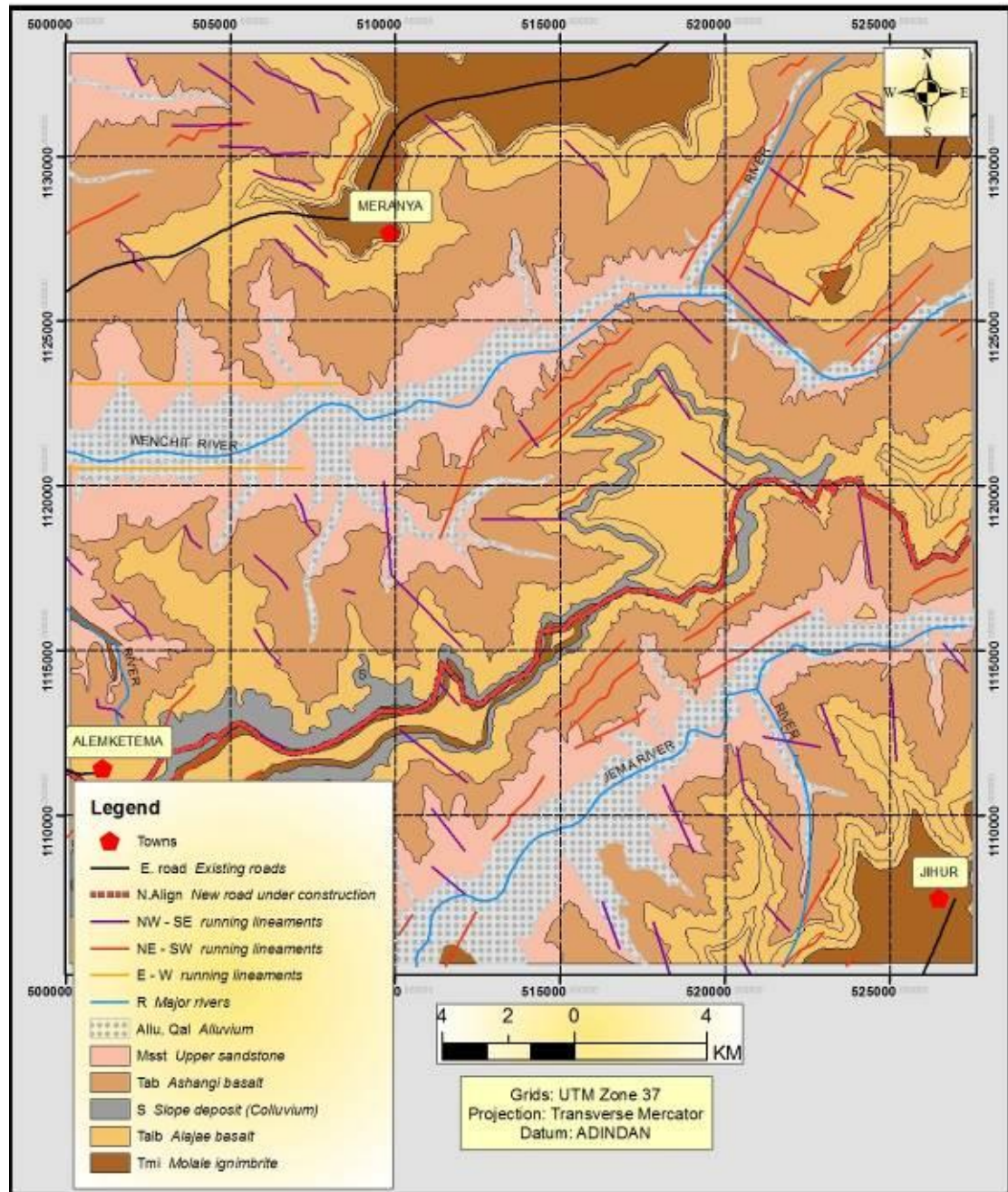
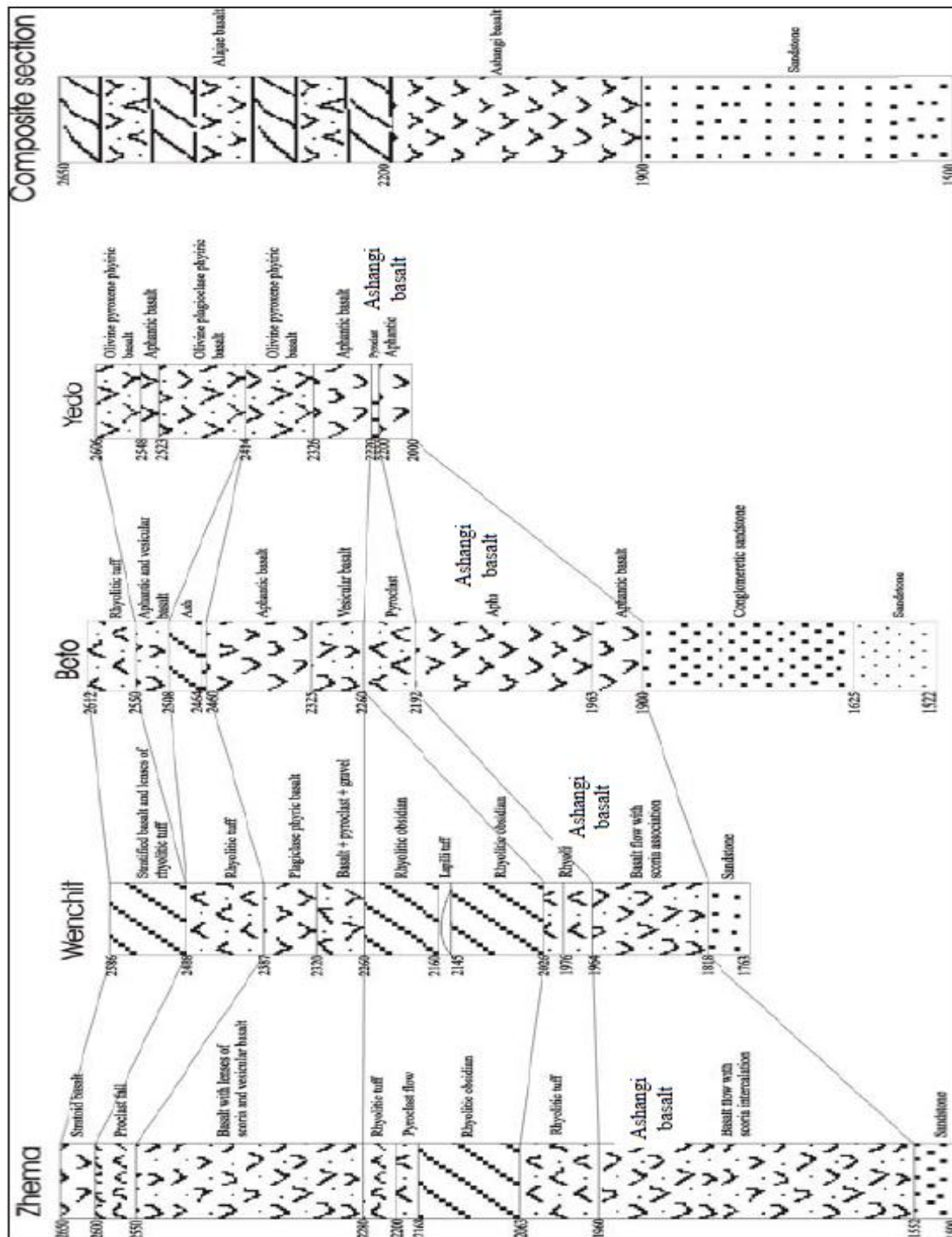


Fig. 4.2 Geological map of the study area

(c) Molale ignimbrite (Tmi)

The name Molale ignimbrite is given to this lithological unit after the town of Molale, where the rocks are well exposed. In the type area the ignimbrite is 34 m thick and consists of

yellowish gray to gray, fine to medium grained, slightly weathered and fractured ignimbrite with minor rhyolitic tuff, and rhyolitic obsidian (Tigel Belay *et al.*, 2009).



(Source: Adopted from *The Geology of Were-Ilu area, Tigel Belay et al., 2009*).

Fig 4.3 Lithostratigraphic correlation of Mesozoic sediments and Tertiary volcanics of the study area

(See Fig 4.4 for location of the sections)

It is exposed in the present study the area, forming ridges and hills, river and road sections and hill slopes. It accounts to about 10.6 % of the mapped area (Fig.4.2). Backed contacts separate the unit from the underlying Alajae basalt. Plagioclase phyrlic basalt horizon separates the unit from the overlying Tarmaber Megezez basalt.

The Molale ignimbrite is yellowish grey to grey, fine grained and slightly to moderately weathered, fractured and columnarly jointed. It has light grey, greenish grey, light green and pink to grayish purple weathering color. At places, the rock is phenocrysts-rich with quartz and k-feldspar crystals and rarely contains obsidian fragments.

(d) Quaternary superficial deposits

According to Jiri Sima *et al.* (2009) and present field observation, the superficial deposits (soil units) predominantly cover the low-lying flat alluvial plains, intermountain depressions and river channels (bed, bank, flood plain). However, residual and colluvial soils can be also found in hilly relief with medium and even high relief energy.

Generally, the soil cover units in the study area can be classified

based on genesis into three engineering geology soil units namely residual, colluvial and alluvial. However, boundaries between all the genetic groups of soils are obscure because they are a product of mass wasting-transportation processes. During the present study, the mappable soil cover units identified and mapped are colluvium and alluvium (Fig 4.2).

The general distribution of the Quaternary (recent) deposits in the area is found on gentle slopes of terraces in front of the volcanic cliffs and along rivers in deep gorges. The area covered by the Quaternary deposit is large.

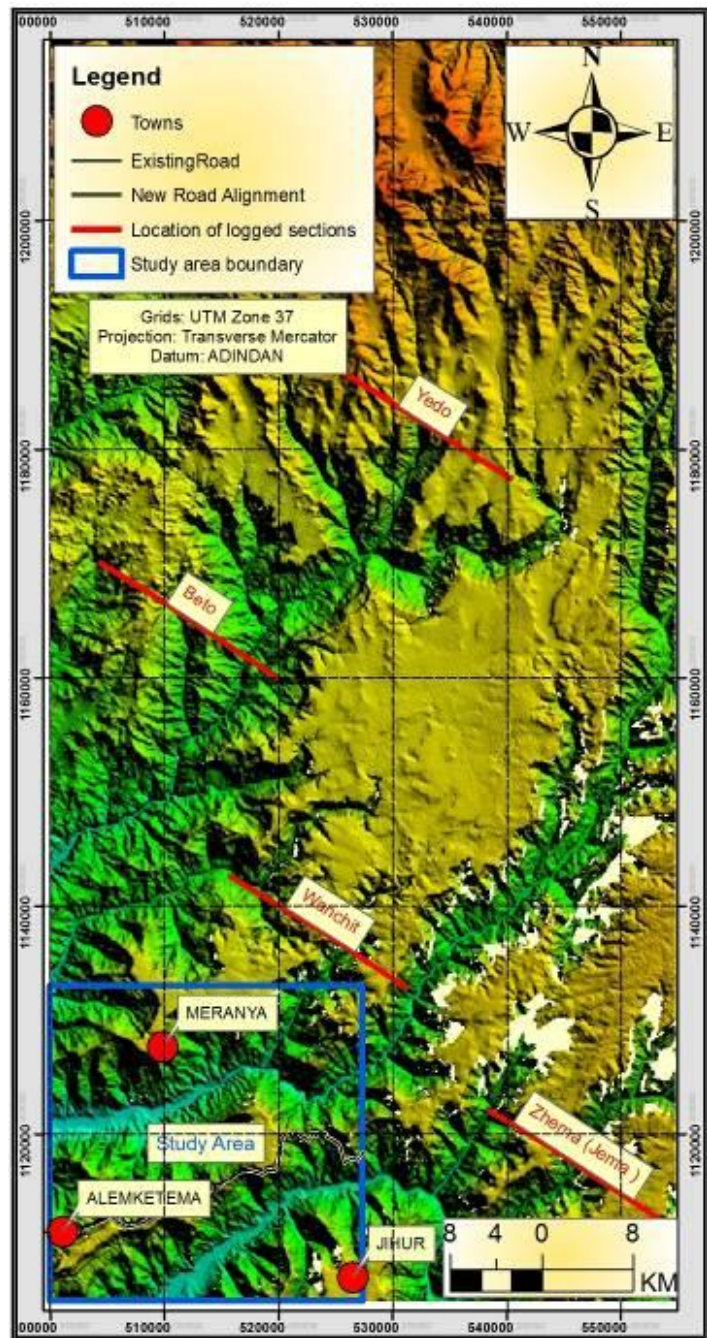


Fig 4.4 Showing location of logged sections (i.e. Zhemra (Jema), Wanchit, Beto, and Yedo) that are shown in Fig 4.3 .



Fig 4.5a. A very thick colluvial deposit in front of the volcanic cliff.



Fig 4.5b. Colluvial deposit consisting of boulders, cobbles, pebbles and black cotton soils.



Fig 4.5c. Surface cracks on colluvial deposits at road cut section.

The thickness of these deposits is variable from place to place, typically from 2 to 6 meters in most places. However, there are thicker colluvial deposits of estimated thickness of greater than 20m observed in some places along the road corridor (Fig 4.5a.). The slope deposit contains rock blocks, boulders, cobbles, and silty clay materials. Major rock blocks are glassy trachyte and basalts (Fig 4.5b and c).

4.3 Geological Structures

In Central Afar, the Red Sea and Aden propagators meet with northern portion of the Main Ethiopian Rift (MER), deforming a broad area and developing microplates (Danakil microplate; McKenzie *et al.*, 1970; Le Pichon and Francheteau, 1978 as cited in Acocella *et*

al., 2011) and producing the Archetypal rift-rift-rift triple junction zone associated with a mantle plume (Wolfenden *et al.*, 2004).

The Ethiopian rift system is on the Ethiopia-Yemen plateau that is thought to have developed above a mantle plume (e.g., Schilling, 1973 Ebinger and Sleep, 1998; George *et al.*, 1998 as cited in Kier *et al.*, 2006). A ~2-km-thick sequence of flood basalts and rhyolites erupted across the Ethiopia-Yemen plateau region between 45 and 22Ma (e.g., George *et al.*, 1998; Kieffer *et al.*, 2004 as cited in Kier *et al.*, 2006). The majority erupted at ~30Ma along the Red Sea margins (e.g., Hofmann *et al.*, 1997; Ukstins *et al.*, 2002 as cited in Kier *et al.*, 2006) coincident with the opening of the Red Sea and Gulf of Aden (Wolfenden *et al.*, 2005 as cited in Kier *et al.*, 2006).

According to Wolfenden *et al.* (2004), the MER is clearly the least evolved of the three triple junction arms, but their new data show that it is also ~18 My younger than the Red Sea and Aden rift. Rifting initiated in the southern and central Main Ethiopian rift between 18 and 15 Ma but the northern Main Ethiopian rift only developed after ~11Ma (Wolde Gebriel *et al.*, 1990 as cited in Kier *et al.*, 2006; Wolfenden *et al.*, 2004). The volcanically active Main Ethiopian rift (MER) marks the transition from continental rifting in the East African rift to incipient seafloor spreading in Afar (Kier *et al.*, 2006). The predominantly N35 - 45⁰E faults active during the accumulation of the Kesem formation are superseded by N15⁰E - striking faults during and after the Balchi formation was erupted, suggesting a change in extension direction after ~3Ma.

4.3.1 Lineaments

Lineaments of different orientation are common in the mapped area. The three main trends discernible are: NE-SW, NW-SE & E-W. The NE-SW trend is parallel to the faulting of the Ethiopian rift. They are NNE- to NE-, E-W and NW- striking with the NNE- to NE-striking lineaments being predominant (Fig 4.6, Fig 4.7a.). The NNE- to NE- striking lineaments controls the flow of Jema, and Wenchit rivers (Fig 4.6).

These lineaments are mostly long and subparallel, suggesting that they are reactivated preexisting basement structures. Field observations and DEM interpretations show that the E-W striking lineaments crosscut the NE-striking lineaments, suggesting that they are of younger age (Tigel Belay *et al.*, 2009).

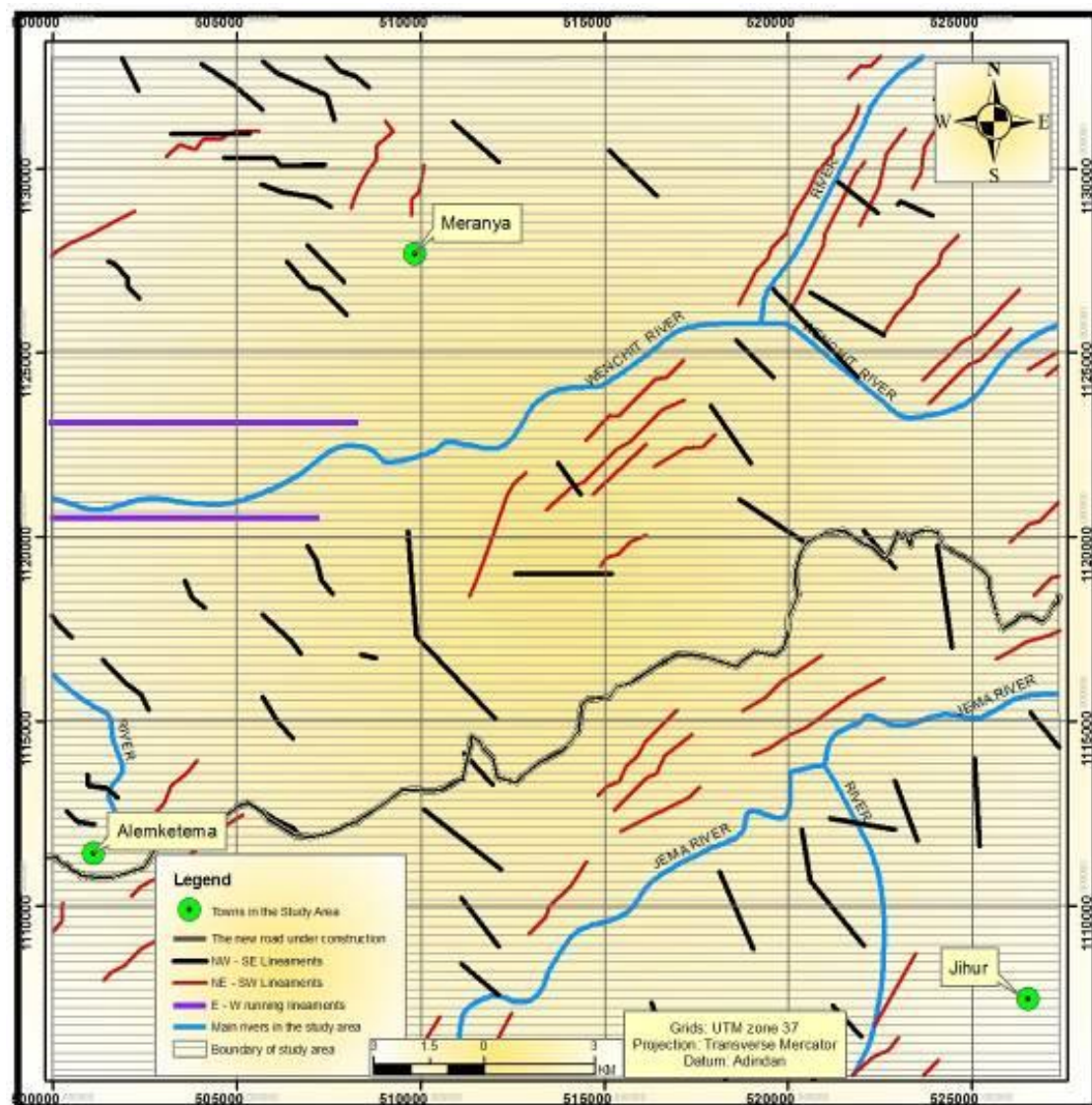
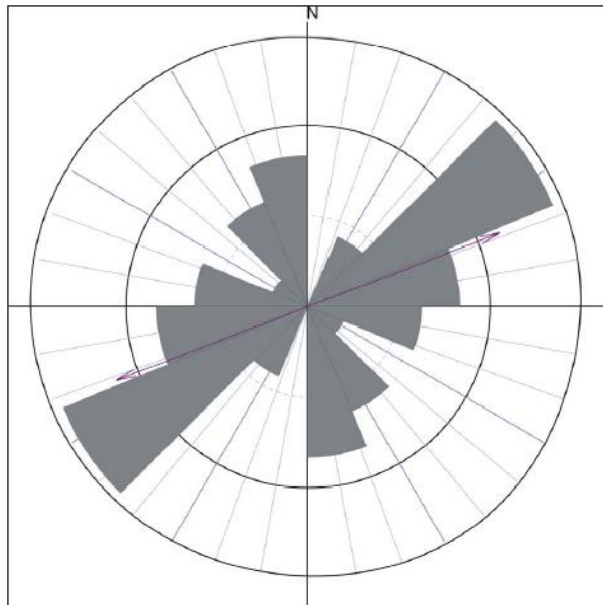


Fig 4.6 Major lineaments identified in the study area



(Source: Adopted from Tigel Belay et al., 2009).

Fig 4.7a. Rose diagram showing the orientation of lineaments



Fig 4.7b. Surface cracks observed on colluvial soil with strike in N - S direction.

4.3.2 Joints

The joints are dominantly columnar with some irregular and tectonically induced types of vertical and horizontal ones (Fig 4.8a,b, &c). The columnar joints are five to six faced and closely spaced with typical arrangement and reach up to 80 m in height forming very steep cliffs (Fig 4.9a).

4.3.3 Fractures and surface cracks

The ignimbrites and rhyolites are affected by concoidal and irregular fractures with varying trends (Fig 4.5c and Fig 4.7b).

4.3.4 Planar Bedding and Laminations

Planar beds and laminations are found mainly in Mesozoic sandstone and Tertiary sediments (Tigel Belay *et al.*, 2009).

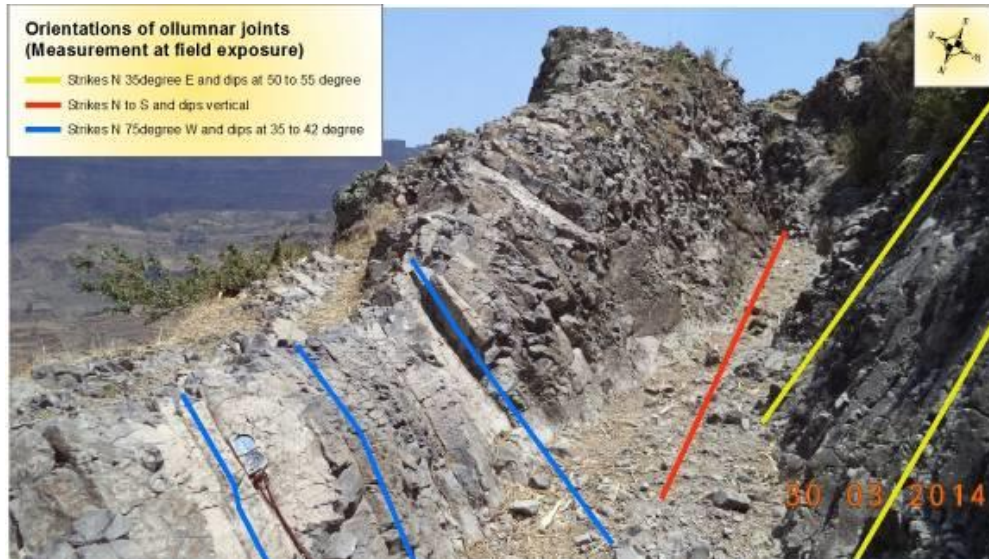


Fig 4.8a. Columnar joints tilted in N 35° E, N - S, and N 75° W strike directions



Fig 4.8b Columnar joints tilted in N - W directions



Fig 4.8c Five to six faced, closely spaced columnar joints.



Fig 4.9a. Open Joints at the top of the cliff with orientation strike N 20°-30° E and dip more or less vertical.



Fig 4.9b. Concoidal and irregular fractures with varying trends at stream cut in Alagae basalts

CHAPTER V

METODOLOGY

5.1 Background

The well-known Rock mass classification schemes such as RMR system, Q system and etc, were developed based on an empirical approaches gained from many years of past experiences of working with rock mass of different varieties and properties faced on various civil engineering construction projects (Bieniawski, 1979; Ambalagan, 1992).

Although, all of these classification systems have limitations, they have gained wide attention and have frequently been in use in rock engineering and design (Palmstrom and Broch, 2006). According to Palmstrom and Broch (2006), these systems are valuable tools if applied appropriately and with care.

Based on similar approaches, Raghuvanshi et al. (2014) developed a new Slope Stability Susceptibility Evaluation Parameter (SSEP) rating scheme – an approach for landslide hazard zonation. The SSEP rating scheme was developed by considering intrinsic and external triggering parameters that are responsible for slope instability. The intrinsic parameters which were considered are; slope geometry, slope material (lithology or soil type), structural discontinuities, land use and land cover and groundwater. Besides, external triggering parameters such as, seismicity, rainfall and manmade activities were also considered.

The primary objective of the present research study is to prepare a Landslide Hazard Zonation (LHZ) map of the study area and then to validate the prepared LHZ map by overlaying the landslide event map on the prepared LHZ map. In order to meet these objectives the expert evaluation technique (Heuristic approach) particularly the SSEP technique developed by Raghuvanshi et al. (2014) was used for the purpose of landslide hazard zonation mapping of the study area whereas delineation of the landslide event maps were carried out by using pre-field data, satellite images and field reconnaissance surveys.

According to Anbalagan (1992), the methodology used for preparation of landslide hazard zonation maps should be systematic, practicable and, as far as possible, simple so that the practicing engineers, geologists and planners may understand and use them effectively. Hence, it was based on these criteria that SSEP was chosen to be applied in the present study. Moreover, the SSEP technique incorporates both intrinsic and external landslide triggering parameters in order to generate the hazard map. It does not only provide landslide hazard

susceptibility at the time of investigation but it also anticipate hazards for adverse condition to which slopes may likely be subjected. Further, the technique is mostly based on the actual field observations.

5.2 General Methodology

As a general methodology in this study, first of all, survey of literature and web browsing was conducted to review all existing methods of landslide hazard assessment and zonation mapping in the mountainous area. In addition to this, collection and review of existing secondary data and literature sources of the study area were carried out on Topographical, Meteorological, Geological, Geo-morphological, Hydro-geological, Engineering geological and Structural outlines of the area.

Next to this, preparation of thematic maps and pre - field maps were conducted under desk study. Later, during field work, primary data collection was conducted and the pre - field maps prepared during desk study were verified/ modified and finalized based on the new information gained in field. Finally, numerical ratings were assigned for intrinsic causative factors and external triggering factors and landslide hazard zonation (LHZ) map of the study area (1:50,000) was prepared which was later validated by overlaying the past landslide event maps. The general methodology followed during the present study is presented in Fig 5.1.

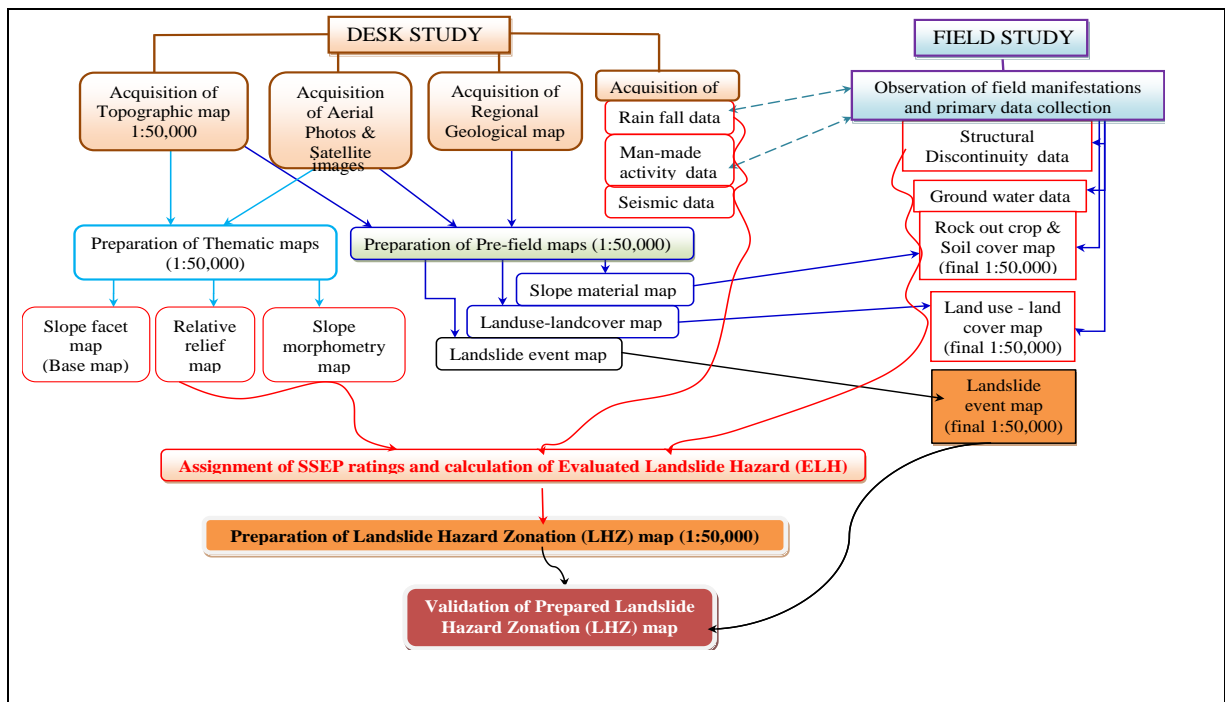


Fig 5.1 Summary of the general methodology followed during the present study.

5.3 Data Procurement

The procedures followed for data procurement in the present study had two parts. The first part was desk study and the second part was field work.

5.3.1 Desk study

During desk study, acquisition of all available secondary data pertaining to the present study, and preparation of thematic and pre - field maps were carried out.

i) Thematic maps

The thematic maps prepared in the present study include: Facet (base) map (1:50,000), relative relief map (1:50,000) and slope morphometry maps (1:50,000).

ii) Pre - field maps

The Pre - field maps prepared during desk study include: (a) Slope material map (pre - field), (b) Landuse - landcover map (pre - field) and (c) Landslide event map (pre - field). All of these pre - field maps (1:50,000) were prepared by utilizing the collected secondary data, and satellites and Google earth images. Later, these pre - field maps were updated and finalized based on new information obtained from the field work.

5.3.2 Field Data Collection

During field work primary data collection for various slope instability factors were conducted and the pre - field maps prepared under desk study were modified and final maps were prepared. The works performed during the field work is described as under:

a) Slope material map

During desk study, pre - field slope material map was prepared by transferring pre existing lithological and soil maps over the slope facet map. Later, during the field work the various rock types were classified in terms of intact rock strength and degree of weathering. The soil type was classified based on visual observations and soil depth was assessed from the slope cuts along the road side, stream cuts or any other surface indications.

b) Structural discontinuity data

The various discontinuity sets present within a slope facet were measured for their orientations in terms of dip direction and dip amount during field work. Besides, observations

were made for general condition of rock mass and characteristics of discontinuities such as; spacing, continuity, surface characteristics, separation of discontinuity surface and thickness and nature of filling material within the discontinuity surfaces. Later, parallelism between discontinuities and slope face strike was computed. Besides, relationship between dip of discontinuity and inclination of slope was also determined.

c) Landuse - landcover map (final)

During field work the various landuse and land cover units observed were classified and the pre - field map prepared during desk study was modified and finalized.

d) Ground Water data

During field work the indirect measures on surface indications of groundwater such as; damp, wet, dripping and flowing were observed and recorded slope facet wise.

e) Rain induced manifestation data

Data pertaining to the rain induced manifestation on slope such as; gully formation, toe erosion, stream bank erosion etc were collected during the field work. The impact of rainfall on slope instability factors such as; type of slope material, discontinuity orientation with respect to slope, slope morphometry were also considered.

f) Manmade activities data

The major manmade activities in hilly areas are road or building construction and cultivation practices. During field work, facet wise observations were made for such developmental activities to know in what manner the slopes were cut, how the excavated slope material was disposed off and what type and in what manner slope stabilization and drainage measures were adopted. Besides, for cultivation, type of irrigation being practiced was considered.

5.4 Data Processing and Analysis

Immediately after field work was completed, all efforts were made to combine and process all the data collected (both primary and secondary data); to convert it into manageable formats for analysis. Hence, the data processing and analysis works was conducted on the collected data. As for the present study SSEP empirical technique was adopted, therefore numerical ratings were assigned to each of the intrinsic and triggering parameters on the basis of their contribution towards instability of slope. The assignment of numerical ratings in SSEP technique is based on logical judgments acquired from experience of studies of

intrinsic and external triggering factors and their relative impact on instability of slopes. The distribution of maximum SSEP ratings assigned to different intrinsic and external triggering factors is based on their relative order of importance in inducing instability to the slope (Table 5.1).

Table 5.1 Distribution of maximum SSEP ratings assigned to different intrinsic and external triggering Factors (Raghuvanshi et al., 2014)

Distribution of maximum SSEP ratings assigned to different intrinsic and external triggering factors	
Slope Stability Susceptibility Evaluation Parameter	Maximum Rating
Intrinsic Parameters	
Slope Geometry	Relative Relief Slope Morphometry
	1 2
Slope Material	1
Structural Discontinuities	2.5
Landuse and landcover	1.5
Groundwater	2
External Triggering Parameters	
Seismicity	2
Rainfall	1.5
Manmade Activities	1.5
Total	15

5.5 Landslide Evaluation

In order to evaluate landslide hazard zonation of an area individual facet wise ratings for causative intrinsic parameters and external triggering parameter ratings were summed up. The sum total of all ratings for causative intrinsic parameters and external triggering parameter were represented as Evaluated landslide hazard (ELH).

5.6 Landslide Hazard Zonation

The Landslide Hazard Zonation of the study area was carried out through Evaluated landslide hazard (ELH) which indicates the net probability of instability and was determined facet wise. The ELH for an individual facet was obtained by adding the ratings of individual intrinsic factors and external triggering parameter obtained from the SSEP rating scheme. After collecting primary data for the rating values facet wise and evaluating them, the study area was divided into classes of hazard zones as per the SSEP rating scheme and the Landslide hazard zonation map of the study area was produced. Finally, validity of the produced LHZ map was done by overlaying landslide inventory map of the area on the prepared landslide hazard zonation (LHZ) map.

CHAPTER VI

LANDSLIDES AND SLOPE INSTABILITY IN THE STUDY AREA

6.1 Landslide Inventory

The beginning of any landslide hazard assessment is the identification and mapping of all landslide phenomena or preparation of landslide inventory. Soeters and VanWesten (1996) stated that a reliable landslide inventory defining the type and activity of all landslides, as well as their spatial distribution is essential, before any analysis of the occurrence of landslides and their relationship to environmental conditions is undertaken.

In the present study a detailed inventory of slope instability processes in the study area was carried out based on the secondary data procured during desk study, information obtained from satellite image interpretation, and also from primary data collected during the field work.

Recorded past landslide events were found only from Ethio Infra Plc's slope instability report (Ethio Infra, 2012). It involves, only, locations of 21 past landslide events records. This data gives information on location of slope instabilities; however, it does not give information on the coverage of area damaged by slope instabilities. The data obtained from Ethio Infra (2012) is illustrated in Table 6.1.

In the present study, these data (21 point location data) were used to start with delineation of past landslide events in the study area. First, the data was transferred on Google earth; then, the damaged areas were delineated around the respective point locations. However, these points were inventoried along the route corridor only and do not represent the whole study area; because, much of the wider part of the study area was left untouched. Due to this reason, it was found essential to make additional inventories of slope instability processes in the area in-order to cover the entire study area. For this purpose, the boundary and facet map of the study area (prepared in the present study) was transferred on Google earth; afterwards, additional areas were delineated aided by information obtained from satellite image interpretation and secondary data reviewed.

Later, the delineated map was checked and confirmed during field work with the new primary data collected; finally, final map of landslide inventory of the study area was produced in Arc-Gis 9.3 (Table 6.2 and Fig 6.1).

Table 6.1 Past landslide events inventoried by Ethio Infra (2012)

No	Site_Id	Easting (m)	Northing (m)	Elevation (m)	Chainage
1	ak 5	512228	1113216	2369	102.12 - 102.13
2	ak 6	511968	1113723	2385	102.81 - 102.72
3	ak 7	511252	1113672	2364	104.82 - 104.68
4	st2	505201	1112709	2307	111.92 - 111.78
5	st 7	510320	1113121	2388	106.12 - 106.0
6	st 8	514251	1114429	2412	99.71 - 99.64
7	st 9a	518117	1116764	2414	94.4 - 93.7
8	st 9b	518608	1116499	2432	
9	st 11	519998	1117728	2430	91.51 - 91.44
10	st 12	520225	1118387	2437	90.8 - 90.72
11	st 13	520340	1119480	2390	89.6 - 89.5
12	st 14	520452	1119636	2400	89.36 - 89.3
13	st 19	523399	1120487	2223	84.84 - 84.76
14	st 21	523450	1120350	2100	
15	st 22	524116	1119847	2014	82.3 - 82.22
16	st 26	525815	1117468	2025	78.86 - 78.78
17	st 27a	526211	1117748	2011	78.41 - 78.25
18	st 27b	526119	1117714	1999	
19	st 30	527280	1118337	1976	78.3 - 76.24
20	st 31	527347	1118669	1960	75.58 - 75.5
21	st 33	528221	1119983	2040	73.86 - 73.64

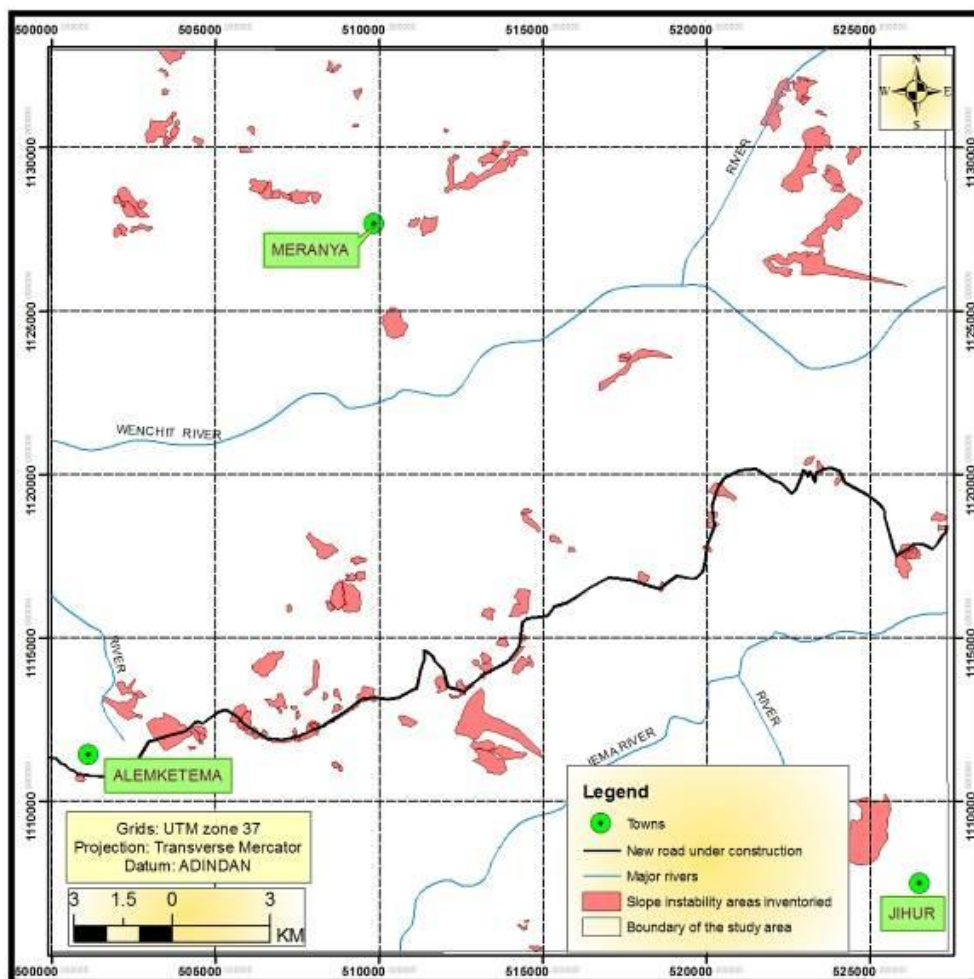


Fig 6.1 Landslide Inventory map of the study area

Table 6.2 provides detailed information about the types (name) of landslides observed, their respective shape length and area coverage, and the distribution of each landslide type. Fig 6.1 Shows the final product of landslide inventory conducted in the present study area and gives the spatial distribution of mass movements, which were represented on the map as affected areas to scale.

Generally, in the present study, a total of 137 slope instability processes (Table 6.2) were identified and mapped (Fig 6.1). The total area damaged by these landslide events is about 21.01 Km² (Table 6.2 and Fig 6.1). This amounts to 2.78 % of the study area (the study area being about 756.49 Km² areal coverage). From this figures it can easily be understood that landslide hazards are one of the serious geo-hazard problems in the study area.

6.2 Landslide Distribution

Among the total number of slope instability processes identified and mapped in the study area (i.e. 137), 87 are found in the eastern, central, and southwestern part of the study area. In this area the landslide coverage is about 10 Km² which is about 49 % of the total inventoried area (Table 6.2, Fig 6.2 & 6.3). About 9 landslides with about 4 Km² of area coverage was identified in northeastern parts of the study area that is about 21 % of the total (Table 6.2, Fig 6.2 & 6.3). In the northwestern part of the study area, about 37 landslides events were mapped within about 4 Km² area amounting to about 19 % of the total mapped area (Table 6.2, Fig 6.2 & 6.3). The remaining 4 landslide events mapped in the southeastern part of the study area covers about 2 Km² and are about 11% of the total area (Table 6.2, Fig 6.2 & 6.3). The landslide distribution map of the study area (Fig 6.2) and the pie chart showing the distribution of landslides in the study area (Fig 6.3) clearly indicate that there have been more landslides in the eastern, central and southern part of the study area; whereas, landslides observed in southeastern part of the study area are less. As can be observed from Fig 6.2, the general distribution of most of the inventoried landslides are in close vicinity of the major lineaments identified in the study area.

6.1.3 Type of Landslides

The differentiation of slope instability according to type of movement is important, not only because different types of mass movement will occur under different terrain conditions, but also because the impact of slope failures on the environment has to be evaluated according to type of failure (Soeters and VanWesten, 1996).

Table 6.2 Slope instability processes inventoried in the present study area

NAME	KML_FOLDER	Shape_Length	Shape_Area	Landslide Distribution
Lsd1	Past LSD event Inventory23042014	517.0565788	13749.1289	Eastern, Central, and Southwestern part
Lsd2	Past LSD event Inventory23042014	737.7958501	28806.52847	Eastern, Central, and Southwestern part
Lsd3	Past LSD event Inventory23042014	920.2622294	41577.44039	Eastern, Central, and Southwestern part
Lsd4	Past LSD event Inventory23042014	1127.355407	50136.84533	Eastern, Central, and Southwestern part
Lsd5_slides	Past LSD event Inventory23042014	957.0290133	59613.39516	Eastern, Central, and Southwestern part
Lsd6_slides	Past LSD event Inventory23042014	1259.196251	64628.12399	Eastern, Central, and Southwestern part
Lsd7_topple, rckfall & slides zone	Past LSD event Inventory23042014	2234.723463	255890.6974	Eastern, Central, and Southwestern part
Lsd8_Rotatn & slides	Past LSD event Inventory23042014	2902.218161	384910.4128	Eastern, Central, and Southwestern part
Lsd9_erosion & creep	Past LSD event Inventory23042014	2872.199166	301988.5754	Eastern, Central, and Southwestern part
Lsd10_rotational	Past LSD event Inventory23042014	1975.831527	188380.2737	Eastern, Central, and Southwestern part
Lsd11_rotational	Past LSD event Inventory23042014	1115.014937	44168.97755	Eastern, Central, and Southwestern part
Lsd12_slides	Past LSD event Inventory23042014	607.1893451	21214.37615	Eastern, Central, and Southwestern part
Lsd13_rotational & surface cracks	Past LSD event Inventory23042014	1197.598827	82024.03597	Eastern, Central, and Southwestern part
Lsd13a_minorscarp of a Rotation	Past LSD event Inventory23042014	920.4318254	43331.62789	Eastern, Central, and Southwestern part
Lsd13b_minorscarp	Past LSD event Inventory23042014	592.8488437	18283.49256	Eastern, Central, and Southwestern part
Lsd14_Fall, slides, Rotaion	Past LSD event Inventory23042014	619.797402	24324.36389	Eastern, Central, and Southwestern part
Lsd15_topple, fall, slides	Past LSD event Inventory23042014	498.2563449	12852.93007	Eastern, Central, and Southwestern part
Lsd16_rockfall zone	Past LSD event Inventory23042014	2158.716661	146554.9664	Eastern, Central, and Southwestern part
Lsd17_Debris	Past LSD event Inventory23042014	1416.556911	58200.21819	Eastern, Central, and Southwestern part
Lsd18_rotation	Past LSD event Inventory23042014	878.8023952	38830.04494	Eastern, Central, and Southwestern part
Lsd19_slides	Past LSD event Inventory23042014	559.4258707	14464.69318	Eastern, Central, and Southwestern part
Lsd20_rotation	Past LSD event Inventory23042014	1259.908239	65767.89601	Eastern, Central, and Southwestern part
Lsd21_creep	Past LSD event Inventory23042014	3848.292987	865590.9809	Eastern, Central, and Southwestern part
Lsd22	Past LSD event Inventory23042014	957.4697959	34578.65473	Eastern, Central, and Southwestern part
Lsd23	Past LSD event Inventory23042014	1222.845031	82900.23499	Eastern, Central, and Southwestern part
Lsd24_rockfall	Past LSD event Inventory23042014	1358.65373	94829.66537	Eastern, Central, and Southwestern part
Lsd25_rotational	Past LSD event Inventory23042014	1652.141037	113011.669	Eastern, Central, and Southwestern part
Lsd25_body of the slide mass	Past LSD event Inventory23042014	1147.097112	49150.4679	Eastern, Central, and Southwestern part
Lsd26	Past LSD event Inventory23042014	2233.874978	229991.7391	Eastern, Central, and Southwestern part
Lsd27_rotatation & slides	Past LSD event Inventory23042014	850.6429291	42974.46078	Eastern, Central, and Southwestern part
Lsd28_rockfall, slides	Past LSD event Inventory23042014	657.9340449	23124.47969	Eastern, Central, and Southwestern part
Lsd29_rockfall, slides	Past LSD event Inventory23042014	981.0644339	54219.44611	Eastern, Central, and Southwestern part
Lsd30_topple, rockfall, slides	Past LSD event Inventory23042014	1413.575835	112258.1579	Eastern, Central, and Southwestern part
Lsd31_slides	Past LSD event Inventory23042014	549.0638249	12510.59579	Eastern, Central, and Southwestern part
Lsd32_rotation	Past LSD event Inventory23042014	516.9869424	10956.84558	Eastern, Central, and Southwestern part
Lsd33_rotation, slides	Past LSD event Inventory23042014	1871.562978	60680.09028	Eastern, Central, and Southwestern part
Lsd34_rotation	Past LSD event Inventory23042014	938.1023528	46270.89916	Eastern, Central, and Southwestern part
Lsd35_rotation	Past LSD event Inventory23042014	648.4578293	23875.43362	Eastern, Central, and Southwestern part
Lsd36_rotation	Past LSD event Inventory23042014	1646.948931	140053.1411	Eastern, Central, and Southwestern part
Lsd37_rockfall zone	Past LSD event Inventory23042014	1706.47245	58012.80771	Eastern, Central, and Southwestern part
Lsd38_rotation, creep	Past LSD event Inventory23042014	1717.599155	172512.9331	Eastern, Central, and Southwestern part
Lsd39_rotation, slides	Past LSD event Inventory23042014	2114.943455	83273.15467	Eastern, Central, and Southwestern part
Lsd40_rotation	Past LSD event Inventory23042014	961.7323719	38121.142	Eastern, Central, and Southwestern part
Lsd41_translation	Past LSD event Inventory23042014	695.0023212	24852.74372	Eastern, Central, and Southwestern part
Lsd42_rockfall, slides	Past LSD event Inventory23042014	2656.009128	141088.7906	Eastern, Central, and Southwestern part
Lsd43_translation	Past LSD event Inventory23042014	681.665004	26787.52009	Eastern, Central, and Southwestern part
Lsd44_translation	Past LSD event Inventory23042014	574.4838386	18638.11116	Eastern, Central, and Southwestern part
Lsd45_rockfall,rotation	Past LSD event Inventory23042014	676.1675417	24171.19435	Eastern, Central, and Southwestern part
Lsd46_rockfall,rotation,slides	Past LSD event Inventory23042014	1583.648636	92798.78265	Eastern, Central, and Southwestern part
Lsd47_slides	Past LSD event Inventory23042014	649.6489894	20272.464	Eastern, Central, and Southwestern part
Lsd48_transln,creep, slides	Past LSD event Inventory23042014	662.9910212	26921.33298	Eastern, Central, and Southwestern part
LSD49_slides	Past LSD event Inventory23042014	866.0724265	30009.76584	Eastern, Central, and Southwestern part
LSD50_slides	Past LSD event Inventory23042014	835.0355009	34353.51877	Eastern, Central, and Southwestern part
LSD51_rotatation and slides	Past LSD event Inventory23042014	879.5068749	33699.88771	Southeastern part of study area
Lsd52_rockfall, rotation, slides	Past LSD event Inventory23042014	1220.601028	86643.09896	Eastern, Central, and Southwestern part
Lsd53_rotation	Past LSD event Inventory23042014	776.0091609	26619.36536	Eastern, Central, and Southwestern part
Lsd54_rotation	Past LSD event Inventory23042014	757.9429928	26213.36358	Eastern, Central, and Southwestern part
Lsd55_rotation, slides	Past LSD event Inventory23042014	1060.361586	55108.20388	Eastern, Central, and Southwestern part
Lsd56_	Past LSD event Inventory23042014	960.1653578	58081.03731	Eastern, Central, and Southwestern part
Lsd57_rotation, slides	Past LSD event Inventory23042014	2235.387772	196714.0567	Eastern, Central, and Southwestern part
Lsd58_rotation	Past LSD event Inventory23042014	778.9141437	32408.48664	Eastern, Central, and Southwestern part
Lsd59	Past LSD event Inventory23042014	405.2718016	9959.144259	Eastern, Central, and Southwestern part
Lsd60_slides	Past LSD event Inventory23042014	1129.823952	48034.85909	Northwestern part of study area
Lsd61_rockfalls	Past LSD event Inventory23042014	1721.694412	77355.13036	Northwestern part of study area
Psd62_rockfalls	Past LSD event Inventory23042014	860.4905199	43944.13249	Northwestern part of study area
Lsd63_rockfall, rotation, slides	Past LSD event Inventory23042014	1103.655516	58495.17107	Northwestern part of study area
Lsd64_rotation	Past LSD event Inventory23042014	874.7655947	48438.94328	Northwestern part of study area
Lsd65_slides, rotation, rockfall	Past LSD event Inventory23042014	2948.09571	245823.5575	Northwestern part of study area
Lsd66_rotation,creep	Past LSD event Inventory23042014	1666.105205	131110.757	Northwestern part of study area
Lsd67_rockfall, rotation	Past LSD event Inventory23042014	972.2090219	48456.64876	Northwestern part of study area
Lsd68_rockfall, rotation	Past LSD event Inventory23042014	1012.917682	57701.14419	Northwestern part of study area
Lsd69_rockfall, slides, rotation	Past LSD event Inventory23042014	1781.228256	163846.2882	Northwestern part of study area
Lsd70_rockfall & Debris slide	Past LSD event Inventory23042014	1145.372944	76475.77456	Northwestern part of study area

Table 6.2 Continued.....

Table 6.2 Continued.....

Lsd71_slides	Past LSD event Inventory23042014	966.6194192	53322.55127	Northwestern part of study area
Lsd72_slides	Past LSD event Inventory23042014	868.0652884	37860.6522	Northwestern part of study area
Lsd73_rockfall, rotation	Past LSD event Inventory23042014	1796.537887	174600.1567	Northwestern part of study area
Lsd74_rotation & slides	Past LSD event Inventory23042014	1616.962666	113337.503	Northwestern part of study area
Lsd75_slides	Past LSD event Inventory23042014	513.4624382	10722.4432	Northwestern part of study area
Lsd76_rockfall	Past LSD event Inventory23042014	1016.345392	42712.23539	Northwestern part of study area
Lsd77_rotation & slides	Past LSD event Inventory23042014	783.9647752	30776.33852	Northwestern part of study area
Lsd78_rotation, slides	Past LSD event Inventory23042014	520.6858269	9899.769259	Eastern, Central, and Southwestern part
Lsd79_rotation, slides	Past LSD event Inventory23042014	1280.634222	89432.38305	Eastern, Central, and Southwestern part
Psd80_creep, rotation, slides	Past LSD event Inventory23042014	1333.930916	85936.2468	Eastern, Central, and Southwestern part
Lsd81_slides	Past LSD event Inventory23042014	918.688838	26255.29263	Eastern, Central, and Southwestern part
Lsd82_rotation	Past LSD event Inventory23042014	638.3597402	29230.83352	Eastern, Central, and Southwestern part
Lsd83_rotation, slides	Past LSD event Inventory23042014	855.0434676	36133.45189	Eastern, Central, and Southwestern part
Lsd84_rotation	Past LSD event Inventory23042014	612.0516546	20793.1834	Eastern, Central, and Southwestern part
Lsd85_slides, rotation	Past LSD event Inventory23042014	1025.110863	64168.7633	Eastern, Central, and Southwestern part
Lsd86_slides, rockfall, rotation	Past LSD event Inventory23042014	684.0977339	22929.87259	Eastern, Central, and Southwestern part
Lsd87_slides	Past LSD event Inventory23042014	1158.255804	68472.68267	Eastern, Central, and Southwestern part
Lsd88_rotation, slides	Past LSD event Inventory23042014	873.1823539	31358.23529	Eastern, Central, and Southwestern part
Lsd89_rotation	Past LSD event Inventory23042014	833.2284004	27635.58828	Eastern, Central, and Southwestern part
Lsd90_rotation, slides	Past LSD event Inventory23042014	1596.620446	135005.8101	Eastern, Central, and Southwestern part
Lsd91_slides	Past LSD event Inventory23042014	758.3575398	28572.72234	Eastern, Central, and Southwestern part
Lsd92_rockfall	Past LSD event Inventory23042014	1833.279576	108707.5595	Eastern, Central, and Southwestern part
Lsd93_Rockfall zone	Past LSD event Inventory23042014	6863.299461	2174888.214	Southeastern part of study area
Lsd94_rotation & slides	Past LSD event Inventory23042014	906.9540391	38262.62307	Northwestern part of study area
Lsd95_rotation	Past LSD event Inventory23042014	1117.439543	63348.10599	Northwestern part of study area
Lsd96_slides	Past LSD event Inventory23042014	1083.02101	56961.36156	Northwestern part of study area
Lsd97_slides	Past LSD event Inventory23042014	2010.295108	198277.3796	Northwestern part of study area
Lsd98_slides and flow	Past LSD event Inventory23042014	2872.278775	480058.7799	Northwestern part of study area
LSD99_slides and fall	Past LSD event Inventory23042014	797.1589654	20420.61529	Southeastern part of study area
LSD100_slides	Past LSD event Inventory23042014	383.6274891	6923.441745	Southeastern part of study area
LSD101_slides	Past LSD event Inventory23042014	2889.07079	316379.2057	Eastern, Central, and Southwestern part
LSD102_rockfall and slides	Past LSD event Inventory23042014	1301.950176	89184.05222	Eastern, Central, and Southwestern part
LSD103_rockfall	Past LSD event Inventory23042014	5626.839736	402626.4833	Eastern, Central, and Southwestern part
LSD104_slides	Past LSD event Inventory23042014	3169.220703	446991.9279	Eastern, Central, and Southwestern part
LSD105_slides & rotation	Past LSD event Inventory23042014	2743.582592	239763.1931	Eastern, Central, and Southwestern part
LSD106_slides	Past LSD event Inventory23042014	1897.851253	162978.7075	Eastern, Central, and Southwestern part
LSD107_slides & flow	Past LSD event Inventory23042014	7810.051909	1505849.455	Eastern, Central, and Southwestern part
LSD108_fall and slides	Past LSD event Inventory23042014	1714.332001	139078.6118	Eastern, Central, and Southwestern part
LSD109_slides	Past LSD event Inventory23042014	2859.467041	394887.3692	Eastern, Central, and Southwestern part
LSD110_slides & flow	Past LSD event Inventory23042014	3811.775629	373449.5877	Eastern, Central, and Southwestern part
LSD111_slides	Past LSD event Inventory23042014	3082.705052	172341.6416	Eastern, Central, and Southwestern part
LSD112_slides	Past LSD event Inventory23042014	848.3989283	26567.95996	Northwestern part of study area
LSD113_slides	Past LSD event Inventory23042014	627.2323815	22101.74116	Northwestern part of study area
LSD114_slides	Past LSD event Inventory23042014	770.4576642	27397.12219	Northwestern part of study area
LSD115_Creep and slides	Past LSD event Inventory23042014	3053.124362	351293.2405	Northwestern part of study area
LSD116_slides	Past LSD event Inventory23042014	764.4928251	22076.00479	Northwestern part of study area
LSD117_slides	Past LSD event Inventory23042014	513.8181558	16364.64196	Northwestern part of study area
LSD118_slides	Past LSD event Inventory23042014	512.5246335	17933.42488	Northwestern part of study area
LSD119_slides and rockfall	Past LSD event Inventory23042014	7112.79477	634537.0544	Northwestern part of study area
LSD120_slides	Past LSD event Inventory23042014	397.0034957	11051.69869	Northwestern part of study area
LSD121_slides	Past LSD event Inventory23042014	1790.022625	134091.8788	Northwestern part of study area
LSD122_slides	Past LSD event Inventory23042014	1627.358876	107229.3788	Northwestern part of study area
LSD123_slides	Past LSD event Inventory23042014	2341.969061	157630.1424	Northwestern part of study area
LSD124_slides & rotation	Past LSD event Inventory23042014	895.2504697	24727.36027	Northwestern part of study area
LSD125_slides	Past LSD event Inventory23042014	2126.569539	204097.7025	Northwestern part of study area
LSD127_rockfall & slides	Past LSD event Inventory23042014	5328.458248	509871.3443	Northeastern part of study area
LSD128_slides	Past LSD event Inventory23042014	860.4073508	22348.80581	Northeastern part of study area
LSD129_slides	Past LSD event Inventory23042014	4786.44414	274302.3168	Northeastern part of study area
LSD130_slides & fall	Past LSD event Inventory23042014	6929.896495	1098142.456	Northeastern part of study area
LSD131_slides	Past LSD event Inventory23042014	12837.6275	1186675.454	Northeastern part of study area
LSD132_slides	Past LSD event Inventory23042014	6131.389215	895780.5261	Northeastern part of study area
LSD133_slides & rotation	Past LSD event Inventory23042014	1065.874109	64726.87583	Northeastern part of study area
LSD134_slides	Past LSD event Inventory23042014	2345.869757	231024.364	Northeastern part of study area
LSD135_Rock fall and slides	Past LSD event Inventory23042014	1569.090561	140567.783	Northeastern part of study area
LSD136_slides	Past LSD event Inventory23042014	900.7010977	46509.05999	Eastern, Central, and Southwestern part
LSD137_slides	Past LSD event Inventory23042014	1035.342466	45120.21969	Eastern, Central, and Southwestern part
Total			21076322.91	

In the present study area, various types of mass movements (landslides) were observed. These landslides were categorized into four according to type based on the definitions from Cruden and Varnes (1996). These include: (i) Rock falls, (ii) Rock slides, (iii) Soil slides, and (iv) Flows.

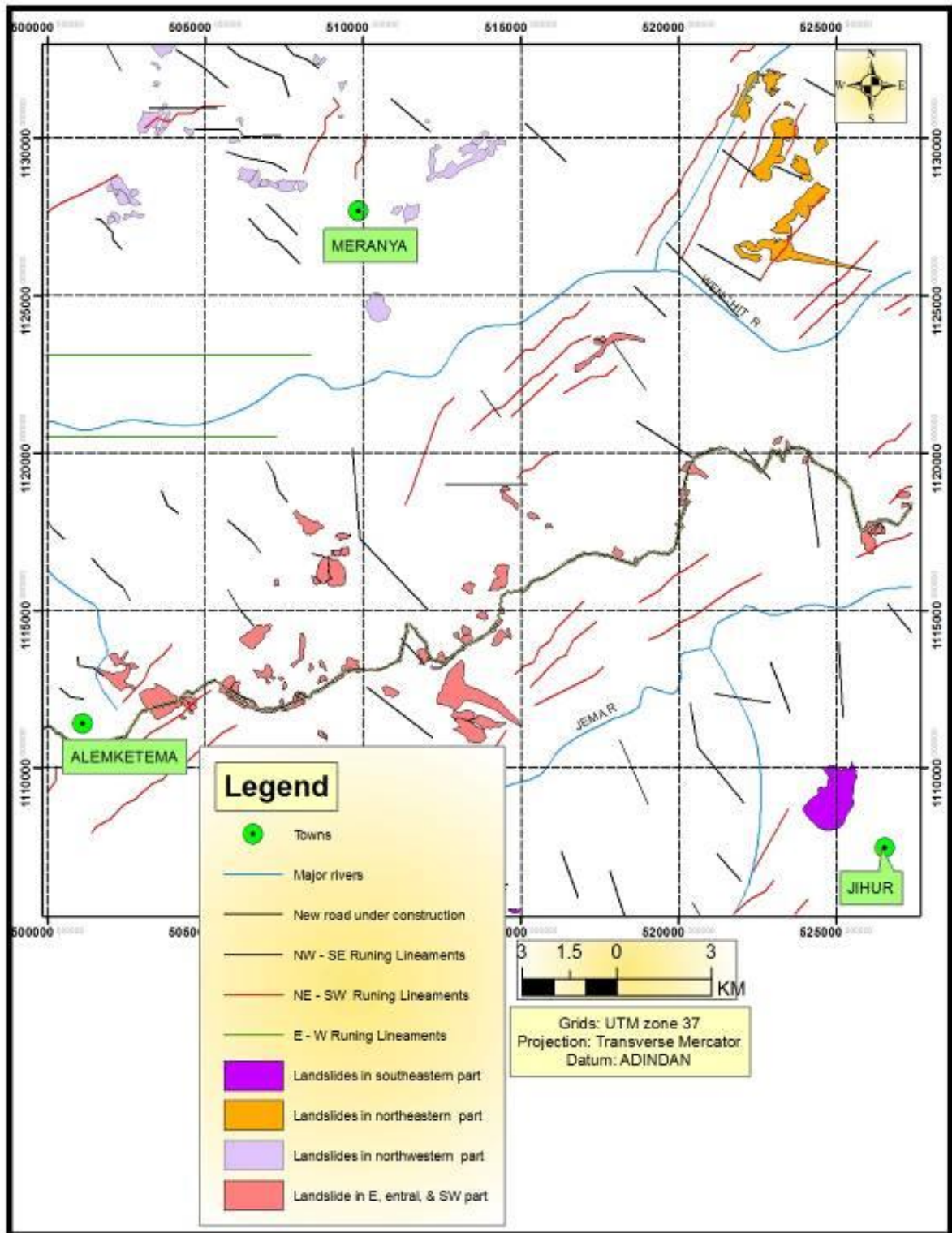


Fig 6.2 Landslide Distribution map of the study area

Although it is classified into four for description purposes, it does not mean that a single type of landslide was found to occur in one separate inventoried area. In most places, it was observed that two or more of these types of landslides were observed to occur together (Table 6.2).

(a) Rock-fall

A fall starts with the detachment of soil or rock from a steep slope along a surface on which little or no shear displacement takes place. The material then descends mainly through the air by falling, bouncing, or rolling. The unpredictability of the frequency and magnitude of rock-fall potentially endangers human lives and infrastructure. Rock-fall is a relatively small landslide confined to the removal of individual and superficial rocks from a cliff face (Selby, 1982 as cited in Dorren, 2003).

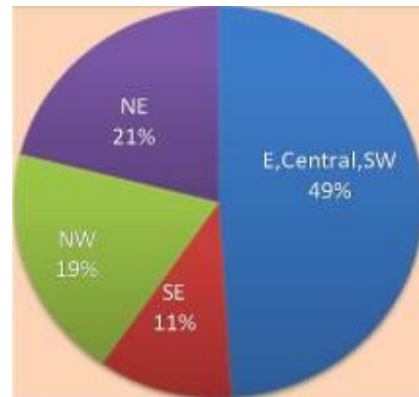


Fig 6.3 Pie chart showing the distribution of landslides in the study area

In the present study area, rock-fall is a daily occurrence. Even during the field work, rock fall activities were observed occurring randomly. Plates 6.1 to 6.5 provides illustrations of some of the rock fall activities observed in the study area during present field study.

b) Rock Slides

Rock-fall can generate large-scale mass movements of rock material, but these processes are defined as rockslides or rock avalanches (Cruden and Varnes, 1996; Dorren, 2003). Rock slides can be: translational rock slide, wedge slide, rock slump (rotational slide), compound rock slide, or rock collapse. In the present study area, translational rock slides and Rotational rock slides were observed (Plates 6.8 and 6.7, respectively).

C) Soil Slides

In the present study area, translational soil slides, rotational soil slides, and debris slides were observed. Plates 6.9, 6.10, and 6.11 gives illustrations of some of the soil slides observed in the study area.



Plate 6.1 Photo showing Rock fall

Plate 6.2 Eroded tufaceous rock susceptible to fall & collapse

Plate 6.3 Showing rock falls and accumulation of scree



Plate 6.4 Photo showing zones (modes) of motion of rock fall

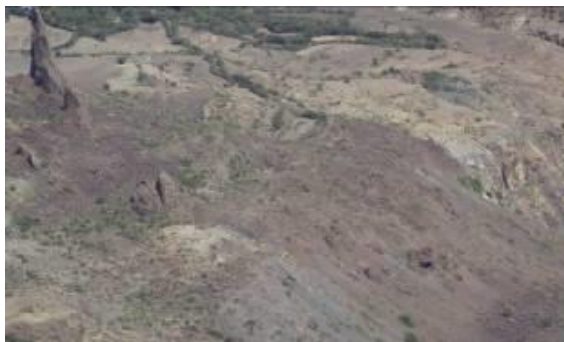


Plate 6.5 Photo showing area affected by rock falls



Plate 6.6 Photo showing rock block susceptible to fall or topple

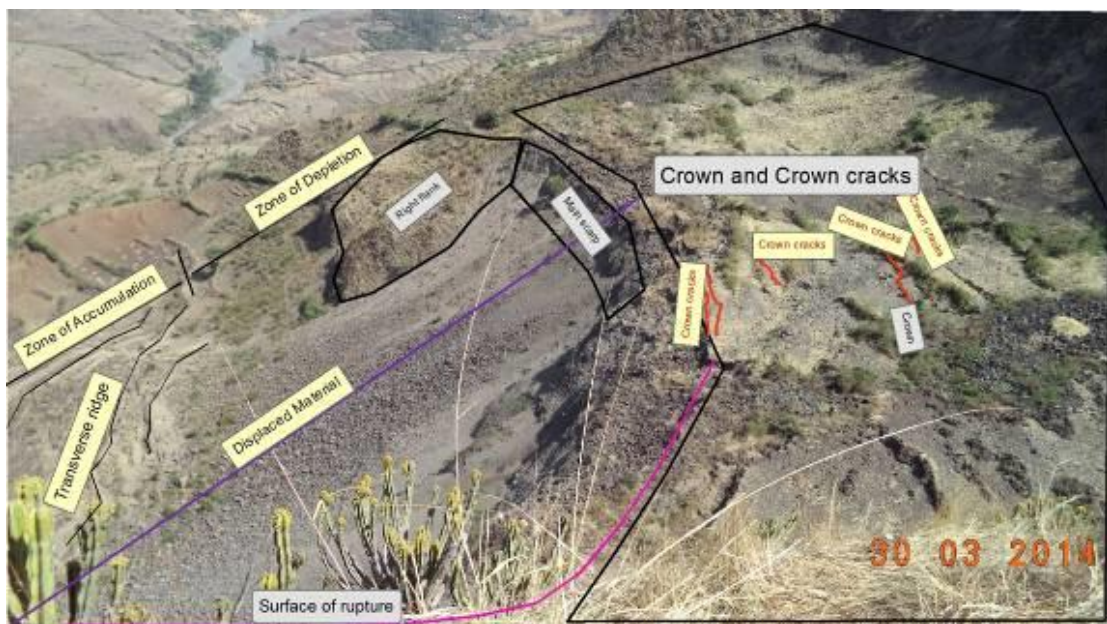


Plate 6.7 Photo showing rock slump or rotational rock slide and rock fall



Plate 6.8 Photo showing translational rock slides in the study area

Plate 6.9 shows one of the translational soil slides observed in the study area. Photo shown on Plate 6.10 (a) denotes one of the slope cut sections along the new road under construction that was failed as rotational slide in soil. Most parts of the slope cut sections for the new road under construction have failed in similar manner as shown in Plate 6.10 (b). Pictures shown on Plate 6.10 (c) and (d), captured during field work, also give idea about the rotational soil slides occurring in the study area. Debris slides have also been observed in the study area and illustration is given in Plate 6.11.



Plate 6.9 Photo showing translational slide in soil



Plate 6.10 (a) Rotational slide in cut soil slope

d) Flows

Flows are also among the various mass movement activities observed in the present study area. The major type of flows observed during the field work in the present study is debris flows. Illustrations for the observed debris flows are presented in Plate 6.12.

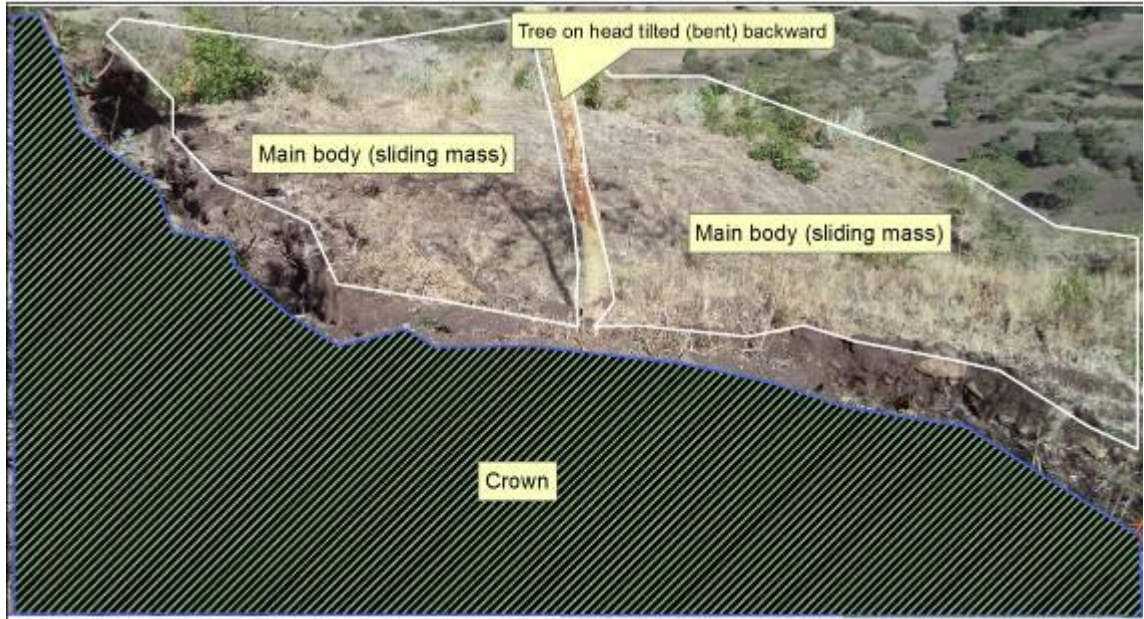


Plate 6.10 (b) Photo showing rotational soil slide



Plate 6.10 (c) Part of road under construction affected by rotational soil slide

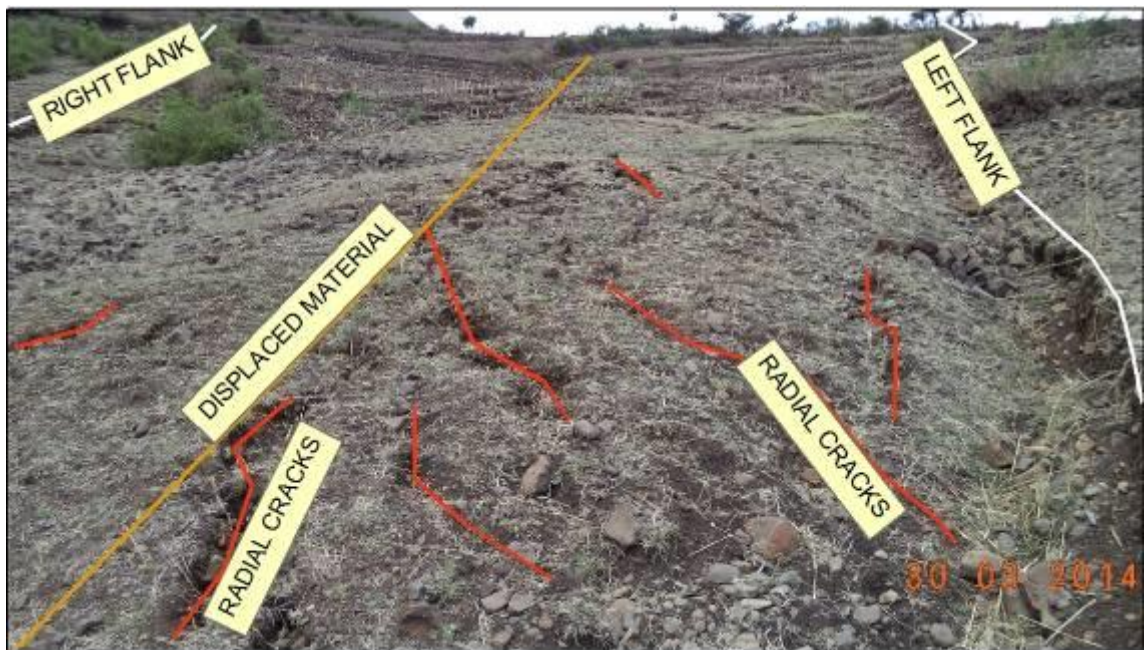


Plate 6.10 (d) Photo showing rotational soil slide



Plate 6.11 Photo showing Debris slide in the study area



Plate 6.12 Illustrating Debris flow observed in the study area

6.1.4 Manifestations of Landslides and related instabilities in the area

During the landslide susceptibility zoning major considerations are given to the evidence of recent landslide features such as: cracks in soils and engineering structures, fresh rock falls, slope and geomorphological setting, lithology and structure, geotechnical characteristics of soils and rocks, water flux during rainy season and groundwater levels, distance from active sites that might generate potential landslide to adjacent units, the presence of structures

constructed for stabilization of existing landslides, land use, other anthropogenic factors such as quarrying and deforestation (Tenalem Ayenew & Barbiery, 2005).

In the present study, observations were made on manifestations of landslides and related instabilities in the study area. Among the observed field manifestations are: Vertical tension cracks, stream bank erosion, vertical to sub vertical open joints on very steep slope, fallen rock blocks on gentler areas, gabion protections along streams, and traces of major and minor scarps of rock slides.



Plate 6.13 Photo showing loosening by opening of tension cracks in upper part of the slope



Plate 6.14 Photo showing Stream bank erosion



Plate 6.15 Photo showing rocks with open sub-vertical joints on cliff susceptible to fall/topple



Plate 6.16 Fallen rocks observed on very gentle slope below the cliff shown on Plate 6.15



Plate 6.17 One of the gabion protections observed as manifestations of presence of slope instability in the area

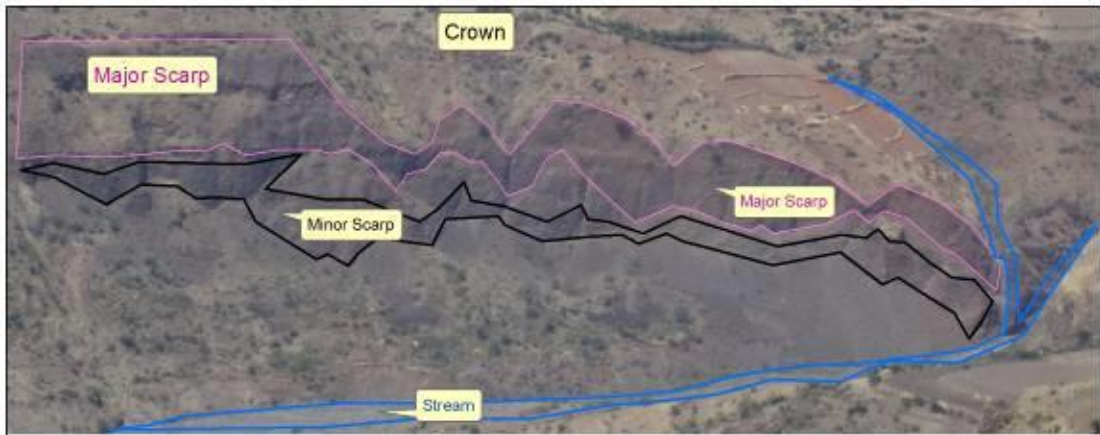


Plate 6.18 Traces of major and minor scarps of rock slides observed in the study area



Plate 6.19 Bending of trees manifesting slope instability process in the area



Plate 6.20 Photo showing disposal material placed at lower side of the road cut slope



Plate 6.21 Deep vertical tension cracks observed after disposal material is damped on the slope

Moreover, bending of trees, dumping of road cut material (disposal) on the down slope side, and vertical deep tension cracks were observed. These vertical deep cracks were manifested after road cut material was disposed on the down slope side of the cut road slope section. The illustrations of the observed landslide and slope instability in the present study area are shown in Plates 6.13 to 6.21.

6.2 Possible causes and Mechanism

Some of the basic causes of slope instability are inherent in the rock or soil, in its composition or structure; some, like inclination of undisturbed slopes, are relatively constant and some are variable, such as groundwater levels; some are transient (seismic vibration) and some are imposed by new events, such as construction activity (Varnes, 1984).

Generally, the major causes and mechanisms for landslides and slope instability problems observed in the present study area can be categorized in to two as internal causative factors and external triggering factors. The major intrinsic factors include slope geometry, slope material (lithology or soil type), structural discontinuities, land use and land cover and groundwater; whereas, external triggering parameters responsible are seismicity, rainfall and manmade activities.



Plate 6.22 Showing contribution of ground water on causing slope instability

Most of the slope failures observed in the present study area is the result of the combined effect of all of these causative and triggering factors as described above. Illustrations for

some of the factors responsible for slope instabilities in the study area are shown in Plate 6.22, 6.23, and 6.24.



Plate 6.23 Soil slide triggered by slope cutting activities during road construction



Intensive farming observed during field work



Firing and deforestation observed during field work

Plate 6.24 Intensive farming and firing observed during the present field work

Plate 6.22 indicates the effect of ground water (as internal causative factor) contributing to slope instability in colluvial soil deposit (as internal causative factor). Plate 6.23 shows the man-made activities such as slope cuts for road construction and subsequent slope failure (rotational soil slide). Plate 6.24 is also an illustration of manmade activity such as; intensive farming on slopes and demolishing the forest with fire.

6.3 Potential Slope Instabilities

Prediction of landslide hazard for areas not currently subject to land sliding is based on the assumption that hazardous phenomena that have occurred in the past can provide useful information for prediction of future occurrences. Therefore, mapping these phenomena and the factors thought to be of influence is very important in hazard zonation (Soeters and VanWesten, 1996).

As such landslide inventory map of the study area was prepared in the present study as shown in Fig 6.1. Such mass movement inventory maps are the basis for most other landslide hazard zonation techniques. However, they can also be used as an elementary form of hazard map because they display the location of a particular type of slope movement.

According to Soeters and VanWesten (1996), such maps provide information only for the period shortly preceding the date that satellite images were taken or the fieldwork was conducted. They provide no insight into temporal changes in mass movement distribution. Many landslides that occurred sometime before photographs or satellite images were taken may have become undetectable. Slope instability processes are results of combined effect of many terrain factors that need consideration during slope instability assessments. Hence, during the application of landslide hazard zonation techniques, in addition to giving emphasis to a detailed inventory of-slope instability processes and the study of these processes in relation to their environmental setting, the analysis of conditioning and triggering factors as well as the representation of the spatial distributions of these factors is very crucial.

In the present study, the analysis of potential slope instabilities in the area was conducted by utilizing Slope Stability Susceptibility Evaluation Parameter rating scheme (SSEP) proposed by Raghuvanshi *et al.* (2014) considering both intrinsic slope instability causative factors and external triggering factors. The details of the analysis carried out and the results obtained are discussed in Chapter - 7.

CHAPTER VII

LANDSLIDE EVALUATION AND ZONATION

7.1 Preamble

Landslides are among the most common natural hazards and are the most damaging, leading to a variety of human and environmental impacts (Chingkhai *et al.*, 2013). The planning, design and execution of developmental schemes, such as road and building construction, are often carried out too quickly due to financial, time and other constraints. Due to this reason, the incidence of landslide is increasing greatly because many projects may not incorporate adequate details of geological and geotechnical considerations. This indicates that preparation of multipurpose terrain evaluation maps, based on the geo-environment of the mountainous terrain is crucial because this map can be used as the basis for planning future development schemes (Ambalagan, 1992).

Landslide Hazard Zonation (LHZ) map of the present study area was prepared by considering various causative and triggering factors. Landslide is the result of a wide variety of processes which include geological, geomorphologic and meteorological factors (Chingkhai *et al.*, 2013).

According to Varnes (1984), most of the elements that affect slope stability can be recognized and their effects rated or weighted; some can be mapped and correlated with each other and with past failures in a given area. Thus, according to him, a summary of the degree of potential hazard in areas can be built up, depending on the number of failure - inducing factors present, their severity, and their interaction.

Preparation of landslide hazard zonation map of the study area, being the major objective of the present study, intrinsic causative and external triggering factors were considered for the evaluation of landslide hazard in the area. For the processing of data in this study, a technique Slope stability susceptibility evaluation parameter rating scheme (SSEP) proposed by Raghuvanshi *et al.* (2014) was adopted.

For the purpose of landslide hazard mapping (LHZ) the area of slopes to be covered was divided into individual slope facets. First of all, topographic maps (1:50,000) of the study area was procured from the Ethiopian Mapping Agency. On the topographic maps, delineation of the boundary for the present study area was done. Then, the area of slopes to

7.2 Intrinsic Causative Factors Evaluation

Intrinsic parameters are the causative parameters which define the favorable or unfavorable stability conditions within the slope. The intrinsic causative factors considered in the present study include; Relative Relief, Slope Morphometry, Slope Material, Structural Discontinuity, Landuse and Landcover, and Ground water.

7.2.1 Slope Geometry

The most important geomorphological characteristic to be considered in landslide zonation is the presence or absence of former landslides (Varnes, 1984) which has already been discussed in detail in chapter six. Slope geometry of the area is also a very important factor that needs consideration in landslide hazard zonation. Slope geometry includes relative relief and slope morphometry of the slope.

a) Relative relief

Relative relief map of the study area was prepared with the help of topographical map. For each individual slope facet, maximum and minimum elevations were noted and the difference of the two elevations was used to classify the slope facet into various relative relief classes. Consequently, the relative relief map of the study area (1: 50,000) was prepared (Fig 7.2).

Relative relief of the study area was categorized into five classes; low (< 50 m), moderate (51-100 m), medium (101-200 m), high (201-300 m) and very high (>301 m) (Table 7.1). As can be observed in Fig 7.1, 44 km² (5.8 %) of the study area is Low relief, 40.6km². (5%) is Moderate relief, 48.6 km² (6 %) is High relief, and 581km² (76.8 %) is Very High relief zones.

Table 7.1 Slope stability susceptibility evaluation parameter rating for Relative relief.

a) Relative Relief		
Class	Value Range	Ratings
Very High	>300m	1
High	201-300m	0.8
Medium	101-200m	0.6
Moderate	51-100m	0.2
Low	<50m	0.1

From this we can understand that majority of the area lies within Very High relief zone and this leads to higher slope instability in the area. Because, slope will be more prone for

instability if the relative relief is more (Hoek and Bray, 1981); accordingly, Slope Stability Susceptibility Parametr (SSEP) ratings were assigned for each facet (Table 7.1). Summary of SSEP ratings assigned for relative relief is presented in Annexure I.

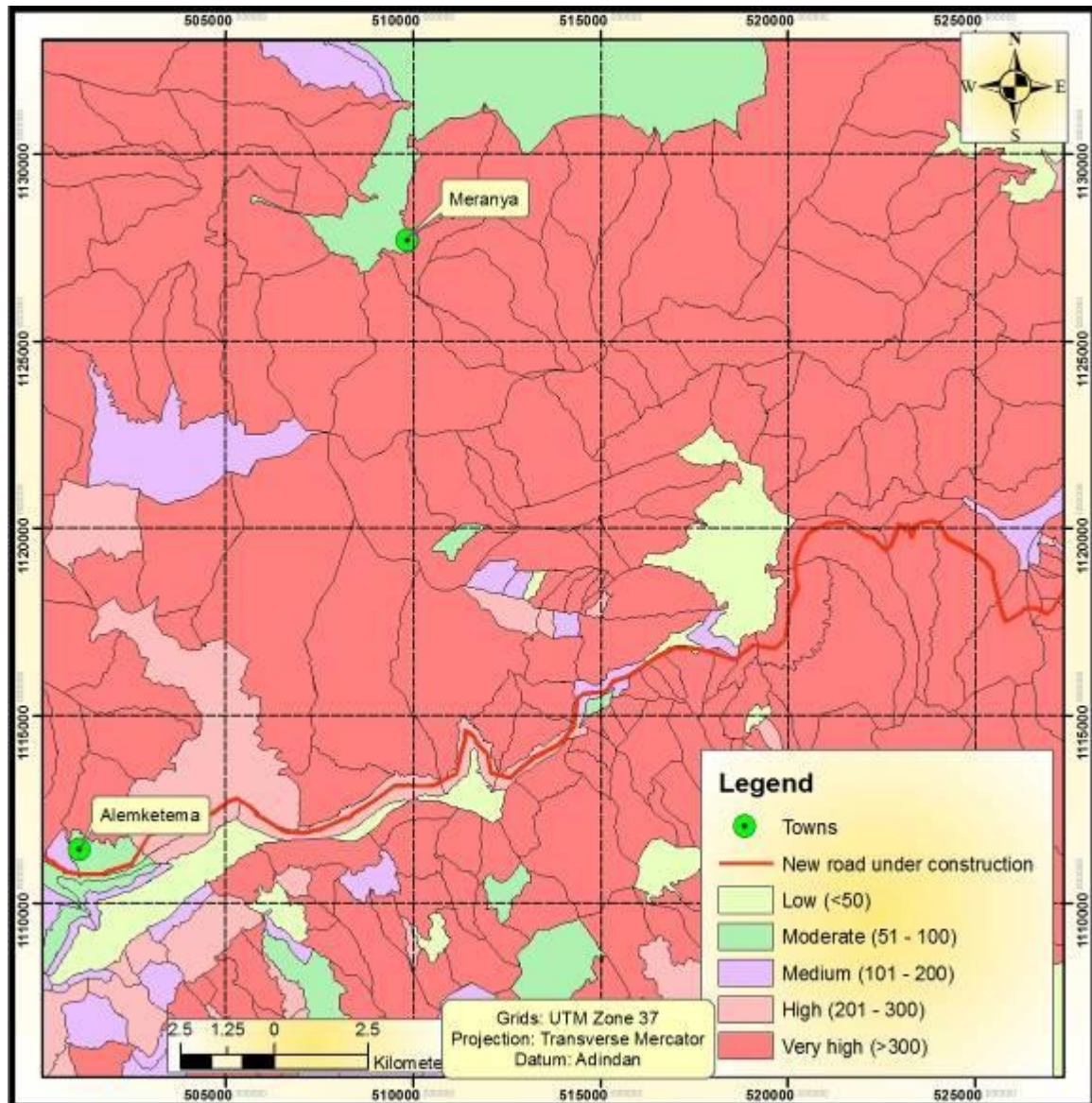


Fig 7.2 Relative relief map of the study area

b) Slope morphometry

Steepness of slope in relation to the strength of the slope - forming materials is given special attention in landslide hazard zonation, and the slope inclination is often grouped into ranges of degrees or percentage to be used to prepare slope morphometry map of the given area (Varnes, 1984).

Slope morphometry maps define slope categories on the basis of the frequency of occurrence of particular angles of slope. The geomorphological history of the area determines

distribution of the slope categories as the angle of slope of each unit reveals a series of localized processes and controls which has been imposed on the facet (Raghuvanshi *et al.*, 2014).

This is an important factor with regard to landslide initiation. In most studies of landslides, the slope steepness is taken into account as the major causative factor of landslide (Asmelash Abay and Barbieri, 2012). The slope morphometry indicates the steepness of the slope. To prepare the slope morphometry map slope sections along general slope direction within the individual slope facet is prepared and slope angle is measured. With this consideration, slope map of the study area was prepared by dividing the larger topographical map into smaller units (Fig 7.3). For the estimation of the slope angle, a method proposed by Anbalagan (1992) was adopted (Table 7.2 a).

Table 7.2 a) Estimation of Slope Angle (adopted from Anbalagan, 1992).

Estimation of Slope Angle (Anbalagan, 1992)	
Number of contour lines over one cm length (1: 50,000)	Slope Angle
> 25	> 45°
19 - 25	36° - 45°
13 - 18	26° - 35°
8 - 12	16° - 25°
< 7	< 15°

Table 7.2 b) Slope stability susceptibility evaluation parameter rating for Slope morphometry.

b) Slope Morphometry		
Class	Value Range	Rating
Escarpment/cliff	>45°	2
Steep slope	36°-45°	1.7
Moderately steep slope	26°-35°	1
Gentle slope	16°-25°	0.6
Very gentle slope	< 15°	0.3

The slope morphometric classes were adopted same as that of Anbalagan's (1992) LHEF rating scheme, accordingly the classes were; escarpment/cliff (> 45°), steep slope (36°-45°), moderately steep slope (26°-35°), gentle slope (16°-25°) and very gentle slope (< 15°) (Table 7.2 b).

In the present study area as shown in Fig 7.3, Very gentle slope covers about 458.8 km², Gentle slope is 227.5 km², Moderately steep is 62.2 km², Steep and Escarpment cliff cover 7.6 km² and 0.2 km² areas, respectively. This indicates that about 60 % of the study area is very gentle and only about 1% of the area falls under steep to Escarpment cliff.

Depending upon the slope class, ratings were assigned to individual facets on the basis of SSEP technique. Summary of the ratings assigned to individual facets is given in Annexure I.

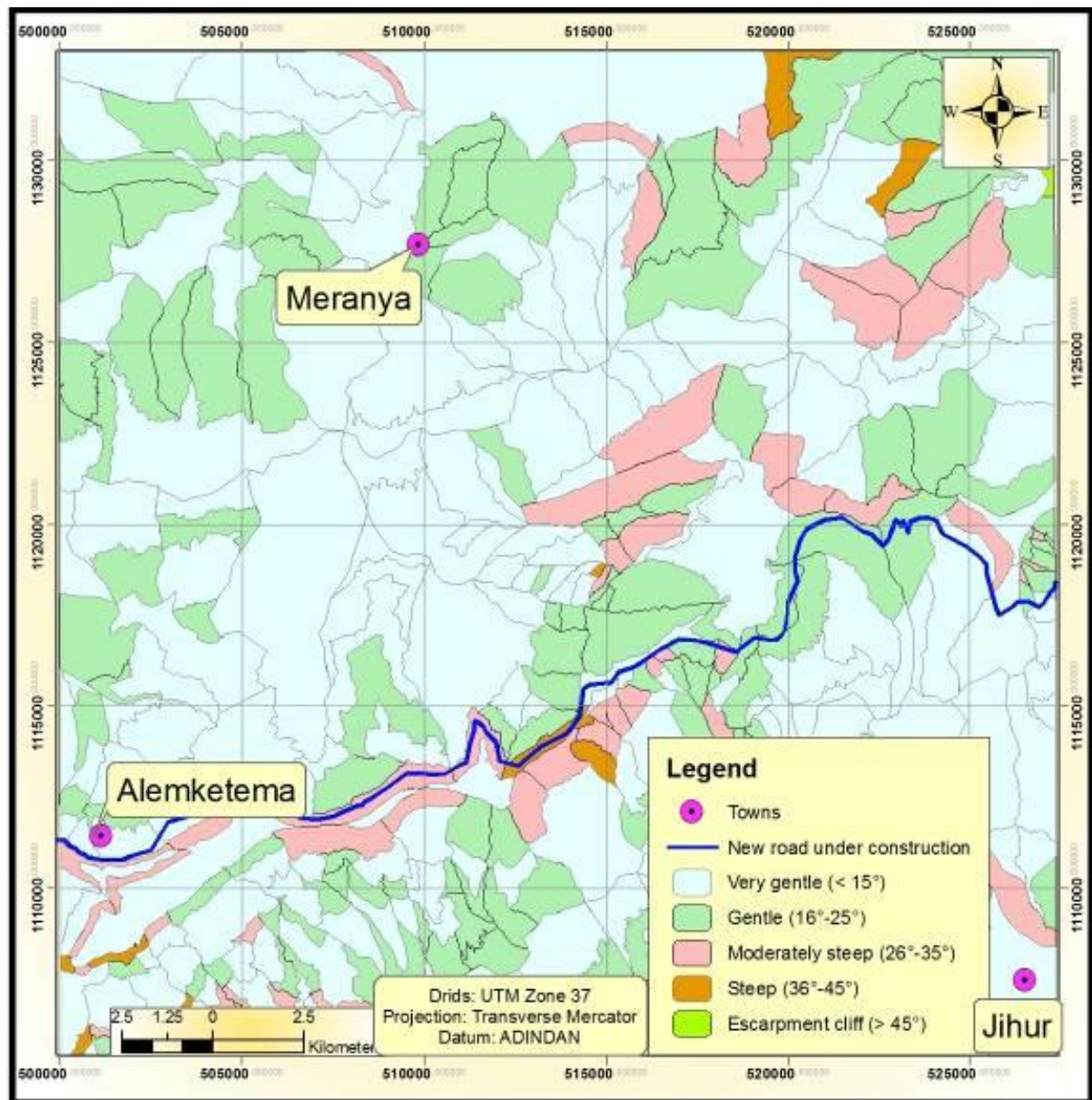


Fig 7.3 Slope morphometry map of the study area

7.2.2 Slope Material

Slopes may be composed of rock mass or soils or both. The criteria for assigning ratings to sub classes of rock type were based on intact rock strength and degree of weathering. The erodability of rocks is highly influenced by the strength of the rock. Rocks which possess high strength are relatively more resistant to erosion. The rock sub classes were adopted from classification of rocks based on uniaxial compressive strength proposed by Hoek (1997) as suggested in SSEP technique. These classes were; Very weak rock (1-5 MPa), Weak rock (5-25 MPa), Medium strong rock (25-50 MPa), Strong rock (50-100 MPa), Very strong rock

(100-250 MPa) and Extremely strong rock (>250 MPa). However, the classes observed in the present study area are; Medium strong rock (25-50 MPa), Strong rock (50-100 MPa), and Very strong rock (100-250 MPa) as shown on Fig 7.4.

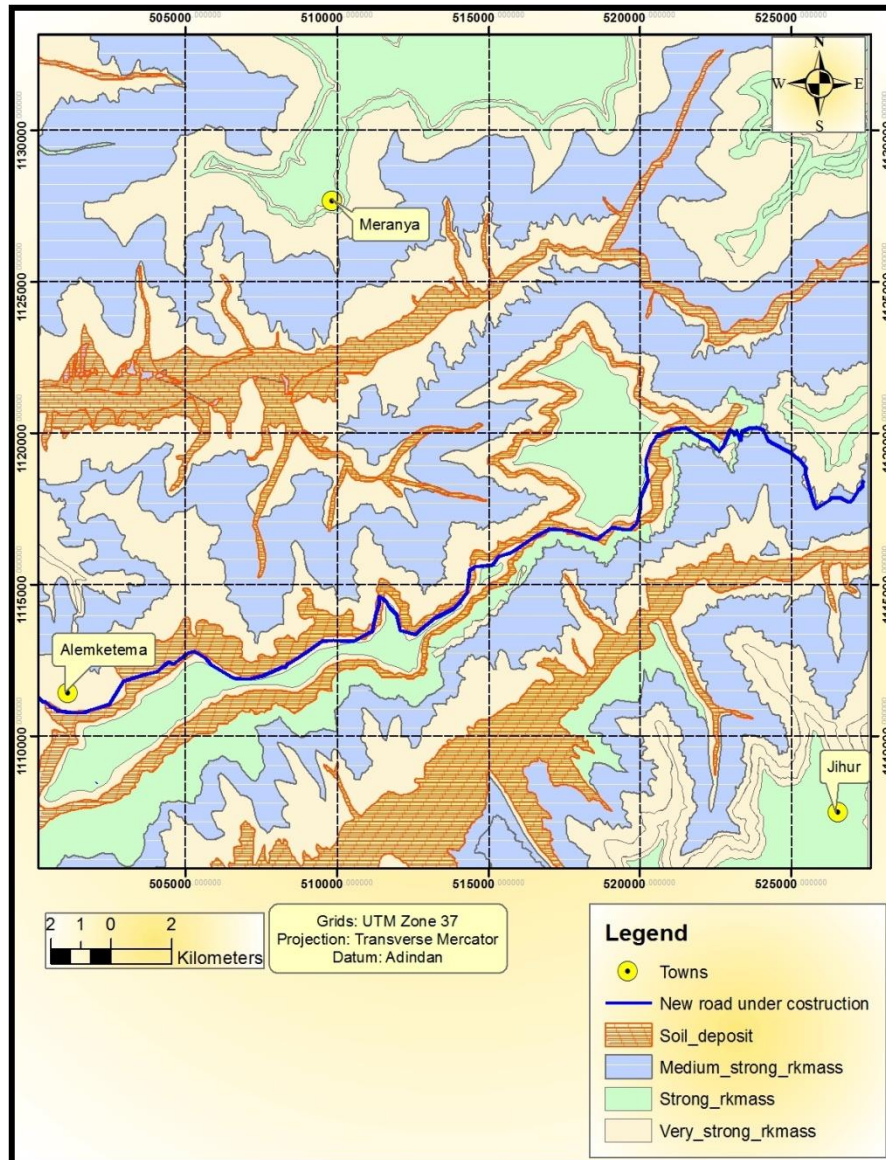


Fig 7.4 Slope material map of the study area

About 35 % of outcropped rock mass in the study area is medium strong; 15 % is strong; 36% is very strong rock mass. Degree of weathering may affect the relative strength of the rocks therefore it was considered while assigning ratings to the rock type. The degree of weathering was considered as; Fresh, Slightly weathered, Moderately weathered, Highly weathered, Extremely weathered and Rock as soil. The description of weathering classes is given in Table 7.3. Thus, depending upon weathering class rock type rating was adjusted (Annexure II). The adjustment factor for each weathering class is also given in Table 7.3.

From Fig 7.4 it can be deduced that about 13 % of the study area is covered with soil deposits. These soil deposits are categorized into two genetic groups as colluvial and alluvial (Fig 4.2 in Chapter Four). The colluvial deposits are the product of mass wasting transportation processes and are found on gentle slopes of terraces in front of the volcanic cliffs in the study area. The new road under construction in the study area passes along this deposit. The alluvial deposits are found mainly along the Wenchit and Jema River gorges and their tributary streams.

In most places, the soil deposits have thickness ranging from 2 to 6 meters; however, thicker colluvial deposits of estimated thickness of greater than 20m were also observed along the route corridor.

For the case when slopes are covered by soils the rating criteria is based on the genetic class and depth of the soil cover (Raghuvanshi *et al.*, 2014). The various soil types considered and their relative ratings are presented in Table 7.3. Thus, depth of soil cover was also considered while assigning ratings to various soil types.

7.2.3 Structural Discontinuity

Structures in rock mass refers to primary and secondary discontinuities such as; beddings, foliations, joints and faults. These structural discontinuities play an important role in defining stability condition of the rock slopes (Hoek and Bray, 1997).

The important factors of structural discontinuity planes which influence the stability of the rock mass and considered in the present study were; orientation, spacing, continuity, surface characteristics, separation of discontinuity surface and thickness and nature of filling material within the discontinuity surfaces. Orientation of the discontinuity planes plays an important role in stability condition of the rock mass. The rock mass may fail along one or more discontinuity planes. The major structures identified in the present study area are illustrated in Fig 4.6 (in Chapter Four).

For the stability condition of rock mass following points are important;

- a) The extent of parallelism between the directions of the discontinuity, or the line of intersection of two discontinuities and the slope,
- b) Discontinuity plane or plunge of line of intersection of two wedge forming planes day light into the slope at less than the slope angle.

Tab 7.3 Slope Stability Susceptibility Evaluation Parameter (SSEP) Rating Scheme for Slope Material (Raghuvanshi *et al.*, 2014)

(c) Slope Material			
(i) Rock Type			
	Class *	Description*	Rating
Grade I	Very weak rock	Strength: 1-5 MPa ; Field Estimate of Strength: Crumbles under firm blows with point of a geological hammer, can be peeled by a pocket knife. Examples: Highly weathered or altered rock.	1
	Weak rock	Strength: 5-25 MPa ; Field Estimate of Strength: Can be peeled with a pocket knife with difficulty, shallow indentation made by firm blow with point of a geological hammer. Examples: Chalk, rocksalt, potash.	0.8
Grade II	Medium strong rock	Strength: 25-50 MPa; Field Estimate of Strength: Cannot be scraped or peeled with a pocket knife, specimen can be fractured with a single blow from a geological hammer. Examples: Claystone, coal, concrete, schist, shale, siltstone.	0.5
	Strong rock	Strength: 50-100 MPa ; Field Estimate of Strength: Specimen requires more than one blow of geological hammer to fracture. Examples: Limestone, marble, phyllite, sandstone, schist, shale.	0.4
Grade III	Very strong rock	Strength: 100-250 MPa ; Field Estimate of Strength: Specimen requires many blows of a geological hammer to fracture it. Examples: Amphibolite, sandstone, basalt, gabbro, gneiss, granodiorite, limestone, marble, rhyolite, tuff.	0.3
	Extremely strong rock	Strength: >250 MPa; Field Estimate of Strength: Specimen can only be chipped with a geological hammer. Examples: Fresh basalt, chert, diabase, gneiss, granite, quartzite.	0.1
Adjustment Factor for Weathering grade for rock mass			
Weathering Grade**	Description**	Adjustment Factor	
Fresh	No visible sign of rock material weathering; perhaps slight discoloration on major discontinuity surfaces	1	
Slightly weathered	Discoloration indicates weathering of the rock material and discontinuity surfaces	1.2	
Moderately weathered	Less than 35% of the rock material is decomposed and/or disintegrated to a soil. Fresh or discoloured rock is present either as a continuous framework as core stone	1.5	
Highly weathered	More than 35% of the rock material is decomposed and/or disintegrated to a soil. Fresh or discoloured rock is present either as a continuous framework as core stone	1.65	
Extremely weathered	All the rock material is decomposed and/or disintegrated to a soil. The original mass structure is still largely intact	1.8	
Residual soil	All the rock material is converted to soils, the mass structure and material fabrics are destroyed	2	
Note: The adjustment factor for weathering of rock has to be multiplied to the respective rating of fresh rock type of Grade II and Grade III rocks.			
* Rock mass classification and description adopted from Hoek 1997			
** Weathering class and description adopted from Irfan and Dearman, 1978			
(ii) Soil Type			
Class	Description	Ratings	
Collapsible Soil	Loose mix of granular material comprising mainly sand and silt. Mainly cohesionless material which may undergo suffusion.	1	
Alluvial Deposits	Well graded material comprising mix of cobble/ pebbles, sand and silt in a matrix of clay.	0.8	
Residual Expansive Soils	Mainly comprising clay. Exhibits swelling when saturated and typical shrinkage cracks when dry.	0.6	
Poorly Graded Colluvial Material	Poorly graded rounded to sub-rounded rock fragments/ cobble/pebbles mixed in a matrix of fine grained sand or silt.	0.5	
Fluvio-glacial Deposits	Well graded angular rock fragments mixed in a matrix of clayey material. Partial interlocking of angular rock fragments.	0.4	
Well Graded Colluvial Material	Well graded angular to sub-angular rock fragments mixed in a matrix of clayey material. Partial or well interlocking of angular rock fragments.	0.3	
Residual Soils	Well compacted residual deposits of soil mainly comprising silt and clay.	0.2	

(ii) Soil Type		
Class	Description	Ratings
Collapsible soil	Loose mix of granular material comprising mainly sand and silt. Mainly cohesionless material which may undergo suffusion.	1
Alluvial Deposits	Well graded material comprising mix of cobble/ pebbles, sand and silt in a matrix of clay.	0.8
Residual Expansive Soils	Mainly comprising clay. Exhibits swelling when saturated and typical shrinkage cracks when dry.	0.6
Poorly Graded Colluvial Material	Poorly graded rounded to sub-rounded rock fragments/ cobble/pebbles mixed in a matrix of fine grained sand or silt.	0.5
Fluvio-glacial Deposits	Well graded angular rock fragments mixed in a matrix of clayey material. Partial interlocking of angular rock fragments.	0.4
Well Graded Colluvial Material	Well graded angular to sub-angular rock fragments mixed in a matrix of clayey material. Partial or well interlocking of angular rock fragments.	0.3
Residual Soils	Well compacted residual deposits of soil mainly comprising silt and clay.	0.2

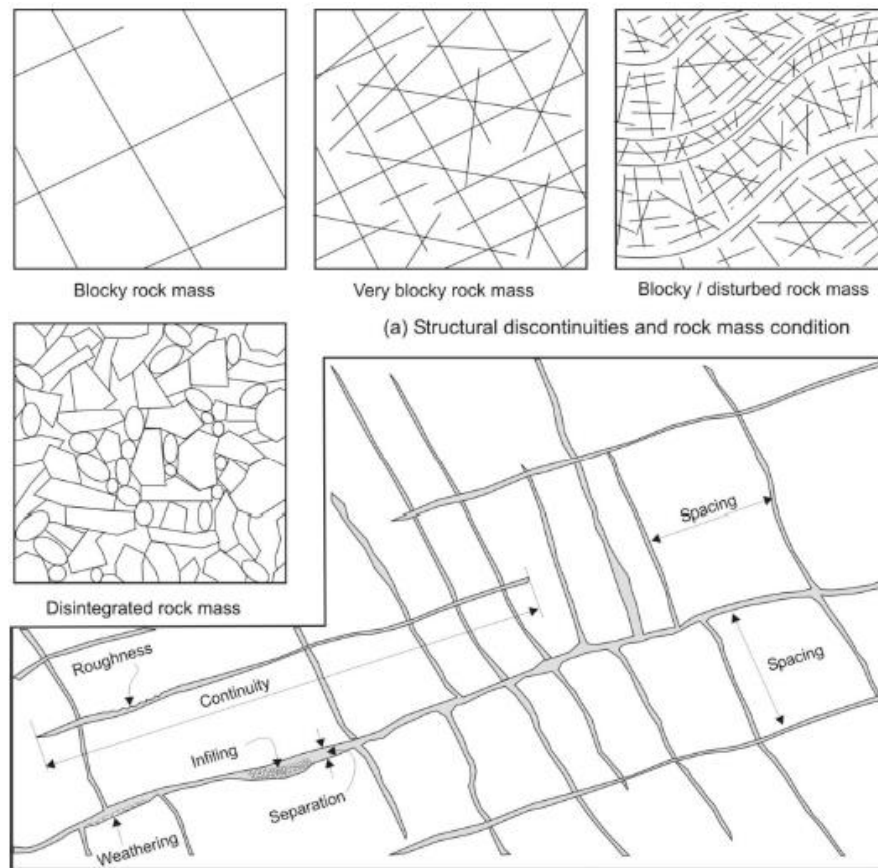
These conditions make the slope kinematically unstable (Johnson and DeGraff, 1991; Hoek and Bray, 1981; Yoon *et al.*, 2002 as cited in Raghuvanshi *et al.*, 2014). The spacing of discontinuity also affects the stability condition of the rock mass. If the spacing of discontinuities is less the rock mass will be more prone for instability condition (Johnson and DeGraff, 1991 as cited in Raghuvanshi *et al.*, 2014).

The continuity of discontinuity planes influence the stability of the rock mass provided the orientation of the discontinuity is kinematically critical. If the continuity of the discontinuity planes is more the rock mass will show more unstable condition in comparison to the case when continuity is less and there are intact rock bridges in between (Fig 7.5).

Three factors are involved when the surface characteristics of discontinuities are considered.

- (a) The waviness or undulation of the surface.
- (b) The smaller scale roughness of the surface.
- (c) The physical properties of the in-filled material between the two surfaces of discontinuity plane.

These surface characteristics of discontinuities are also important in defining stability condition of rock mass (Johnson and Degraff, 1991 as cited in Raghuvanshi *et al.*, 2014).



(Source: Adopted from Raghuvanshi et al., 2013)

Fig 7.5 Structural discontinuities and rock mass condition and discontinuity characteristics

Therefore, in the present study, data pertaining to structural discontinuities orientation has been observed facet wise from the exposed rock mass and its relation to slope inclinations was determined.

The rock mass condition with respect to structural discontinuities was also observed. Besides, data on characteristics of structural discontinuities with respect to spacing, continuity, and surface characteristics, separation of discontinuity surface and thickness and nature of filling material within the discontinuity surfaces has also been collected.

The major structural discontinuities identified in the present study area, preferred orientation, and site exposures are illustrated in Fig 4.6, Fig 6.7a & b, and Fig 4.8 a, b, & c (in Chapter Four). Accordingly, while assigning ratings characteristics of structural discontinuities, their interrelationship, and their extent of parallelism to slope has been considered (Table 7.4). SSEP ratings assigned to each parameters of structural discontinuities facet wise are shown in Annexure III.

7.2.4 Landuse and Landcover

The stability condition of a hill slope to a large extent is influenced by land-use and land-cover. A thick vegetation cover over a slope is an indication of stable condition as the vegetation cover prevents excess seepage of water into the slope (Arora, 1997 as cited in Raghuvanshi *et al.*, 2013). Besides, the roots of the plants bind the soil mass thus contributing to increase the shear strength of the soil mass (Turrini and Visintainer, 1998).

Surface erosion in the form of gullies is also checked with thick vegetation cover. The type of groundcover affects the stability of a slope: as the areas that are barren are more prone to erosion and weathering (Turrini and Visintainer, 1998). Barren and sparsely vegetated lands are more prone to soil erosion and slope failures (Wang and Niu, 2009 as cited in Raghuvanshi *et al.*, 2014). Cultivation is the main land-use activity which is performed on the hill slopes. Thus, while assigning rating for land-use and land-cover above mentioned points were considered in SSEP rating scheme (Table 7.5).

In the present study, land use - land cover map of the study area was prepared from secondary data and satellite image interpretation under desk study. Then, during field work, this map was modified and updated based on visual field observation and the final map was produced in Arc Gis 9.3 after field work (Fig 7.6).

Later, in order to assign SSEP ratings for individual facet, facet wise percentage area coverage of land use - land cover was generated by geo-processing in GIS environment.

From perusal of Fig 7.6 it can be deduced that 33.4 % of the study area is moderately vegetated, 27.4 % is cultivated land, 21.2 % is sparsely vegetated, 15.5 % is bare-land and 1.8% is thickly vegetated, and ratings were assigned to each parameter facet wise accordingly (Annexure IV).

7.2.5 Groundwater

Groundwater plays an important role in slope stability condition (Hoek and Bray, 1981). Slope stability studies for hazard mapping over relatively large areas makes it difficult to have direct observations of groundwater behavior within slopes. Moreover, information on water table levels and fluctuations is rarely available. For a quick appraisal, indirect measures can be used to assess the role of groundwater in inducing instability to a slope. These indirect

measures are the surface indications of groundwater such as; damp, wet, dripping and flowing (Anbalagan, 1992).

Tab 7.4 Slope Stability Susceptibility Evaluation Parameter (SSEP) Rating Scheme for Structural discontinuity

(d) Structural Discontinuities							
(i) Parallelism between discontinuities dip direction and slopes				(ii) Relationship between dip of discontinuity and inclination of slope			
$(a_j - a_s)$ or $(a_i - a_s)$	Rating	Planer Mode of Failure $(a_j - a_s)$ Wedge Mode of Failure $(a_i - a_s)$		$(\beta_j - \beta_s)$ or $(\beta_i - \beta_s)$	Rating	Planer Mode of Failure $(\beta_j - \beta_s)$ Wedge Mode of Failure $(\beta_i - \beta_s)$	
0^0	0.5			$< (-10^0)$	0.5		
$1^0 - 5^0$	0.4	a_j - Discontinuity dip direction		$0^0 - (-10^0)$	0.4	β_j - Dip of Discontinuity plane	
$6^0 - 10^0$	0.3	a_i - Direction of line of intersection of two wedge forming discontinuities		0^0	0.2	β_i - Plunge of line of intersection of two wedge forming discontinuities	
$11^0 - 15^0$	0.25			$10^0 - 0^0$	0.15		
$16^0 - 20^0$	0.2	a_s - Direction of Slope inclination		$> 10^0$	0.1	β_s - Direction of Slope inclination	
$> 20^0$	0.1			(iii) Dip of discontinuity or plunge of line of Intersection of wedge forming planes			
(iv) Soil cover depth				(β_i) or (β_s)	Rating		
Depth	Rating			$> 45^0$	0.5		
$> 20m$	2.5			$45^0 - 35^0$	0.4		
20 - 15m	1.8			$34^0 - 30^0$	0.25		
14 - 10m	1.4			$29^0 - 20^0$	0.15		
9 - 5m	1			$< 20^0$	0.1		
$< 5m$	0.5						
(v) Structural discontinuities and rockmass condition***							
Condition						Rating	
Disintegrated – poorly interlocked, heavily broken rock mass with a mixture or angular and rounded rock pieces.						0.25	
Blocky/ Disturbed – folded and/or faulted with angular blocks formed by many intersecting discontinuity sets.						0.2	
Very Blocky – interlocked, partially disturbed rock mass with multifaceted angular blocks formed by four or more discontinuity sets.						0.1	
Blocky – very well interlocked undisturbed rock mass consisting of cubical blocks formed by three orthogonal discontinuity sets.						0.05	
(vi) Characteristics of structural discontinuity							
Continuity	Rating	Seperation	Rating	Roughness	Rating	Infilling	Rating
$< 1m$	0.02	None	0.02	Very rough	0.02	None	0.02
1 - 2m	0.04	$< 0.1mm$	0.05	Rough	0.03	Hard filling $< 5mm$	0.04
3 - 9m	0.07	0.1 - 0.9mm	0.07	Slightly rough	0.07	Hard filling $> 5mm$	0.07
10 - 20m	0.1	1 - 5mm	0.12	Smooth	0.1	Soft filling $< 5mm$	0.12
$> 20m$	0.15	$> 5mm$	0.15	Slickensided	0.15	Soft filling $> 5mm$	0.15
Weathering	Rating	**** Hoek & Bray 1997					
Unweathered	0.02						
Slightly weathered	0.05						
Moderately weathered	0.07						
Highly weathered	0.1						
Decomposed	0.15						

Tab 7.5 Slope Stability Susceptibility Evaluation Parameter (SSEP) Rating Scheme for Landuse and Landcover

(e) Land-use and Land-cover	
Class / Description	Rating
Barren land - No vegetation, land not used for any activity	1.5
Sparsely vegetated - Very thin scattered vegetation in the form of wild grass, bushes, scrub and random	1.2
Moderately vegetated area - Moderately covered vegetation land in the form of wild grass, scrub and trees	0.75
Thickly vegetated forest area - Dense forest area with thick vegetation cover.	0.4
Cutivated land with populated area	0.4

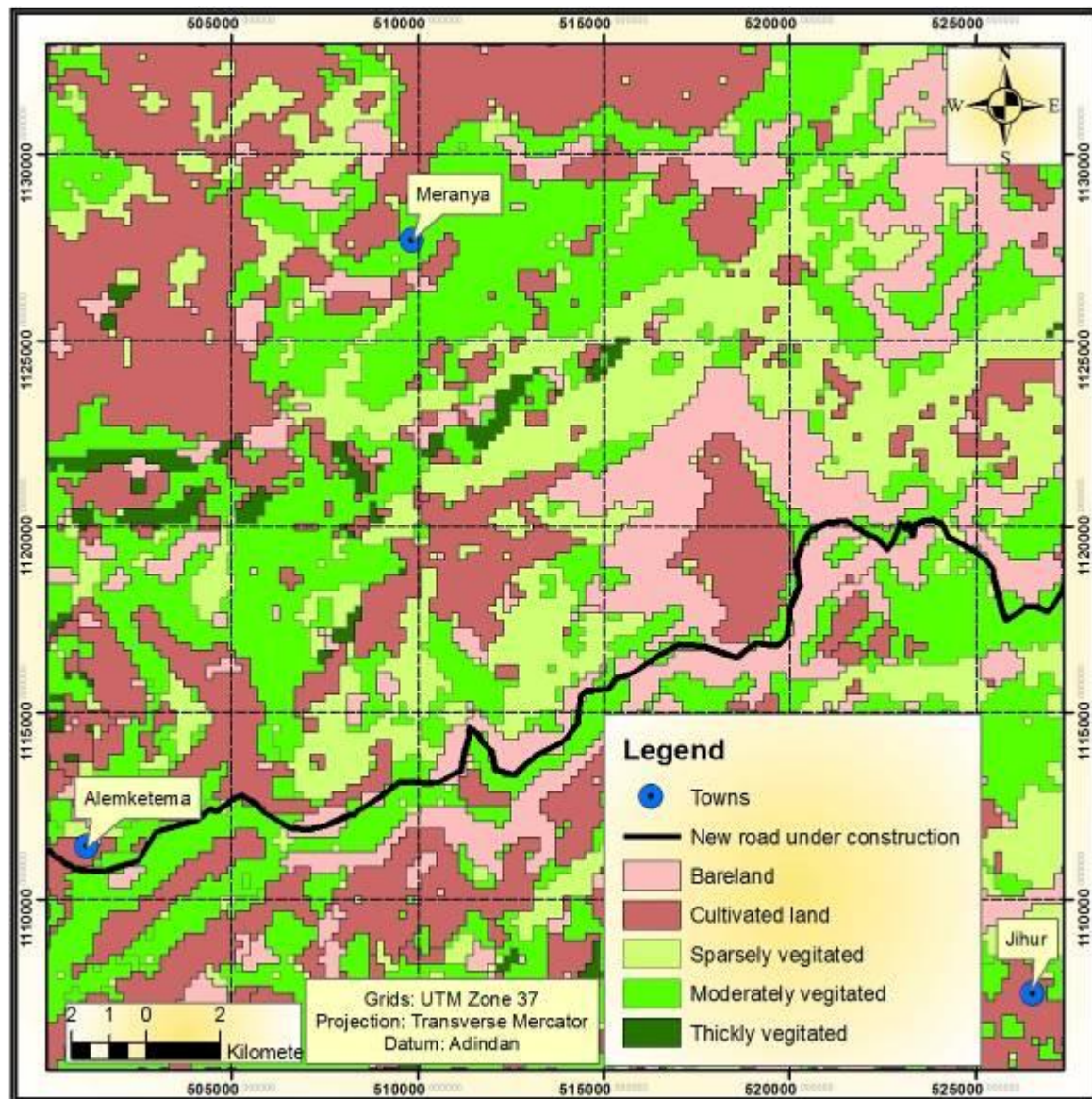


Fig 7.6 Land use - Land cover map of the study area

Therefore, while assigning ratings to ground water in the present study as suggested in SSEP technique, other surface traces such as algal growth, water marks etc. was considered (Table 7.6) as such surface traces may give some idea about the degree of saturation of slope for prolonged period of time. Further, during field work in the present study, data on locations of hand pumps and springs was collected and compiled as shown in Fig 7.7.

Tab 7.6 Slope Stability Susceptibility Evaluation Parameter (SSEP) Rating Scheme for Ground Water

(f) Ground Water	
Surface traces of groundwater	Ratings
Flowing – presence of spring on slope face	2
Dripping – dripping of water through structural discontinuities.	1.5
Wet – water marks on rock surface, some droplets along structural discontinuities, algal growth in shadow areas.	1
Damp – Moist conditions on rock face surface, moss and algal growth in shadow areas.	0.6
Dry – rock face surface is dry, no water traces along structural discontinuity surfaces	0

Thus, in assigning ratings for individual facets, the presence of these springs and hand pumps were also considered and ratings were given based on their location and density within individual facet. For instance, the presence of springs around the top part of the slope of the facet is assigned higher rating than those located around toe of the slope. Accordingly, ratings were assigned for ground water and the details are shown in Annexure V.

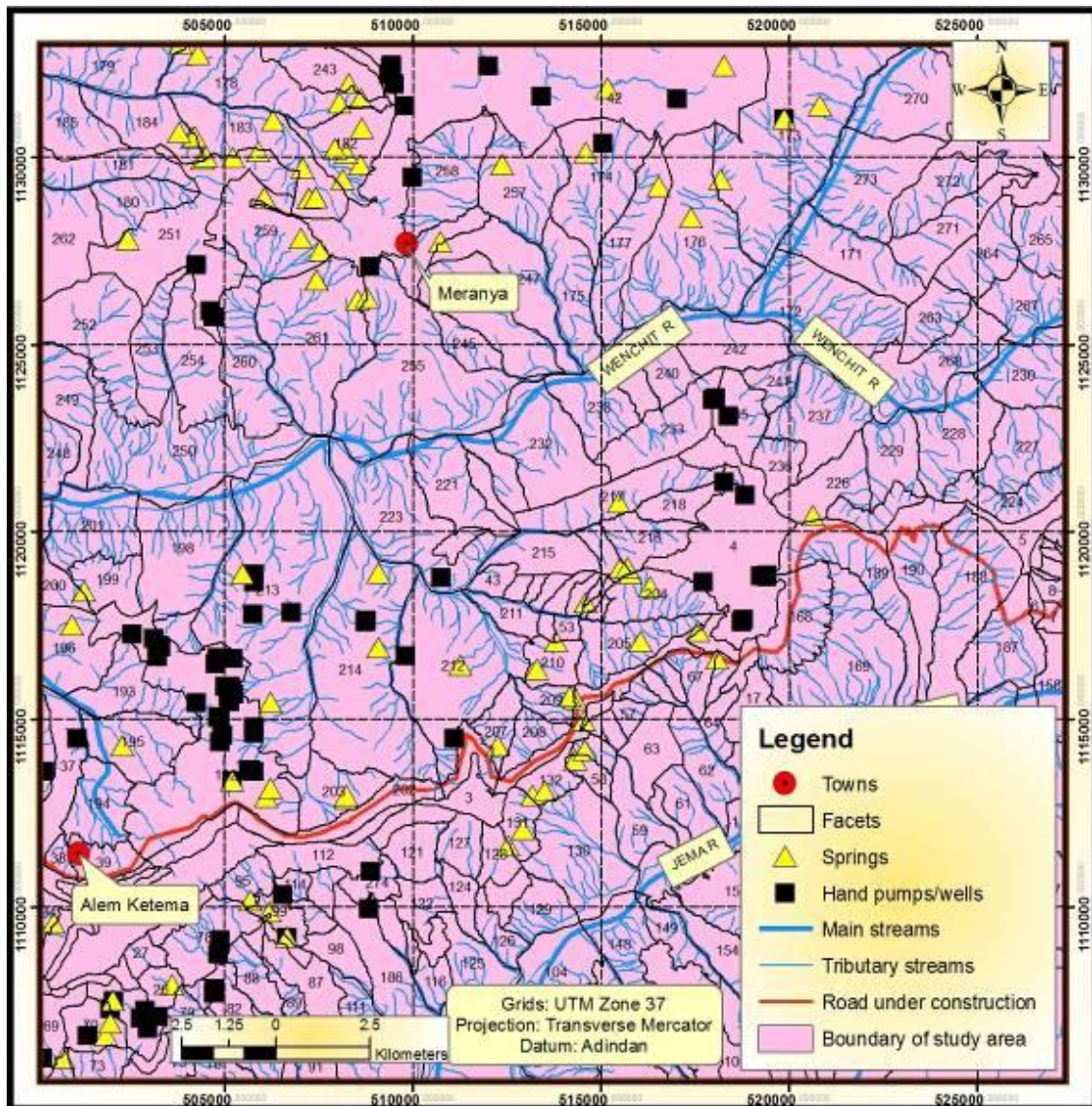


Fig 7.7 Illustration of surface and ground water potential of the study area

7.3 External Triggering Factors Evaluation

The most important external parameters which may trigger instability in slopes and considered in the present study are rainfall, seismicity and manmade activities.

7.3.1 Seismicity

Seismicity produces ground acceleration which results into landslides or slope failures (Keefer, 2000; Parise and Jibson, 2000 as cited in Raghuvanshi *et al.*, 2014; Bommer and Rodriguez, 2002).

The ground acceleration can be related to the intensity of the seismic activity. Hays (1980 as cited in Raghuvanshi *et al.*, 2014) developed a relationship between intensity of earthquake, based on Modified Mercalli intensity scale, and the ground acceleration (Fig. 7.8). This provides indications of g – values; ground motion expressed in terms of gravitational accelerations appropriate to engineering calculations (Johnson and DeGraff, 1991 as cited in Raghuvanshi *et al.*, 2014).

The intensity of earthquakes in the present study area was determined from the seismic map of Ethiopia as shown in Fig 1.8 in Chapter One. Thus, based on the relationship between intensity of earthquake (Modified Mercalli intensity scale) and the ground acceleration, SSEP ratings were assigned as presented in Table 7.7.

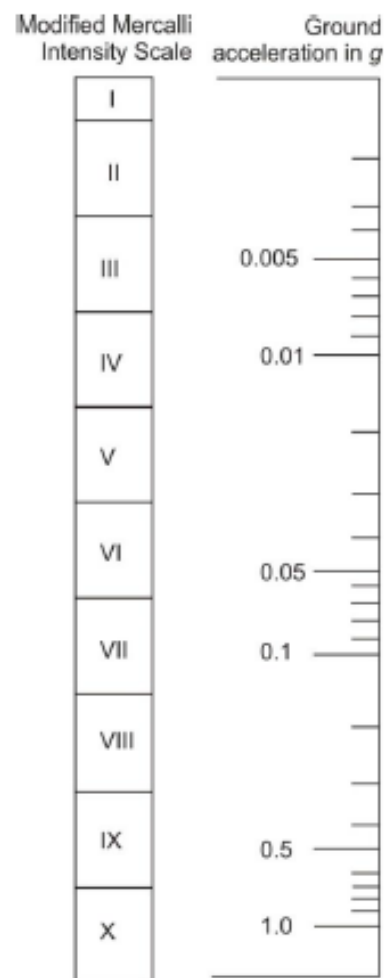


Fig 7.8 Relationship between intensity of earthquake, based on Modified Mercalli intensity scale, and the ground acceleration.

Based on Fig 1.8 and Fig 7.8, the present study area lies in a Modified Mercalli intensity scale of VIII and the estimated horizontal earthquake acceleration comes out to be 0.1 - 0.2g,

with an average value 0.15g. Hence, based on Table 7.7, corresponding rating was assigned for seismicity as given in Annexure I.

7.3.2 Rainfall

Field observation, consultation with local people, and information obtained from Merhabete and Mida Weremo Weredas Agriculture Development Offices during the present study, indicates that the majority of the landslide and flood hazards in the study area occurred during rainy season followed by heavy rainfall (Annexures XI, XII, XIII).

Thus, rainfall can be considered as an important slope instability triggering external parameter in the study area. This is the reason why slope failure increases during the rainy season in the area.

The rainfall recharges the groundwater and in general saturates the slope. In rock slopes the groundwater within the discontinuities develops water pressure which results into decrease of shear strength along the discontinuity planes (Hoek and Bray, 1981).

Also, groundwater lubricates the discontinuity surfaces thus facilitating the process of rock sliding. In soil slopes after saturation from rain water the weight of soil mass increases and thus it adds to the instability of the soil mass. Besides, groundwater helps in pore water pressure development within the soil mass which again aggravate instability (Arora, 1997 as cited in Raghuvanshi *et al.*, 2014).

In order to incorporate rainfall effect in SSEP rating scheme mean annual rainfall was considered as a means to assign ratings. The long-term average annual precipitation in the study area as obtained from Alemketema meteorology station is 1038 mm/year; from Meragna meteorology station, the average annual precipitation is 1049 mm/year and from Jihur meteorological station the average precipitation is 778 mm/year (Annexure V). This indicates that the mean annual rainfall in the study area falls within the moderate class (i.e. 701 - 1100 mm) of the SSEP rating scheme (Table 7.7).

Accordingly, the corresponding SSEP rating was assigned for mean annual rainfall. Further, the rain induced manifestation on slope such as; gully formation, toe erosion, stream bank erosion etc. was also considered while assigning ratings for rainfall (Fig 7.9).

As can be observed from Fig 7.9, the major part of the manifested area (57 - 59 %) is affected by gully and stream bank erosion; and about 1 % is manifested to be slope toe erosion.

In order to assess the impact of rainfall on slope instability factors such as; type of slope material, discontinuity orientation with respect to slope, slope morphometry was also considered (Table 7.7) and (Fig 7.10).

Tab 7.7 Slope Stability Susceptibility Evaluation Parameter (SSEP) Rating Scheme for Eternal Parameters

(a) Rain Fall			(b) Seismicity	
(i) Mean annual rainfall (mm)			Ground acceleration*	Rating
Class	Mean annual rainfall (mm)	Rating	1 - 0.5g	2.0
Very High	> 1500	0.75	0.5 - 0.1g	1.5
High	1101 - 1500	0.60	0.1 - 0.05g	1.0
Moderate	701 - 1100	0.30	0.05 - 0.01g	0.8
Low	300 - 700	0.20	0.01 - 0.005g	0.4
Very low	< 300	0.10	< 0.005	0.4
(ii) Rainfall induced manifestation on slope				
Surface Traces				Rating
Slope Toe erosion – Toe of the slope is eroded by stream flow, Surface material overhangs and prone for failure.				0.25
Stream bank erosion – Stream water has undercut the banks and made the sides of the slope hang.				0.15
Gully erosion over the slope face				0.10
No Rain induced manifestation on slope				0.00
(iii) Slope Material				
Description				Rating
Soil mass – Rainfall will saturate soil mass and pore water pressures will develop.				0.25
Disintegrated – heavily broken rock mass. Much of the rain water will seep into the rock mass and will recharge groundwater considerably.				0.2
Blocky/ Disturbed – folded and/or faulted with angular blocks formed by many intersecting discontinuity sets.				0.15
Very Blocky – Partially disturbed rock mass having four or more discontinuity sets.				0.1
Blocky – Undisturbed rock mass consisting of cubical blocks formed by three orthogonal discontinuity sets.				0.05
(iv) Discontinuity Orientation with respect to slope				
Soil Mass				0.25
More than one discontinuity dipping into the hill or the bedding joint/discontinuity dipping into the hill.				0.25
At least one discontinuity dipping into the hill. Which may or may not be a bedding joint.				0.12
None of the discontinuities dips into the hill.				0.00
Rainfall adjustment factor for slope morphometry #				
Class	Value Range		Adjustment factor	
Escarpment/cliff	> 45 ⁰		0.1	
Steep slope	35 ⁰ - 45 ⁰		0.3	
Moderately steep slope	25 ⁰ - 35 ⁰		0.5	
Gentle slope	15 ⁰ - 25 ⁰		0.8	
Very gentle slope	< 15 ⁰		1.0	
# Rainfall adjustment factor for slope morphometry has to be multiplied with Rainfall rating after summing up (i, ii, iii and iv).				

Thus, from Fig 7.10 it can be deduced that about 13.3% of the outcropped area is soil deposit, 50.3% is disintegrated, and 36.4% is blocky disturbed. Accordingly, ratings were assigned for each element within individual facet, and the summary of SSEP ratings assigned to individual facets for rain fall is presented in Annexure I.

7.3.3 Man made Activities

In addition to natural triggering parameters, manmade activities also increase the potential instability of the slopes (Wang and Niu, 2009 as cited in Raghuvanshi *et al.*, 2014). Manmade activities in hilly terrains which affect the slope stability conditions are the developmental activities such as; road or building construction and cultivation activities. All these activities results into increasing moisture in the soil or rock mass and in changing the slope form.

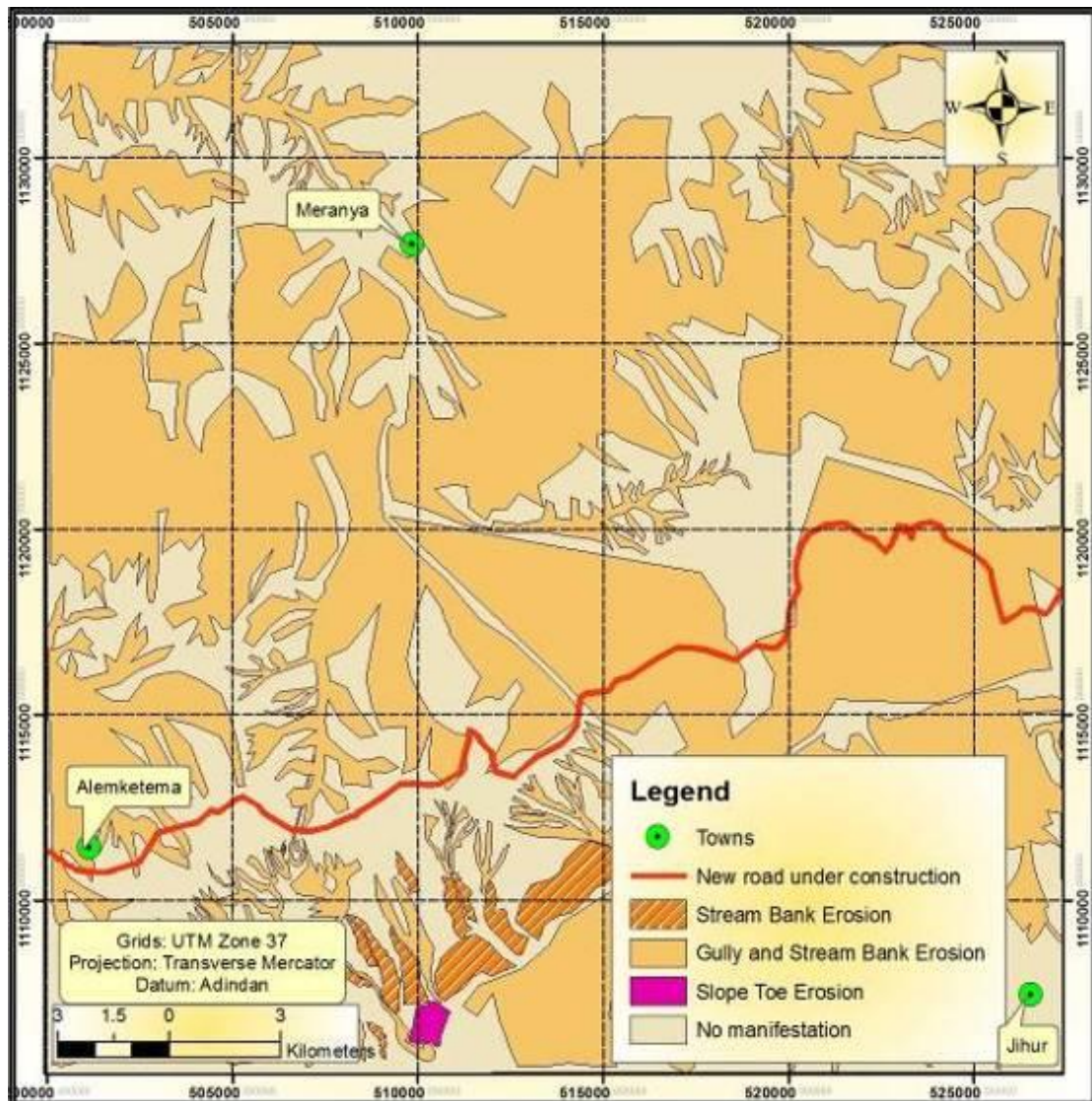


Fig 7.9 Rain induced manifestation map of the study area

Road or building construction involves cutting or blasting of slope material which is often carried out in an unplanned manner. Normally, slopes are cut steep and, in general, toe support is removed thus, the soil or rock mass overhangs which may fail easily. Besides, the excavated slope material very often is dumped on down slopes in an unplanned manner (Plate 6.19 in Fig 6.8 in Chapter six). Such loose dumped material is prone for failure when saturated by rain water (Raghuvanshi *et al.*, 2014).

According to Raghuvanshi *et al.* (2014), cultivation over slopes also increases instability by increase in moisture of the soil mass due to irrigation practice. For cultivation purpose hill slopes are made flat and cut into terraced land (Plate 6.19 in Chapter six). In general, such dressing of slopes into terraced design stabilizes the slopes. However, poor irrigation practice on such terraced land may lead to excessive recharge of groundwater which may result into instability of the slope.

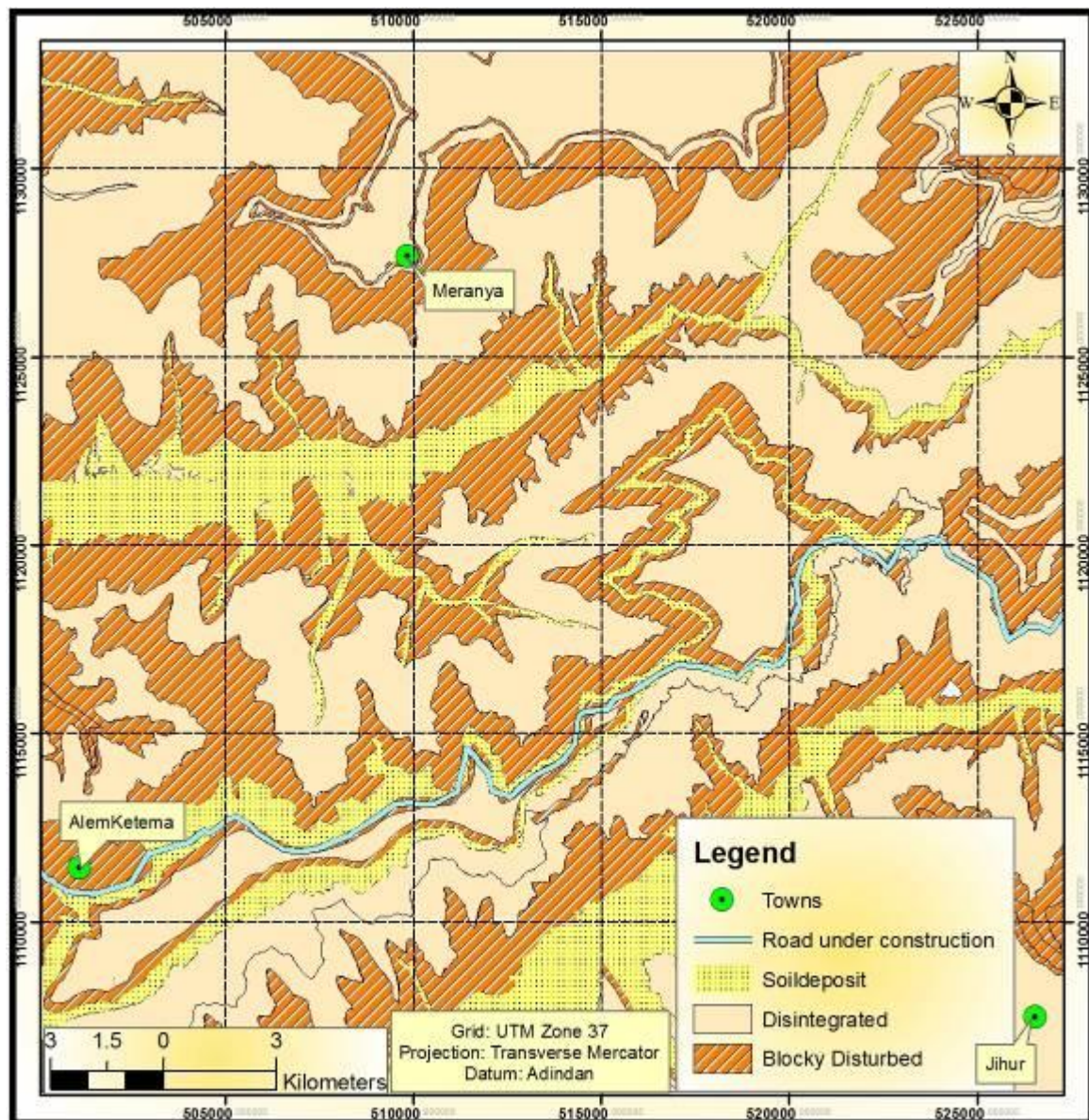


Fig 7.10 Slope material as rainfall parameter

Thus, while assigning SSEP ratings above mentioned factors were considered. Facet wise observations were made for such developmental activities to know in what manner the slopes were cut, how the excavated slope material was disposed off and what type and in what manner slope stabilization and drainage measures were adopted.



Plate 7.1 Photo showing the excavation activities taking place during field work

Besides, for cultivation type of irrigation being practiced was considered. Accordingly SSEP ratings were assigned for manmade activities (Annexure - I).

The main manmade activities in the present study area are: developmental activities (such as; excavations for road construction), and cultivation activities (such as intensive farming and setting fire to vegetation to prepare land for farming).

Based on the site observation in the present study and from the secondary data analysis, the major developmental activities in the present study can be summarized as; dumped excavated material, soil mass cut on gentle slope, moderate steep soil mass cut, steep soil mass cut, rock mass cut in gentle slope, moderate steep rock mass cut, and steep rock mass cut.

Moreover, the cultivation activities in the study area can be reviewed as densely cultivated, and sparsely cultivated. Some of the main man made activities that are observed in the present study area are shown in Plate 7.2, and the details are illustrated in Fig 7.11.



Plate 7.2 Photo showing manmade activities taking place during field work

Fig. 7.11 shows the manmade activities in the study area. Perusal of Fig. 7.11 clearly indicates that 80 % area is covered by cultivation activities whereas 20% area is occupied by construction activities. 1.5% slope is cut steep in rock, 35% is sparsely cultivated land, and 44.9% land is densely cultivated.

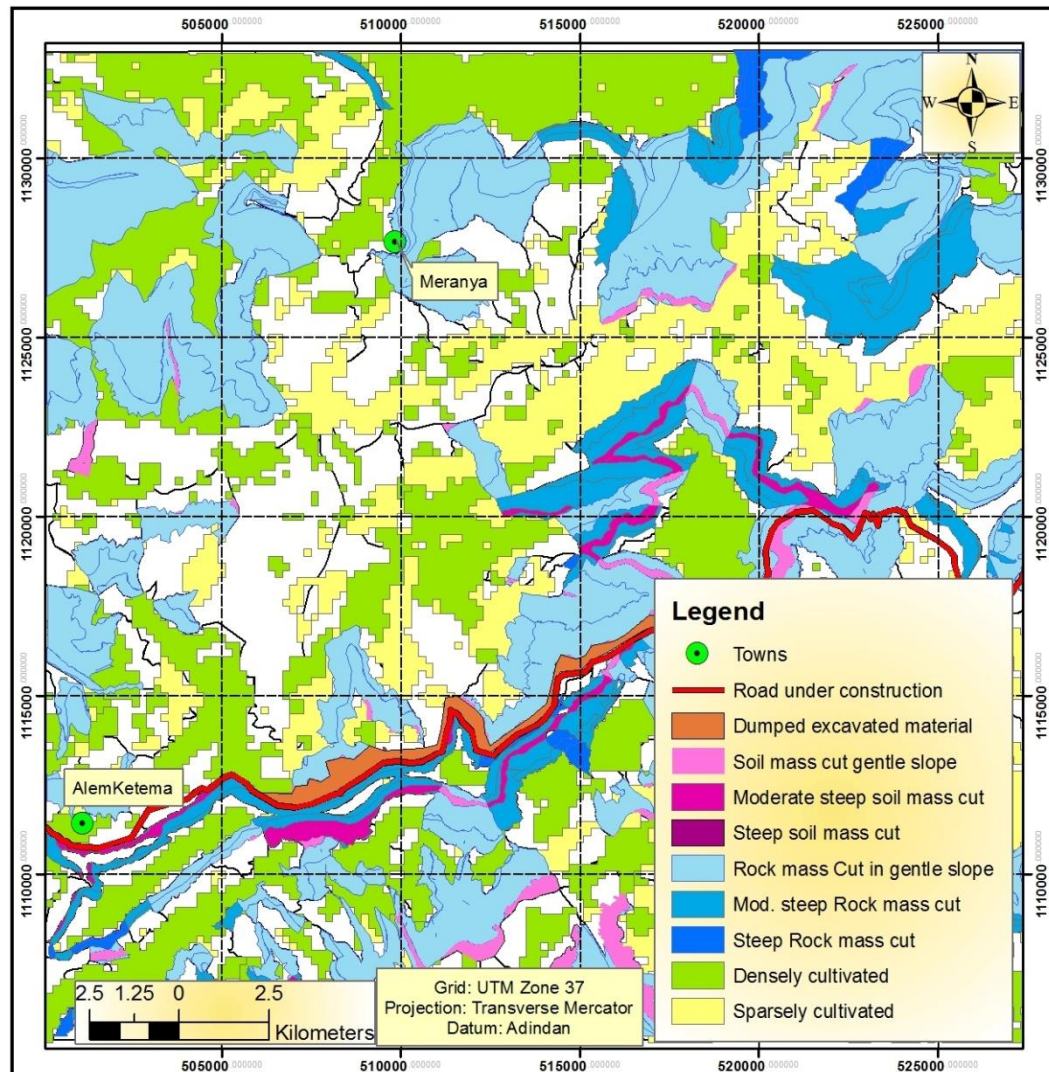


Fig 7.11 Manmade activities in the study area

7.4 Landslide Evaluation

In order to evaluate landslide hazard zonation of an area individual facet wise ratings for causative intrinsic parameters and external triggering parameter ratings were summed up. The sum total of all ratings for causative intrinsic parameters and external triggering parameter are represented as Evaluated landslide hazard (ELH) (eq.7.1).

$$ELH = \text{Sum of Ratings of intrinsic parameters (relative relief + slope morphometry + slope material + structural discontinuity + Landuse and landcover + Groundwater + Sum of ratings of External parameters (Rainfall + Seismicity + Manmade activities))} \dots\dots eq. 7.1.$$

The ELH was categorized into five classes as presented in Table 7.8. The SSEP rating scheme facilitates to evaluate an area for landslide hazard zonation under existing and/ or anticipated adverse conditions. The anticipated adverse conditions to which the given area

can be subjected may be represented when there will be heavy rains or when the slopes will be subjected to dynamic loading due to seismic activities or both.

Tab 7.8 Evaluated Landslide Hazard

Landslide Hazard Zone	Landslide Hazard Class	Evaluated Landslide hazard
Very high hazard zone (VHHZ)	V	> 12
High hazard zone (HHZ)	IV	12 - 8
Moderate hazard zone (MHZ)	III	7.9 - 5
Low hazard zone (LHZ)	III	4.9 - 2
Very low hazard zone (VLHZ)	I	< 2

Accordingly, the present study area was evaluated and the result indicates that the whole study area falls in to two landslide hazard classes, typically, landslide hazard class III and IV. The minimum Evaluated Landslide Hazard value resulted is, 5.9 which shows Landslide Hazard Class of III and Moderated Hazard Zone, whereas, the maximum Evaluated Landslide Hazard value obtained is 10.4 that indicates Landslide Hazard Class of IV and High Hazard Zone (Annexure I).

7.5 Landslide Zonation

As discussed in the preceding sections above, the ELH for an individual facet was obtained by adding the ratings of individual intrinsic factors and external triggering parameter obtained from the SSEP rating scheme. After collecting primary data for the rating values facet wise and evaluating them, the study area was divided into classes of hazard zones as per the SSEP rating scheme and the Landslide hazard zonation map of the study area was produced in GIS environment. The produced Landslide Hazard Zonation (LHZ) map is illustrated in Fig. 7.12 below.

From Fig. 7.12 it can be clearly seen that, about 66.9 % of the study area is found within the High Hazard Zone and the remaining 33.1 % falls into Moderate Hazard Zone. This indicates that slope instability in the study area is a serious problem as no area is free of landslide hazard. Field observation during present study, literature review on previous works, as well as reports on damages resulted by landslide (both from Merhabete Wereda and Mida Weremo Weredas) confirms that no place in the study area is free of slope instability problems (Annexure XI, XII, and XIII).

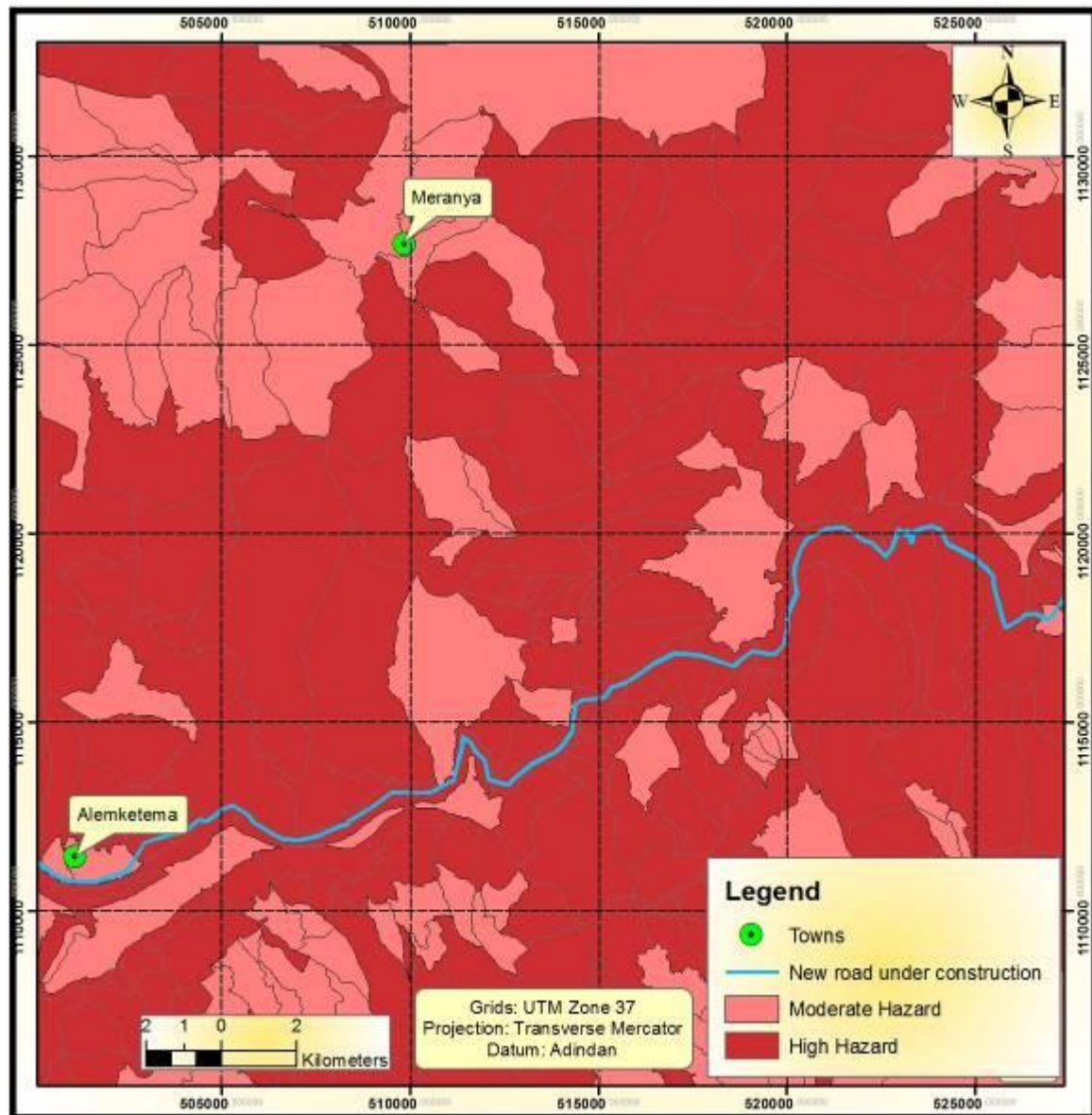


Fig 7.12 Landslide Hazard Zonation map of the study area

High Hazard Zones

The total area in the present study covers about 756km². About 66.9 % of the area is found within the High Hazard Zone that is about 506 km² area. The high hazard zones in the study area generally are characterized by moderate steep to steep slopes and significant groundwater surface traces such as flowing and dripping. The slope material covering in this zone are mainly soil slope deposits and disintegrated rock mass. The rock mass has moderate weathering and the effect of structural discontinuities in inducing slope instability in this zone is also one of the important factors.

Field observation, data analysis, and the results of the present study indicate that this zone is highly susceptible landslide hazards and hence, proper care and concern has to be taken during design and planning of future developmental activities and irrigation practices.

Moderate Hazard Zone

About 33.1 % of the present study area falls in to Moderate Hazard Zone which is about 250 km². The Moderate Hazard Zones in the study area are generally characterized by relatively gentler slopes with dry to low groundwater surface traces. The slope material in this zone alluvial soil deposit, and blocky disturbed (mainly) and disintegrated rock mass; however, the degree of weathering is less (i.e fresh to slightly weathered) and the effect of structural discontinuities is relatively less.

7.6 Validation of LHZ Map

In the present study area, a total of about 137 past landslide events were inventoried (Table 6.2 in Chapter Six). Landslide inventory map of the study area was also prepared as shown in Fig 6.1 (Chapter Six). Considering both intrinsic and extrinsic landslide triggering factors, landslide hazards in the study area was evaluated and landslide hazard zonation map of the study area was produced as illustrated in Fig 7.12.

In order to check the validity of the produced map, Landslide Inventory map of the study area (Fig 6.1) was overlaid on Landslide Hazard Zonation map (Fig 7.12) of the study area as shown in Fig 7.13.

Fig 7.13 shows that among the total number of past landslide events identified in the study area, 110 past landslide events have fallen in High hazard zone whereas 27 past landslide events have been identified in moderate hazard zone. This shows that 80.3 % of the total past landslide events identified are found within High hazard zone.

However, around 20 % of the past landslide activities has not fallen in to High Hazard Zone. Rather, it falls into Moderate Hazard Zone. It is obvious that the technique followed in the present study (SSEP) is the fastest technique that is applied to cover a large area within a short time. In the present study, the scale of work and produced map is 1:50,000 which is medium scale.

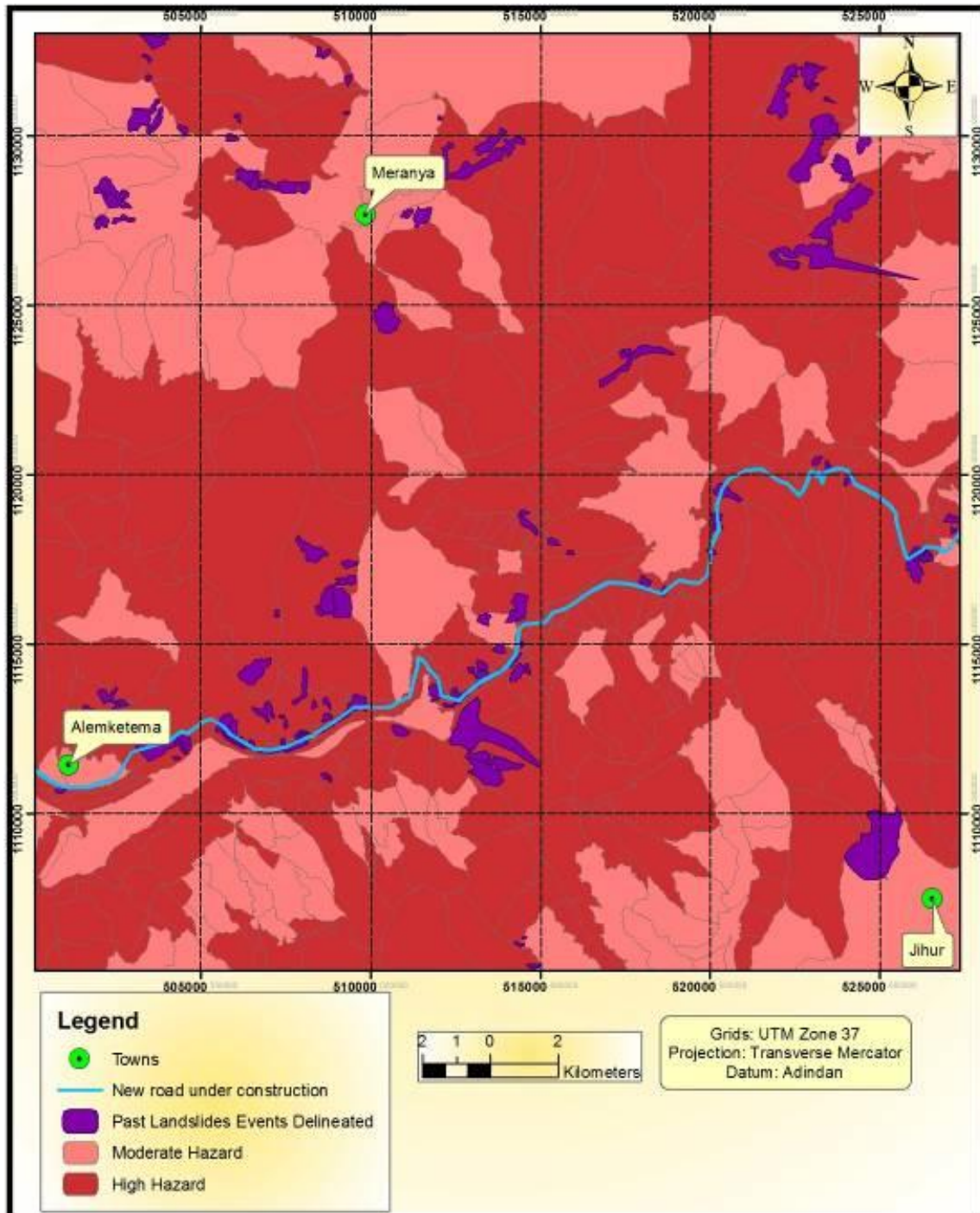


Fig 7.13 Map showing past landslide events overlaid on LHZ map of the study area

As mentioned above, the total area covered is around 756 km² (which is one full topographic sheet). Therefore, the scale of mapping being medium, might be one of the reasons why the remaining 20 % of past landslide events have not fallen in to High Hazard Zone. In addition, the topographic map of the study area available (as purchased from Ethiopian Mapping Agency) has only 40 m of contour interval. All the thematic and pre-field maps were prepared based on this map and it might have reduced the prediction of the relative contribution of Slope Morphometry as it was prepared from this topo map. In general, it is fair

and reasonable to accept the 20 % unconformity since the eighty % of past landslides activities have fallen in the high hazard zone satisfying the intended purpose.

Thus, the satisfactory agreement confirms the rationality of considered governing parameters, and the validity of the prepared LHZ map of the study area.

7.7 Remedial Measures and Recommendation

Ethiopia is prone to natural risks like landslides, rockfalls, and flooding. Consideration should be given to both slow- and rapid-onset disasters; to large-scale as well as localized but frequently occurring disasters such as landslides, flash floods, fires, and storms, bearing in mind that they may require different approaches (Jiri Sima et al., 2009)

The causes of slope instability in the present study area are wide and multi-directional; therefore, integrated approach of remedial measures may be more appropriate to mitigate the possible landslide hazard in the area.

Residual-colluvial soils and scree accumulations at the toes of quickly deteriorating rock walls can have a considerable volume and a low stability reserve. They serve as a source of destructive mud/debris flow (Plate 6.12). The risk of mud/debris flow considerably increases under conditions of high precipitation, or seasonally or by occasional storms. Besides local, predominantly shallow landslides, colluvial soils and scree are also activated as a part of complex medium (Plates 6.1 to 6.6) or large landslides.

Besides local, predominantly shallow landslides, colluvial, Colluvial-alluvial soil accumulations at places are rich in clays and organic matter. That makes them highly problematic for building. Moreover the river basin bottom areas are seasonally flooded.

High deforestation and unplanned irrigation and developmental activities are taking place in the present study area (Plate 7.2), and slow disaster of intensive erosional stripping of soils, is occurring in areas recently deforested.

The intensity of earthquakes in the present study area (as determined from the seismic map of Ethiopia Fig 1.8) is a Modified Mercalli intensity scale of VII (8 MM) which is very strong that makes it difficult to stand; furniture will be broken; damage is negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures;

considerable in poorly built or badly designed structures; with some chimneys broken. It is also noticed by people driving motor cars.

Educating public about the causes and characteristics of landslides and preparedness measures is necessary. It can be created through sensitization and training programme for community, architects, engineers, builders, masons, teachers, government functionaries' teachers and students (Vihar, 2006). Some methods of rock fall hazard mitigation include Catch ditches, Benches, Scaling and trimming, Cable and mesh, Shotcrete and gunite, Anchors, Bolts, Dowels, and Controlled blasting.

Due to the speed and intensity of most debris flows, they are very hard to stop once they have started. However, methods are available to contain and deflect debris flows primarily through the use of retaining walls and debris-flow basins. Other mitigation methods include modifying slopes (preventing them from being vulnerable to debris-flow initiation through the use of erosion control), revegetation, and the prevention of wildfires, which are known to intensify debris flows on steep slopes.

Stability increases when ground water is prevented from rising in the slide mass by: directing surface water away from landslide, draining ground water away from the landslide to reduce the potential for rise in ground water level, covering the landslide with an impermeable membrane, and /or, minimizing surface irrigation. Slope stability is also increased when weight or retaining structures are placed at the toe of the landslide or when mass (weight) is removed from the head of the slope (USGS, 2008).

Retaining walls can be built to stop land from slipping (these walls are commonly seen along roads in hill stations). These are constructed to prevent smaller sized and secondary landslides that often occur along the toe portion of the larger landslides (Vihar, 2006). They are also used whenever space requirements make it impractical to slope the side of an excavation, or to prevent sloughing of loose hill slope soils onto roads or property (USGS, 2008).

Therefore, consideration has better be given to all these factors in the area while designing future developmental activities.

The proposed development should take into consideration the protection and conservation of the natural resources of the area. Particular interest should be paid to soil conservation and

groundwater protection using the appropriate agricultural methods to decrease soil erosion, and applying afforestation - reforestation activities is also important.

Increasing environmental care and protection of natural resources will contribute to better living standards of the people living within the basin and also to an increase in their working output leading to an increase in food security in the study area.

CHAPTER VIII

CONCLUSION AND RECOMMENDATION

8.1 Conclusion

The present study area is located at about 120 km north of Addis Ababa which is situated in the north-eastern part of Jemma River basin (sub - basin of Abay) in Central Ethiopia. Specifically, it is present in the Northern part of North Showa Zone and Southern part of South Wallo Zonal Administration in Amhara National Regional State. Geographically the study area is bounded from north to south by latitudes 1132955mN (10⁰15'N) and 1105376mN (10⁰00'N) and from East to West by longitudes 527387mE (39⁰15'E) and 500000mE (39⁰00'E). In the study area, the new road under construction extends about 39 km from Alemketema town (with a geographic coordinates of E 37 0500000, N 1111420 and Elevation of 2249m amsl) to Wenchit and SI - E (around Ambat village) area (with a geographic coordinates of E 37 0527392, N 1118529 and Elevation of 2000m amsl).

The area is characterized by deeply dissected gorges, plateau and high altitude continuous chain of mountains and ridges. The major rainfall in the study area occurs during the summer season mainly from June to September. The rainfall peaks in July or August is at about 330 to 520 mm per month. Reports on damages caused by floods and landslides (obtained from Agriculture and Rural Development offices of Merhabete Wereda and Mida Weremo Wereda), as well as previous studies conducted in the area indicates that, it is during this peak rain fall time that landslide and flood hazards create damages to farm land, houses and property in the study area.

It has been reported by various researchers that the hilly and mountainous terrains of the highlands of Ethiopia are characterized by variable topographical, geological, hydrological (surface and groundwater) and land-use conditions, and are frequently being affected by rainfall-triggered slope failures. However, much has not been reported on earthquake triggered landslides in the country. Thus, the present study was conceived with the idea of incorporating the effect of both rainfall and earthquake in triggering landslides in the present study area.

The major objectives of the present study was to prepare Landslide Hazard Zonation (LHZ) map of the study area, by considering both inherent causative and external triggering factors and then, to check the validity of the produced LHZ map. It was also intended to identify the

types of landslides occurring in the study area, and to understand the possible factors leading to slope failures in the area.

To achieve these objectives a thorough literature review was conducted to develop a conceptual framework of the problem and to identify the appropriate technique required to achieve the goal within the given time. Accordingly, Slope Stability Susceptibility Evaluation Parameter (SSEP) rating scheme was adopted to prepare LHZ map in the present study.

As a general methodology, desk study, field study, and data compilation, analysis and interpretation was conducted. Under desk study, procurement of secondary data and preparation of thematic maps (such as: facet, relative relief, and slope morphometry) and pre-field maps (such as: slope material, landuse/ landcover, and landslide inventory) were carried out. During field study, collection of various primary data and finalization of the pre-field maps were conducted. Moreover, field observations and data collections were made to identify the type of landslides occurring in the study area. The identified landslide types in the present study area include; Rock falls, Rock slides, Soil slides, and Flows. After field work, data analysis, interpretation and compilation of report was undertaken.

In applying SSEP rating scheme, the relative contribution of each of the intrinsic slope instability causative factors and the effect of each extrinsic triggering factors were evaluated and ratings were assigned accordingly facet wise for each factor. The sum total of all ratings for causative intrinsic parameters and external triggering parameters were represented as Evaluated Landslide Hazard (ELH). According to the results of the ELH obtained, the study area is represented by two Landslide Hazard zones; "High Hazard" and "Moderately Hazard" zones.

After collecting primary data for the rating values facet wise and evaluating them, the study area was divided into classes of hazard zones as per the SSEP rating scheme and the LHZ map of the study area was produced in GIS environment. The produced LHZ map of the study area indicates that the study area falls in to two Landslide Hazard Zones (i.e. Moderate Hazard and High Hazard Zones). Over all result of the study indicates that about 66.9 % of the present study area falls within the High Hazard Zone and the remaining 33.1 % falls in Moderate Hazard Zone. In such type of terrain, like the present study area, preparation of LHZ map of the area by considering various slope instability causative and triggering factors and applying various LHZ techniques is mandatory to mitigate landslide hazards effectively.

Such LHZ map may be used as base map for future land-use planning and developmental activities.

Moreover, in the present study, the validity of the prepared LHZ map was checked by overlying Landslide Inventory map over the produced LHZ map. About 80.3 % of the past landslide events inventoried has confirmed the validity of the prepared LHZ map of the study area by falling in the High Hazard Zone.

8.2 Recommendation

Based on the results of the present study, the following recommendations are forwarded:

- LHZ map of the study area prepared in the present study shows that the entire study area falls into High Hazard (66.9%) and Moderate Hazard (33.1%). Since the majority of the area falls into a high hazard zone, it is not possible to avoid the high hazard zone from any developmental activities; rather, systematic efforts have to be made to analyze and manage the causes of disasters, to reduce social and economic vulnerability to hazards, and to improve preparedness for adverse events.
- It is recommended that further LHZ mapping and slope stability analysis be carried out in the area with a larger scale applying different techniques; such as deterministic techniques and considering all possible slope instability causative and triggering parameters in the area.
- It has also been identified that the major landslide and flood hazards have been occurring during rainy season following heavy rainfall. It is known that the rainfall recharges the groundwater and in general saturates the slope. In rock slopes the groundwater within the discontinuities develops water pressure which results into decrease of shear strength along the discontinuity planes (Hoek and Bray, 1981). Also, groundwater lubricates the discontinuity surfaces thus facilitating the process of rock sliding. In soil slopes after saturation from rain water the weight of soil mass increases and thus it adds to the instability of the soil mass. Besides, groundwater helps in pore water pressure development within the soil mass which again aggravate instability (Arora, 1997). Rainfall is an important slope instability triggering external parameter. Therefore, it is recommended that the drainage system for critical slopes must be properly designed and managed. This may include: construction of trench drain, interceptor drain and construction of collection chamber and diverting the water to the existing drainage

systems. Though, such drainage design would require more systematic future studies for individual slopes.

- It has also been observed during field work in the present study that there is big deforestation such as firing and intensive farming on gentle to moderate steep slopes. In general, developmental activities like road construction and cultivation activities are also observed to have affected the stability condition of the slope. Therefore, it is recommended that intensive work needs to be done to increase the awareness of local dwellers about deforestation in causing slope instability in the area, and it is important to regenerate the afforestation and reforestation activities in the area.
- The new road under construction in the study area passes through the soil deposit (slope deposit) that is genetically known as colluvial deposit. Most of the slope sections opened for road construction have failed (slided) and removal of the failed slope material was taking place during field work in the present study. Therefore, it is recommended that detail slope stability evaluation may be undertaken in such places specially, at the deep cut, high fill, steep natural slopes and landslide prone slope sections. Also, it is recommended not to dump the waste material down the slope along the road cut as it adds to slope instability and triggers new failures.
- The results generated through this study are based on elaborate field work and by following systematic methodology with standard procedures for its execution. However, all such efforts were made under the limitations of time, finance and resources. Therefore, inaccuracy in findings due to these limitations may not be ruled out. More systematic studies would be required before implementing the results of the present study for planning and development in the area.

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Annexure I Ratings assigned to individual facets for internal and external parameters

Facet Id and Area		SSEP Ratings for Internal Causative Factors						SSEP Ratings for External triggering Factors			Evaluated Landslide Hazard (ELH)	Land slide Hazard Class	Land slide Hazard Zone
Facet ID	Facet Area (m ²)	Relative Relief	Slope Morphometry	Slope Material	Structural Discontinuity	Landuse Land cover	Ground Water	Seismicity	Rain Fall	Man Made Activity			
1	6627559.6	0.1	0.3	0.5	1.4	0.5	0.2	2.0	0.7	0.6	6.3	III	(MHZ)
2	554908.5	0.1	0.3	0.5	0.7	0.8	0.4	2.0	0.7	0.6	6.0	III	(MHZ)
3	1538655.2	0.1	0.3	0.5	0.7	0.6	0.8	2.0	0.7	0.6	6.3	III	(MHZ)
4	10018818.7	0.1	0.3	0.5	0.7	0.5	1.3	2.0	0.7	0.6	6.7	III	(MHZ)
5	1524444.2	0.6	0.3	0.4	1.1	0.9	0.5	2.0	0.7	0.6	7.1	III	(MHZ)
6	347149.6	1.0	0.6	0.6	1.7	1.2	0.4	2.0	0.5	0.6	8.7	IV	(HHZ)
7	494925.7	1.0	0.3	0.8	1.4	0.8	0.4	2.0	0.7	0.6	7.9	III	(MHZ)
8	522796.6	1.0	0.6	0.4	1.9	1.2	0.6	2.0	0.5	0.6	8.8	IV	(HHZ)
9	100504.5	1.0	0.6	0.4	1.9	1.5	0.4	2.0	0.5	0.6	8.9	IV	(HHZ)
10	285117.7	1.0	0.6	0.4	1.5	1.4	0.5	2.0	0.5	0.6	8.6	IV	(HHZ)
11	167219.8	1.0	0.6	0.4	1.5	0.8	0.3	2.0	0.6	0.6	7.9	III	(MHZ)
12	81323.5	0.8	1.0	0.4	1.7	0.8	0.4	2.0	0.4	0.9	8.2	IV	(HHZ)
13	209654.2	0.6	0.6	0.6	1.5	0.8	0.7	2.0	0.5	0.6	8.0	IV	(HHZ)
14	48502.6	0.6	0.6	0.4	1.6	0.9	0.3	2.0	0.5	0.6	7.5	III	(MHZ)
15	343271.9	1.0	0.6	0.6	1.5	0.7	0.4	2.0	0.5	0.6	8.0	IV	(HHZ)
16	282839.8	0.1	0.3	0.8	1.1	0.6	0.5	2.0	0.7	0.6	6.7	III	(MHZ)
17	1378893.4	1.0	0.6	0.8	1.5	1.0	0.6	2.0	0.5	0.6	8.6	IV	(HHZ)
18	241349.9	0.6	0.3	0.6	1.0	1.2	0.8	2.0	0.9	0.8	8.2	IV	(HHZ)
19	459341.8	1.0	0.3	0.6	1.1	0.8	0.6	2.0	0.9	0.8	8.0	IV	(HHZ)
20	314939.5	0.8	0.6	0.6	1.4	0.7	0.7	2.0	0.1	0.9	7.8	III	(MHZ)
21	305705.8	1.0	0.6	0.6	1.4	0.6	0.8	2.0	0.1	0.6	7.7	III	(MHZ)
22	368155.5	0.8	0.3	0.4	1.0	0.9	0.6	2.0	0.7	0.6	7.4	III	(MHZ)
23	689713.9	1.0	0.3	0.4	1.0	0.9	0.6	2.0	0.9	0.6	7.7	III	(MHZ)
24	139884.4	0.6	1.0	0.6	1.1	0.8	0.8	2.0	0.4	1.1	8.3	IV	(HHZ)
25	99059.5	0.6	1.7	0.4	1.9	0.8	0.6	2.0	0.7	1.4	10.0	IV	(HHZ)
26	1021523.4	0.6	0.3	0.6	1.8	0.5	1.0	2.0	0.9	0.8	8.5	IV	(HHZ)
27	808634.0	0.8	0.6	0.8	2.0	0.8	1.0	2.0	0.1	0.8	8.8	IV	(HHZ)
28	373523.1	0.8	0.6	0.8	2.0	0.6	0.9	2.0	0.1	0.9	8.5	IV	(HHZ)
29	277522.0	0.6	1.0	0.4	1.6	0.7	0.5	2.0	0.4	0.8	8.1	IV	(HHZ)
30	455165.9	0.6	1.0	0.6	1.3	0.7	0.9	2.0	0.4	0.1	7.7	III	(MHZ)
31	865506.3	0.2	0.3	0.9	2.5	0.7	1.1	2.0	0.9	0.9	9.5	IV	(HHZ)
32	678021.0	0.6	1.7	0.6	2.0	0.8	0.7	2.0	0.2	1.4	9.9	IV	(HHZ)
33	805929.1	0.2	0.3	0.9	1.2	1.0	0.9	2.0	0.9	0.9	8.1	IV	(HHZ)
34	827332.8	0.6	0.3	0.6	0.8	0.8	0.7	2.0	0.9	0.9	7.4	III	(MHZ)
35	855917.4	0.2	0.6	0.8	2.3	0.7	1.4	2.0	0.1	0.8	8.9	IV	(HHZ)
36	1218618.2	0.8	1.0	0.6	2.1	0.8	0.9	2.0	0.4	1.1	9.7	IV	(HHZ)
37	3206491.2	1.0	0.3	0.6	1.2	0.7	0.9	2.0	0.7	0.6	8.0	IV	(HHZ)
38	596172.2	0.6	0.3	0.6	1.1	0.5	0.7	2.0	0.8	0.8	7.5	III	(MHZ)
39	1641655.5	0.2	0.3	0.4	1.1	0.7	0.7	2.0	0.8	0.8	7.1	III	(MHZ)
40	5215620.1	0.1	0.3	0.4	0.7	0.8	0.6	2.0	0.6	0.6	6.0	III	(MHZ)
41	11696697.0	0.1	0.3	0.6	0.7	0.6	0.8	2.0	0.7	0.6	6.3	III	(MHZ)
42	27985707.9	0.2	0.3	0.6	0.7	0.5	1.5	2.0	0.7	0.6	7.0	III	(MHZ)
43	812276.7	0.6	0.3	0.6	2.0	0.5	0.8	2.0	0.9	0.8	8.4	IV	(HHZ)
44	370683.0	0.6	0.3	0.8	2.2	1.0	0.6	2.0	0.9	0.8	9.1	IV	(HHZ)
45	250334.0	0.1	0.3	0.8	2.2	1.2	0.7	2.0	0.9	0.8	8.9	IV	(HHZ)
46	455083.3	1.0	0.3	0.8	2.2	1.0	0.7	2.0	0.9	0.8	9.7	IV	(HHZ)
47	562106.5	1.0	0.6	0.8	1.9	1.0	0.8	2.0	0.1	0.8	9.0	IV	(HHZ)
48	486339.2	1.0	0.6	0.8	2.0	1.0	0.8	2.0	0.1	0.8	9.0	IV	(HHZ)
49	183505.3	1.0	0.6	0.6	2.0	1.2	0.8	2.0	0.1	0.6	8.9	IV	(HHZ)
50	235334.3	1.0	0.6	0.6	1.9	1.2	1.0	2.0	0.1	0.8	9.3	IV	(HHZ)
51	217259.4	0.8	0.6	0.8	1.9	1.5	0.6	2.0	0.1	0.8	9.1	IV	(HHZ)
52	293876.0	0.8	0.6	0.8	1.4	1.2	0.8	2.0	0.1	0.6	8.1	IV	(HHZ)
53	451505.3	0.6	0.6	0.8	1.4	1.0	0.8	2.0	0.1	0.6	7.8	III	(MHZ)
54	291684.1	0.2	1.0	0.6	1.9	0.8	1.1	2.0	0.4	0.9	8.8	IV	(HHZ)

Annexure I continued...

Facet Id and Area		SSEP Ratings for Internal Causative Factors						SSEP Ratings for External triggering Factors			Evaluated Landslide Hazard (ELH)	Landslide Hazard Class	Landslide Hazard Zone
Facet ID	Facet Area (m ²)	Relative Relief	Slope Morphometry	Slope Material	Structural Discontinuity	Landuse Land cover	Ground Water	Seismicity	Rain Fall	Man Made Activity			
55	223923.4	1.0	1.0	0.6	2.1	0.8	0.7	2.0	0.4	1.1	9.7	IV	(HHZ)
56	451054.3	1.0	1.0	0.6	2.1	1.2	0.7	2.0	0.4	1.1	10.2	IV	(HHZ)
57	601990.7	1.0	1.0	0.6	2.1	1.3	0.6	2.0	0.4	1.1	10.2	IV	(HHZ)
58	807347.1	1.0	0.6	0.6	2.2	0.8	1.1	2.0	0.1	0.9	9.2	IV	(HHZ)
59	2425031.7	1.0	0.3	0.6	1.0	0.8	0.8	2.0	0.9	0.9	8.2	IV	(HHZ)
60	628799.4	1.0	0.3	0.6	1.8	0.8	0.5	2.0	0.9	0.9	8.8	IV	(HHZ)
61	2048380.2	1.0	0.3	0.6	1.6	0.9	0.8	2.0	0.9	0.9	8.9	IV	(HHZ)
62	2733875.8	1.0	0.3	0.6	1.8	0.9	0.6	2.0	0.9	0.9	8.9	IV	(HHZ)
63	2505303.0	1.0	0.3	0.8	1.4	0.6	0.5	2.0	0.7	0.6	7.9	III	(MHZ)
64	1030569.5	1.0	0.6	0.6	1.0	0.8	0.8	2.0	0.1	0.9	7.7	III	(MHZ)
65	613308.0	1.0	0.6	0.8	2.2	1.2	0.6	2.0	0.1	0.9	9.4	IV	(HHZ)
66	686402.7	0.6	1.0	0.6	2.2	1.3	0.9	2.0	0.4	1.1	10.1	IV	(HHZ)
67	1348593.0	1.0	0.6	0.8	1.0	1.2	0.7	2.0	0.1	0.9	8.2	IV	(HHZ)
68	568673.2	1.0	0.6	0.8	2.1	1.4	1.1	2.0	0.1	0.9	9.9	IV	(HHZ)
69	1742427.4	0.8	0.3	0.8	1.3	0.6	0.8	2.0	0.9	0.9	8.2	IV	(HHZ)
70	1893002.1	0.6	0.3	0.6	1.2	0.6	1.4	2.0	0.9	0.8	8.4	IV	(HHZ)
71	2093292.3	0.8	0.3	0.6	1.2	0.6	1.4	2.0	0.9	0.8	8.6	IV	(HHZ)
72	350160.8	0.8	0.3	0.6	1.4	0.7	1.3	2.0	0.7	0.6	8.4	IV	(HHZ)
73	1236057.9	1.0	0.6	0.8	1.5	1.0	0.9	2.0	0.1	0.6	8.4	IV	(HHZ)
74	421661.8	0.6	1.0	0.6	1.4	1.0	0.9	2.0	0.4	0.9	8.7	IV	(HHZ)
75	1306914.2	0.6	0.3	0.8	1.0	0.8	0.5	2.0	0.7	0.6	7.3	III	(MHZ)
76	1209357.7	1.0	0.3	0.4	1.2	0.7	0.8	2.0	0.7	0.6	7.7	III	(MHZ)
77	341105.9	1.0	0.6	0.6	1.7	1.2	1.1	2.0	0.1	0.6	8.8	IV	(HHZ)
78	3272571.9	0.8	0.3	0.8	1.9	0.6	0.9	2.0	0.9	0.8	8.9	IV	(HHZ)
79	939680.2	1.0	0.3	0.6	1.9	1.1	0.9	2.0	0.7	0.6	9.0	IV	(HHZ)
80	377896.8	1.0	0.6	0.6	1.9	1.4	1.1	2.0	0.1	0.6	9.2	IV	(HHZ)
81	282263.1	1.0	0.6	0.6	1.6	0.7	0.7	2.0	0.1	0.6	7.8	III	(MHZ)
82	1666190.0	1.0	0.3	0.6	0.8	0.7	1.0	2.0	0.7	0.6	7.7	III	(MHZ)
83	450846.5	0.8	0.3	0.4	1.1	0.7	0.6	2.0	0.7	0.6	7.3	III	(MHZ)
84	1202518.5	1.0	0.3	0.4	1.8	1.0	0.8	2.0	0.9	0.9	9.0	IV	(HHZ)
85	691780.1	1.0	0.6	0.6	2.1	0.9	0.9	2.0	0.1	0.9	9.0	IV	(HHZ)
86	754126.3	1.0	0.3	0.6	1.5	0.7	0.9	2.0	0.9	0.9	8.7	IV	(HHZ)
87	2373469.1	0.2	0.3	0.8	0.8	0.7	0.8	2.0	0.9	0.8	7.3	III	(MHZ)
88	1677107.8	1.0	0.3	0.6	0.9	0.9	0.9	2.0	0.7	0.6	7.9	III	(MHZ)
89	749449.4	0.8	0.3	0.4	1.2	0.8	0.6	2.0	0.9	0.8	7.7	III	(MHZ)
90	614470.0	0.8	0.6	0.6	1.4	0.6	0.7	2.0	0.1	0.9	7.5	III	(MHZ)
91	1067939.6	0.6	0.3	0.8	1.8	0.7	0.7	2.0	0.9	0.9	8.6	IV	(HHZ)
92	464925.4	0.8	1.0	0.4	1.6	0.4	0.8	2.0	0.4	1.1	8.6	IV	(HHZ)
93	2465746.4	0.6	0.3	0.6	1.6	0.8	0.9	2.0	0.9	0.9	8.4	IV	(HHZ)
94	4578096.0	0.6	0.3	0.8	1.7	0.7	1.0	2.0	0.9	0.9	8.8	IV	(HHZ)
95	1497268.6	1.0	0.6	0.8	2.3	0.7	1.1	2.0	0.1	0.9	9.4	IV	(HHZ)
96	779320.4	0.6	1.0	0.6	1.5	0.7	0.9	2.0	0.4	1.1	8.8	IV	(HHZ)
97	467750.1	0.6	1.7	0.6	1.7	0.6	1.1	2.0	0.2	0.9	9.3	IV	(HHZ)
98	1480797.3	1.0	0.3	0.6	0.7	0.9	0.7	2.0	0.7	0.6	7.4	III	(MHZ)
99	1242693.5	0.1	0.3	0.6	0.7	0.5	1.3	2.0	0.9	0.9	7.2	III	(MHZ)
100	2297922.8	0.6	0.6	0.8	1.6	0.8	0.3	2.0	0.1	0.6	7.3	III	(MHZ)
101	1117823.8	0.6	0.6	0.8	1.9	0.8	0.7	2.0	0.1	0.6	8.0	IV	(HHZ)
102	3097830.1	1.0	0.3	0.8	2.3	0.8	1.2	2.0	0.9	0.9	10.1	IV	(HHZ)
103	2228665.1	1.0	0.6	0.8	2.3	0.8	1.0	2.0	0.1	0.9	9.4	IV	(HHZ)
104	4183554.5	0.2	0.3	0.8	2.5	0.7	1.2	2.0	0.9	0.9	9.4	IV	(HHZ)
105	470590.5	0.1	0.3	0.6	0.7	1.2	0.7	2.0	0.6	0.6	6.8	III	(MHZ)
106	1661178.8	1.0	0.3	0.4	0.7	1.0	0.6	2.0	0.6	0.6	7.1	III	(MHZ)
107	1364506.7	0.8	0.6	0.4	0.9	1.0	0.7	2.0	0.0	0.6	7.0	III	(MHZ)
108	2277212.3	0.0	0.6	0.6	0.9	1.1	0.7	2.0	0.1	0.8	6.8	III	(MHZ)
109	3766866.4	0.8	0.6	0.8	1.1	0.9	0.6	2.0	0.1	0.8	7.6	III	(MHZ)

Annexure I continued...

Facet Id and Area		SSEP Ratings for Internal Causative Factors						SSEP Ratings for External triggering Factors			Evaluated Landslide Hazard (ELH)	Land slide Hazard Class	Land slide Hazard Zone
Facet ID	Facet Area (m ²)	Relative Relief	Slope Morphometry	Slope Material	Structural Discontinuity	Landuse Land cover	Ground Water	Seismicity	Rain Fall	Man Made Activity			
110	884753.0	0.8	0.6	0.6	2.1	0.8	0.6	2.0	0.1	0.8	8.3	IV	(HHZ)
111	1093026.2	1.0	0.6	0.6	0.9	0.7	0.8	2.0	0.1	0.6	7.2	III	(MHZ)
112	2281163.8	1.0	0.6	0.8	2.1	1.1	1.0	2.0	0.1	0.8	9.5	IV	(HHZ)
113	606816.6	1.0	0.6	0.6	0.9	0.9	0.9	2.0	0.1	0.6	7.5	III	(MHZ)
114	571843.2	0.8	0.3	0.8	1.4	0.7	0.9	2.0	0.9	0.9	8.5	IV	(HHZ)
115	821002.3	1.0	0.3	0.8	1.4	1.0	0.7	2.0	0.9	0.8	8.9	IV	(HHZ)
116	1139469.4	1.0	0.6	0.4	1.4	0.9	0.8	2.0	0.9	0.8	8.8	IV	(HHZ)
117	844381.6	1.0	0.3	0.6	1.2	0.4	0.7	2.0	0.9	0.9	7.9	III	(MHZ)
118	639688.3	0.1	0.3	0.6	0.5	0.5	0.5	2.0	0.8	0.6	5.8	III	(MHZ)
119	314719.6	0.8	0.3	0.6	1.5	0.5	0.7	2.0	0.9	0.9	8.1	IV	(HHZ)
120	1057288.2	1.0	1.0	0.8	2.1	1.0	0.8	2.0	0.4	0.8	9.9	IV	(HHZ)
121	1925284.9	1.0	0.3	0.8	2.1	0.9	0.9	2.0	0.9	0.9	9.7	IV	(HHZ)
122	1672202.7	1.0	0.3	0.8	0.7	0.6	0.7	2.0	0.8	0.6	7.5	III	(MHZ)
123	945553.8	1.0	0.3	0.6	0.7	0.5	0.7	2.0	0.8	0.6	7.2	III	(MHZ)
124	1203575.2	1.0	0.3	0.6	0.7	0.5	0.8	2.0	0.8	0.6	7.3	III	(MHZ)
125	2402359.4	1.0	0.6	0.6	2.2	1.0	1.2	2.0	0.1	0.9	9.4	IV	(HHZ)
126	1303088.7	1.0	0.6	0.4	0.7	0.7	0.8	2.0	0.1	0.9	7.1	III	(MHZ)
127	1581980.6	1.0	0.6	0.6	2.0	1.3	0.6	2.0	0.1	0.8	9.0	IV	(HHZ)
128	1285186.2	1.0	0.6	0.6	2.2	1.1	1.0	2.0	0.1	0.8	9.4	IV	(HHZ)
129	2092648.6	1.0	0.6	0.6	2.2	1.0	1.0	2.0	0.1	0.8	9.3	IV	(HHZ)
130	6630782.2	1.0	0.3	0.6	2.2	0.8	1.0	2.0	0.9	0.9	9.6	IV	(HHZ)
131	1479715.1	1.0	1.0	0.6	2.1	1.2	1.2	2.0	0.4	0.9	10.3	IV	(HHZ)
132	1343354.8	1.0	1.0	0.6	2.0	1.1	1.2	2.0	0.4	1.1	10.4	IV	(HHZ)
133	1035377.2	0.8	1.0	0.8	2.1	1.1	0.8	2.0	0.4	1.1	10.2	IV	(HHZ)
134	990087.5	0.6	0.6	0.6	2.1	1.1	0.9	2.0	0.1	1.1	9.1	IV	(HHZ)
135	444441.9	1.0	0.6	0.8	1.9	1.4	0.5	2.0	0.1	0.9	9.1	IV	(HHZ)
136	453155.4	1.0	0.6	0.8	2.2	1.2	0.6	2.0	0.1	0.9	9.3	IV	(HHZ)
137	506437.4	1.0	0.6	0.8	1.4	1.1	0.5	2.0	0.1	0.9	8.3	IV	(HHZ)
138	479809.8	0.1	0.3	0.6	2.5	1.0	0.8	2.0	0.9	0.9	9.0	IV	(HHZ)
139	2836444.3	1.0	0.6	0.6	0.9	1.3	0.7	2.0	0.1	0.6	7.7	III	(MHZ)
140	7821325.7	1.0	0.6	0.6	1.9	1.3	0.9	2.0	0.1	0.8	9.1	IV	(HHZ)
141	550891.1	1.0	1.0	0.4	0.9	1.2	0.6	2.0	0.5	0.8	8.5	IV	(HHZ)
142	694998.0	1.0	1.0	0.4	0.9	1.1	0.6	2.0	0.4	0.8	8.3	IV	(HHZ)
143	969989.5	1.0	1.0	0.6	1.0	1.0	0.7	2.0	0.4	0.8	8.5	IV	(HHZ)
144	1894869.3	0.6	0.6	0.4	0.9	0.8	0.6	2.0	0.7	0.6	7.3	III	(MHZ)
145	887177.4	1.0	1.0	0.6	0.9	0.8	0.6	2.0	0.4	0.8	8.1	IV	(HHZ)
146	830052.7	1.0	0.6	0.6	0.9	0.8	0.6	2.0	0.1	0.6	7.1	III	(MHZ)
147	1963637.3	1.0	0.6	0.6	0.9	0.9	1.0	2.0	0.1	0.6	7.6	III	(MHZ)
148	3183645.3	1.0	0.3	0.8	1.0	0.8	1.2	2.0	0.9	0.9	8.8	IV	(HHZ)
149	1627369.7	1.0	0.3	0.8	1.0	0.8	0.8	2.0	0.9	0.9	8.3	IV	(HHZ)
150	5108462.7	0.1	0.3	0.8	1.4	0.8	1.5	2.0	0.9	0.9	8.6	IV	(HHZ)
151	5167373.3	1.0	0.3	0.6	1.6	0.9	0.8	2.0	0.9	0.9	8.9	IV	(HHZ)
152	1644283.9	1.0	0.3	0.6	0.7	1.0	0.6	2.0	0.7	0.6	7.4	III	(MHZ)
153	1845055.7	1.0	0.3	0.6	0.7	1.0	0.8	2.0	0.7	0.6	7.7	III	(MHZ)
154	2977536.1	1.0	0.3	0.8	1.2	0.9	1.2	2.0	0.8	0.8	9.0	IV	(HHZ)
155	4610268.3	1.0	0.6	0.6	0.9	0.9	0.7	2.0	0.1	0.9	7.6	III	(MHZ)
156	3330111.9	1.0	0.6	0.4	1.8	1.1	0.5	2.0	0.1	0.6	8.1	IV	(HHZ)
157	2149335.8	1.0	0.6	0.4	1.8	1.3	0.5	2.0	0.0	0.6	8.2	IV	(HHZ)
158	1975865.5	1.0	0.3	0.6	1.4	1.0	0.9	2.0	0.8	0.6	8.5	IV	(HHZ)
159	3974080.0	1.0	0.3	0.6	1.6	1.0	0.6	2.0	0.8	0.8	8.6	IV	(HHZ)
160	603143.5	0.8	1.0	0.4	0.9	0.8	0.3	2.0	0.4	0.8	7.5	III	(MHZ)
161	652537.3	0.6	0.6	0.4	0.7	0.8	0.5	2.0	0.1	0.6	6.2	III	(MHZ)
162	1037720.7	1.0	0.6	0.4	0.7	1.2	0.8	2.0	0.1	0.6	7.4	III	(MHZ)
163	2684781.0	1.0	0.6	0.6	1.9	1.1	0.8	2.0	0.1	0.8	8.9	IV	(HHZ)
164	3645406.6	1.0	0.6	0.6	2.2	0.9	0.8	2.0	0.1	0.8	9.0	IV	(HHZ)

Annexure I continued...

Facet Id and Area		SSEP Ratings for Internal Causative Factors						SSEP Ratings for External triggering Factors			Evaluated Landslide Hazard (ELH)	Land slide Hazard Class	Land slide Hazard Zone
Facet ID	Facet Area (m ²)	Relative Relief	Slope Morphometry	Slope Material	Structural Discontinuity	Landuse Land cover	Ground Water	Seismicity	Rain Fall	Man Made Activity			
165	4956310.4	1.0	0.3	0.6	1.9	1.1	1.2	2.0	0.9	0.9	9.8	IV	(HHZ)
166	4167868.4	1.0	0.3	0.6	1.9	1.0	1.0	2.0	0.9	0.8	9.4	IV	(HHZ)
167	6579563.7	1.0	0.3	0.6	1.6	0.9	0.4	2.0	0.9	0.8	8.4	IV	(HHZ)
168	3965419.3	1.0	0.6	0.6	2.1	1.2	0.7	2.0	0.1	0.8	9.1	IV	(HHZ)
169	9142760.2	1.0	0.6	0.6	1.6	1.0	0.7	2.0	0.1	0.9	8.3	IV	(HHZ)
170	430581.9	0.6	0.6	0.4	1.8	0.7	0.4	2.0	0.1	0.6	7.1	III	(MHZ)
171	4432546.5	0.6	0.3	0.6	1.4	1.1	0.8	2.0	0.8	0.8	8.4	IV	(HHZ)
172	8752818.8	1.0	0.3	0.6	1.4	1.0	0.6	2.0	0.9	0.8	8.6	IV	(HHZ)
173	14794833.4	1.0	0.6	0.6	1.7	1.0	1.5	2.0	0.1	0.8	9.2	IV	(HHZ)
174	6289160.2	1.0	0.6	0.6	1.7	0.7	1.2	2.0	0.1	0.8	8.7	IV	(HHZ)
175	3816414.4	1.0	0.3	0.6	1.4	0.8	0.6	2.0	0.9	0.9	8.4	IV	(HHZ)
176	10760874.3	1.0	0.3	0.6	1.7	0.9	0.5	2.0	0.9	0.9	8.7	IV	(HHZ)
177	4628871.7	1.0	0.3	0.6	1.4	0.9	1.0	2.0	0.9	0.9	8.9	IV	(HHZ)
178	6407194.9	1.0	0.3	0.8	0.7	0.6	1.5	2.0	0.8	0.8	8.6	IV	(HHZ)
179	4076478.3	1.0	0.3	0.6	1.4	0.6	1.0	2.0	0.8	0.8	8.5	IV	(HHZ)
180	2749644.4	1.0	0.3	0.8	0.7	0.7	1.0	2.0	0.7	0.6	7.8	III	(MHZ)
181	3189653.1	1.0	0.3	0.8	0.7	0.7	0.6	2.0	0.7	0.6	7.3	III	(MHZ)
182	3796520.2	1.0	0.3	0.6	0.9	1.1	1.6	2.0	0.7	0.6	8.8	IV	(HHZ)
183	5780476.1	1.0	0.3	0.8	0.9	0.9	1.5	2.0	0.7	0.6	8.7	IV	(HHZ)
184	3442219.4	1.0	0.3	0.6	0.7	0.5	1.3	2.0	0.7	0.6	7.6	III	(MHZ)
185	3423294.1	1.0	0.3	0.6	0.7	0.7	0.9	2.0	0.7	0.6	7.4	III	(MHZ)
186	4738209.2	1.0	0.3	0.6	1.4	0.8	1.0	2.0	0.9	0.9	8.8	IV	(HHZ)
187	4389478.0	1.0	0.3	0.6	2.2	1.0	0.5	2.0	0.9	0.8	9.3	IV	(HHZ)
188	7434066.7	1.0	0.6	0.6	1.4	1.0	0.7	2.0	0.1	0.8	8.1	IV	(HHZ)
189	5718607.2	1.0	0.3	0.6	1.4	1.1	0.9	2.0	0.9	0.8	8.9	IV	(HHZ)
190	4572632.3	1.0	0.3	0.6	0.7	1.1	0.8	2.0	0.9	0.8	8.1	IV	(HHZ)
191	1203812.2	1.0	0.3	0.8	1.4	0.6	0.9	2.0	0.7	0.6	8.2	IV	(HHZ)
192	15351617.2	1.0	0.3	0.6	2.0	0.6	1.8	2.0	0.9	0.9	9.9	IV	(HHZ)
193	3480358.9	0.8	0.3	0.6	0.7	0.8	0.8	2.0	0.7	0.6	7.2	III	(MHZ)
194	3153731.1	1.0	0.3	0.6	1.7	1.0	0.9	2.0	0.7	0.6	8.7	IV	(HHZ)
195	3959161.2	1.0	0.3	0.6	1.0	0.8	1.1	2.0	0.7	0.6	8.2	IV	(HHZ)
196	3960670.4	1.0	0.3	0.6	1.4	0.7	1.2	2.0	0.9	0.9	8.9	IV	(HHZ)
197	865804.2	1.0	0.3	0.6	1.7	0.8	0.6	2.0	0.8	0.6	8.4	IV	(HHZ)
198	7094803.7	1.0	0.6	0.6	2.2	1.0	0.6	2.0	0.1	0.9	8.9	IV	(HHZ)
199	2276930.0	1.0	0.6	0.6	1.6	1.0	0.9	2.0	0.1	0.6	8.3	IV	(HHZ)
200	1814255.3	1.0	0.6	0.6	1.3	0.9	0.9	2.0	0.1	0.8	8.2	IV	(HHZ)
201	4539231.0	1.0	0.3	0.6	2.1	0.8	1.3	2.0	0.9	0.9	9.7	IV	(HHZ)
202	2775214.2	0.8	0.3	0.6	2.2	1.0	1.6	2.0	0.9	0.8	10.1	IV	(HHZ)
203	2950376.4	0.8	1.0	0.8	1.4	0.9	1.5	2.0	0.4	1.1	9.9	IV	(HHZ)
204	3181082.3	1.0	0.3	0.8	2.2	1.4	1.2	2.0	0.9	0.8	10.6	IV	(HHZ)
205	3593574.4	1.0	0.6	0.6	2.2	1.1	1.0	2.0	0.1	0.8	9.4	IV	(HHZ)
206	1320829.6	1.0	0.6	0.8	2.3	1.1	0.8	2.0	0.1	0.8	9.5	IV	(HHZ)
207	1600958.6	0.8	0.3	0.6	2.1	1.1	1.0	2.0	0.9	0.8	9.7	IV	(HHZ)
208	1507613.3	1.0	0.3	0.6	2.2	1.3	0.9	2.0	0.9	0.8	9.9	IV	(HHZ)
209	1242956.4	1.0	0.6	0.6	0.9	1.2	1.0	2.0	0.1	0.6	7.9	III	(MHZ)
210	1747834.0	1.0	0.6	0.6	0.9	1.1	1.3	2.0	0.1	0.8	8.4	IV	(HHZ)
211	1289264.8	1.0	0.6	0.6	1.6	1.0	0.9	2.0	0.1	0.8	8.5	IV	(HHZ)
212	10562947.1	0.8	0.3	0.6	0.7	1.0	0.8	2.0	0.9	0.8	7.8	III	(MHZ)
213	20201645.6	1.0	0.3	0.6	1.6	0.8	1.5	2.0	0.9	0.9	9.5	IV	(HHZ)
214	14482015.6	1.0	0.3	0.8	1.6	0.9	1.6	2.0	0.9	0.9	9.9	IV	(HHZ)
215	2631332.8	1.0	0.3	0.6	2.1	0.6	1.1	2.0	0.9	0.8	9.4	IV	(HHZ)
216	2357863.1	1.0	0.3	0.6	1.9	1.4	0.7	2.0	0.9	0.8	9.6	IV	(HHZ)
217	4410989.7	1.0	1.0	0.6	1.1	1.3	0.8	2.0	0.4	1.1	9.3	IV	(HHZ)
218	1732701.6	1.0	0.3	0.6	2.1	1.2	0.9	2.0	0.9	0.8	9.8	IV	(HHZ)

Annexure I continued...

Facet Id and Area		SSEP Ratings for Internal Causative Factors						SSEP Ratings for External triggering Factors			Evaluated Landslide Hazard (ELH)	Land slide Hazard Class	Land slide Hazard Zone
Facet ID	Facet Area (m ²)	Relative Relief	Slope Morphometry	Slope Material	Structural Discontinuity	Landuse Land cover	Ground Water	Seismicity	Rain Fall	Man Made Activity			
219	935811.3	1.0	0.3	0.6	2.1	1.3	1.3	2.0	0.9	0.8	10.3	IV	(HHZ)
220	596606.4	1.0	0.6	0.8	0.7	0.4	0.6	2.0	0.1	0.6	6.7	III	(MHZ)
221	3780812.7	0.2	0.3	0.6	1.1	0.9	0.8	2.0	0.9	0.9	7.7	III	(MHZ)
223	8104638.7	1.0	0.3	0.6	1.8	0.8	1.3	2.0	0.9	0.9	9.5	IV	(HHZ)
224	2524106.1	1.0	0.3	0.6	1.7	1.3	0.4	2.0	0.8	0.6	8.7	IV	(HHZ)
225	1435299.1	1.0	0.6	0.8	2.3	1.3	0.6	2.0	0.1	0.8	9.5	IV	(HHZ)
226	3154563.9	1.0	1.0	0.6	1.1	1.3	1.1	2.0	0.4	1.1	9.6	IV	(HHZ)
227	3930473.1	1.0	0.6	0.6	0.7	1.1	0.3	2.0	0.1	0.6	6.9	III	(MHZ)
228	4901858.5	1.0	0.3	0.8	1.4	1.0	0.4	2.0	0.9	0.8	8.5	IV	(HHZ)
229	2915089.8	1.0	0.6	0.8	0.9	1.1	0.4	2.0	0.1	0.8	7.6	III	(MHZ)
230	3829676.6	1.0	0.6	0.8	0.7	0.9	0.9	2.0	0.1	0.9	7.8	III	(MHZ)
231	904207.4	1.0	0.3	0.4	0.7	0.9	0.6	2.0	0.9	0.9	7.7	III	(MHZ)
232	6025705.9	1.0	0.3	0.6	1.4	1.0	1.0	2.0	0.9	0.9	9.1	IV	(HHZ)
233	4125199.4	1.0	0.3	0.6	2.2	1.3	0.8	2.0	0.9	0.8	9.9	IV	(HHZ)
234	1621621.5	1.0	1.0	0.6	1.1	0.9	0.8	2.0	0.4	1.2	9.1	IV	(HHZ)
235	2508189.6	1.0	0.3	0.6	1.1	1.4	1.0	2.0	0.9	0.8	9.1	IV	(HHZ)
236	1588557.2	1.0	0.6	0.6	1.1	1.5	0.5	2.0	0.1	0.8	8.2	IV	(HHZ)
237	4708416.6	1.0	0.6	0.8	0.7	1.2	0.4	2.0	0.1	0.8	7.5	III	(MHZ)
238	3251807.2	1.0	0.3	0.6	1.1	1.1	1.0	2.0	0.9	0.9	8.9	IV	(HHZ)
239	1428467.6	1.0	0.3	0.6	1.1	1.2	0.8	2.0	0.9	0.9	8.8	IV	(HHZ)
240	2316496.8	1.0	0.3	0.6	1.1	1.1	0.8	2.0	0.9	0.9	8.7	IV	(HHZ)
241	1367420.2	1.0	0.3	0.8	0.7	1.1	0.4	2.0	0.9	0.6	7.7	III	(MHZ)
242	4695546.2	1.0	0.3	0.6	2.1	1.0	0.8	2.0	0.9	0.8	9.5	IV	(HHZ)
243	2806166.4	1.0	0.3	0.4	0.7	0.7	0.9	2.0	0.8	0.6	7.4	III	(MHZ)
244	603283.1	0.6	0.3	0.4	1.9	0.7	0.9	2.0	0.8	0.6	8.3	IV	(HHZ)
245	1575743.7	0.6	1.0	0.6	0.7	0.8	0.7	2.0	0.4	0.8	7.6	III	(MHZ)
246	5741270.5	1.0	0.3	0.6	1.4	0.9	0.8	2.0	0.9	0.9	8.7	IV	(HHZ)
247	4738389.7	1.0	0.3	0.6	0.7	0.7	0.7	2.0	0.9	0.9	7.7	III	(MHZ)
248	2117872.6	1.0	0.3	0.6	2.0	0.7	1.0	2.0	0.9	0.9	9.3	IV	(HHZ)
249	3517849.8	1.0	0.3	0.6	0.7	0.6	0.9	2.0	0.9	0.9	7.7	III	(MHZ)
250	9837503.4	1.0	0.3	0.8	2.3	0.8	1.0	2.0	0.9	0.9	9.9	IV	(HHZ)
251	9673452.6	0.6	0.3	0.6	0.7	0.6	1.7	2.0	0.8	0.6	7.8	III	(MHZ)
252	6387960.7	1.0	0.3	0.8	0.7	0.6	0.8	2.0	0.8	0.7	7.7	III	(MHZ)
253	2811803.6	1.0	0.3	0.8	0.7	0.5	0.7	2.0	0.8	0.6	7.4	III	(MHZ)
254	4533740.2	1.0	0.3	0.6	0.7	0.5	0.7	2.0	0.9	0.8	7.5	III	(MHZ)
255	13289486.0	1.0	0.3	0.6	0.9	0.9	1.1	2.0	0.9	0.9	8.5	IV	(HHZ)
256	1869683.4	1.0	0.3	0.4	0.9	0.8	1.0	2.0	0.7	0.6	7.7	III	(MHZ)
257	4962566.3	1.0	0.6	0.6	2.0	0.9	0.8	2.0	0.1	0.6	8.5	IV	(HHZ)
258	5074299.1	1.0	0.6	0.4	0.7	0.7	0.8	2.0	0.1	0.6	6.9	III	(MHZ)
259	5444062.3	1.0	0.3	0.4	0.9	0.8	1.3	2.0	0.7	0.6	8.0	IV	(HHZ)
260	4832028.7	1.0	0.6	0.6	0.9	0.8	0.9	2.0	0.1	0.8	7.6	III	(MHZ)
261	9863402.2	1.0	0.6	0.6	0.7	0.9	1.2	2.0	0.1	0.8	7.9	III	(MHZ)
262	4308461.1	1.0	0.3	0.8	0.7	0.7	0.9	2.0	0.7	0.6	7.6	III	(MHZ)
263	2348394.5	1.0	0.3	0.4	2.0	1.2	0.6	2.0	0.7	0.6	8.8	IV	(HHZ)
264	3224281.1	1.0	1.0	0.4	1.7	1.1	0.6	2.0	0.4	0.8	9.1	IV	(HHZ)
265	2538409.8	1.0	1.0	0.4	0.9	1.3	0.5	2.0	0.4	0.9	8.4	IV	(HHZ)
266	230734.4	1.0	0.6	0.6	0.9	0.8	0.5	2.0	0.1	0.6	7.0	III	(MHZ)
267	3207477.1	0.8	0.6	0.8	0.9	1.0	0.7	2.0	0.1	0.9	7.7	III	(MHZ)
268	5659774.2	1.0	0.3	0.8	0.9	1.1	0.8	2.0	0.9	0.8	8.5	IV	(HHZ)
269	4442424.5	1.0	0.6	0.4	0.9	1.4	0.9	2.0	0.0	0.6	7.8	III	(MHZ)
270	6290792.5	1.0	0.6	0.6	2.2	1.3	0.9	2.0	0.1	0.8	9.5	IV	(HHZ)
271	3556649.6	1.0	0.6	0.4	1.6	1.2	0.8	2.0	0.0	0.6	8.2	IV	(HHZ)
272	3484512.9	1.0	0.6	0.4	0.9	1.3	0.7	2.0	0.0	0.6	7.5	III	(MHZ)
273	6078924.2	1.0	0.6	0.6	2.2	1.1	0.8	2.0	0.1	0.8	9.2	IV	(HHZ)
274	1179274.3	1.0	0.6	0.6	2.1	0.5	1.0	2.0	0.1	0.9	8.7	IV	(HHZ)

Annexure II Ratings assigned to Slope material for individual facets

ID	Very_Strong (0.3)			Strong_Rock (0.4)			Medium_Strong (0.5)			Soil_Deposit (0.5)		Soil_Deposit (0.7)		SSEP Rating
	%	Adju. fact.	Rating	%	Adju. fact.	Rating	%	Adju. fact.	Rating	%	Rating	%	Rating	
1	1.3	1.2	0.0	98.7	1.35	0.5	0.0	1.5	0.0	0.0	0.0	0.0	0.0	0.5
2	0.3	1.2	0.0	99.7	1.35	0.5	0.0	1.5	0.0	0.0	0.0	0.0	0.0	0.5
3	5.0	1.2	0.0	95.0	1.35	0.5	0.0	1.5	0.0	0.0	0.0	0.0	0.0	0.5
4	1.8	1.2	0.0	98.2	1.35	0.5	0.0	1.5	0.0	0.0	0.0	0.0	0.0	0.5
5	68.4	1.2	0.2	31.6	1.35	0.2	0.0	1.5	0.0	0.0	0.0	0.0	0.0	0.4
6	32.6	1.2	0.1	0.0	1.35	0.0	67.4	1.5	0.5	0.0	0.0	0.0	0.0	0.6
7	8.0	1.2	0.0	0.0	1.35	0.0	92.0	1.5	0.7	0.0	0.0	0.0	0.0	0.7
8	80.8	1.2	0.3	1.0	1.35	0.0	18.2	1.5	0.1	0.0	0.0	0.0	0.0	0.4
9	81.9	1.2	0.3	18.1	1.35	0.1	0.0	1.5	0.0	0.0	0.0	0.0	0.0	0.4
10	68.1	1.2	0.2	24.8	1.35	0.1	7.2	1.5	0.1	0.0	0.0	0.0	0.0	0.4
11	59.2	1.2	0.2	40.8	1.35	0.2	0.0	1.5	0.0	0.0	0.0	0.0	0.0	0.4
12	4.3	1.2	0.0	95.7	1.35	0.5	0.0	1.5	0.0	0.0	0.0	0.0	0.0	0.5
13	40.0	1.2	0.1	30.0	1.35	0.2	30.0	1.5	0.2	0.0	0.0	0.0	0.0	0.5
14	100.0	1.2	0.4	0.0	1.35	0.0	0.0	1.5	0.0	0.0	0.0	0.0	0.0	0.4
15	29.0	1.2	0.1	41.0	1.35	0.2	30.0	1.5	0.2	0.0	0.0	0.0	0.0	0.6
16	2.5	1.2	0.0	0.0	1.35	0.0	97.5	1.5	0.7	0.0	0.0	0.0	0.0	0.7
17	0.6	1.2	0.0	17.4	1.35	0.1	82.0	1.5	0.6	0.0	0.0	0.0	0.0	0.7
18	46.7	1.2	0.2	0.0	1.35	0.0	2.5	1.5	0.0	50.7	0.3	0.0	0.0	0.4
19	18.2	1.2	0.1	0.0	1.35	0.0	32.4	1.5	0.2	49.4	0.2	0.0	0.0	0.6
20	61.1	1.2	0.2	0.0	1.35	0.0	38.3	1.5	0.3	0.6	0.0	0.0	0.0	0.5
21	54.7	1.2	0.2	0.0	1.35	0.0	45.3	1.5	0.3	0.0	0.0	0.0	0.0	0.5
22	95.0	1.2	0.3	0.0	1.35	0.0	5.0	1.5	0.0	0.0	0.0	0.0	0.0	0.4
23	78.5	1.2	0.3	0.0	1.35	0.0	14.8	1.5	0.1	6.7	0.0	0.0	0.0	0.4
24	75.3	1.2	0.3	0.0	1.35	0.0	0.0	1.5	0.0	0.0	0.0	24.7	0.2	0.4
25	95.7	1.2	0.3	4.3	1.35	0.0	0.0	1.5	0.0	0.0	0.0	0.0	0.0	0.4
26	1.4	1.2	0.0	81.8	1.35	0.4	0.0	1.5	0.0	0.0	0.0	16.9	0.1	0.6
27	43.7	1.2	0.2	22.8	1.35	0.1	0.0	1.5	0.0	0.0	0.0	33.4	0.2	0.5
28	31.3	1.2	0.1	30.6	1.35	0.2	0.0	1.5	0.0	0.0	0.0	38.1	0.3	0.5
29	83.8	1.2	0.3	16.2	1.35	0.1	0.0	1.5	0.0	0.0	0.0	0.0	0.0	0.4
30	62.9	1.2	0.2	20.8	1.35	0.1	0.0	1.5	0.0	0.0	0.0	16.3	0.1	0.5
31	2.9	1.2	0.0	0.0	1.35	0.0	0.0	1.5	0.0	0.0	0.0	97.1	0.7	0.7
32	47.3	1.2	0.2	42.5	1.35	0.2	0.0	1.5	0.0	0.0	0.0	10.1	0.1	0.5
33	22.1	1.2	0.1	0.0	1.35	0.0	0.0	1.5	0.0	0.0	0.0	87.9	0.6	0.7
34	78.0	1.2	0.3	0.0	1.35	0.0	0.0	1.5	0.0	0.0	0.0	22.0	0.2	0.4
35	45.3	1.2	0.2	0.0	1.35	0.0	0.0	1.5	0.0	0.0	0.0	54.7	0.4	0.5
36	53.6	1.2	0.2	18.6	1.35	0.1	0.0	1.5	0.0	0.0	0.0	27.9	0.2	0.5
37	45.2	1.2	0.2	0.0	1.35	0.0	54.8	1.5	0.4	0.0	0.0	0.0	0.0	0.6
38	86.2	1.2	0.3	0.0	1.35	0.0	0.0	1.5	0.0	0.0	0.0	13.8	0.1	0.4
39	93.4	1.2	0.3	0.0	1.35	0.0	0.0	1.5	0.0	0.0	0.0	6.6	0.0	0.4
40	83.3	1.2	0.3	16.7	1.35	0.1	0.0	1.5	0.0	0.0	0.0	0.0	0.0	0.4
41	3.2	1.2	0.0	96.8	1.35	0.5	0.0	1.5	0.0	0.0	0.0	0.0	0.0	0.5
42	5.0	1.2	0.0	95.0	1.35	0.5	0.0	1.5	0.0	0.0	0.0	0.0	0.0	0.5
43	43.2	1.2	0.2	0.0	1.35	0.0	29.3	1.5	0.2	27.5	0.1	0.0	0.0	0.5
44	19.1	1.2	0.1	0.0	1.35	0.0	63.4	1.5	0.5	17.5	0.1	0.0	0.0	0.6
45	5.6	1.2	0.0	0.0	1.35	0.0	82.6	1.5	0.6	11.8	0.1	0.0	0.0	0.7
46	1.7	1.2	0.0	0.0	1.35	0.0	90.4	1.5	0.7	7.9	0.0	0.0	0.0	0.7
47	16.9	1.2	0.1	0.0	1.35	0.0	71.9	1.5	0.5	11.2	0.1	0.0	0.0	0.7
48	22.7	1.2	0.1	0.0	1.35	0.0	67.4	1.5	0.5	9.9	0.0	0.0	0.0	0.6
49	33.3	1.2	0.1	0.0	1.35	0.0	66.7	1.5	0.5	0.0	0.0	0.0	0.0	0.6
50	29.6	1.2	0.1	0.0	1.35	0.0	66.3	1.5	0.5	4.1	0.0	0.0	0.0	0.6
51	0.0	1.2	0.0	0.0	1.35	0.0	93.7	1.5	0.7	6.3	0.0	0.0	0.0	0.7
52	0.0	1.2	0.0	0.0	1.35	0.0	100.0	1.5	0.8	0.0	0.0	0.0	0.0	0.8
53	0.0	1.2	0.0	0.0	1.35	0.0	100.0	1.5	0.8	0.0	0.0	0.0	0.0	0.8
54	38.3	1.2	0.1	61.7	1.35	0.3	0.0	1.5	0.0	0.0	0.0	0.0	0.0	0.5
55	45.7	1.2	0.2	24.8	1.35	0.1	0.0	1.5	0.0	0.0	0.0	29.5	0.2	0.5

Annexure II continued...

ID	Very Strong (0.3)			Strong Rock (0.4)			Medium Strong (0.5)			Soil Deposit (0.5)		Soil Deposit (0.7)		SSEP Rating
	%	Adju. fact.	Rating	%	Adju. fact.	Rating	%	Adju. fact.	Rating	%	Rating	%	Rating	
56	19.6	1.2	0.1	56.5	1.35	0.3	8.0	1.5	0.1	0.0	0.0	16.0	0.1	0.5
57	30.0	1.2	0.1	42.8	1.35	0.2	6.8	1.5	0.1	0.0	0.0	20.4	0.1	0.5
58	17.9	1.2	0.1	26.7	1.35	0.1	51.7	1.5	0.4	0.0	0.0	3.7	0.0	0.6
59	57.4	1.2	0.2	0.0	1.35	0.0	38.9	1.5	0.3	3.7	0.0	0.0	0.0	0.5
60	41.6	1.2	0.1	0.0	1.35	0.0	18.7	1.5	0.1	39.8	0.2	0.0	0.0	0.5
61	37.8	1.2	0.1	0.0	1.35	0.0	31.8	1.5	0.2	30.4	0.2	0.0	0.0	0.5
62	56.8	1.2	0.2	0.0	1.35	0.0	37.2	1.5	0.3	6.0	0.0	0.0	0.0	0.5
63	0.4	1.2	0.0	1.4	1.35	0.0	98.2	1.5	0.7	0.0	0.0	0.0	0.0	0.7
64	40.1	1.2	0.1	1.7	1.35	0.0	46.2	1.5	0.3	12.0	0.1	0.0	0.0	0.6
65	18.5	1.2	0.1	48.9	1.35	0.3	12.2	1.5	0.1	0.0	0.0	20.4	0.1	0.6
66	81.3	1.2	0.3	6.5	1.35	0.0	0.0	1.5	0.0	0.0	0.0	12.2	0.1	0.4
67	9.6	1.2	0.0	39.8	1.35	0.2	40.8	1.5	0.3	1.4	0.0	8.4	0.1	0.6
68	2.9	1.2	0.0	42.5	1.35	0.2	40.3	1.5	0.3	0.0	0.0	14.3	0.1	0.6
69	6.4	1.2	0.0	62.1	1.35	0.3	0.0	1.5	0.0	0.0	0.0	31.5	0.2	0.6
70	0.0	1.2	0.0	99.8	1.35	0.5	0.0	1.5	0.0	0.0	0.0	0.2	0.0	0.5
71	5.4	1.2	0.0	83.9	1.35	0.5	0.0	1.5	0.0	0.0	0.0	10.7	0.1	0.5
72	0.0	1.2	0.0	77.7	1.35	0.4	22.3	1.5	0.2	0.0	0.0	0.0	0.0	0.6
73	0.0	1.2	0.0	29.8	1.35	0.2	70.2	1.5	0.5	0.0	0.0	0.0	0.0	0.7
74	0.0	1.2	0.0	73.9	1.35	0.4	26.1	1.5	0.2	0.0	0.0	0.0	0.0	0.6
75	3.9	1.2	0.0	11.3	1.35	0.1	84.8	1.5	0.6	0.0	0.0	0.0	0.0	0.7
76	91.6	1.2	0.3	0.0	1.35	0.0	8.4	1.5	0.1	0.0	0.0	0.0	0.0	0.4
77	10.4	1.2	0.0	33.0	1.35	0.2	56.6	1.5	0.4	0.0	0.0	0.0	0.0	0.6
78	3.4	1.2	0.0	66.2	1.35	0.4	0.0	1.5	0.0	0.0	0.0	30.4	0.2	0.6
79	26.6	1.2	0.1	41.1	1.35	0.2	32.3	1.5	0.2	0.0	0.0	0.0	0.0	0.6
80	8.6	1.2	0.0	41.4	1.35	0.2	50.0	1.5	0.4	0.0	0.0	0.0	0.0	0.6
81	0.0	1.2	0.0	57.0	1.35	0.3	43.0	1.5	0.3	0.0	0.0	0.0	0.0	0.6
82	18.0	1.2	0.1	28.5	1.35	0.2	53.5	1.5	0.4	0.0	0.0	0.0	0.0	0.6
83	100.0	1.2	0.4	0.0	1.35	0.0	0.0	1.5	0.0	0.0	0.0	0.0	0.0	0.4
84	83.6	1.2	0.3	0.0	1.35	0.0	0.0	1.5	0.0	16.4	0.1	0.0	0.0	0.4
85	15.1	1.2	0.1	50.8	1.35	0.3	18.8	1.5	0.1	0.0	0.0	15.3	0.1	0.6
86	48.2	1.2	0.2	0.0	1.35	0.0	20.0	1.5	0.2	31.7	0.2	0.0	0.0	0.5
87	22.1	1.2	0.1	1.5	1.35	0.0	76.3	1.5	0.6	0.0	0.0	0.0	0.0	0.7
88	19.4	1.2	0.1	28.2	1.35	0.2	52.4	1.5	0.4	0.0	0.0	0.0	0.0	0.6
89	96.2	1.2	0.3	0.0	1.35	0.0	3.6	1.5	0.0	0.1	0.0	0.0	0.0	0.4
90	55.4	1.2	0.2	0.0	1.35	0.0	0.0	1.5	0.0	44.6	0.2	0.0	0.0	0.4
91	22.3	1.2	0.1	0.0	1.35	0.0	0.0	1.5	0.0	77.7	0.4	0.0	0.0	0.5
92	89.9	1.2	0.3	0.0	1.35	0.0	2.1	1.5	0.0	8.1	0.0	0.0	0.0	0.4
93	36.1	1.2	0.1	0.0	1.35	0.0	0.0	1.5	0.0	63.9	0.3	0.0	0.0	0.4
94	12.2	1.2	0.0	0.0	1.35	0.0	0.0	1.5	0.0	87.8	0.4	0.0	0.0	0.5
95	23.9	1.2	0.1	20.8	1.35	0.1	0.0	1.5	0.0	0.0	0.0	55.3	0.4	0.6
96	45.7	1.2	0.2	53.6	1.35	0.3	0.0	1.5	0.0	0.0	0.0	0.7	0.0	0.5
97	0.0	1.2	0.0	49.2	1.35	0.3	50.8	1.5	0.4	0.0	0.0	0.0	0.0	0.6
98	28.4	1.2	0.1	15.1	1.35	0.1	56.5	1.5	0.4	0.0	0.0	0.0	0.0	0.6
99	0.7	1.2	0.0	93.1	1.35	0.5	0.1	1.5	0.0	0.0	0.0	6.1	0.0	0.5
100	0.0	1.2	0.0	0.0	1.35	0.0	100.0	1.5	0.8	0.0	0.0	0.0	0.0	0.8
101	3.5	1.2	0.0	0.0	1.35	0.0	96.5	1.5	0.7	0.0	0.0	0.0	0.0	0.7
102	0.0	1.2	0.0	0.0	1.35	0.0	22.0	1.5	0.2	78.0	0.4	0.0	0.0	0.6
103	2.3	1.2	0.0	0.0	1.35	0.0	57.8	1.5	0.4	39.8	0.2	0.0	0.0	0.6
104	0.8	1.2	0.0	0.0	1.35	0.0	0.6	1.5	0.0	98.6	0.5	0.0	0.0	0.5
105	14.3	1.2	0.1	85.7	1.35	0.5	0.0	1.5	0.0	0.0	0.0	0.0	0.0	0.5
106	80.3	1.2	0.3	0.0	1.35	0.0	19.7	1.5	0.1	0.0	0.0	0.0	0.0	0.4
107	79.0	1.2	0.3	21.0	1.35	0.1	0.0	1.5	0.0	0.0	0.0	0.0	0.0	0.4
108	69.8	1.2	0.3	0.0	1.35	0.0	28.8	1.5	0.2	1.4	0.0	0.0	0.0	0.5
109	0.8	1.2	0.0	0.0	1.35	0.0	80.1	1.5	0.6	19.1	0.1	0.0	0.0	0.7
110	43.0	1.2	0.2	0.0	1.35	0.0	0.9	1.5	0.0	56.2	0.3	0.0	0.0	0.4
111	73.0	1.2	0.3	0.0	1.35	0.0	27.0	1.5	0.2	0.0	0.0	0.0	0.0	0.5

Annexure II continued...

ID	Very_Strong (0.3)			Strong_Rock (0.4)			Medium_Strong (0.5)			Soil_Deposit (0.5)		Soil_Deposit (0.7)		SSEP Rating
	%	Adju. fact.	Rating	%	Adju. fact.	Rating	%	Adju. fact.	Rating	%	Rating	%	Rating	
112	26.6	1.2	0.1	10.5	1.35	0.1	0.0	1.5	0.0	0.0	0.0	62.9	0.4	0.6
113	0.0	1.2	0.0	67.3	1.35	0.4	32.7	1.5	0.2	0.0	0.0	0.0	0.0	0.6
114	1.4	1.2	0.0	67.0	1.35	0.4	0.0	1.5	0.0	0.0	0.0	31.6	0.2	0.6
115	2.4	1.2	0.0	51.2	1.35	0.3	32.6	1.5	0.2	0.0	0.0	13.8	0.1	0.6
116	84.7	1.2	0.3	0.0	1.35	0.0	1.0	1.5	0.0	14.3	0.1	0.0	0.0	0.4
117	31.2	1.2	0.1	8.7	1.35	0.0	56.7	1.5	0.4	3.4	0.0	0.0	0.0	0.6
118	29.2	1.2	0.1	0.0	1.35	0.0	70.8	1.5	0.5	0.0	0.0	0.0	0.0	0.6
119	66.8	1.2	0.2	0.0	1.35	0.0	11.0	1.5	0.1	22.3	0.1	0.0	0.0	0.4
120	41.7	1.2	0.2	23.6	1.35	0.1	0.0	1.5	0.0	0.0	0.0	34.7	0.2	0.5
121	2.2	1.2	0.0	57.7	1.35	0.3	21.1	1.5	0.2	0.0	0.0	19.0	0.1	0.6
122	6.6	1.2	0.0	13.7	1.35	0.1	79.7	1.5	0.6	0.0	0.0	0.0	0.0	0.7
123	25.1	1.2	0.1	0.0	1.35	0.0	74.9	1.5	0.6	0.0	0.0	0.0	0.0	0.7
124	60.2	1.2	0.2	0.0	1.35	0.0	39.8	1.5	0.3	0.0	0.0	0.0	0.0	0.5
125	69.1	1.2	0.2	0.0	1.35	0.0	7.5	1.5	0.1	23.5	0.1	0.0	0.0	0.4
126	91.8	1.2	0.3	0.0	1.35	0.0	1.9	1.5	0.0	6.4	0.0	0.0	0.0	0.4
127	15.1	1.2	0.1	47.8	1.35	0.3	27.8	1.5	0.2	0.0	0.0	9.2	0.1	0.6
128	6.3	1.2	0.0	59.1	1.35	0.3	30.4	1.5	0.2	0.0	0.0	4.2	0.0	0.6
129	70.3	1.2	0.3	0.0	1.35	0.0	6.3	1.5	0.0	23.4	0.1	0.0	0.0	0.4
130	51.8	1.2	0.2	2.9	1.35	0.0	28.9	1.5	0.2	16.4	0.1	0.0	0.0	0.5
131	11.3	1.2	0.0	73.9	1.35	0.4	0.6	1.5	0.0	0.0	0.0	14.2	0.1	0.5
132	36.9	1.2	0.1	44.4	1.35	0.2	2.3	1.5	0.0	0.0	0.0	16.5	0.1	0.5
133	48.5	1.2	0.2	16.7	1.35	0.1	0.0	1.5	0.0	0.0	0.0	34.8	0.2	0.5
134	64.7	1.2	0.2	5.2	1.35	0.0	0.0	1.5	0.0	0.0	0.0	30.1	0.2	0.5
135	14.9	1.2	0.1	52.8	1.35	0.3	5.7	1.5	0.0	0.0	0.0	26.6	0.2	0.6
136	0.6	1.2	0.0	52.6	1.35	0.3	37.1	1.5	0.3	0.0	0.0	9.7	0.1	0.6
137	1.0	1.2	0.0	39.5	1.35	0.2	48.1	1.5	0.4	0.0	0.0	11.3	0.1	0.7
138	15.2	1.2	0.1	7.1	1.35	0.0	0.0	1.5	0.0	0.0	0.0	77.7	0.5	0.6
139	66.4	1.2	0.2	10.2	1.35	0.1	23.4	1.5	0.2	0.0	0.0	0.0	0.0	0.5
140	53.2	1.2	0.2	4.6	1.35	0.0	39.4	1.5	0.3	2.8	0.0	0.0	0.0	0.5
141	94.6	1.2	0.3	0.0	1.35	0.0	5.4	1.5	0.0	0.0	0.0	0.0	0.0	0.4
142	77.1	1.2	0.3	0.0	1.35	0.0	22.9	1.5	0.2	0.0	0.0	0.0	0.0	0.4
143	56.5	1.2	0.2	0.0	1.35	0.0	43.5	1.5	0.3	0.0	0.0	0.0	0.0	0.5
144	100.0	1.2	0.4	0.0	1.35	0.0	0.0	1.5	0.0	0.0	0.0	0.0	0.0	0.4
145	35.7	1.2	0.1	0.0	1.35	0.0	64.3	1.5	0.5	0.0	0.0	0.0	0.0	0.6
146	34.4	1.2	0.1	0.0	1.35	0.0	65.6	1.5	0.5	0.0	0.0	0.0	0.0	0.6
147	30.8	1.2	0.1	10.0	1.35	0.1	59.2	1.5	0.4	0.0	0.0	0.0	0.0	0.6
148	7.1	1.2	0.0	0.0	1.35	0.0	1.0	1.5	0.0	92.0	0.5	0.0	0.0	0.5
149	0.0	1.2	0.0	0.0	1.35	0.0	15.8	1.5	0.1	84.2	0.4	0.0	0.0	0.5
150	5.4	1.2	0.0	11.6	1.35	0.1	0.0	1.5	0.0	83.0	0.4	0.0	0.0	0.5
151	10.4	1.2	0.0	44.7	1.35	0.2	33.8	1.5	0.3	11.1	0.1	0.0	0.0	0.6
152	68.6	1.2	0.2	0.0	1.35	0.0	31.4	1.5	0.2	0.0	0.0	0.0	0.0	0.5
153	34.6	1.2	0.1	12.2	1.35	0.1	53.1	1.5	0.4	0.0	0.0	0.0	0.0	0.6
154	0.2	1.2	0.0	19.1	1.35	0.1	43.4	1.5	0.3	37.4	0.2	0.0	0.0	0.6
155	11.7	1.2	0.0	51.6	1.35	0.3	36.0	1.5	0.3	0.7	0.0	0.0	0.0	0.6
156	74.3	1.2	0.3	17.7	1.35	0.1	8.0	1.5	0.1	0.0	0.0	0.0	0.0	0.4
157	82.1	1.2	0.3	0.0	1.35	0.0	17.9	1.5	0.1	0.0	0.0	0.0	0.0	0.4
158	40.3	1.2	0.1	0.0	1.35	0.0	32.0	1.5	0.2	27.7	0.1	0.0	0.0	0.5
159	30.5	1.2	0.1	0.0	1.35	0.0	61.8	1.5	0.5	7.7	0.0	0.0	0.0	0.6
160	100.0	1.2	0.4	0.0	1.35	0.0	0.0	1.5	0.0	0.0	0.0	0.0	0.0	0.4
161	100.0	1.2	0.4	0.0	1.35	0.0	0.0	1.5	0.0	0.0	0.0	0.0	0.0	0.4
162	95.9	1.2	0.3	4.1	1.35	0.0	0.0	1.5	0.0	0.0	0.0	0.0	0.0	0.4
163	48.6	1.2	0.2	0.0	1.35	0.0	49.9	1.5	0.4	1.5	0.0	0.0	0.0	0.6
164	26.5	1.2	0.1	0.0	1.35	0.0	62.4	1.5	0.5	11.1	0.1	0.0	0.0	0.6
165	40.5	1.2	0.1	0.0	1.35	0.0	34.9	1.5	0.3	24.6	0.1	0.0	0.0	0.5
166	32.2	1.2	0.1	0.0	1.35	0.0	60.4	1.5	0.5	7.3	0.0	0.0	0.0	0.6
167	34.7	1.2	0.1	0.0	1.35	0.0	56.1	1.5	0.4	9.2	0.0	0.0	0.0	0.6

Annexure II continued...

ID	Very Strong (0.3)			Strong Rock (0.4)			Medium Strong (0.5)			Soil Deposit (0.5)		Soil Deposit (0.7)		SSEP
	%	Adju. fact.	Rating	%	Adju. fact.	Rating	%	Adju. fact.	Rating	%	Rating	%	Rating	Rating
168	38.5	1.2	0.1	32.3	1.35	0.2	4.0	1.5	0.0	0.0	0.0	25.2	0.2	0.5
169	28.9	1.2	0.1	3.6	1.35	0.0	47.2	1.5	0.4	20.3	0.1	0.0	0.0	0.6
170	100.0	1.2	0.4	0.0	1.35	0.0	0.0	1.5	0.0	0.0	0.0	0.0	0.0	0.4
171	60.1	1.2	0.2	5.5	1.35	0.0	30.9	1.5	0.2	3.5	0.0	0.0	0.0	0.5
172	25.4	1.2	0.1	0.6	1.35	0.0	55.0	1.5	0.4	19.0	0.1	0.0	0.0	0.6
173	34.3	1.2	0.1	8.7	1.35	0.0	53.4	1.5	0.4	3.6	0.0	0.0	0.0	0.6
174	36.9	1.2	0.1	7.8	1.35	0.0	55.3	1.5	0.4	0.0	0.0	0.0	0.0	0.6
175	44.2	1.2	0.2	0.0	1.35	0.0	38.1	1.5	0.3	17.7	0.1	0.0	0.0	0.5
176	43.6	1.2	0.2	4.3	1.35	0.0	45.9	1.5	0.3	6.1	0.0	0.0	0.0	0.6
177	38.2	1.2	0.1	1.6	1.35	0.0	53.2	1.5	0.4	7.0	0.0	0.0	0.0	0.6
178	10.2	1.2	0.0	1.1	1.35	0.0	86.9	1.5	0.7	1.8	0.0	0.0	0.0	0.7
179	55.0	1.2	0.2	0.4	1.35	0.0	33.4	1.5	0.3	11.2	0.1	0.0	0.0	0.5
180	0.1	1.2	0.0	0.0	1.35	0.0	99.9	1.5	0.7	0.0	0.0	0.0	0.0	0.7
181	1.9	1.2	0.0	9.4	1.35	0.1	88.7	1.5	0.7	0.0	0.0	0.0	0.0	0.7
182	54.4	1.2	0.2	16.6	1.35	0.1	29.0	1.5	0.2	0.0	0.0	0.0	0.0	0.5
183	18.1	1.2	0.1	7.6	1.35	0.0	74.3	1.5	0.6	0.0	0.0	0.0	0.0	0.7
184	36.2	1.2	0.1	0.0	1.35	0.0	63.8	1.5	0.5	0.0	0.0	0.0	0.0	0.6
185	49.7	1.2	0.2	0.0	1.35	0.0	50.3	1.5	0.4	0.0	0.0	0.0	0.0	0.6
186	60.1	1.2	0.2	1.3	1.35	0.0	25.6	1.5	0.2	13.0	0.1	0.0	0.0	0.5
187	33.3	1.2	0.1	0.6	1.35	0.0	56.6	1.5	0.4	9.2	0.0	0.0	0.0	0.6
188	41.4	1.2	0.1	1.8	1.35	0.0	46.9	1.5	0.4	7.7	0.0	0.0	0.0	0.5
189	22.2	1.2	0.1	25.5	1.35	0.1	37.0	1.5	0.3	7.3	0.0	7.9	0.1	0.6
190	22.3	1.2	0.1	23.9	1.35	0.1	45.9	1.5	0.3	2.1	0.0	5.8	0.0	0.6
191	20.4	1.2	0.1	0.0	1.35	0.0	79.6	1.5	0.6	0.0	0.0	0.0	0.0	0.7
192	65.8	1.2	0.2	0.0	1.35	0.0	2.4	1.5	0.0	0.0	0.0	31.8	0.2	0.5
193	31.4	1.2	0.1	0.0	1.35	0.0	68.6	1.5	0.5	0.0	0.0	0.0	0.0	0.6
194	38.3	1.2	0.1	0.0	1.35	0.0	61.7	1.5	0.5	0.0	0.0	0.0	0.0	0.6
195	39.5	1.2	0.1	0.0	1.35	0.0	60.5	1.5	0.5	0.0	0.0	0.0	0.0	0.6
196	62.5	1.2	0.2	0.0	1.35	0.0	37.5	1.5	0.3	0.0	0.0	0.0	0.0	0.5
197	60.4	1.2	0.2	0.0	1.35	0.0	39.6	1.5	0.3	0.0	0.0	0.0	0.0	0.5
198	51.4	1.2	0.2	0.0	1.35	0.0	26.6	1.5	0.2	21.9	0.1	0.0	0.0	0.5
199	59.8	1.2	0.2	0.0	1.35	0.0	40.2	1.5	0.3	0.0	0.0	0.0	0.0	0.5
200	63.0	1.2	0.2	0.0	1.35	0.0	32.5	1.5	0.2	4.5	0.0	0.0	0.0	0.5
201	48.8	1.2	0.2	0.0	1.35	0.0	0.0	1.5	0.0	51.2	0.3	0.0	0.0	0.4
202	38.8	1.2	0.1	42.0	1.35	0.2	0.0	1.5	0.0	0.0	0.0	19.2	0.1	0.5
203	46.3	1.2	0.2	0.0	1.35	0.0	14.7	1.5	0.1	0.0	0.0	39.0	0.3	0.5
204	60.7	1.2	0.2	1.0	1.35	0.0	24.3	1.5	0.2	0.0	0.0	13.9	0.1	0.5
205	60.5	1.2	0.2	0.0	1.35	0.0	27.4	1.5	0.2	0.0	0.0	12.1	0.1	0.5
206	38.1	1.2	0.1	30.7	1.35	0.2	0.0	1.5	0.0	0.0	0.0	31.2	0.2	0.5
207	53.9	1.2	0.2	0.0	1.35	0.0	23.3	1.5	0.2	0.0	0.0	22.8	0.2	0.5
208	77.5	1.2	0.3	0.0	1.35	0.0	12.8	1.5	0.1	0.0	0.0	9.7	0.1	0.4
209	61.3	1.2	0.2	0.0	1.35	0.0	38.7	1.5	0.3	0.0	0.0	0.0	0.0	0.5
210	50.8	1.2	0.2	0.0	1.35	0.0	49.1	1.5	0.4	0.0	0.0	0.0	0.0	0.6
211	30.0	1.2	0.1	0.0	1.35	0.0	63.2	1.5	0.5	6.7	0.0	0.0	0.0	0.6
212	46.9	1.2	0.2	0.0	1.35	0.0	49.5	1.5	0.4	2.4	0.0	1.2	0.0	0.6
213	35.4	1.2	0.1	0.0	1.35	0.0	42.8	1.5	0.3	21.8	0.1	0.0	0.0	0.6
214	32.9	1.2	0.1	0.0	1.35	0.0	51.8	1.5	0.4	6.9	0.0	8.4	0.1	0.6
215	30.3	1.2	0.1	0.0	1.35	0.0	61.9	1.5	0.5	7.8	0.0	0.1	0.0	0.6
216	43.0	1.2	0.2	19.9	1.35	0.1	14.0	1.5	0.1	0.0	0.0	23.1	0.2	0.5
217	34.1	1.2	0.1	3.4	1.35	0.0	48.1	1.5	0.4	5.1	0.0	9.2	0.1	0.6
218	44.7	1.2	0.2	29.7	1.35	0.2	7.1	1.5	0.1	0.0	0.0	18.5	0.1	0.5
219	46.7	1.2	0.2	0.0	1.35	0.0	34.0	1.5	0.3	0.3	0.0	19.0	0.1	0.6
220	9.5	1.2	0.0	0.0	1.35	0.0	90.5	1.5	0.7	0.0	0.0	0.0	0.0	0.7
221	34.3	1.2	0.1	0.0	1.35	0.0	42.0	1.5	0.3	23.7	0.1	0.0	0.0	0.6
223	43.2	1.2	0.2	0.0	1.35	0.0	14.4	1.5	0.1	42.4	0.2	0.0	0.0	0.5
224	65.5	1.2	0.2	34.5	1.35	0.2	0.0	1.5	0.0	0.0	0.0	0.0	0.0	0.4

Annexure II continued...

ID	Very Strong (0.3)			Strong Rock (0.4)			Medium Strong (0.5)			Soil Deposit (0.5)		Soil Deposit (0.7)		SSEP Rating
	%	Adju. fact.	Rating	%	Adju. fact.	Rating	%	Adju. fact.	Rating	%	Rating	%	Rating	
225	45.8	1.2	0.2	11.7	1.35	0.1	1.5	1.5	0.0	0.0	0.0	41.0	0.3	0.5
226	33.0	1.2	0.1	9.8	1.35	0.1	48.5	1.5	0.4	0.0	0.0	8.7	0.1	0.6
227	28.8	1.2	0.1	0.0	1.35	0.0	71.2	1.5	0.5	0.0	0.0	0.0	0.0	0.6
228	17.4	1.2	0.1	1.3	1.35	0.0	75.4	1.5	0.6	5.9	0.0	0.0	0.0	0.7
229	12.9	1.2	0.0	6.4	1.35	0.0	77.9	1.5	0.6	2.7	0.0	0.0	0.0	0.7
230	0.0	1.2	0.0	0.0	1.35	0.0	95.6	1.5	0.7	4.4	0.0	0.0	0.0	0.7
231	78.3	1.2	0.3	0.0	1.35	0.0	21.0	1.5	0.2	0.7	0.0	0.0	0.0	0.4
232	43.0	1.2	0.2	0.0	1.35	0.0	45.6	1.5	0.3	11.4	0.1	0.0	0.0	0.6
233	53.9	1.2	0.2	4.9	1.35	0.0	27.3	1.5	0.2	0.0	0.0	13.9	0.1	0.5
234	71.9	1.2	0.3	0.0	1.35	0.0	25.5	1.5	0.2	2.5	0.0	0.0	0.0	0.5
235	58.5	1.2	0.2	19.2	1.35	0.1	11.3	1.5	0.1	0.0	0.0	11.0	0.1	0.5
236	60.2	1.2	0.2	22.0	1.35	0.1	0.0	1.5	0.0	0.0	0.0	17.8	0.1	0.5
237	14.7	1.2	0.1	0.0	1.35	0.0	83.9	1.5	0.6	1.4	0.0	0.0	0.0	0.7
238	37.8	1.2	0.1	0.0	1.35	0.0	57.3	1.5	0.4	5.0	0.0	0.0	0.0	0.6
239	38.1	1.2	0.1	0.0	1.35	0.0	55.7	1.5	0.4	6.2	0.0	0.0	0.0	0.6
240	29.0	1.2	0.1	0.0	1.35	0.0	61.4	1.5	0.5	9.7	0.0	0.0	0.0	0.6
241	0.0	1.2	0.0	0.0	1.35	0.0	100.0	1.5	0.8	0.0	0.0	0.0	0.0	0.8
242	26.0	1.2	0.1	0.0	1.35	0.0	70.2	1.5	0.5	3.8	0.0	0.0	0.0	0.6
243	90.5	1.2	0.3	0.0	1.35	0.0	9.5	1.5	0.1	0.0	0.0	0.0	0.0	0.4
244	80.7	1.2	0.3	19.3	1.35	0.1	0.0	1.5	0.0	0.0	0.0	0.0	0.0	0.4
245	49.3	1.2	0.2	0.0	1.35	0.0	50.7	1.5	0.4	0.0	0.0	0.0	0.0	0.6
246	39.1	1.2	0.1	0.0	1.35	0.0	49.3	1.5	0.4	11.5	0.1	0.0	0.0	0.6
247	47.0	1.2	0.2	0.0	1.35	0.0	46.5	1.5	0.3	6.5	0.0	0.0	0.0	0.6
248	67.2	1.2	0.2	0.0	1.35	0.0	4.1	1.5	0.0	28.7	0.1	0.0	0.0	0.4
249	41.8	1.2	0.2	0.0	1.35	0.0	44.2	1.5	0.3	14.0	0.1	0.0	0.0	0.6
250	23.2	1.2	0.1	0.0	1.35	0.0	6.1	1.5	0.0	70.8	0.4	0.0	0.0	0.5
251	69.4	1.2	0.2	0.2	1.35	0.0	30.4	1.5	0.2	0.0	0.0	0.0	0.0	0.5
252	22.2	1.2	0.1	0.0	1.35	0.0	77.8	1.5	0.6	0.0	0.0	0.0	0.0	0.7
253	11.2	1.2	0.0	0.0	1.35	0.0	88.8	1.5	0.7	0.0	0.0	0.0	0.0	0.7
254	50.9	1.2	0.2	0.0	1.35	0.0	45.6	1.5	0.3	3.4	0.0	0.0	0.0	0.5
255	36.9	1.2	0.1	1.1	1.35	0.0	37.8	1.5	0.3	24.1	0.1	0.0	0.0	0.5
256	71.8	1.2	0.3	13.3	1.35	0.1	15.0	1.5	0.1	0.0	0.0	0.0	0.0	0.4
257	48.3	1.2	0.2	7.6	1.35	0.0	44.1	1.5	0.3	0.0	0.0	0.0	0.0	0.5
258	63.2	1.2	0.2	32.9	1.35	0.2	3.9	1.5	0.0	0.0	0.0	0.0	0.0	0.4
259	75.8	1.2	0.3	11.9	1.35	0.1	12.3	1.5	0.1	0.0	0.0	0.0	0.0	0.4
260	42.7	1.2	0.2	0.0	1.35	0.0	57.1	1.5	0.4	0.2	0.0	0.0	0.0	0.6
261	45.8	1.2	0.2	0.8	1.35	0.0	48.6	1.5	0.4	4.8	0.0	0.0	0.0	0.6
262	0.1	1.2	0.0	0.0	1.35	0.0	99.9	1.5	0.7	0.0	0.0	0.0	0.0	0.7
263	83.6	1.2	0.3	11.9	1.35	0.1	4.5	1.5	0.0	0.0	0.0	0.0	0.0	0.4
264	71.5	1.2	0.3	27.1	1.35	0.1	1.4	1.5	0.0	0.0	0.0	0.0	0.0	0.4
265	69.8	1.2	0.3	16.9	1.35	0.1	13.3	1.5	0.1	0.0	0.0	0.0	0.0	0.4
266	26.2	1.2	0.1	73.8	1.35	0.4	0.0	1.5	0.0	0.0	0.0	0.0	0.0	0.5
267	1.8	1.2	0.0	0.0	1.35	0.0	80.1	1.5	0.6	18.0	0.1	0.0	0.0	0.7
268	7.0	1.2	0.0	0.0	1.35	0.0	66.8	1.5	0.5	26.2	0.1	0.0	0.0	0.7
269	59.8	1.2	0.2	36.0	1.35	0.2	4.1	1.5	0.0	0.0	0.0	0.0	0.0	0.4
270	46.5	1.2	0.2	23.9	1.35	0.1	27.1	1.5	0.2	2.6	0.0	0.0	0.0	0.5
271	72.2	1.2	0.3	27.7	1.35	0.1	0.1	1.5	0.0	0.0	0.0	0.0	0.0	0.4
272	77.4	1.2	0.3	22.3	1.35	0.1	0.3	1.5	0.0	0.0	0.0	0.0	0.0	0.4
273	34.4	1.2	0.1	9.0	1.35	0.0	53.0	1.5	0.4	3.6	0.0	0.0	0.0	0.6
274	1.8	1.2	0.0	88.3	1.35	0.5	3.7	1.5	0.0	0.0	0.0	6.2	0.0	0.6

Annexure III SSEP Ratings assigned to each parameters of Structural Discontinuity

Code	Type of Structural Discontinuity										Max. SSEP rating value
A	Relationship between dip of discontinuities and inclination of the slope										0.5
B	Parallelism between discontinuities dip direction and slope inclination										0.5
C	Dip of discontinuities										0.5
D	Soil cover depth										2.5
E	Structural discontinuities and rock mass condition										0.25
F	Continuity										0.15
G	Separation										0.15
H	Roughness										0.15
I	Infiling										0.15
J	Weathering										0.15
Facet	A	B	C	D	E	F	G	H	I	J	Total
1	0.2	0.5	0.1	0	0.05	0.15	0.15	0.02	0.15	0.07	1.39
2	0.1	0.1	0.1	0	0.05	0.04	0.07	0.07	0.12	0.02	0.67
3	0.1	0.1	0.1	0	0.05	0.04	0.07	0.07	0.12	0.02	0.67
4	0.1	0.1	0.1	0	0.05	0.04	0.07	0.07	0.12	0.02	0.67
5	0.2	0.4	0.1	0	0.05	0.04	0.07	0.07	0.12	0.02	1.07
6	0.15	0.4	0.25	0	0.25	0.15	0.15	0.15	0.15	0.06	1.71
7	0.15	0.4	0.25	0	0.1	0.1	0.12	0.1	0.12	0.06	1.4
8	0.15	0.4	0.4	0	0.25	0.15	0.15	0.15	0.15	0.05	1.85
9	0.15	0.4	0.4	0	0.25	0.15	0.15	0.15	0.15	0.05	1.85
10	0.15	0.4	0.4	0	0.1	0.1	0.12	0.1	0.12	0.02	1.51
11	0.15	0.4	0.4	0	0.1	0.1	0.12	0.1	0.12	0.05	1.54
12	0.15	0.5	0.4	0	0.1	0.1	0.12	0.1	0.12	0.07	1.66
13	0.15	0.4	0.4	0	0.1	0.1	0.12	0.1	0.12	0.05	1.54
14	0.15	0.3	0.25	0	0.25	0.15	0.15	0.15	0.15	0.06	1.61
15	0.15	0.4	0.4	0	0.1	0.1	0.12	0.1	0.12	0.05	1.54
16	0.15	0.1	0.25	0	0.1	0.1	0.12	0.1	0.12	0.05	1.09
17	0.15	0.25	0.4	0	0.1	0.15	0.12	0.1	0.12	0.07	1.46
18	0.1	0.2	0.15	0	0.1	0.1	0.12	0.1	0.12	0.02	1.01
19	50%=0.2	50%=0.075	50%=0.2	50%=1.25	50%=0.125	50%=0.075	50%=0.075	50%=0.075	50%=0.075	50%=0.025	1.05
20	0.15	0.4	0.25	0	0.1	0.1	0.12	0.1	0.12	0.05	1.39
21	0.15	0.4	0.25	0	0.1	0.1	0.12	0.1	0.12	0.05	1.39
22	0.1	0.2	0.15	0	0.1	0.1	0.12	0.1	0.12	0.035	1.025
23	0.1	0.2	0.15	0	0.1	0.1	0.12	0.1	0.12	0.05	1.04
24	50%=0.2	50%=0.075	50%=0.2	50%=1.25	50%=0.125	50%=0.075	50%=0.075	50%=0.075	50%=0.075	50%=0.025	1.05
25	0.15	0.4	0.5	0	0.2	0.15	0.15	0.15	0.15	0.035	1.885
26	80%=0.16	80%=0.4	80%=0.2	20%=0.5	80%=0.08	80%=0.12	80%=0.096	80%=0.056	80%=0.096	80%=0.056	1.764
27	80%=0.1	80%=0.4	80%=0.36	20%=0.5	80%=0.2	80%=0.12	80%=0.12	80%=0.12	80%=0.12	80%=0.04	1.98
28	70%=0.07	70%=0.28	70%=0.28	30%=0.75	70%=0.175	70%=0.105	70%=0.105	70%=0.105	70%=0.105	70%=0.035	1.98
29	0.15	0.1	0.4	0	0.25	0.15	0.15	0.15	0.15	0.05	1.55
30	0.15	0.1	0.4	0	0.05	0.15	0.15	0.15	0.15	0.035	1.335
31	0	0	0	100%=2.5	0	0	0	0	0	0	2.5
32	0.15	0.5	0.5	0	0.2	0.15	0.15	0.15	0.15	0.035	1.985
33	80%=0.08	80%=0.08	80%=0.08	20%=0.5	80%=0.08	80%=0.08	80%=0.08	80%=0.08	80%=0.08	80%=0.028	1.168
34	0.1	0.1	0.1	0	0.05	0.02	0.05	0.15	0.15	0.035	0.755
35	20%=0.04	20%=0.08	20%=0.03	80%=2	20%=0.05	20%=0.03	20%=0.03	20%=0.03	20%=0.03	20%=0.007	2.327
36	80%=0.12	80%=0.4	80%=0.4	20%=0.5	80%=0.2	80%=0.12	80%=0.12	80%=0.12	80%=0.12	80%=0.04	2.14
37	0.1	0.2	0.4	0	0.05	0.15	0.05	0.03	0.12	0.05	1.15
38	0.1	0.2	0.4	0	0.05	0.15	0.05	0.03	0.12	0.035	1.135
39	0.1	0.2	0.4	0	0.05	0.15	0.05	0.03	0.12	0.035	1.135
40	0.1	0.1	0.1	0	0.05	0.04	0.07	0.07	0.12	0.02	0.67
41	0.1	0.1	0.1	0	0.05	0.04	0.07	0.07	0.12	0.02	0.67

Annexure III Continued..

Facet	A	B	C	D	E	F	G	H	I	J	Total
42	0.1	0.1	0.1	0	0.05	0.04	0.07	0.07	0.12	0.02	0.67
43	70%=0.07	70%=0.28	70%=0.28	30%=0.75	70%=0.175	70%=0.105	70%=0.105	70%=0.105	70%=0.105	70%=0.035	1.98
44	90%=0.135	90%=0.45	90%=0.36	10%=0.23	90%=0.045	90%=0.135	90%=0.63	90%=0.135	90%=0.018	90%=0.045	2.203
45	90%=0.135	90%=0.45	90%=0.36	10%=0.24	90%=0.045	90%=0.135	90%=0.63	90%=0.135	90%=0.018	90%=0.045	2.203
46	90%=0.135	90%=0.45	90%=0.36	10%=0.25	90%=0.045	90%=0.135	90%=0.63	90%=0.135	90%=0.018	90%=0.045	2.203
47	0.15	0.4	0.5	0	0.2	0.15	0.15	0.15	0.15	0.07	1.92
48	0.15	0.4	0.5	0	0.25	0.15	0.15	0.15	0.15	0.07	1.97
49	0.15	0.4	0.5	0	0.25	0.15	0.15	0.15	0.15	0.1	2
50	0.15	0.4	0.5	0	0.2	0.15	0.15	0.15	0.15	0.07	1.92
51	0.15	0.4	0.5	0	0.2	0.15	0.15	0.15	0.15	0.07	1.92
52	0.1	0.25	0.5	0	0.1	0.15	0.05	0.07	0.12	0.05	1.39
53	0.1	0.25	0.5	0	0.1	0.15	0.05	0.07	0.12	0.05	1.39
54	0.15	0.4	0.5	0	0.2	0.15	0.15	0.15	0.15	0.07	1.92
55	50%=0.25	50%=0.075	50%=0.075	50%=1.25	50%=0.125	50%=0.075	50%=0.075	50%=0.05	50%=0.075	50%=0.025	2.075
56	80%=0.12	80%=0.4	80%=0.4	20%=0.5	80%=0.2	80%=0.12	80%=0.12	80%=0.12	80%=0.12	80%=0.04	2.14
57	80%=0.12	80%=0.4	80%=0.4	20%=0.5	80%=0.2	80%=0.12	80%=0.12	80%=0.12	80%=0.12	80%=0.04	2.14
58	90%=0.135	90%=0.45	90%=0.36	10%=0.25	90%=0.045	90%=0.135	90%=0.63	90%=0.135	90%=0.018	90%=0.045	2.203
59	0.1	0.2	0.15	0	0.1	0.1	0.12	0.1	0.12	0.02	1.01
60	40%=0.08	40%=0.09	40%=0.09	60%=1.08	40%=0.04	40%=0.06	40%=0.06	40%=0.06	40%=0.06	40%=0.2	1.82
61	60%=0.06	60%=0.06	60%=0.09	40%=1	60%=0.03	60%=0.09	60%=0.09	60%=0.09	60%=0.09	60%=0.042	1.642
62	90%=0.09	90%=0.135	90%=0.36	10%=0.18	90%=0.045	90%=0.135	90%=0.63	90%=0.135	90%=0.018	90%=0.045	1.773
63	0.1	0.25	0.4	0	0.1	0.15	0.12	0.07	0.12	0.05	1.36
64	0.1	0.2	0.15	0	0.1	0.1	0.12	0.1	0.12	0.02	1.01
65	90%=0.135	90%=0.45	90%=0.36	10%=0.25	90%=0.045	90%=0.135	90%=0.63	90%=0.135	90%=0.018	90%=0.045	2.203
66	90%=0.135	90%=0.45	90%=0.36	10%=0.25	90%=0.045	90%=0.135	90%=0.63	90%=0.135	90%=0.018	90%=0.045	2.203
67	0.1	0.2	0.15	0	0.1	0.1	0.12	0.1	0.12	0.02	1.01
68	90%=0.135	90%=0.45	90%=0.36	10%=0.18	90%=0.045	90%=0.135	90%=0.63	90%=0.135	90%=0.018	90%=0.045	2.133
69	0.1	0.4	0.15	0	0.1	0.15	0.15	0.03	0.15	0.07	1.3
70	0.1	0.25	0.25	0	0.05	0.15	0.12	0.03	0.15	0.07	1.17
71	0.1	0.1	0.5	0	0.1	0.1	0.07	0.07	0.12	0.07	1.23
72	0.1	0.1	0.4	0	0.25	0.15	0.15	0.03	0.12	0.07	1.37
73	0.1	0.1	0.4	0	0.2	0.15	0.15	0.2	0.15	0.05	1.5
74	0.1	0.5	0.25	0	0.05	0.1	0.15	0.02	0.15	0.05	1.37
75	0.2	0.5	0.1	0	0.05	0.02	0.02	0.02	0.02	0.06	0.99
76	0.1	0.1	0.4	0	0.05	0.15	0.15	0.15	0.02	0.035	1.155
77	0.1	0.3	0.4	0	0.25	0.15	0.15	0.15	0.15	0.05	1.7
78	60%=0.06	60%=0.06	60%=0.3	40%=1	60%=0.03	60%=0.09	60%=0.09	60%=0.09	60%=0.09	60%=0.042	1.852
79	0.1	0.5	0.5	0	0.1	0.15	0.15	0.15	0.15	0.05	1.85
80	0.15	0.5	0.4	0	0.2	0.15	0.15	0.15	0.15	0.07	1.92
81	0.15	0.4	0.4	0	0.1	0.15	0.12	0.1	0.12	0.05	1.59
82	0.1	0.1	0.25	0	0.05	0.04	0.05	0.07	0.12	0.05	0.83
83	0.1	0.1	0.25	0	0.2	0.1	0.12	0.1	0.12	0.05	1.14
84	90%=0.09	90%=0.27	90%=0.225	10%=0.18	90%=0.045	90%=0.135	90%=0.63	90%=0.135	90%=0.018	90%=0.045	1.773
85	80%=0.12	80%=0.4	80%=0.4	20%=0.5	80%=0.2	80%=0.12	80%=0.12	80%=0.12	80%=0.12	80%=0.04	2.14
86	50%=0.05	50%=0.1	50%=0.125	50%=0.9	50%=0.05	50%=0.05	50%=0.05	50%=0.05	50%=0.06	50%=0.025	1.46
87	0.1	0.1	0.25	0	0.05	0.04	0.05	0.07	0.12	0.06	0.84
88	0.1	0.1	0.25	0	0.05	0.04	0.05	0.07	0.12	0.07	0.85
89	0.15	0.3	0.25	0	0.1	0.04	0.05	0.07	0.12	0.07	1.15
90	50%=0.05	50%=0.05	50%=0.125	50%=0.9	50%=0.05	50%=0.05	50%=0.05	50%=0.05	50%=0.06	50%=0.025	1.41
91	0	0	0	100%=1.8	0	0	0	0	0	0	1.8
92	0.15	0.4	0.5	0	0.2	0.15	0.15	0.02	0.02	0.05	1.64
93	40%=0.04	40%=0.04	40%=0.1	60%=1.08	40%=0.04	40%=0.06	40%=0.06	40%=0.06	40%=0.06	40%=0.02	1.56
94	10%=0.01	10%=0.01	10%=0.01	90%=1.62	10%=0.005	10%=0.005	10%=0.004	10%=0.002	10%=0.002	10%=0.005	1.673
95	30%=0.045	30%=0.09	30%=0.15	70%=1.75	30%=0.03	30%=0.045	30%=0.045	30%=0.045	30%=0.045	30%=0.02	2.265
96	0.15	0.4	0.5	0	0.1	0.15	0.15	0.02	0.02	0.05	1.54
97	0.15	0.4	0.5	0	0.1	0.15	0.15	0.05	0.12	0.05	1.67
98	0.1	0.1	0.1	0	0.05	0.04	0.07	0.07	0.12	0.02	0.67
99	0.1	0.1	0.1	0	0.05	0.04	0.07	0.07	0.12	0.02	0.67
100	0.5	0.15	0.5	0	0.05	0.15	0.05	0.03	0.12	0.05	1.6

Annexure III Continued..

Facet	A	B	C	D	E	F	G	H	I	J	Total
101	0.5	0.15	0.5	0	0.1	0.15	0.15	0.15	0.15	0.05	1.9
102	10%=0.01	10%=0.01	10%=0.01	90%=2.25	10%=0.005	10%=0.005	10%=0.004	10%=0.002	10%=0.002	10%=0.005	2.303
103	30%=0.045	030%=0.09	30%=0.15	70%=1.75	30%=0.03	30%=0.045	30%=0.045	30%=0.045	30%=0.045	30%=0.02	2.265
104	0	0	0	0	100%=2.5	0	0	0	0	0	2.5
105	0.1	0.1	0.1	0	0.05	0.04	0.07	0.07	0.12	0.02	0.67
106	0.1	0.1	0.1	0	0.05	0.04	0.07	0.07	0.12	0.02	0.67
107	0.1	0.1	0.25	0	0.1	0.04	0.07	0.07	0.12	0.035	0.885
108	0.1	0.1	0.25	0	0.1	0.04	0.07	0.07	0.12	0.035	0.885
109	0.15	0.2	0.25	0	0.1	0.1	0.1	0.05	0.12	0.05	1.12
110	40%=0.08	40%=0.09	40%=0.09	60%=1.5	40%=0.04	40%=0.06	40%=0.06	40%=0.06	40%=0.06	40%=0.02	2.06
111	0.1	0.1	0.25	0	0.1	0.04	0.07	0.07	0.12	0.035	0.885
112	40%=0.08	40%=0.09	40%=0.09	60%=1.5	40%=0.04	40%=0.06	40%=0.06	40%=0.06	40%=0.06	40%=0.02	2.06
113	0.1	0.1	0.25	0	0.1	0.04	0.07	0.07	0.12	0.07	0.92
114	70%=0.07	70%=0.07	70%=0.175	30%=0.75	70%=0.035	70%=0.084	70%=0.084	70%=0.07	70%=0.084	70%=0.035	1.373
115	95%=0.095	95%=0.095	90%=0.38	5%=0.125	95%=0.095	95%=0.1425	95%=0.1425	95%=0.1425	95%=0.1425	95%=0.0475	1.4075
116	0.1	0.15	0.4	0	0.2	0.15	0.12	0.07	0.12	0.05	1.36
117	0.15	0.2	0.25	0	0.1	0.1	0.12	0.1	0.12	0.05	1.19
118	0.1	0.1	0.1	0	0.05	0.07	0.02	0.03	0.02	0.02	0.51
119	0.1	0.4	0.25	0	0.1	0.15	0.15	0.15	0.15	0.05	1.5
120	50%=0.25	50%=0.075	50%=0.075	50%=1.25	50%=0.125	50%=0.075	50%=0.075	50%=0.05	50%=0.075	50%=0.025	2.075
121	80%=0.12	80%=0.4	80%=0.4	20%=0.5	80%=0.2	80%=0.12	80%=0.12	80%=0.12	80%=0.12	80%=0.04	2.14
122	0.1	0.1	0.1	0	0.05	0.04	0.07	0.07	0.12	0.07	0.72
123	0.1	0.1	0.1	0	0.05	0.04	0.07	0.07	0.12	0.05	0.7
124	0.1	0.1	0.1	0	0.05	0.04	0.07	0.07	0.12	0.05	0.7
125	80%=0.16	80%=0.2	80%=0.4	20%=0.5	80%=0.4	80%=0.12	80%=0.12	80%=0.12	80%=0.12	80%=0.04	2.18
126	0.1	0.1	0.1	0	0.05	0.04	0.07	0.07	0.12	0.035	0.685
127	90%=0.0.09	90%=0.27	90%=0.36	10%=0.25	90%=0.045	90%=0.135	90%=0.63	90%=0.135	90%=0.018	90%=0.045	1.978
128	90%=0.135	90%=0.45	90%=0.36	10%=0.25	90%=0.045	90%=0.135	90%=0.63	90%=0.135	90%=0.018	90%=0.045	2.203
129	90%=0.135	90%=0.45	90%=0.36	10%=0.25	90%=0.045	90%=0.135	90%=0.63	90%=0.135	90%=0.018	90%=0.045	2.203
130	90%=0.135	90%=0.45	90%=0.36	10%=0.25	90%=0.045	90%=0.135	90%=0.63	90%=0.135	90%=0.018	90%=0.045	2.203
131	80%=0.12	80%=0.4	80%=0.4	20%=0.5	80%=0.2	80%=0.12	80%=0.12	80%=0.12	80%=0.12	80%=0.04	2.14
132	70%=0.07	70%=0.28	70%=0.28	30%=0.75	70%=0.175	70%=0.105	70%=0.105	70%=0.105	70%=0.105	70%=0.035	1.98
133	70%=0.105	70%=0.28	70%=0.35	30%=0.75	70%=0.175	70%=0.105	70%=0.105	70%=0.105	70%=0.105	70%=0.049	2.129
134	70%=0.105	70%=0.28	70%=0.35	30%=0.76	70%=0.175	70%=0.105	70%=0.105	70%=0.105	70%=0.105	70%=0.049	2.129
135	0.15	0.4	0.5	0	0.2	0.15	0.15	0.15	0.15	0.07	1.92
136	90%=0.135	90%=0.45	90%=0.36	10%=0.25	90%=0.045	90%=0.135	90%=0.63	90%=0.135	90%=0.018	90%=0.045	2.203
137	95%=0.095	95%=0.095	90%=0.38	5%=0.125	95%=0.095	95%=0.1425	95%=0.1425	95%=0.1425	95%=0.1425	95%=0.0475	1.4075
138	0	0	0	100%=2.5	0	0	0	0	0	0	2.5
139	0.1	0.1	0.25	0	0.1	0.04	0.07	0.07	0.12	0.035	0.885
140	0.15	0.4	0.5	0	0.2	0.15	0.15	0.15	0.15	0.07	1.92
141	0.1	0.1	0.25	0	0.1	0.04	0.07	0.07	0.12	0.035	0.885
142	0.1	0.1	0.25	0	0.1	0.04	0.07	0.07	0.12	0.035	0.885
143	0.1	0.1	0.4	0	0.1	0.04	0.07	0.07	0.12	0.035	1.035
144	0.1	0.1	0.25	0	0.1	0.04	0.07	0.07	0.12	0.035	0.885
145	0.1	0.1	0.25	0	0.1	0.04	0.07	0.07	0.12	0.035	0.885
146	0.1	0.1	0.25	0	0.1	0.04	0.07	0.07	0.12	0.035	0.885
147	0.1	0.1	0.25	0	0.1	0.04	0.07	0.07	0.12	0.035	0.885
148	0	0	0	100%=1.1	0	0	0	0	0	0	1
149	0	0	0	100%=1.0	0	0	0	0	0	0	1
150	0	0	0	100%=1.4	0	0	0	0	0	0	1.4
151	90%=0.09	90%=0.18	90%=0.225	10%=0.20	90%=0.045	90%=0.135	90%=0.63	90%=0.018	90%=0.018	90%=0.045	1.566
152	0.1	0.1	0.1	0	0.05	0.04	0.07	0.07	0.12	0.02	0.67
153	0.1	0.1	0.1	0	0.05	0.04	0.07	0.07	0.12	0.02	0.67
154	60%=0.06	60%=0.06	60%=0.09	40%=0.56	60%=0.03	60%=0.09	60%=0.09	60%=0.09	60%=0.09	60%=0.042	1.202
155	0.1	0.1	0.25	0	0.1	0.04	0.07	0.07	0.12	0.035	0.885
156	0.15	0.4	0.4	0	0.2	0.15	0.15	0.15	0.15	0.05	1.8
157	0.1	0.4	0.5	0	0.1	0.15	0.15	0.15	0.15	0.05	1.75
158	70%=0.07	70%=0.07	70%=0.175	30%=0.75	70%=0.035	70%=0.084	70%=0.084	70%=0.07	70%=0.084	70%=0.035	1.373

Annexure III Continued..

Facet	A	B	C	D	E	F	G	H	I	J	Total
159	90%=0.09	90%=0.18	90%=0.225	10%=0.20	90%=0.045	90%=0.135	90%=0.63	90%=0.018	90%=0.018	90%=0.045	1.566
160	0.1	0.1	0.25	0	0.1	0.04	0.07	0.07	0.12	0.035	0.885
161	0.1	0.1	0.1	0	0.05	0.04	0.07	0.07	0.12	0.02	0.67
162	0.1	0.1	0.1	0	0.05	0.04	0.07	0.07	0.12	0.02	0.67
163	0.15	0.4	0.5	0	0.2	0.15	0.15	0.15	0.15	0.07	1.92
164	90%=0.135	90%=0.45	90%=0.36	10%=0.25	90%=0.045	90%=0.135	90%=0.63	90%=0.135	90%=0.018	90%=0.045	2.203
165	90%=0.135	90%=0.45	90%=0.225	10%=0.18	90%=0.045	90%=0.135	90%=0.63	90%=0.018	90%=0.018	90%=0.045	1.881
166	90%=0.135	90%=0.45	90%=0.225	10%=0.19	90%=0.045	90%=0.135	90%=0.63	90%=0.018	90%=0.018	90%=0.045	1.881
167	90%=0.09	90%=0.18	90%=0.225	10%=0.20	90%=0.045	90%=0.135	90%=0.63	90%=0.018	90%=0.018	90%=0.045	1.566
168	80%=0.12	80%=0.4	80%=0.4	20%=0.5	80%=0.2	80%=0.12	80%=0.12	80%=0.12	80%=0.12	80%=0.04	2.14
169	90%=0.09	90%=0.18	90%=0.225	10%=0.20	90%=0.045	90%=0.135	90%=0.63	90%=0.018	90%=0.018	90%=0.045	1.566
170	0.1	0.4	0.5	0	0.1	0.15	0.15	0.15	0.15	0.05	1.75
171	0.1	0.1	0.4	0	0.1	0.15	0.15	0.15	0.15	0.05	1.35
172	95%=0.095	95%=0.095	90%=0.38	5%=0.125	95%=0.095	95%=0.1425	95%=0.1425	95%=0.1425	95%=0.1425	95%=0.0475	1.4075
173	0.15	0.2	0.5	0	0.2	0.15	0.15	0.15	0.15	0.05	1.7
174	0.15	0.2	0.5	0	0.2	0.15	0.15	0.15	0.15	0.05	1.7
175	95%=0.095	95%=0.095	90%=0.38	5%=0.125	95%=0.095	95%=0.1425	95%=0.1425	95%=0.1425	95%=0.1425	95%=0.0475	1.4075
176	0.15	0.2	0.5	0	0.2	0.15	0.15	0.15	0.15	0.07	1.72
177	95%=0.095	95%=0.095	90%=0.38	5%=0.125	95%=0.095	95%=0.1425	95%=0.1425	95%=0.1425	95%=0.1425	95%=0.0475	1.4075
178	0.1	0.1	0.1	0	0.05	0.04	0.07	0.07	0.12	0.035	0.685
179	95%=0.095	95%=0.095	90%=0.38	5%=0.09	95%=0.095	95%=0.1425	95%=0.1425	95%=0.1425	95%=0.1425	95%=0.0475	1.3725
180	0.1	0.1	0.1	0	0.05	0.04	0.07	0.07	0.12	0.035	0.685
181	0.1	0.1	0.1	0	0.05	0.04	0.07	0.07	0.12	0.035	0.685
182	0.1	0.1	0.1	0	0.25	0.04	0.07	0.07	0.12	0.07	0.92
183	0.1	0.1	0.1	0	0.25	0.04	0.07	0.07	0.12	0.07	0.92
184	0.1	0.1	0.1	0	0.05	0.04	0.07	0.07	0.12	0.035	0.685
185	0.1	0.1	0.1	0	0.05	0.04	0.07	0.07	0.12	0.035	0.685
186	95%=0.095	95%=0.095	90%=0.38	5%=0.09	95%=0.095	95%=0.1425	95%=0.1425	95%=0.1425	95%=0.1425	95%=0.0475	1.3725
187	90%=0.135	90%=0.45	90%=0.36	10%=0.25	90%=0.045	90%=0.135	90%=0.63	90%=0.135	90%=0.018	90%=0.045	2.203
188	95%=0.095	95%=0.095	90%=0.38	5%=0.09	95%=0.095	95%=0.1425	95%=0.1425	95%=0.1425	95%=0.1425	95%=0.0475	1.3725
189	95%=0.095	95%=0.095	90%=0.38	5%=0.09	95%=0.095	95%=0.1425	95%=0.1425	95%=0.1425	95%=0.1425	95%=0.0475	1.3725
190	0.1	0.1	0.1	0	0.05	0.04	0.07	0.07	0.12	0.035	0.685
191	0.1	0.1	0.4	0	0.1	0.15	0.15	0.15	0.15	0.05	1.35
192	70%=0.105	70%=0.35	70%=0.175	30%=0.75	70%=0.175	70%=0.105	70%=0.105	70%=0.07	70%=0.105	70%=0.035	1.975
193	0.1	0.1	0.1	0	0.05	0.04	0.07	0.07	0.12	0.035	0.685
194	0.1	0.2	0.5	0	0.2	0.15	0.15	0.15	0.15	0.05	1.65
195	0.1	0.1	0.5	0	0.05	0.15	0.02	0.05	0.02	0.05	1.04
196	0.1	0.25	0.5	0	0.1	0.15	0.05	0.07	0.12	0.05	1.39
197	0.15	0.5	0.4	0	0.1	0.15	0.05	0.15	0.15	0.05	1.7
198	90%=0.135	90%=0.45	90%=0.36	10%=0.25	90%=0.045	90%=0.135	90%=0.63	90%=0.135	90%=0.018	90%=0.045	2.203
199	0.15	0.25	0.4	0	0.25	0.15	0.15	0.07	0.12	0.05	1.59
200	0.15	0.1	0.4	0	0.25	0.02	0.05	0.1	0.12	0.07	1.26
201	50%=0.25	50%=0.075	50%=0.075	50%=1.25	50%=0.125	50%=0.075	50%=0.075	50%=0.05	50%=0.075	50%=0.025	2.075
202	70%=0.105	70%=0.35	70%=0.35	30%=0.75	70%=0.175	70%=0.105	70%=0.105	70%=0.07	70%=0.105	70%=0.035	2.15
203	70%=0.07	70%=0.07	70%=0.175	30%=0.75	70%=0.035	70%=0.084	70%=0.084	70%=0.07	70%=0.084	70%=0.035	1.373
204	90%=0.135	90%=0.45	90%=0.36	10%=0.25	90%=0.045	90%=0.135	90%=0.63	90%=0.135	90%=0.018	90%=0.045	2.203
205	90%=0.135	90%=0.45	90%=0.36	10%=0.26	90%=0.045	90%=0.135	90%=0.63	90%=0.135	90%=0.018	90%=0.045	2.203
206	50%=0.25	50%=0.075	50%=0.25	50%=1.25	50%=0.125	50%=0.075	50%=0.075	50%=0.05	50%=0.075	50%=0.025	2.25
207	80%=0.12	80%=0.4	80%=0.4	20%=0.5	80%=0.2	80%=0.12	80%=0.12	80%=0.12	80%=0.12	80%=0.04	2.14
208	90%=0.135	90%=0.45	90%=0.36	10%=0.25	90%=0.045	90%=0.135	90%=0.63	90%=0.135	90%=0.018	90%=0.045	2.203
209	0.1	0.1	0.1	0	0.25	0.04	0.07	0.07	0.12	0.07	0.92
210	0.1	0.1	0.1	0	0.25	0.04	0.07	0.07	0.12	0.07	0.92
211	90%=0.09	90%=0.18	90%=0.225	10%=0.18	90%=0.045	90%=0.135	90%=0.63	90%=0.018	90%=0.018	90%=0.045	1.566
212	0.1	0.1	0.1	0	0.05	0.04	0.07	0.07	0.12	0.035	0.685
213	90%=0.135	90%=0.45	90%=0.135	10%=0.25	90%=0.09	90%=0.135	90%=0.135	90%=0.135	90%=0.135	10%=0.045	1.645
214	90%=0.09	90%=0.18	90%=0.225	10%=0.18	90%=0.045	90%=0.135	90%=0.63	90%=0.018	90%=0.018	90%=0.045	1.566
215	80%=0.12	80%=0.4	80%=0.4	20%=0.5	80%=0.2	80%=0.12	80%=0.12	80%=0.12	80%=0.12	80%=0.04	2.14
216	0.15	0.4	0.5	0	0.2	0.15	0.15	0.15	0.15	0.07	1.92

Annexure III Continued..

Facet	A	B	C	D	E	F	G	H	I	J	Total
217	90%=0.09	90%=0.09	90%=0.36	10%=0.25	90%=0.045	90%=0.135	90%=0.018	90%=0.09	90%=0.135	10%=0.045	1.123
218	80%=0.12	80%=0.4	80%=0.4	20%=0.5	80%=0.2	80%=0.12	80%=0.12	80%=0.12	80%=0.12	80%=0.04	2.14
219	80%=0.12	80%=0.4	80%=0.4	20%=0.6	80%=0.2	80%=0.12	80%=0.12	80%=0.12	80%=0.12	80%=0.04	2.14
220	0.1	0.1	0.1	0	0.05	0.04	0.07	0.07	0.12	0.035	0.685
221	90%=0.09	90%=0.09	90%=0.36	10%=0.25	90%=0.045	90%=0.135	90%=0.018	90%=0.09	90%=0.135	10%=0.045	1.123
223	90%=0.09	90%=0.45	90%=0.45	10%=0.25	90%=0.09	90%=0.135	90%=0.135	90%=0.135	90%=0.135	10%=0.045	1.845
224	0.15	0.3	0.4	0	0.2	0.15	0.15	0.15	0.15	0.07	1.72
225	30%=0.045	030%=0.09	30%=0.15	70%=1.75	30%=0.03	30%=0.045	30%=0.045	30%=0.045	30%=0.045	30%=0.02	2.265
226	90%=0.09	90%=0.09	90%=0.36	10%=0.25	90%=0.045	90%=0.135	90%=0.018	90%=0.09	90%=0.135	10%=0.045	1.123
227	0.1	0.1	0.1	0	0.05	0.04	0.07	0.07	0.12	0.035	0.685
228	95%=0.095	95%=0.095	90%=0.38	5%=0.125	95%=0.095	95%=0.1425	95%=0.1425	95%=0.1425	95%=0.1425	95%=0.0475	1.4075
229	0.1	0.1	0.25	0	0.1	0.04	0.07	0.07	0.12	0.035	0.885
230	0.1	0.1	0.1	0	0.05	0.04	0.07	0.07	0.12	0.035	0.685
231	0.1	0.1	0.1	0	0.05	0.04	0.07	0.07	0.12	0.035	0.685
232	95%=0.095	95%=0.095	90%=0.38	5%=0.125	95%=0.095	95%=0.1425	95%=0.1425	95%=0.1425	95%=0.1425	95%=0.0475	1.4075
233	90%=0.135	90%=0.45	90%=0.36	10%=0.25	90%=0.045	90%=0.135	90%=0.63	90%=0.135	90%=0.18	90%=0.045	2.203
234	90%=0.09	90%=0.09	90%=0.36	10%=0.25	90%=0.045	90%=0.135	90%=0.018	90%=0.09	90%=0.135	10%=0.045	1.123
235	90%=0.09	90%=0.09	90%=0.36	10%=0.25	90%=0.045	90%=0.135	90%=0.018	90%=0.09	90%=0.135	10%=0.045	1.123
236	90%=0.09	90%=0.09	90%=0.36	10%=0.26	90%=0.045	90%=0.135	90%=0.018	90%=0.09	90%=0.135	10%=0.046	1.123
237	0.1	0.1	0.1	0	0.05	0.04	0.07	0.07	0.12	0.035	0.685
238	90%=0.09	90%=0.09	90%=0.36	10%=0.25	90%=0.045	90%=0.135	90%=0.018	90%=0.09	90%=0.135	10%=0.045	1.123
239	90%=0.09	90%=0.09	90%=0.36	10%=0.25	90%=0.045	90%=0.135	90%=0.018	90%=0.09	90%=0.135	10%=0.046	1.123
240	90%=0.09	90%=0.09	90%=0.36	10%=0.25	90%=0.045	90%=0.135	90%=0.018	90%=0.09	90%=0.135	10%=0.047	1.123
241	0.1	0.1	0.1	0	0.05	0.04	0.07	0.07	0.12	0.035	0.685
242	80%=0.12	80%=0.4	80%=0.4	20%=0.5	80%=0.2	80%=0.12	80%=0.12	80%=0.12	80%=0.12	80%=0.04	2.14
243	0.1	0.1	0.1	0	0.05	0.04	0.07	0.07	0.12	0.035	0.685
244	0.15	0.5	0.4	0	0.2	0.15	0.15	0.15	0.15	0.07	1.92
245	0.1	0.1	0.1	0	0.05	0.04	0.07	0.07	0.12	0.035	0.685
246	95%=0.095	95%=0.095	90%=0.38	5%=0.125	95%=0.095	95%=0.1425	95%=0.1425	95%=0.1425	95%=0.1425	95%=0.0475	1.4075
247	0.1	0.1	0.1	0	0.05	0.04	0.07	0.07	0.12	0.035	0.685
248	70%=0.105	70%=0.35	70%=0.175	30%=0.75	70%=0.175	70%=0.105	70%=0.105	70%=0.07	70%=0.105	70%=0.035	1.975
249	0.1	0.1	0.1	0	0.05	0.04	0.07	0.07	0.12	0.035	0.685
250	20%=0.02	20%=0.1	20%=0.03	80%=2	20%=0.05	20%=0.03	20%=0.03	20%=0.014	20%=0.03	20%=0.01	2.314
251	0.1	0.1	0.1	0	0.05	0.04	0.07	0.07	0.12	0.035	0.685
252	0.1	0.1	0.1	0	0.05	0.04	0.07	0.07	0.12	0.035	0.685
253	0.1	0.1	0.1	0	0.05	0.04	0.07	0.07	0.12	0.035	0.685
254	0.1	0.1	0.1	0	0.05	0.04	0.07	0.07	0.12	0.035	0.685
255	90%=0.09	90%=0.09	90%=0.135	10%=0.25	90%=0.045	90%=0.135	90%=0.018	90%=0.09	90%=0.135	10%=0.047	0.898
256	0.1	0.1	0.25	0	0.1	0.04	0.07	0.07	0.12	0.035	0.885
257	0.15	0.5	0.5	0	0.2	0.15	0.15	0.15	0.15	0.05	2
258	0.1	0.1	0.1	0	0.05	0.04	0.07	0.07	0.12	0.035	0.685
259	0.1	0.1	0.25	0	0.1	0.04	0.07	0.07	0.12	0.035	0.885
260	0.1	0.1	0.25	0	0.1	0.04	0.07	0.07	0.12	0.035	0.885
261	0.1	0.1	0.1	0	0.05	0.04	0.07	0.07	0.12	0.035	0.685
262	0.1	0.1	0.1	0	0.05	0.04	0.07	0.07	0.12	0.035	0.685
263	0.15	0.5	0.5	0	0.2	0.15	0.15	0.15	0.15	0.05	2
264	0.15	0.2	0.5	0	0.2	0.15	0.15	0.15	0.15	0.05	1.7
265	0.1	0.1	0.25	0	0.1	0.04	0.07	0.07	0.12	0.035	0.885
266	0.1	0.1	0.25	0	0.1	0.04	0.07	0.07	0.12	0.035	0.885
267	90%=0.09	90%=0.09	90%=0.135	10%=0.25	90%=0.045	90%=0.135	90%=0.018	90%=0.09	90%=0.135	10%=0.047	0.898
268	90%=0.09	90%=0.09	90%=0.135	10%=0.25	90%=0.045	90%=0.135	90%=0.018	90%=0.09	90%=0.135	10%=0.048	0.898
269	0.1	0.1	0.25	0	0.1	0.04	0.07	0.07	0.12	0.035	0.885
270	90%=0.135	90%=0.45	90%=0.36	10%=0.25	90%=0.045	90%=0.135	90%=0.63	90%=0.135	90%=0.018	90%=0.045	2.203
271	0.1	0.1	0.5	0	0.2	0.15	0.15	0.15	0.15	0.05	1.55
272	0.1	0.1	0.25	0	0.1	0.04	0.07	0.07	0.12	0.035	0.885
273	90%=0.135	90%=0.45	90%=0.36	10%=0.25	90%=0.045	90%=0.135	90%=0.63	90%=0.135	90%=0.018	90%=0.045	2.203
274	80%=0.12	80%=0.4	80%=0.4	20%=0.5	80%=0.2	80%=0.12	80%=0.12	80%=0.12	80%=0.12	80%=0.04	2.14

Annexure IV SSEP Ratings assigned to each parameters of Land use - Land cover

Facet ID	Grass Land (0.75)		Bare Land (1.5)		Cultivated Land (0.4)		Shrub Land (1.2)		Grass Land (1.2)		Forest_PL (0.4)		Cultivated Land (0.4)		Bare Land (1.5)		Shrub Land (1.2)		Total SSEP Rating
	%	Rating	%	Rating	%	Rating	%	Rating	%	Rating	%	Rating	%	Rating	%	Rating	%	Rating	
1	37.22	0.28	0.00	0.00	61.08	0.24	1.70	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.54
2	93.69	0.70	1.10	0.02	0.00	0.00	5.21	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.78
3	46.03	0.35	0.23	0.00	51.10	0.20	0.28	0.00	2.36	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.58
4	2.89	0.02	6.86	0.10	85.80	0.34	2.01	0.02	0.00	0.00	2.44	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.50
5	83.55	0.63	10.51	0.16	0.00	0.00	5.94	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.86
6	35.59	0.27	64.41	0.97	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.23
7	100.00	0.75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.75
8	38.60	0.29	61.40	0.92	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.21
9	0.00	0.00	100.00	1.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.50
10	2.41	0.02	87.65	1.31	9.94	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.37
11	58.46	0.44	20.00	0.30	21.54	0.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.82
12	100.00	0.75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.75
13	87.76	0.66	12.24	0.18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.84
14	67.27	0.50	21.82	0.33	10.91	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.88
15	94.74	0.71	0.00	0.00	5.26	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.73
16	35.19	0.26	4.01	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	60.80	0.24	0.00	0.00	0.00	0.00	0.57
17	40.59	0.30	42.11	0.63	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.46	0.06	2.84	0.04	0.00	0.00	1.04
18	1.80	0.01	0.00	0.00	0.00	0.00	98.20	1.18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.19
19	41.86	0.31	0.00	0.00	0.00	0.00	29.17	0.35	0.00	0.00	0.00	0.00	28.98	0.12	0.00	0.00	0.00	0.00	0.78
20	13.37	0.10	0.00	0.00	0.00	0.00	34.82	0.42	0.00	0.00	0.00	0.00	50.70	0.20	0.00	0.00	1.11	0.01	0.73
21	61.86	0.46	0.00	0.00	0.00	0.00	2.26	0.03	0.00	0.00	0.00	0.00	35.88	0.14	0.00	0.00	0.00	0.00	0.63
22	18.50	0.14	0.00	0.00	0.00	0.00	49.65	0.60	0.00	0.00	0.00	0.00	31.85	0.13	0.00	0.00	0.00	0.00	0.86
23	28.66	0.21	1.14	0.02	2.15	0.01	45.83	0.55	0.00	0.00	0.00	0.00	22.22	0.09	0.00	0.00	0.00	0.00	0.88
24	98.18	0.74	0.00	0.00	0.00	0.00	1.82	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.76
25	100.00	0.75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.75
26	2.05	0.02	0.00	0.00	88.24	0.35	0.26	0.00	9.46	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.48
27	80.53	0.60	0.00	0.00	8.98	0.04	4.92	0.06	5.56	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.77
28	65.05	0.49	0.00	0.00	33.33	0.13	0.00	0.00	1.62	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.64
29	95.31	0.71	0.00	0.00	4.69	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.73
30	98.48	0.74	0.00	0.00	0.95	0.00	0.57	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.75
31	87.04	0.65	0.00	0.00	12.46	0.05	0.00	0.00	0.50	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.71
32	87.92	0.66	8.61	0.13	3.47	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.80
33	68.61	0.51	30.84	0.46	0.54	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.98
34	12.91	0.10	0.00	0.00	45.50	0.18	0.00	0.00	41.59	0.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.78
35	39.61	0.30	10.08	0.15	47.15	0.19	1.63	0.02	1.53	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.67
36	92.98	0.70	0.00	0.00	2.76	0.01	4.25	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.76
37	19.88	0.15	0.60	0.01	11.66	0.05	6.32	0.08	6.81	0.08	0.00	0.00	37.97	0.15	9.87	0.15	6.89	0.08	0.74
38	4.24	0.03	0.00	0.00	81.58	0.33	13.74	0.16	0.44	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.53
39	39.35	0.30	1.05	0.02	36.23	0.14	6.96	0.08	11.97	0.14	0.00	0.00	0.00	0.00	4.43	0.07	0.00	0.00	0.75
40	26.20	0.20	12.72	0.19	43.43	0.17	0.00	0.00	17.60	0.21	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.77
41	26.15	0.20	9.63	0.14	57.20	0.23	6.28	0.08	0.00	0.00	0.73	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.65
42	10.59	0.08	0.95	0.01	84.68	0.34	0.96	0.01	0.00	0.00	2.83	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.46
43	0.00	0.00	0.00	0.00	93.60	0.37	3.31	0.04	0.00	0.00	0.00	0.00	0.00	0.00	3.09	0.05	0.00	0.00	0.46
44	0.00	0.00	0.00	0.00	26.64	0.11	67.99	0.82	0.00	0.00	0.00	0.00	0.00	0.00	5.37	0.08	0.00	0.00	1.00
45	10.53	0.08	0.00	0.00	0.00	0.00	89.47	1.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.15
46	47.26	0.35	0.00	0.00	0.00	0.00	52.74	0.63	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.99
47	41.09	0.31	0.00	0.00	0.00	0.00	58.91	0.71	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.02
48	59.71	0.45	16.93	0.25	0.00	0.00	18.89	0.23	0.00	0.00	0.00	0.00	0.00	0.00	4.46	0.07	0.00	0.00	1.00
49	35.38	0.27	58.02	0.87	0.00	0.00	6.60	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.21
50	30.57	0.23	47.55	0.71	0.00	0.00	9.06	0.11	0.00	0.00	0.00	0.00	0.00	0.00	12.83	0.19	0.00	0.00	1.24
51	0.40	0.00	62.55	0.94	0.00	0.00	10.36	0.12	0.00	0.00	0.00	0.00	0.00	0.00	26.69	0.40	0.00	0.00	1.47
52	0.00	0.00	0.00	0.00	0.00	0.00	100.00	1.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.20
53	29.75	0.22	0.00	0.00	8.64	0.03	51.44	0.62	0.00	0.00	0.00	0.00	0.00	0.00	10.17	0.15	0.00	0.00	1.03
54	100.00	0.75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.75
55	93.23	0.70	6.77	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.80
56	41.31	0.31	57.53	0.86	1.16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.18
57	31.62	0.24	67.38	1.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.02	0.00	0.00	1.26
58	9.74	0.07	30.19	0.45	60.06	0.24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.77
59	24.66	0.18	0.00	0.00	31.84	0.13	36.63	0.44	0.00	0.00	0.00	0.00	1.75	0.01	3.61	0.05	1.50	0.02	0.83
60	21.37	0.16	0.00	0.00	39.86	0.16	29.45	0.35	0.00	0.00	0.00	0.00	0.14	0.00	7.26	0.11	1.92	0.02	0.81
61	29.17	0.22	0.00	0.00	7.18	0.03	23.82	0.29	0.00	0.00	0.00	0.00	13.08	0.05	0.00	0.00	26.75	0.32	0.91
62	51.64	0.39	0.00	0.00	8.07	0.03	31.50	0.38	0.00	0.00	0.00	0.00	2.25	0.01	4.06	0.06	2.48	0.03	0.90
63	5.12	0.04	1.70	0.03	78.65	0.31	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.53	0.22	0.00	0.00	0.60
64	94.10	0.71	2.11	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.45	0.01	0.34	0.01	0.00	0.00	0.76
65	23.10	0.17																	

Annexure IV continued...

Facet ID	Grass Land (0.75)		Bare Land (1.5)		Cultivated Land (0.4)		Shrub Land (1.2)		Grass Land (1.2)		Forest_PL (0.4)		Cultivated Land (0.4)		Bare Land (1.5)		Shrub Land (1.2)		Total SSEP Rating
	%	Rating	%	Rating	%	Rating	%	Rating	%	Rating	%	Rating	%	Rating	%	Rating	%	Rating	
208	24.81	0.19	54.47	0.82	0.00	0.00	20.72	0.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.25
209	14.14	0.11	23.96	0.36	0.14	0.00	61.77	0.74	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.21
210	18.93	0.14	0.00	0.00	0.20	0.00	80.87	0.97	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.11
211	0.00	0.00	0.00	0.00	24.33	0.10	64.96	0.78	0.00	0.00	0.00	0.00	0.00	0.00	10.71	0.16	0.00	0.00	1.04
212	27.94	0.21	6.43	0.10	19.27	0.08	41.07	0.49	0.00	0.00	0.00	0.00	0.00	0.00	5.30	0.08	0.00	0.00	0.96
213	70.81	0.53	0.78	0.01	12.77	0.05	9.69	0.12	0.61	0.01	0.00	0.00	2.03	0.01	0.85	0.01	2.46	0.03	0.77
214	26.07	0.20	5.76	0.09	25.66	0.10	37.53	0.45	0.00	0.00	0.00	0.00	0.00	0.00	1.13	0.02	3.85	0.05	0.90
215	24.92	0.19	1.09	0.02	58.20	0.23	15.80	0.19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.63
216	0.00	0.00	82.57	1.24	2.29	0.01	15.15	0.18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.43
217	2.76	0.02	66.21	0.99	9.72	0.04	21.01	0.25	0.00	0.00	0.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.31
218	1.80	0.01	66.92	1.00	26.10	0.10	5.19	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.18
219	7.41	0.06	43.19	0.65	0.00	0.00	49.40	0.59	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.30
220	0.00	0.00	0.00	0.00	96.32	0.39	3.68	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.43
221	18.04	0.14	0.00	0.00	31.93	0.13	38.28	0.46	0.00	0.00	0.00	0.00	1.13	0.00	4.58	0.07	6.05	0.07	0.87
223	24.53	0.18	0.00	0.00	40.52	0.16	20.52	0.25	0.00	0.00	0.00	0.00	2.10	0.01	2.71	0.04	9.63	0.12	0.76
224	14.86	0.11	63.41	0.95	0.00	0.00	21.73	0.26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.32
225	26.54	0.20	72.79	1.09	0.00	0.00	0.67	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.30
226	6.93	0.05	61.05	0.92	0.00	0.00	30.87	0.37	0.00	0.00	0.00	0.00	1.16	0.00	0.00	0.00	0.00	0.00	1.34
227	6.28	0.05	0.71	0.01	15.44	0.06	77.57	0.93	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.05
228	4.38	0.03	0.12	0.00	25.30	0.10	64.36	0.77	0.00	0.00	0.00	0.00	0.00	0.00	5.84	0.09	0.00	0.00	1.00
229	9.96	0.07	3.82	0.06	13.06	0.05	73.17	0.88	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.06
230	0.00	0.00	6.49	0.10	44.22	0.18	46.94	0.56	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.36	0.03	0.87
231	7.31	0.05	0.00	0.00	28.01	0.11	60.64	0.73	0.00	0.00	0.00	0.00	4.04	0.02	0.00	0.00	0.00	0.00	0.91
232	16.55	0.12	10.91	0.16	14.69	0.06	47.95	0.58	0.00	0.00	0.00	0.00	4.04	0.02	0.06	0.00	5.80	0.07	1.01
233	14.70	0.11	60.61	0.91	0.00	0.00	24.68	0.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.32
234	6.87	0.05	0.00	0.00	27.60	0.11	44.31	0.53	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	21.21	0.25	0.95
235	5.52	0.04	80.82	1.21	3.09	0.01	10.58	0.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.39
236	3.77	0.03	90.27	1.35	0.00	0.00	5.96	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.45
237	6.77	0.05	26.28	0.39	0.00	0.00	54.98	0.66	0.00	0.00	0.00	0.00	11.97	0.05	0.00	0.00	0.00	0.00	1.15
238	13.55	0.10	0.00	0.00	0.23	0.00	76.55	0.92	0.00	0.00	0.00	0.00	1.06	0.00	3.75	0.06	4.86	0.06	1.14
239	2.74	0.02	0.00	0.00	0.00	0.00	83.88	1.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	13.38	0.16	1.19
240	16.52	0.12	0.00	0.00	1.57	0.01	71.54	0.86	0.00	0.00	0.00	0.00	4.19	0.02	2.17	0.03	4.01	0.05	1.09
241	11.29	0.08	1.21	0.02	0.00	0.00	82.49	0.99	0.00	0.00	0.00	0.00	5.01	0.02	0.00	0.00	0.00	0.00	1.11
242	20.75	0.16	0.35	0.01	0.00	0.00	67.46	0.81	0.00	0.00	0.00	0.00	8.94	0.04	2.50	0.04	0.00	0.00	1.04
243	18.35	0.14	0.00	0.00	55.41	0.22	14.49	0.17	11.74	0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.67
244	74.47	0.56	0.00	0.00	14.35	0.06	9.82	0.12	0.00	0.00	1.36	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.74
245	53.81	0.40	0.00	0.00	0.00	0.00	28.04	0.34	0.00	0.00	0.00	0.00	18.16	0.07	0.00	0.00	0.00	0.00	0.81
246	63.78	0.48	1.83	0.03	4.90	0.02	25.38	0.30	0.00	0.00	0.00	0.00	3.14	0.01	0.51	0.01	0.45	0.01	0.86
247	73.24	0.55	0.00	0.00	6.15	0.02	5.01	0.06	0.00	0.00	0.00	0.00	15.60	0.06	0.00	0.00	0.00	0.00	0.70
248	49.03	0.37	0.00	0.00	34.42	0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	16.55	0.20	0.70
249	18.50	0.14	6.34	0.10	68.64	0.27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.52	0.08	0.59
250	26.89	0.20	5.57	0.08	40.57	0.16	0.48	0.01	0.00	0.00	0.00	0.00	1.85	0.01	8.46	0.13	16.17	0.19	0.78
251	4.41	0.03	3.17	0.05	78.03	0.31	14.39	0.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.57
252	0.00	0.00	8.10	0.12	79.20	0.32	4.97	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	7.73	0.09	0.59
253	0.00	0.00	0.00	0.00	89.02	0.36	10.98	0.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.49
254	0.00	0.00	0.00	0.00	91.38	0.37	7.00	0.08	0.00	0.00	0.00	0.00	0.00	0.00	1.61	0.02	0.00	0.00	0.47
255	43.73	0.33	2.63	0.04	6.44	0.03	29.25	0.35	0.00	0.00	0.00	0.00	7.14	0.03	6.86	0.10	3.96	0.05	0.92
256	73.77	0.55	11.95	0.18	11.67	0.05	2.60	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.81
257	65.18	0.49	25.24	0.38	6.56	0.03	2.38	0.03	0.00	0.00	0.65	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.92
258	77.94	0.58	0.00	0.00	14.17	0.06	6.81	0.08	0.00	0.00	1.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.73
259	29.67	0.22	4.37	0.07	40.71	0.16	25.14	0.30	0.00	0.00	0.00	0.00	0.11	0.00	0.00	0.00	0.00	0.00	0.75
260	28.54	0.21	23.63	0.35	38.06	0.15	2.82	0.03	0.00	0.00	0.00	0.00	6.76	0.03	0.20	0.00	0.00	0.00	0.78
261	50.58	0.38	7.69	0.12	9.84	0.04	25.56	0.31	0.00	0.00	0.00	0.00	5.75	0.02	0.58	0.01	0.00	0.00	0.87
262	19.07	0.14	0.00	0.00	57.96	0.23	22.97	0.28	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.65
263	45.66	0.34	54.34	0.82	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.16
264	48.15	0.36	51.12	0.77	0.00	0.00	0.73	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.14
265	9.00	0.07	81.52	1.22	9.48	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.33
266	66.31	0.50	11.11	0.17	10.75	0.04	0.00	0.00	11.83	0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.85
267	48.34	0.36	3.78	0.06	0.00	0.00	47.85	0.57	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.99
268	23.17	0.17	12.85	0.19	0.14	0.00	63.53	0.76	0.00	0.00	0.00	0.00	0.31	0.00	0.00	0.00	0.00	0.00	1.13
269	14.81	0.11	72.47	1.09	0.00	0.00	12.72	0.15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.35
270	13.30	0.10	62.00	0.93	0.15	0.00	23.93	0.29	0.61	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.32
271	20.24	0.15	53.24	0.80	3.76	0.02	21.88	0.26	0.00	0.00	0.00	0.00	0.00	0.00	0.88	0.01	0.00	0.00	1.24
272	5.56	0.04	73.22	1.10	7.13	0.03	9.50	0.11	0.67	0.01	3.59								

Annexure V Percentage area coverage of Ground water for individual facets

Percentage Area coverage of Ground water for individual facets.						
Facets	Flowing	Dripping	Wet	Damp	Dry	Total
Max SSEP	2	1.5	1	0.6	0	2
1				30%=0.18	70%=0	0.18
2				60%=0.36	40%=0	0.36
3			50%=0.5	50%=0.3		0.8
4		50%=0.75	50%=0.5			1.25
5			30%=0.3	40%=0.24	30%=0	0.54
6			20%=0.2	40%=0.24	40%=0	0.44
7			10%=0.1	50%=0.3	40%=0	0.4
8			40%=0.4	40%=0.24	20%=0	0.64
9			20%=0.2	40%=0.24	40%=0	0.44
10			30%=0.3	40%=0.24	30%=0	0.54
11				50%=0.3	50%=0	0.3
12			10%=0.06	50%=0.3	50%=0	0.36
13			40%=0.4	50%=0.3	10%=0	0.7
14				50%=0.3	50%=0	0.3
15			10%=0.1	50%=0.3	40%=0	0.4
16			30%=0.3	40%=0.24	30%=0	0.54
17			10%=0.1	80%=0.48	10%=0	0.58
18			50%=0.5	50%=0.3		0.8
19			30%=0.3	50%=0.3	20%=0	0.6
20			50%=0.5	40%=0.24	10%=0	0.74
21			50%=0.5	50%=0.3		0.8
22			40%=0.4	40%=0.24	20%=0	0.64
23			40%=0.4	40%=0.24	20%=0	0.64
24			50%=0.5	50%=0.3		0.8
25			30%=0.3	50%=0.3	20%=0	0.6
26	40%=0.8		40%=0.4	20%=0.12		1.32
27	20%=0.4	10%=0.15	40%=0.4	20%=0.12		1.07
28		10%=0.15	40%=0.4	50%=0.3		0.85
29			10%=0.1	70%=0.42	20%=0	0.52
30	10%=0.2	20%=0.3	20%=0.2	30%=0.18	20%=0	0.88
31	20%=0.4	20%=0.3	30%=0.3	20%=0.12	10%=0	1.12
32		10%=0.15	30%=0.3	40%=0.24	20%=0	0.69
33	20%=0.4	20%=0.3	20%=0.2	30%=0.18	20%=0	1.08
34	10%=0.2	10%=0.15	30%=0.3	30%=0.18	20%=0	0.65
35	30%=0.6	30%=0.45	30%=0.3	10%=0.06		1.41
36		10%=0.15	60%=0.6	30%=0.18		0.93
37		20%=0.3	55%=0.55	15%=0.09	10%=0	0.94
38			40%=0.4	50%=0.3	10%=0	0.7
39			40%=0.4	50%=0.3	10%=0	0.7
40			40%=0.4	30%=0.18	30%=0	0.58
41			40%=0.4	60%=0.36		0.76
42	40%=0.8	20%=0.3	40%=0.4			1.5
43	10%=0.2		40%=0.4	30%=0.18	20%=0	0.78
44			50%=0.5	30%=0.18	20%=0	0.58
45			50%=0.5	40%=0.24	10%=0	0.74
46			50%=0.5	40%=0.24	10%=0	0.74
47			60%=0.6	40%=0.24		0.84
48		10%=0.15	40%=0.4	40%=0.24	10%=0	0.79
49	10%=0.2		40%=0.4	40%=0.24	10%=0	0.84
50	20%=0.4		40%=0.4	40%=0.24		1.04
51			40%=0.4	40%=0.24	20%=0	0.64
52	10%=0.2		40%=0.4	30%=0.18	20%=0	0.78
53	10%=0.2		40%=0.4	30%=0.18	20%=0	0.78

Annexure V continued...

Facets	Flowing	Dripping	Wet	Damp	Dry	Total
Max SSEP	2	1.5	1	0.6	0	2
54	20%=0.4	10%=0.15	30%=0.3	40%=0.24		1.09
55			50%=0.5	40%=0.24	10%=0	0.74
56			50%=0.5	40%=0.24	10%=0	0.74
57			40%=0.4	40%=0.24	10%=0	0.64
58	30%=0.6		30%=0.3	40%=0.24		1.14
59		10%=0.15	40%=0.4	40%=0.24	10%=0	0.79
60			30%=0.3	40%=0.24	30%=0	0.54
61		10%=0.15	40%=0.4	40%=0.24	10%=0	0.79
62			30%=0.3	50%=0.3	20%=0	0.6
63			30%=0.3	40%=0.24	30%=0	0.54
64		10%=0.15	40%=0.4	40%=0.24	10%=0	0.79
65			40%=0.4	40%=0.24	20%=0	0.64
66	10%=0.2	10%=0.15	40%=0.5	40%=0.24		0.93
67			40%=0.5	40%=0.24		0.74
68	20%=0.4	10%=0.15	40%=0.4	30%=0.18		1.13
69			50%=0.5	50%=0.3		0.8
70	40%=0.8	20%=0.3	10%=0.1	30%=0.18		1.38
71	20%=0.4	50%=0.75	10%=0.1	20%=0.12		1.37
72	30%=0.6	30%=0.45		40%=0.24		1.29
73		20%=0.3	40%=0.4	40%=0.24		0.94
74		10%=0.15	50%=0.5	35%=0.21	5%=0	0.86
75		5%=0.075	15%=0.15	50%=0.3	30%=0	0.525
76		10%=0.15	40%=0.4	40%=0.24	10%=0	0.79
77		20%=0.3	70%=0.7	10%=0.06		1.06
78		20%=0.3	40%=0.4	40%=0.24	10%=0	0.94
79		10%=0.15	50%=0.5	40%=0.24		0.89
80		30%=0.45	50%=0.5	20%=0.12		1.07
81			30%=0.3	60%=0.36	10%=0	0.66
82	10%=0.2	10%=0.15	50%=0.5	30%=0.18		1.03
83		10%=0.15	30%=0.3	50%=0.18	10%=0	0.63
84			50%=0.5	50%=0.3		0.8
85	10%=0.2		40%=0.4	50%=0.3		0.9
86		10%=0.15	50%=0.5	40%=0.24		0.89
87		10%=0.15	40%=0.4	40%=0.24	10%=0	0.79
88		10%=0.15	50%=0.5	40%=0.24		0.89
89			30%=0.3	50%=0.3	20%=0	0.6
90			30%=0.3	60%=0.36	10%=0	0.66
91			40%=0.4	50%=0.3	10%=0	0.7
92		10%=0.15	40%=0.4	40%=0.24	10%=0	0.79
93		10%=0.15	40%=0.4	50%=0.3		0.85
94		30%=0.45	40%=0.4	30%=0.18		1.03
95	20%=0.4	10%=0.15	30%=0.3	40%=0.24		1.09
96		10%=0.15	40%=0.4	50%=0.3		0.85
97	20%=0.4	10%=0.15	30%=0.3	40%=0.24		1.09
98			40%=0.4	50%=0.3	10%=0	0.7
99	30%=0.6	20%=0.3	30%=0.3	20%=0.12		1.32
100			20%=0.2	20%=0.12	60%=0	0.32
101	10%=0.2		30%=0.3	30%=0.18	30%=0	0.68
102	20%=0.4	10%=0.15	50%=0.5	20%=0.12		1.17
103	10%=0.2	40%=0.4	40%=0.4		10%=0	1
104	30%=0.6		40%=0.4	30%=0.18		1.18
105			50%=0.5	40%=0.24	10%=0	0.74
106			40%=0.4	30%=0.18	30%=0	0.58
107			40%=0.4	50%=0.3	10%=0	0.7
108			40%=0.4	50%=0.3	10%=0	0.7

Annexure V continued...

Facets	Flowing	Dripping	Wet	Damp	Dry	Total
Max SSEP	2	1.5	1	0.6	0	2
109			40%=0.4	30%=0.18	30%=0	0.58
110		10%=0.15	30%=0.3	30%=0.18	30%=0	0.63
111		10%=0.15	40%=0.4	40%=0.24	10%=0	0.79
112	10%=0.2	10%=0.15	40%=0.4	40%=0.24		0.99
113		10%=0.15	50%=0.5	40%=0.24		0.89
114		10%=0.15	50%=0.5	40%=0.24		0.89
115			50%=0.5	40%=0.24		0.74
116		10%=0.15	40%=0.4	40%=0.24	10%=0	0.79
117			40%=0.4	50%=0.3	10%=0	0.7
118			10%=0.1	60%=0.36	30%=0	0.46
119			50%=0.5	30%=0.18	20%=0	0.68
120		10%=0.15	40%=0.4	40%=0.24	10%=0	0.79
121		10%=0.15	50%=0.5	40%=0.24		0.89
122			50%=0.5	40%=0.24		0.74
123			50%=0.5	30%=0.18	20%=0	0.68
124		10%=0.15	40%=0.4	40%=0.24	10%=0	0.79
125	20%=0.4	10%=0.15	50%=0.5	20%=0.12		1.17
126		10%=0.15	50%=0.5	20%=0.12	20%=0	0.77
127			40%=0.4	40%=0.24	20%=0	0.64
128	20%=0.4		40%=0.4	40%=0.24		1.04
129	10%=0.2	10%=0.15	50%=0.5	30%=0.18		1.03
130	10%=0.2	10%=0.15	40%=0.4	40%=0.24		0.97
131	20%=0.4	10%=0.15	50%=0.5	20%=0.12		1.17
132	40%=0.8		30%=0.3	20%=0.12	10%=0	1.22
133		20%=0.3	30%=0.3	40%=0.24	10%=0	0.84
134	20%=0.4		30%=0.3	40%=0.24	10%=0	0.94
135			30%=0.3	40%=0.24	30%=0	0.54
136			40%=0.4	40%=0.24	30%=0	0.64
137			30%=0.3	40%=0.24	30%=0	0.54
138	10%=0.2		40%=0.4	30%=0.18	20%=0	0.78
139			40%=0.4	50%=0.3	10%=0	0.7
140	10%=0.2		30%=0.3	60%=0.36		0.86
141			30%=0.3	50%=0.3	10%=0	0.6
142			30%=0.3	50%=0.3	10%=0	0.6
143			30%=0.3	60%=0.36	10%=0	0.66
144			40%=0.4	40%=0.24	20%=0	0.64
145			40%=0.4	40%=0.24	20%=0	0.64
146			40%=0.4	40%=0.24	20%=0	0.64
147	10%=0.2		30%=0.3	70%=0.48		0.98
148	30%=0.6		50%=0.5	20%=0.12		1.22
149			50%=0.5	50%=0.3		0.8
150	50%=1		50%=0.5			1.5
151			30%=0.3	70%=0.48		0.78
152			30%=0.3	50%=0.3	10%=0	0.6
153	10%=0.2		40%=0.4	40%=0.24	10%=0	0.84
154	30%=0.6		50%=0.5	20%=0.12		1.22
155	5%=0.1		35%=0.35	35%=0.21		0.66
156			30%=0.3	40%=0.24	30%=0	0.54
157			30%=0.3	40%=0.24	30%=0	0.54
158	10%=0.2		40%=0.4	50%=0.3		0.9
159	10%=0.2		20%=0.2	30%=0.18	40%=0	0.58
160			10%=0.1	40%=0.24	50%=0	0.34
161				70%=0.48	30%=0	0.48
162	10%=0.2	10%=0.15		70%=0.48		0.83
163		10%=0.15	30%=0.3	60%=0.36		0.81
164	10%=0.2	10%=0.15		70%=0.48		0.83

Annexure V continued...

Facets	Flowing	Dripping	Wet	Damp	Dry	Total
Max SSEP	2	1.5	1	0.6	0	2
165	30%=0.6	20%=0.3		50%=0.3		1.2
166	20%=0.4	10%=0.15	30%=0.3	30%=0.18	10%=0	1.03
167	10%=0.2		10%=0.1	20%=0.12	60%=0	0.42
168		10%=0.15	20%=0.2	60%=0.36	10%=0	0.71
169			20%=0.2	70%=0.48	10%=0	0.68
170			20%=0.2	40%=0.24	40%=0	0.44
171	10%=0.2		40%=0.4	40%=0.24	10%=0	0.84
172	10%=0.2		20%=0.2	40%=0.24	30%=0	0.64
173	40%=0.8	20%=0.3	20%=0.2	20%=0.18		1.48
174	20%=0.4	20%=0.3	30%=0.3	30%=0.18		1.18
175	20%=0.4			30%=0.18	50%=0	0.58
176	20%=0.4		10%=0.06	40%=0.24	30%=0	0.5
177	20%=0.4		40%=0.4	30%=0.18	10%=0	0.98
178	60%=1.2		20%=0.2	20%=0.12		1.52
179	20%=0.4		40%=0.4	30%=0.18	10%=0	0.98
180	20%=0.4		50%=0.5	20%=0.12	10%=0	1.02
181			50%=0.5	20%=0.12	30%=0	0.62
182	70%=1.4		10%=0.06	20%=0.12		1.62
183	60%=1.2		20%=0.2	20%=0.12		1.52
184	40%=0.8		30%=0.3	30%=0.18		1.28
185			80%=0.8	20%=0.12		0.92
186		20%=0.3	50%=0.5	30%=0.18		0.98
187			10%=0.1	70%=0.48	20%=0	0.54
188	10%=0.2			70%=0.48	20%=0	0.68
189	10%=0.2	10%=0.15	35%=0.35	35%=0.21	10%=0	0.91
190	10%=0.2		40%=0.4	40%=0.24	10%=0	0.84
191		20%=0.3	50%=0.5	20%=0.12	10%=0	0.92
192	50%=1	50%=0.75				1.75
193		10%=0.15	40%=0.4	40%=0.24	10%=0	0.79
194		10%=0.15	50%=0.5	40%=0.24		0.89
195	20%=0.4	10%=0.15	35%=0.35	35%=0.21		1.11
196	20%=0.4	20%=0.3	40%=0.4	20%=0.12		1.22
197			40%=0.4	40%=0.24	20%=0	0.64
198			40%=0.4	40%=0.24	10%=0	0.64
199		10%=0.15	60%=0.6	20%=0.12	10%=0	0.87
200	5%=0.1	15%=0.225	50%=0.5	20%=0.12	10%=0	0.945
201	20%=0.4	20%=0.3	50%=0.5	10%=0.06		1.26
202	40%=0.8	30%=0.45	30%=0.3			1.55
203	40%=0.8	20%=0.3	40%=0.4			1.5
204	40%=0.8		20%=0.2	40%=0.24		1.24
205	20%=0.4		20%=0.2	60%=0.36		0.96
206		20%=0.3	30%=0.3	40%=0.24	10%=0	0.84
207	20%=0.4		30%=0.3	50%=0.3		1
208		10%=0.15	50%=0.5	40%=0.24		0.89
209	20%=0.4		40%=0.4	30%=0.18	10%=0	0.98
210	40%=0.8		30%=0.3	30%=0.18		1.28
211		10%=0.15	40%=0.4	50%=0.3		0.85
212		10%=0.15	30%=0.3	50%=0.3	10%=0	0.75
213	40%=0.8	40%=0.6		20%=0.12		1.52
214	40%=0.8	40%=0.6	20%=0.2			1.6
215	10%=0.2	30%=0.45	40%=0.4	10%=0.06	10%=0	1.11
216			40%=0.4	50%=0.3	10%=0	0.7
217	10%=0.2		30%=0.3	50%=0.3	10%=0	0.8
218		10%=0.15	50%=0.5	40%=0.24		0.9
219	40%=0.8		40%=0.4	10%=0.06	10%=0	1.26

Annexure V continued...

Facets	Flowing	Dripping	Wet	Damp	Dry	Total
Max SSEP	2	1.5	1	0.6	0	2
220			40%=0.4	40%=0.24		0.64
221	10%=0.2		40%=0.4	40%=0.24		0.84
223	40%=0.8		40%=0.4	20%=0.12		1.32
224			10%=0.1	50%=0.3	40%=0	0.4
225			40%=0.4	40%=0.24		0.64
226	20%=0.4		50%=0.5	30%=0.18	20%=0	1.08
227				50%=0.3	50%=0	0.3
228	10%=0.2			30%=0.18	60%=0	0.38
229	10%=0.2			30%=0.18	60%=0	0.38
230	20%=0.4		30%=0.3	40%=0.24	10%=0	0.94
231			40%=0.4	40%=0.24	20%=0	0.64
232	20%=0.4		40%=0.4	40%=0.24		1.04
233			50%=0.5	50%=0.3		0.8
234	10%=0.2		40%=0.4	40%=0.24	10%=0	0.84
235	10%=0.2	10%=0.15	40%=0.4	40%=0.24		0.99
236			30%=0.3	40%=0.24	30%=0	0.54
237	10%=0.2			30%=0.18	60%=0	0.38
238	10%=0.2	10%=0.15	40%=0.4	40%=0.24		0.99
239	10%=0.2		40%=0.4	40%=0.24	10%=0	0.84
240	10%=0.2		40%=0.4	40%=0.24	10%=0	0.84
241	10%=0.2			30%=0.18	60%=0	0.38
242	30%=0.6			30%=0.18	40%=0	0.78
243	10%=0.2		50%=0.5	40%=0.24		0.94
244	10%=0.2	10%=0.15	30%=0.3	40%=0.24		0.89
245			40%=0.4	50%=0.3	10%=0	0.7
246			50%=0.5	50%=0.3		0.8
247			40%=0.4	50%=0.3	10%=0	0.7
248	10%=0.2		60%=0.6	30%=0.18		0.98
249		10%=0.15	40%=0.4	50%=0.3		0.85
250	10%=0.2	10%=0.15	40%=0.4	40%=0.24		0.99
251	50%=1	30%=0.45	20%=0.2			1.65
252			60%=0.6	40%=0.24		0.84
253			50%=0.5	40%=0.24	10%=0	0.74
254			50%=0.5	40%=0.24	10%=0	0.74
255	20%=0.4	10%=0.15	30%=0.3	40%=0.24		1.09
256	20%=0.4		40%=0.4	40%=0.24		1.04
257	20%=0.4		30%=0.3	40%=0.24		0.79
258		10%=0.15	40%=0.4	40%=0.24	10%=0	0.79
259	40%=0.8		30%=0.3	40%=0.24		1.34
260		10%=0.15	40%=0.4	50%=0.3		0.85
261	40%=0.8		30%=0.3	25%=0.12	10%=0	1.22
262	10%=0.2	10%=0.15	30%=0.3	40%=0.24		0.89
263			40%=0.4	50%=0.3	20%=0	0.64
264			40%=0.4	50%=0.3	20%=0	0.64
265			30%=0.3	40%=0.24	30%=0	0.54
266				70%=0.48	30%=0	0.48
267	10%=0.2			70%=0.48		0.68
268	10%=0.2		20%=0.2	60%=0.36	10%=0	0.76
269	10%=0.2	10%=0.15	30%=0.3	40%=0.24		0.89
270	10%=0.2		40%=0.4	50%=0.3		0.9
271		10%=0.15	40%=0.4	40%=0.24		0.79
272			30%=0.3	60%=0.36	10%=0	0.66
273	10%=0.2		30%=0.3	50%=0.3	10%=0	0.8
274		20%=0.3	50%=0.5	30%=0.18		0.98

Annexure VI Alemketema Meteorological station monthly precipitation in mm (1990 - 2013)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1990	0.1	63											63.1
1991								342.9			0	7.9	350.8
1992	14.1	48.6	33.2	56.1	15.9	24.8	204.4	326.7	133.9	50.1	112.9	0	1020.7
1993	0	23.5	11.7	123.3	111.4	48.3	345.5	256.6	194.6	23.6	0	0	1138.5
1994	0	0	44	26.2	8.3	98.6	290.7	320.5	170.5	0	2.2	0	961
1995	0	3.4	53.9	43.9	50.1	26	229.2	342	83.3	0	0	12.8	844.6
1996	25.9	6.7	101.6	11.5	79	191.1	319.9	338.5	104	0	16	0	1194.2
1997	20.3	0	49.3	37.1	40.3	190	344.2	252.5	85	76	46.3	2.1	1143.1
1998	17.4	17.6	28.3	25	73.4	66.8	247.2	355.5	87.1			0	918.3
1999	7.2	0	0	1.5	10	39.3	297.4	514.6	66.3	151.8	0	1.3	1089.4
2000	0	0	36.1	103.7	88.1	58.6	449.1	311.5	122.1	7.2	32.2	0.4	1209
2001	0	5	45.7	20.5	29.9	96	373.5	266.5	90.9	0.3	0	6.1	934.4
2002	41.6	38.2	44.8	40.8	9.3	39.3	283.9	282.2	121.1	0	0	13.4	914.6
2003	9	54	53.4	61.3	1.5	90.5	308.8	254	139	2.5	0.5	31.2	1005.7
2004	9.2	6.1	21.9	71.5	23.2	96.4	206.8	258.9	142.8	32.6	1.1	0	870.5
2005	18.9	0	53.6	47	97.9	91.1	273.8	328.7	142	15.4	7.4	0	1075.8
2006	12.6	13	96.4	27.8	31.2	103.7	388.9	355.6	166.1	5.4	6.2	0	1206.9
2007	2.4	37	34.5	57.4	24.3	138.7	373.4	299.4	201.7	8	0	0	1176.8
2008	0	0	0	37.8	46.3	96.5	301	313	106.2	13	47.2	0	961
2009	17.7	2.6	25.2	18.1		24.6	371.8	285.3	71.6	23.1	1	55.7	896.7
2010	0	37.5	22.1	38.3	57.7	13.5	252.5	369.8	156	1.1	13.2	18.4	980.1
2011	2.6	0			30.9	64.6	231.7	362				0	691.8
2012	0					114.3	385.1	399	170.8	0	0	5.3	1074.5
2013	1	0.6	21.7	43.8	30.8	91.1	314.7	325.1	114	82.1	0		1024.9
2013		0.6		43.8	30.8								75.2

Annexure VII Meranya Meteorological station monthly precipitation in mm (1999 - 2013)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1999	0	0	28.3	11.7	5.4	33.3	304	372	44.4	44.9	0	0.3	845
2000			13.6	61.5	29.2	50.6	472	331	134	48.9	1.4	1.3	1143
2001	0	17.5	68.2	19.3	57.2	110	357	236	35.7	1	0	17.8	920
2002	54.7	27.5	52.7	17.1	16.4	49.1	331	311	103	0	0	16.2	979
2003	7.9	51.3	103	84.4	0.4	98.4	375	348	89.7	0.6	0.2	13	1171
2004	6.3	4	40.1	77.2	46.6			289	68.9	27	0.3	0	559
2005	23.4	0.5	44.5	91.1	120	85.1	227	238	139	7.3	7	0	983
2006	10.6	49.2	115	71.9	40.3	38.7	398	344	153	3.3	7.5	14.4	1247
2007	12.6	38.2	25.4	48.3	16.6	128	277	274	177	1.3	0		999
2008	4.2	2.1	0	40	24.1	56	295	231	86.2		32.9	0	771
2009	6.4	9.3	19.9	69.5	47.1	31.4	350	336	42.7	18.5	2	37.6	970
2010	0	49.8	75.4	75.7	149	5.2	367	546	118	0	30.3	13.5	1430
2011	6.1		79.2	14.2	72.4	67				0	81.5	0	320
2012								321	133	5.4			459
2013	1.5	0	40.9	45.6	30.6	126	389	465	72.5	35.8	1.4	0	1208

Annexure VIII Jihur Meteorological station monthly precipitation in mm (2010 - 2013)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	
2010	1.6	55.8	41.4	56.9	59.9		299.8	334	76.1	0	0	20.7	946.2	
2011	2.3	0	94.3	46.2	67.3	33.1	106.9	187.1	90.9	0	3.9		632	
2012								287.8	30.5	0			318.3	
2013	0						24.6	322.5	356.1	58.9	41.6	0	0	803.7

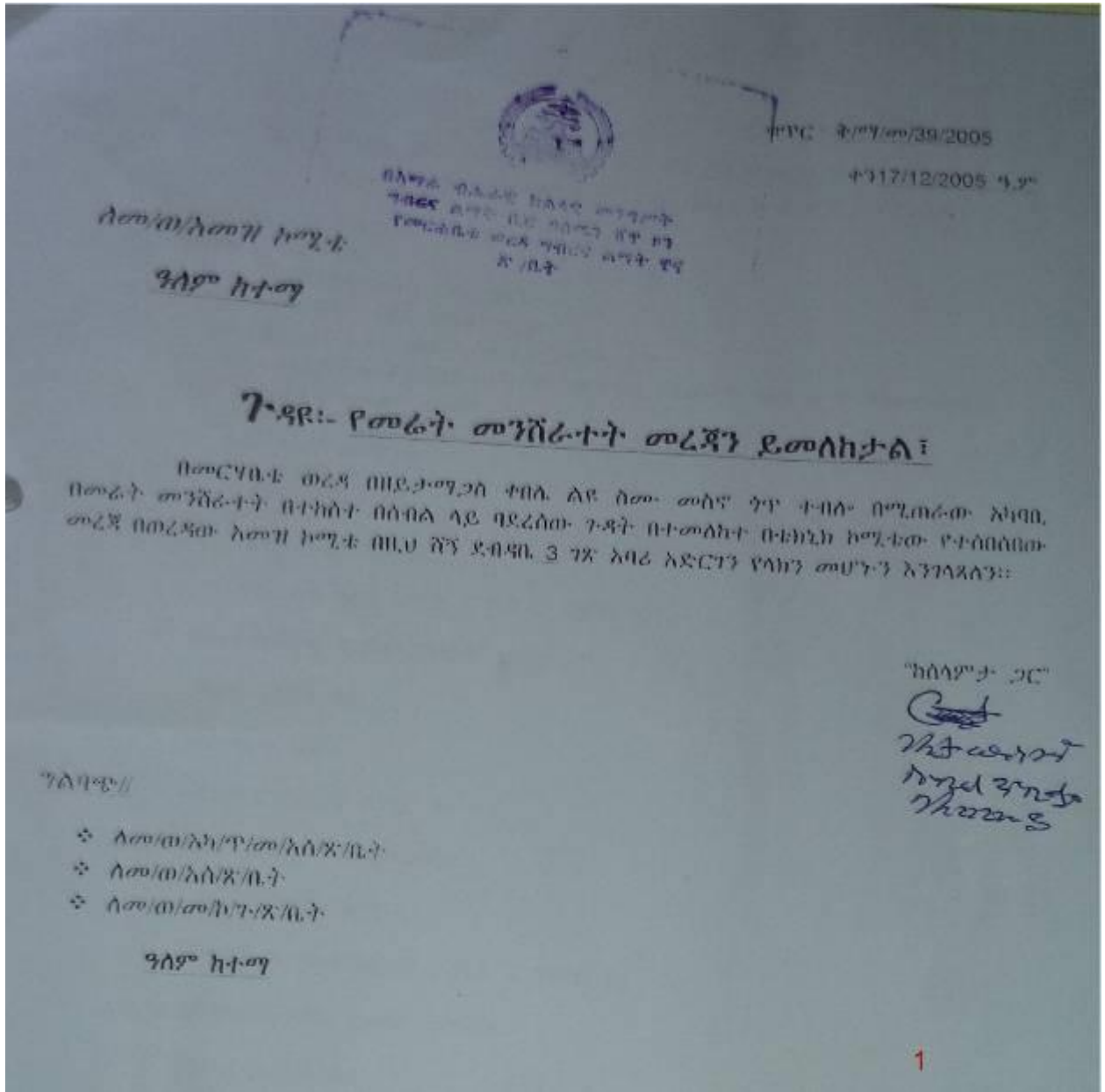
Annexure IX Alemketema Meteorological station Maximum and Minimum temperature in °C (1990 - 2013)

TMP Type	Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
TMPMAX	1990	12.9	14	14.1										41
TMPMAX	1991											11.6	11.8	23.4
TMPMAX	1992	12.7	14.1	14.9	14.9	15.7	15.2	12.7	12.6	12.3	12.6	11.8	11.4	160.9
TMPMAX	1993	13.5	13.9	14.1	13.8	15.3	14.8	12.8	12.9	13.1	13.5	12.7	12.5	162.9
TMPMIN	1994	13.5	14.5	15.3	15.9	16.4	15	12.9	12.8	12.8	13.3	12.9	12.6	167.9
TMPMIN	1995	13.5	14.7	15.1	15.6	15.9	16.2	13.4	12.8	13.7	14	13.1	13.2	171.2
TMPMAX	1996	13.7	14.8	14.8	15.3	15.3	14	12.8	12.4	13.6	13.2	12.2	12.7	164.8
TMPMIN	1997	13.8	13.2	15.2	14.7	15.8	14.6	12.8	13	14.3	14.2	13.8	13.2	168.6
TMPMIN	1998	14.2	15.5	15.6	16.6	16.7	15.8	13.3	13.3	13.6				134.6
TMPMAX	1999							20.6	20.9	22.7	23.2	24.4	24.7	136.5
TMPMAX	1999							12.3	12.4	13.6	13.1	11.5	12.4	75.3
TMPMAX	2000		27.1	28.4	26.5	27.4	26.9	20.9	20.7	22.6	24.5	24.7	25.2	274.9
TMPMAX	2000	12.6	13.5	14.8	13.1	15.7	15.2	12.2	12.3	13.3	12.9	12.3	12.4	160.3
TMPMAX	2001	25.5	27.3	25.7	28.2	27.6	25.4	21.2	20.5	23.3	25.7	25.3	25.7	301.4
TMPMAX	2001	13.3	14.4	14.5	16.1	15.9	14.6	13	13.7	13.8	13.9	12.6	13	168.8
TMPMIN	2002		27.6	27.3	28.4	29.7	27.7	24.2	21.2	23.2	26.1	26.5	25.9	287.8
TMPMIN	2002	13.1	14.5	15.1	15.7	17.6	15.4	14	13.1	14	13.8	12.9	14.2	173.4
TMPMIN	2003	26.7	28.1	27.5	27.7	29.5	26.9	21	20.8	22.4	25.7	25.7	25.4	307.4
TMPMIN	2003	14.1	15.1	15.2	15.8	18	15.7	13.4	13.7	13.5	13.4	13	12.5	173.4
TMPMIN	2004	15	14.1	14.6	15.7	17	15.5	13.1	13.2		12.4	12.7	12.8	156.1
TMPMIN	2004	27.2	27.8	28.1	27	29.2	26	21.9	21.4		24.4	25.5	25.7	284.2
TMPMIN	2005	25.6	27.9	28.3	27.7	26	26.5	21	20.8	23.1	25.3	24.9	24.9	302
TMPMIN	2005	12.9	14.4	14.9	14.7	15.2	15.2	12.8	13	13.2	12.8	11.9	10.7	161.7
TMPMIN	2006	26.4	28	27.2	26.7	28	27.3	22	20.5	22.3	25.6	24.5	25.6	304.1
TMPMIN	2006	12.4	14.3	14.8	15.1	16.1	15.4	13.1	12.7	13.3	14.6	13	13.4	168.2
TMPMIN	2007	26.4	26.8	28.4	27.9	28.8	25.4	20.8	20.6	22.5	24.6	25.5	25.1	302.8
TMPMAX	2007	14.3	14.6	15.4	15.9	16.9	15.2	12.8	12.8	6.7	13.5	12.7	11.9	162.7
TMPMAX	2008	26.5	27.3	29.2	27.8	28.1	26.3	22.4	20.9	23.3	25.3	24.3	25.6	307
TMPMIN	2008	14.1	14.1	15.4	16.2	16.7	14.9	13.1	12.6	13.7	14	12.2	13.1	170.1
TMPMIN	2009	26.4	27.9	28.9	28.8	29.5	29.4	21.2	21.5	24.1	25.3	26.5		289.5
TMPMIN	2009	13.9	14.8	15.8	16.3	17.2	17	12.8	13.1	14.5	13.9	13.2	14.2	176.7
TMPMIN	2010		27.5	28.2	28.4	28.1	28.6	22.7	20.7	23.1	25.9	26.1	25.5	284.8
TMPMIN	2010	14	15.8	15.3	16.2	16.6	16.6	13.4	12.9	13.6	14.4	13.1	13.3	175.2
TMPMIN	2011	14.2	14.1	14.7	16	16.1	15.9	13.3	13.1	13.6	13.7	13.3	12.4	170.4
TMPMIN	2011	26.5	28.6	27	29.1	28.3	27.7	22.6	21.2	23.2	25.9	25.7	26.3	312.1
TMPMAX	2012	27.1					28.3	22.8	21.6	24.6	26.1	27.3	26.5	204.3
TMPMIN	2012	13.5					15.9	12.7	12.5	13.6	13.4	13.8	13.1	108.5
TMPMAX	2013	28	29.3	29.7	30.4	29.4	27.2	20.7	20.6	23.4	24.6	25.8		289.1
TMPMIN	2013	13.8	14.9	15.5	16.1	16.1	15.3	12.8	12.8	13.6	13.3	13.2		157.4

Annexure X Meranya Meteorological station Maximum and Minimum temperature in °C (1999 - 2013)

TMP Type	Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
TMPMAX	1999	24.2	24.7	24.4	25.2	25	24.3	17.7	17.8	20	20.3	21.2	22.1	267
TMPMIN	1999	10.5	11.7	12.6	13.4	14.1	12.1	10.1	10.3	11	10.8	10	10.2	137
TMPMAX	2000		24.2	25.7	24.1	24.4	23.7	18.3	17.5	19.4	20.9	21.4	22.4	242
TMPMIN	2000		11.1	12	11.5	13.4	12.2	9.9	10.2	11	10.5	10	10.3	122
TMPMAX	2001	22.6	24.4	22.7	24.6	24.2	22	18.2	18.1	20.7	22.7	22.3	22.9	265
TMPMIN	2001	10.6	11.8	11.7	13.3	13	11.5	10.7	11.1	11.5	12	10.6	10.9	139
TMPMAX	2002	22.4	24.3	23.9	25.3	26.1	24.2	20.9	18.7	20.3	22.6	23.1	22.9	275
TMPMIN	2002	10.5	12.2	12.3	12.6	14.6	12.4	9.7	10.4	11.1	12.2	10.6	11.8	140
TMPMAX	2003	23.4	25	24.5	24	25.6	23.5	19	18.2	19.6	22.2	22.7	22.5	270
TMPMIN	2003	11.5	12.7	12.1	12.4	13.6	12.5	10.8	10.9	11.2	11.3	10.8	10.5	140
TMPMAX	2004	24	24.7	24.9	23.7	25.2			18.6	19.9	21.4	22.8	23	228
TMPMIN	2004	12.4	11.7	12.2	13.2	14.2			10.6	11.4	10.6	10.7	11.1	118
TMPMAX	2005	22.7	25.8	25.2	24.8	22.9	23.2	18.5	18.9	19.9	22.1	22.3	22.7	269
TMPMIN	2005	10.9	12.5	12.7	13	12.7	13.1	10.8	11.1	11.3	11.4	10.1	9.9	140
TMPMAX	2006	23.6	25.2	23.8	23.1	24.1	23.8	19	17.9	19.6	22.5	22.5	22.2	267
TMPMIN	2006	11.6	12.3	12.2	12	13.4	12.5	11	10.9	11	12	10.7	11.1	141
TMPMAX	2007	23.7	23.7	25.4	24.6	25.3	22.9	18.7	18.3	19.5	21.6	22.3		246
TMPMIN	2007	11.4	12	12.6	12.9	14	12.3	10.9	10.7	11	11	10.3		129
TMPMAX	2008	23.7	24.3	26.1	24.6	25	22.4	19	17.9	20.3		21.4	22.4	247
TMPMIN	2008	11.3	11.2	12.4	12.8	13.9	12.4	10.6	10.8	11.6		9.6	11	128
TMPMAX	2009	22.9	24.3	25.4	25.2	25.5	25.6	17.7	18.7	21.1	22.6	23.1	22.1	274
TMPMIN	2009	11.6	12.4	12.9	13.5	13.8	13.9	10.9	11.3	12.2	11.6	10.8	11.5	146
TMPMAX	2010	26.2	26.9	27.7	30.4	23.3	33.9	19.6	29.1	19.8	22.6	22.2	22.2	304
TMPMIN	2010	12.7	13.8	13.2	15.8	16	15.9	11.2	16.3	11.3	12.1	10.6	10.7	160
TMPMAX	2011	23	24.7	23.1	25.2	23.8	23.2				22.2	22	22.6	210
TMPMIN	2011	11.7	0	11.8	12.9	12.8	12.7				11.5	10.8	9.9	94.1
TMPMAX	2012								17.8	19.4	22.3			59.5
TMPMIN	2012								10.8	11.1	11.8			33.7
TMPMAX	2013	23.6	25.3	25.3	25.7	24.9	23	17.6	17.6	20.4	21.1	22.4	22	269
TMPMAX	2013	23.6	25.3	25.3	25.7	24.9	23	17.6	17.6	20.4	21.1	22.4	22	269
TMPMIN	2013	11.8	12.6	13.3	13.3	13.5	12.3	10.3	10	11.6	11.5	11.1	9.8	141

Annex XIa. Report on damages resulted from Landslide of Nehassie, 2005 E.C. Merhabete Wereda Agriculture Development office, North Shewa, Merhabete.



Annex XIa. Continued...

0.0625 %C
 0.125 %C
 1.125 %C የከርሻ መሬት የተገኘው ተተ መሆኑን

✓ ቢታዩት ለአደጋ የተጋለጠ አካደርቶ አስተጋጅ መፍትሄ የሚሆኑ ፡-

1. አቶ ሞጋም የሰው ክብት ይመር
2. አቶ ታከላ ሞጋም የሰም
3. አቶ በዛቤ አማር ሲሆኑ በተጨማሪም የ8 አካደርቶ ዜጎች በሲታት ላይ መሆኑን አይተናል።

የአደጋ አስተያየት

1ኛ ለአካደርቶ (የከርሻ) ጉዳይ ከመድረሱ በፊት በተጠቀሱት አንድጠላላ ምክረ ተሰጥቷል።

2ኛ የሰጠውን ሁለት ጉዳይ አንድሁም አንስሳቶች በዘመድ ዜጎች መሆናቸውን አንጻራቸው እና ራሳቸውን በማሸበ ላይ መሆናቸውን አስተያየት ተሰጥቷል።

3ኛ የተሸራተተው መሬት ከማንኛውም ገዢ ገን ሆኖ የተ/ወ/ሰ/ራ/ ተሰርቶበት አይገኝም እንደሚረገግ አንድደረግ አስተያየት ተሰጥቷል።

4ኛ ከጤና አገዳሪ ሁለት ሰው አባር መኖር ስለሌለበት ጥንቃቄ ማድረግ የሚሉትን አስተያየት ተሰጥቷል።


አደጋው ያደረሰውን ጉዳት ለማግራት የሚደረግ የአመገብ ስሚቲ አባላት ዘርዘር

ተ.ቁ	ስም	የሚሰሩበት መ/ቤት	ሀላፊነት
1	አቶ ገሰታው ንጋሽ	የመ/ወ/ገ/ገ/ሰ/ራ/ሰ/ት	
2	አቶ ነብሩ ንጉሴ	አስተዳደር ጽ/ቤት	
3	ወ/ሮ ወርቀት አፈራሁ እንግዳላሽ	ጤና ጥበቃ	
4	አ/ቶ ሀይወት አበበ	አካባቢ ጥበቃ	

በአካደሩ የተገሰጡ ጥያቄዎች

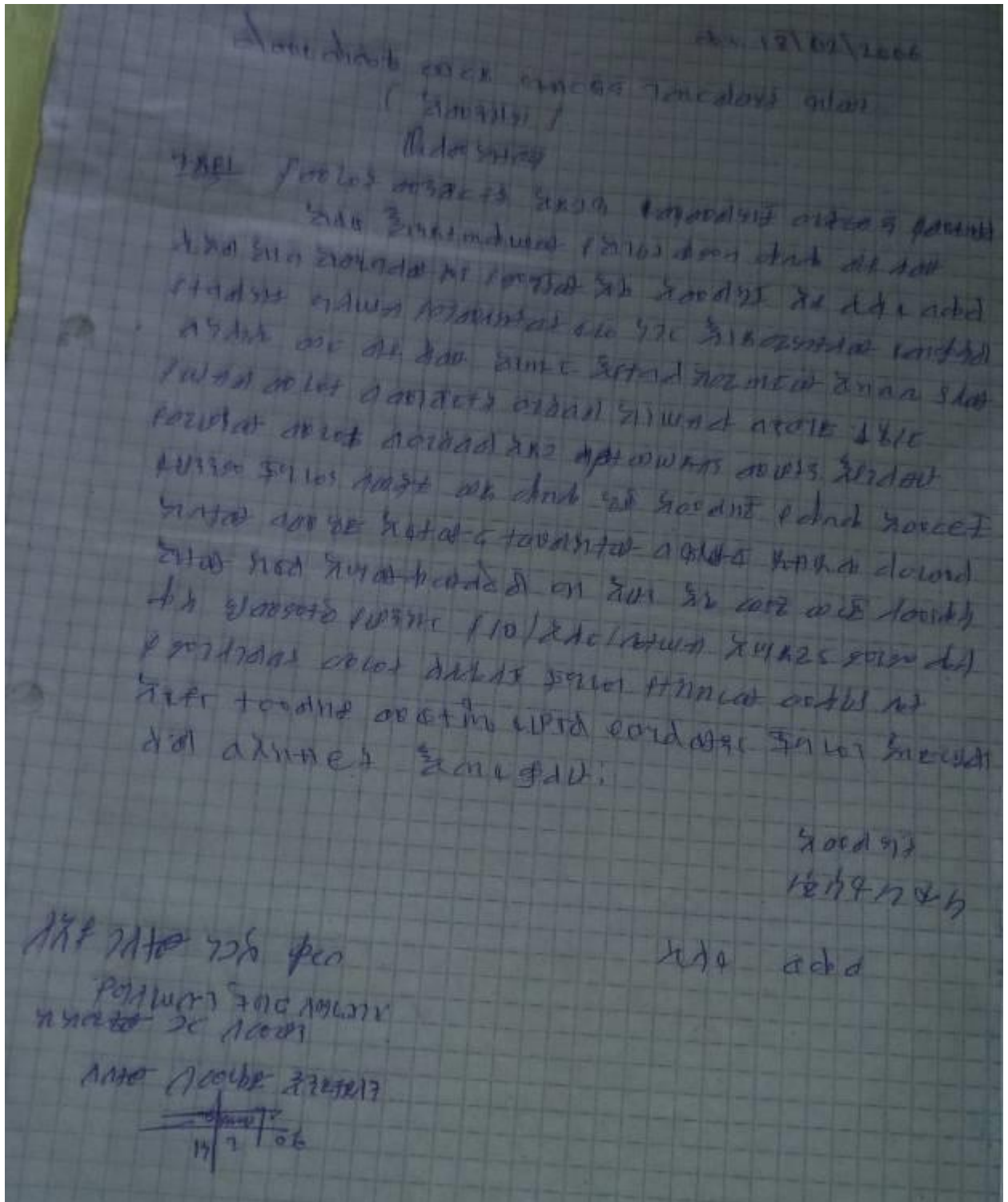
- ለግዢው መጠለያ ድንኩፍን ይሰጡን የሚል ጥያቄ አቀርበዋል።
- ለመደራቱ ጠያቂነት ስራ ስራ ብንሄድ የሚሉ ናቸው።

Report ንጉሴ
 መሪ ገዢዎች አካባቢ
 አባቶ

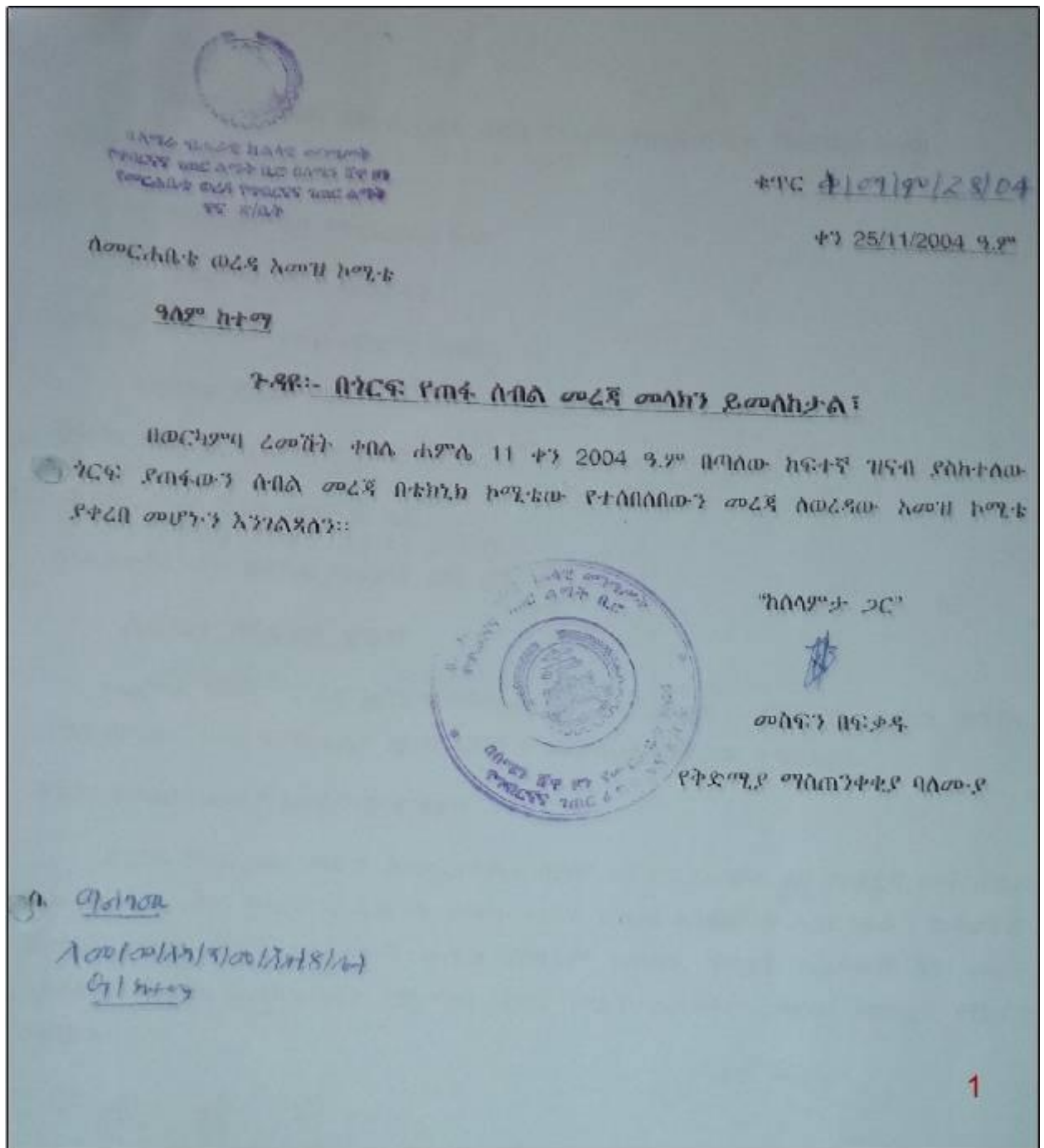


Annex XIb. Report on damages resulted from Landslide of Nehassie, 2006 E.C. Merhabete Wereda

Agriculture and Rural Development office, North Shewa, Merhabete.



Annex XIIa. Report on damages resulted from Flood of Hamle 11, 2004 E.C. Merhabete Wereda Agriculture and Rural Development office, North Shewa, Merhabete.



Annex XIIa. Continued...

በወርካምባ ተበሌ በጎርፍ የጠፋ ሰብል የአመገብ ቴክኒክ ኮሚቴ የሰበሰበው መረጃ
 የተከሰተው አደጋው ዓይነት ጎርፍ
 አደጋው የተከሰተበት ቀን 11/11/2004 ዓ.ም
 አደጋው የተከሰተበት ወረዳ መርከቤቲ
 አደጋው የተከሰተበት ተበሌ ወርካምባ ረመሽት
 በአደጋው የደረሰ ጉዳት

የማሽላ ሰብል በጎርፍ ተወሰዷል።
 የጠፋ
 በአደጋው ሰብል ሽፋን በሄ.ር 35 ሄ.ር ፡፡
 = የጉዳት መጠን 100% = 45%
 በአደጋው የተጋለጡ ቤተሰብ ጋላፊዎች ብዛት 79


አደጋው የደረሰው ጉዳት

አደጋው ህምሌ 11 ቀን 2004 ዓ.ም የተከሰተ ሲሆን በ 35 ሄ.ር ማሳ ላይ የነበረን የማሽላ ሰብል በከፍተኛ ደረጃ አጥፍቷል። 79 ገብሬዎች የማሽላ ሰብል በአደጋው ተጎድቷል።

በጎርፍ የተጠረገ መሬት ቋተፊ ጥርአዊ ገጽታ

በጎርፍ የተጠረገው መሬት በተዳፋታማነቱ በጣም ከፍተኛ በመሆኑ እና የአፈርና ውሃ ጥበቃ ስራ ላይ ሳይሰራለት ለእርሻ አገልግሎት መዋሉ መሬቱ በጎርፍ እንዲጠረገ አድርጎታል። በመሆኑም በተጣይ መሬቱ ለእርሻ አገልግሎት መዋል የለበትም የአካባቢ ጥበቃና አጠቃቀም እና መሬት አስተዳደር ጽ/ቤት አዲስ የይዞታ ማረጋገጫ ሲሰጥ መሬት አጠቃቀም መርህን መሠረት ማድረግ ይገባል።።።

(Handwritten signatures and initials)

31  **2**

Annex XIIa. Continued...

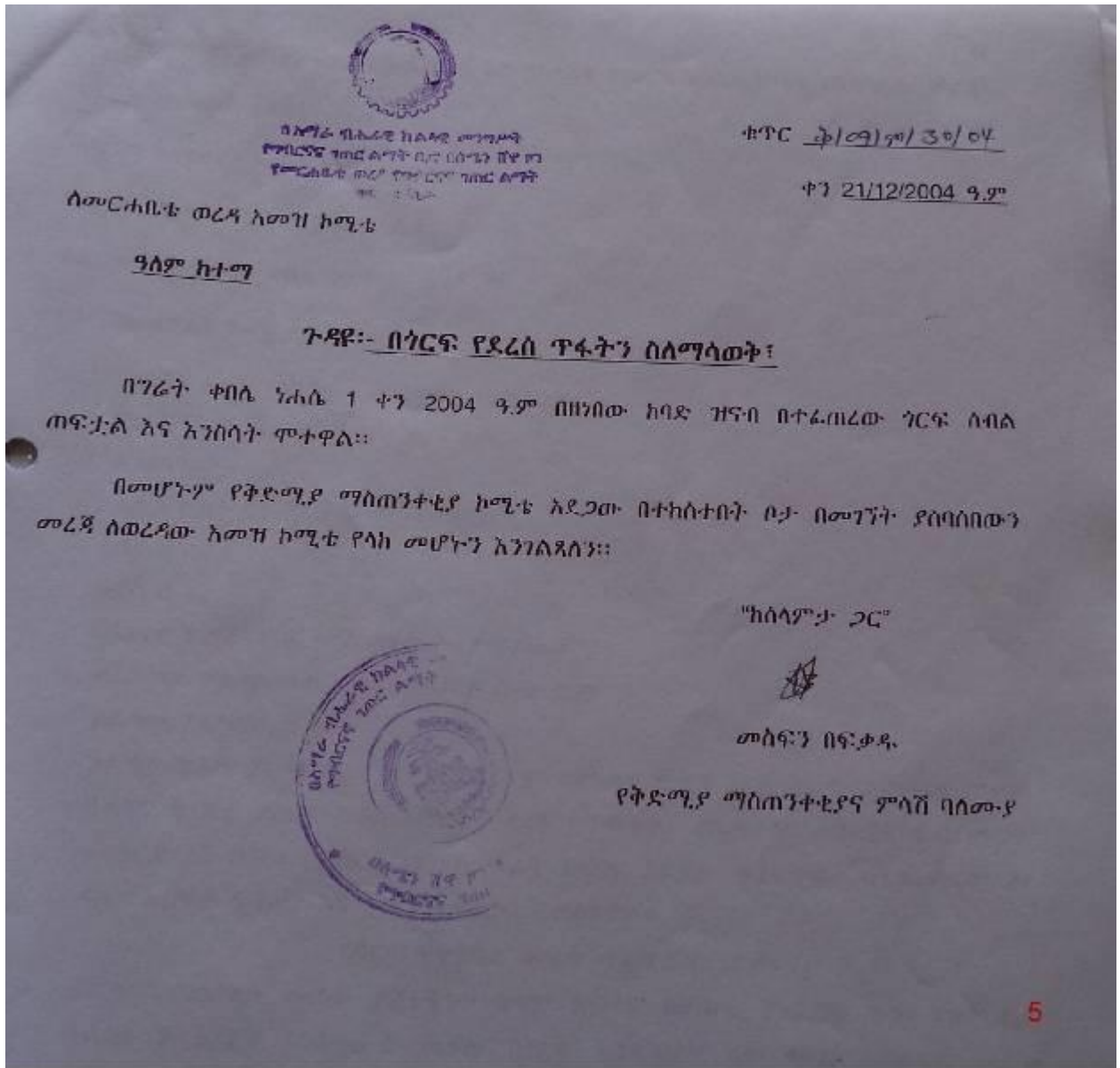
በመርከቻ ላይ ለሚገኙት ተጠቃሚ ሰጠል በጎርፍ ስብል የጠፋባቸው ለ/አደር መረጃ

ተ.ቁ	የአ/አደር ስም	የጠፋ ስብል ዓይነት	የመሬት ስፋት በጥጣጽ
1	ጎሽም ብዙነታ	ማሽላ	3
2	ጉርጥ ስበር	ማሽላ	3
3	እንዳሻው ምንጃ	ማሽላ	2
4	ጉርምስ እሸቱ	ማሽላ	4
5	እዘመራው ጉቶ	ማሽላ	2
6	ድንቡልታ አቅምሰህ	ማሽላ	3
7	ተመን እሸቱ	ማሽላ	2
8	ብሩ ሲጠግን	ማሽላ	2
9	እመቤት ደርሰህ	ማሽላ	2
10	ስበር አቅም የሰህ	ማሽላ	2
11	ይንደዱ ጋሻው በዛ	ማሽላ	2
12	አበበ ጨቡድ	ማሽላ	2
13	ተወደደው ይብቃ	ማሽላ	4
14	አፈወርቅ ጎረመስ	ማሽላ	2
15	ተዋበች ከበደ	ማሽላ	2
16	ባዮ አንበር-በር	ማሽላ	2
17	ጨበር ደሰለኝ	ማሽላ	2
18	ባንጃው ድፋዮ	ማሽላ	2
19	ስለውንድም አምይ	ማሽላ	2
20	ተክተል ድፋዮ	ማሽላ	2
21	አይንዮ አረዳ	ማሽላ	3
22	ስለሽ ተክሉ	ማሽላ	2
23	አበበ በንበሩ	ማሽላ	2
24	ጎረመስ ኃይለማርያም	ማሽላ	3
25	አላዩ አበራ	ማሽላ	2
26	ቄስ ጎረመስ ተሾመ	ማሽላ	3
27	ሰሱ አይተንፍሱ	ማሽላ	4

Annex XIIa. Continued...

ተ.ቁ	የአሰራር ስም	የጠቅላይ ስጦታ ዓይነት	የመሬት ስፋት በጥጣጽ
28	በደርሰ ጌትጥ	ማሽላ	2
29	ለላዩ በላይ	ማሽላ	2
30	ስዘር አቻምላህ	ማሽላ	2
31	መንግስቱ አሸቱ	ማሽላ	2
32	ጋሽው አጻጻር	ማሽላ	1
33	ካሳሁን አቡሽ	ማሽላ	3
34	አሻግር አቡሽ	ማሽላ	2
35	ዘመድ በለው	ማሽላ	2
36	ገሰታው አሰግድ	ማሽላ	3
37	ያብሩ መኮንን	ማሽላ	2
38	አይጋቡዝ ሸቀጥ	ማሽላ	2
39	ሻውል አስቻለው	ማሽላ	2
40	አድማሱ መንበረ	ማሽላ	2
41	ባንጃው ድፊ	ማሽላ	2
42	ቁስ ጌታቸው ጎበዜ	ማሽላ	2
43	አበባይ አራጋው	ማሽላ	5
44	ጌታቸው አራጋው	ማሽላ	2
45	አምታታው ይርጋወሰን	ማሽላ	2
46	ይርጉ ምላ	ማሽላ	2
47	አርቀው ብዙነህ	ማሽላ	2
48	በሀብቱ ድንቢጥ	ማሽላ	2
49	ትልቅ ሰው መሸሻ	ማሽላ	2
50	ቁስ መሸሻ ደምሴ	ማሽላ	2
51	አላዩ ጎንጥ	ማሽላ	2
52	አምሩ ማሙዩ	ማሽላ	2
53	ዝምአርጌ አንድአርጌ	ማሽላ	2
54	አላሳከሽኝ ግዛው	ማሽላ	2

Annex XIIb. Report on damages resulted from Flood of Nehassie 1, 2004 E.C. Merhabete Wereda Agriculture and Rural Development office, North Shewa, Merhabete.



Annex XIIb. Continued...

በግሬት ተበሌ በጎርፍ የጠፋትን ሰብሎች እና እንስሳት የአመዝ ተክሊክ ኮሚቴ የሰብላቤው መረጃ የተከሰተው አደጋ ዓይነት ጎርፍ

አደጋው የተከሰተበት ቀን 01/12/2004 ዓ.ም

አደጋው የተከሰተበት ወረዳ መርከቢቱ

አደጋው የተከሰተበት ተበሌ ግሬት

በአደጋው የደረሰ ጉዳት

1. የማሽላ ሰብል 132.25 ሄ.ር የጉዳት ደረጃ 47%
2. የጤፍ ሰብል 5 ሄ.ር የጉዳት ደረጃ 50%
3. እንስሳት:-
 - ዳልጋ ከብት 21
 - አህያ 5
 - ፍየል 3
 - እንስሳት የጥቁባቸው አርሶ አደሮች 17 ናቸው።
4. ለአደጋው የተጋሰጡ ቤተሰብ ኃላፊዎች ብዛት 228
አደጋው ያደረሰው ጥፋት
አደጋው ነሐሴ 01/12/2004 ቀን 2004 ዓ.ም የተከሰተ ሲሆን በ132.25 ሄ.ር የነበረን የማሽላ ሰብልና 5 ሄ.ር የጤፍ ሰብል በከፍተኛ ደረጃ አጥፍቷል። በአጠቃላይ 137.25 ሄ.ር መሬት ጉዳት ያደረሰ ሲሆን የ228 አ/አደሮች መሬት በጎርፍ አደጋው ተጎድቷል። በተጨማሪም 21 ዳልጋ ከብቶች 5 አህያ እና 3 ፍየል በጎርፍ ተወስደዋል።

በጎርፍ የተጎዳው መሬት ተፈጥሯዊ ገጽታ


በጎርፍ የተጠረገው መሬት ተዳፋትነቱ በጣም ከፍተኛ በመሆኑ የአፈርና ውሃ ጥበቃ ስራ ሳይሰራለት ለእርሻ እገልግሎት መዋሉ በጎርፍ እንዲጠረግ አድርጎታል። በተጣይ መሬቱ ለእርሻ እገልግሎት ከዋሰ ከዚህ የበለጠና የከፋ አደጋ ይደርስበታል።

አ/አደሮቹ የጠየቁትና የሰጡት አስተያየቶች

መሬቱን ልናርስ የቻልነው ሌላ እማራጭ ስለሌለ እና የመሬት ጥበት ስላለ በማረሳችን ይህ ትግር ሊከሰት ትችላል።

በመንግስት ይህንን ትግር በማየት ሌላ ዞታ በሰፊ መልክ በወሰደን ራሳችንን የሚል ጥያቄ አቅርበዋል።

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Annex XIIb. Continued...

መሬቶቹ የተወሰደባቸው በአብዛኛው ወጣቶች ናቸው። ይህም የሆነበት ምክንያት ወጣቶቹ መሬት የሌላቸው በመሆን ለወጣቶች የተሰጠ መሬት ነው።

- መሬቱ የመሬት ማረጋገጫ ደብተር የወጣበት በመሆኑ መንግስት ትኩረት ሊሰጠን ይገባል የሚል ጥያቄ አዘል አስተያየት ሰጥተዋል።
- የቴክኒክ ቡድኑ የሰጠው አስተያየት
- መሬቱ በከፍተኛ ደረጃ ተዳፋት በመሆኑ ወደ ፊት ለአርሻ ስራ ሲውል የበሰጠ በጎርፍ የሚጎዳ መሆኑ፤
- ወደ ፊት መሬቱ ለደን ልማት ይቆያል
- በጣም ብዙ መሬት ለሂደባቸው አ/አደር በቀበሌው ውስጥ የወል መሬት ካለ በትክ መልክ ይሰጣቸዋል።
- እንስሳት የሞቱባቸው አ/አደር ችግራቸው ከፋ በመሆኑ ወደ ፊት ድጋፍ የሚያደርግ እካል /ድርጅት/ ካለ ይደረግላቸዋል።
- በአጠቃላይ በጎርፍ የተጎዱት አ/አደሮች በዚህ በጀት የመክር አመት ምርት ስለሚቀንሰባቸው ድጋፍ ይደረግላቸው የሚል አስተያየት ተሰጥቷል።

አደጋው በተከሰተበት ቦታ በመገኘት አደጋው የደረሰውን ጥፋት ያረጋገጠው የቴክኒክ ኮሚቴ አባላት፤

ተ.ቁ	ስም	የሚሰራበት ጽ/ቤት	ጋላፊነት
1	መስፍን በፍቃዱ	ግብርና ልማት ጽ/ቤት	የትድሚያ ማስጠንቀቂያ ባለሙያ
2	ገለታው ነጋሽ	ግብርና ልማት ጽ/ቤት	የሰብል ልማት ባለሙያ
3	ነብር ንጉሴ	ወረዳ አስተዳደር ጽ/ቤት	ባለሙያ
4	ሀይወት አቤ	የአካ/ጥ/መ/አጠ/አሰ/ጽ/ቤት	ባለሙያ
5	ጥበቡ ገለታ	የጤና ጥበቃ ጽ/ቤት	ባለሙያ

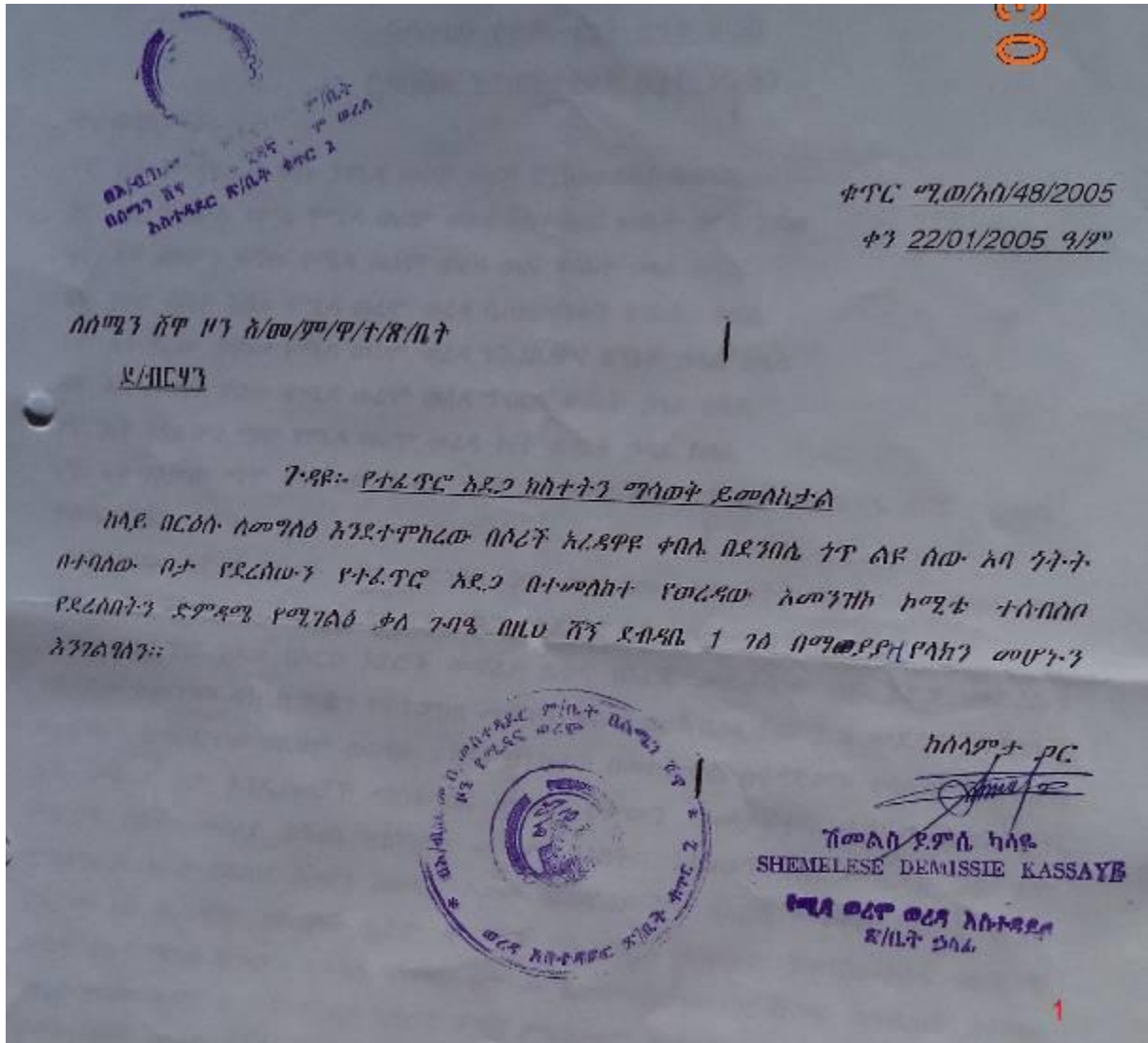
በአደጋው የደረሰ ዝርዝር መረጃ በሚከተለው ሆንጠረዥ ተጻልጿል።

(Handwritten signature)

(Official stamp)

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Annex XIIIa. Report on damages resulted from Landslide of 2005 E.C. Mida Weremo Wereda Agriculture and Rural Development office, North Shewa, Meranya.



Annex XIIIa. Continued..

ተን 21/01/2005 ዓ/ም

የሚያ ወረሞ ወረዳ አመንገዝ ኮሚቴ ስብሰባ
የስብሰባ ቦታ ሚያ ወረሞ ወረዳ አስተዳደር ቤቅ
 ስብሰባው የተጀመረበት ሰዓት 9:30
 ስብሰባው የተጠናቀቀበት ሰዓት 10:30

ተሳታፊዎች:-

- 1ኛ. አቶ ወንዳፍራሽ አባተ የሚያ ወረሞ ወረዳ ም/አስተዳዳሪ ስብሰባ
- 2ኛ. አቶ ሽመልስ ደምሴ የሚያ ወረሞ ወረዳ አስተዳደር ጽ/ቤት ኃላፊ አባል
- 3ኛ. አቶ ለለሞን ቃኝው የሚያ ወረሞ ወረዳ ጤና ጽ/ቤት ኃላፊ አባል
- 4ኛ. ወ/ሮ ብዙዬ እሸቱ የሚያ ወረሞ ወረዳ ሰ/ሀ/ወጣቶች ጽ/ቤት አባል
- 5ኛ. አቶ ቫረው ተሾመ የሚያ ወረሞ ወረዳ ገ/አ/ል/ዋና ጽ/ቤት ኃላፊ አባል
- 6ኛ. አቶ አብነት ፀጋው የሚያ ወረሞ ወረዳ ግብርና ጽ/ቤት ኃላፊ አባል
- 7ኛ. አቶ በላይሁን ማሞ የሚያ ወረሞ ወረዳ ት/ት ጽ/ቤት ኃላፊ አባል
- 8ኛ. አቶ ገለታው ማሞ ከቅ/ሚ/ምላሽ ሰራ ሂደት አስተባባሪ አባልና የዕለቱ ቃለ ጉባዔ ፀሀፊ በመሆን ተሳታፊነቱን አሳይቷል።

የስብሰባው አጀንዳ በሰራተኛ ቀበሌ በደንበላ ንጥ ልዩ ስሙ አባ ንትት በተባለው አካባቢ በ15 አባዎች 73 የቤተሰብ አባላት ላይ የደረሰውን የተፈጥሮ አደጋ በተመለከተ ነው።

ይህ የተፈጥሮ አደጋ በአርሶ አደሮች መኖሪያ ቤትና በእርሻ መሬታቸው ላይ አደጋ መድረሱን በወረዳው አመንገዝ ተክኒክ ቡድን የተረጋገጠ መሆኑን ስብሰባው አብራርተው ምን መደረግ እንዳለበት ለተሳታፊዎች አብራርተው በዚህም ወረዳው ጉዳዩን በትኩረት በመከታተል ለተጎደዎች ቀበሌው ለመኖሪያ ቤት መስሪያ ቦታ እንዲያመቻች ማስተባበር ቀበሌም ቦታውን ማመቻቸትና ሀ/ሰቡን ለተጎደዎች የሚሆን ለቤት መስሪያ ቀላቀስ ማሰጠት መደረግ አለበት። እስካሁን የአደጋ ስጋቱ 25 ሄ/ር የሚያካልል አደጋ የፈጠረ ሰለጠን ለቀጣይ ቦታው ለመኖሪያ ሆነ ለእርሻ ለማዋል ከፍተኛ ስጋት የገጠመ እና የአንዳንድ ነዋሪዎች ቤትም ተሰንጥቆ ያለ የእርሻ መሬቱም የተንሸራተተና በከፍተኛ ሁኔታ የተሰነጠቀ በመሆኑ የተሻለ ባለሙያ በቦታው በመምጣት መያዝ ድጋፍ በመስጠት ለቀጣይ የሚያመጣው ጉዳት ተገምቶ ለአርሶ አደሮች ምላሽ ምክንያቱም አሁንም አ/አደሮች የተዘራ ስብሰባቸው በመሰነጠቅ መሬቱ አደጋ ቢገጥሙም ሌላ አማራጭ ስለሌላቸው ወጣ ገባ በማለት ስራ አየሠሩ ስለሆነ አፋጣኝ ምላሽ በሠጣቸው በሁሉ ሰዓት 5 አ/አደሮች 32 የቤተሰብ አባላት ያላቸው በጎረቤት ተባለ ሳለ ንጥ በሰው ተቆጣሪው ይገኛል። በቀጣይም ወረዳው ችግር መፍትሄ እንዲያገኝ ሁሉም የሚመለከተውን እንዲያቆም በማድረግ ተጎደዎች ተረጋግተው የሚሰፍሩበት ቦታ ማመቻቸትና ለቤት መስሪያ የሚሆን የተሻለ የቀላቀስ ማስጠጠርና ከሀ/ሰቡ እንዲታዘገቡ ማድረግ ይጠበቃል። ዞንም ጉዳዩን ሊያጣራ የሚችል ባለሙያ በቦታው ላይ ለሰለጠኑ አስተያየት በሠጠበት በማለት የዕለቱን ስብሰባ አጠናቀዋል።

አባተ ማሞ

Annex XIIIb. Report on damages resulted from Landslide and Flood of 2004 E.C. Mida Weremo Wereda Agriculture and Rural Development office, North Shewa, Meranya.

