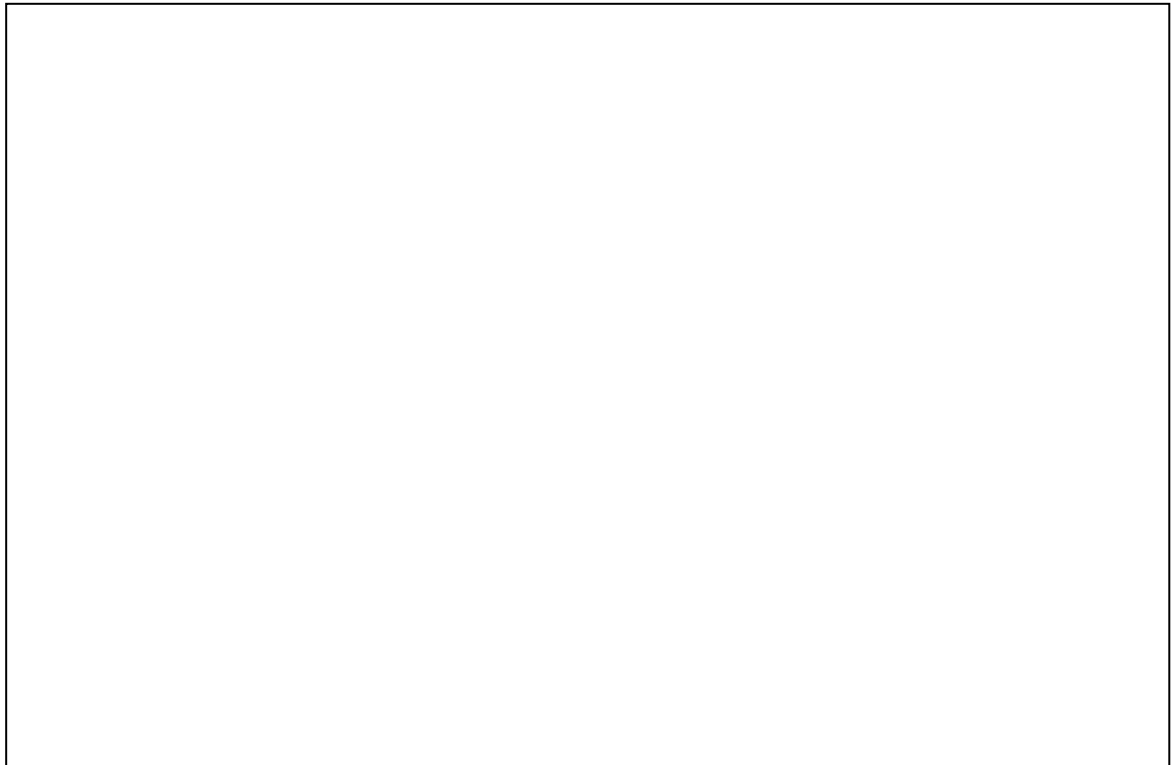


B. GEOLOGICAL STUDIES

B.1 DATA COLLECTION SHEET FOR LAND INSTABILITY STUDIES

Data Collection Sheet: For slope failure/ landslide study



Sketch

1. Description of slope failure:

Location: _____

Geology: _____

Geomorphology: _____

Hydrogeology: _____

Slope failure type: _____

Scale, elevation: _____

2. Recommendations for suitable countermeasures:

a. Control measures:

Earthwork: _____

Bio-engineering: _____

Water management: _____

b. Restraint measures

Slope work: _____

Anchoring: _____

Walls and resisting structures: _____

Protection work: _____

Piling work: _____

B.2 INVENTORY OF EXISTING LAND INSTABILITIES

ID code	Location	Slide		Scale	Dominant cause/ mechanism	Formation	Zone
		Nature	Types				
LS 1	Dhik Gad at road level	D	EF	S	Loose soil mass, toe cutting	Lk	VHH
LS 2	Left bank of Chameliya river	D	C	S	Loose soil mass, road cutting	Lk Fm	VHH
LS 3	Left bank of Chameliya at road level near Salsena	R	RM	S	Poor rock mass, road cutting	Gl Fm	VHH
LS 4	Left bank of Chameliya river	D	C	S	Steep slope, loose colluviums	Gl Fm	VHH
LS 5	Left bank of Chamtari river	D	LS	L	Steep slope, loose colluviums	Gl Fm	VHH
LS 6	Left bank of Chameliya above road level near Jamadi	R	RF	S	Steep slope, highly jointed rock mass	Lk Fm	VHH
LS 7	Right bank of Chadati Khola at road level	D	LS	S	Loose soil	Gl Fm	VHH
LS 8	At Sittad, ward no. 04, Panjunaya	D	LS	L	Loose soil mass, toe cutting	MI Fm	HH
LS 9	Right bank of Jamadi Gad at Panjunaya Goth	R	RF	S	Steep slope, highly jointed rock mass	MI Fm	HH
LS 10	At Bangabagar, left bank of Chameliya	D	DF	L	Crushed rock mass, poor drainage	Bq Fm	HH
LS 11	Right bank of Chameliya, Dethala	D	C	L	Steep slope, Crushed rock mass and poor drainage	Gl Fm	VHH
LS 12	Right bank of Chameliya above road level before Luita	D	LS	S	Steep slope, loose colluviums	Gl Fm	VHH
LS 13	Opposite to Jagannath Lower Secondary School at main road	D	C	S	Steep slope, loose colluviums	Gl Fm	VHH
LS 14	Right bank of Kuku Khola above Osap	D	LS	S	Steep slope, loose colluviums	Gl Fm	VHH
LS 15	Right bank of Chameliya river above Osap	D	LS	L	Steep slope, loose colluviums	Gl Fm	VHH
LS 16	Right bank of Chameliya at Osap	D	LS	S	Steep slope, loose colluviums	Gl Fm	VHH
LS 17		R	RF	S	Loose rock mass, road cutting	Gl Fm	VHH
LS 18		R	RF	M	Highly jointed rock mass, road cutting	Gl Fm	VHH
LS 19		D	C	S	Loose soil mass, road cutting	Gl Fm	VHH
LS 20	Right bank of Chameliya River at confluence with Ghatte Khola	D	C	S	Loose alluviums, road cutting	Gl Fm	VHH
LS 21	Left bank of Chameliya opposite to Agari Gad	D	C	S	Steep slope, loose soil mass	Kk Fm	VHH
LS 22	Upstream of Magarau Khola, opposite to Gokuleshwar	D	C	L	Crushed rock , loose soil mass, poor drainage	Kk Fm	HH
LS 23	Left bank of Mahakali river, Sarkar village	D	C	S	Loose alluvium, road cutting, poor drainage	Gl Fm	HH
LS 24		D	C	S	Loose soil mass, road cutting	Gl Fm	HH
LS 25	Left bank of Mahakali river at Dattu	R	RF	M	Steep slope, highly crushed rock	Gl Fm	HH

ID code	Location	Slide		Scale	Dominant cause/ mechanism	Formation	Zone
		Nature	Types				
LS 26	Left bank of Mahakali at Dattu	D	C	S	Loose colluviums, poor drainage, road cutting	Gl Fm	HH
LS 27	At left bank of Lali Gad	R	RF	L	Steep slope, highly jointed rock mass	MI Fm	MH
LS 28 A & B	Confluence of Mahakali and Chameliya River	R	RF	L	Crushed highly jointed rock mass	Lk Fm	HH
LS 29	Landslide at right bank of Chameliya above Chameliya suspension bridge	R	RM	M	Highly crushed jointed rock mass	Lk Fm	HH
LS 30			PF	S			HH
LS 31			LS	S			HH
LS 32	At confluence of Dhik Gad and Chameliya river	R	RF	M	Highly crushed loose rock mass	Lk Fm	HH
LS 33	Left bank of Mahakali at Jhulaghat	R	RF	M	Steep slope, highly jointed crushed rock mass	Lk Fm	VHH
LS 34		D	C	S	Loose colluviums, road cutting	Gl Fm	VHH
LS 35	Along newly cut road to Budda	D	C	S	Loose colluviums, road cutting	Gl Fm	VHH

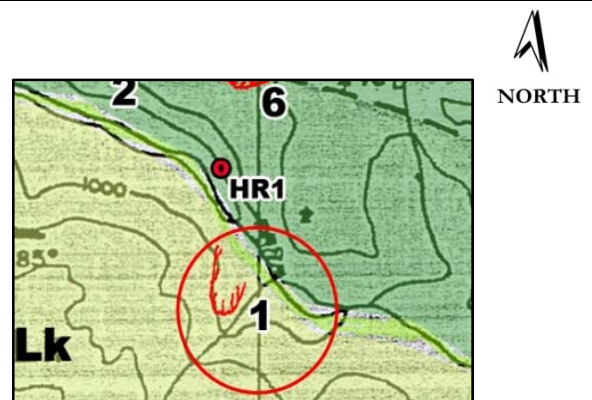
LANDSLIDE 1**Location**

Dhik Gad at road level

Easting	451199	Northing	3276268	Elevation	765
----------------	--------	-----------------	---------	------------------	-----

Characteristics of slide

Size (m²)	40 × 30
Geomorphology	Moderate to steep slope
Geology	Loose soil mixed with Colluviums
Formation	Lakharpata
Hydrology	Damp
Failure type	Embankment Failure
Scale	Small
Nature	Debris
Dominant mechanism	Loose soil mass, toe cutting
Hazard rating	Very high

**Proposed stabilization measures**

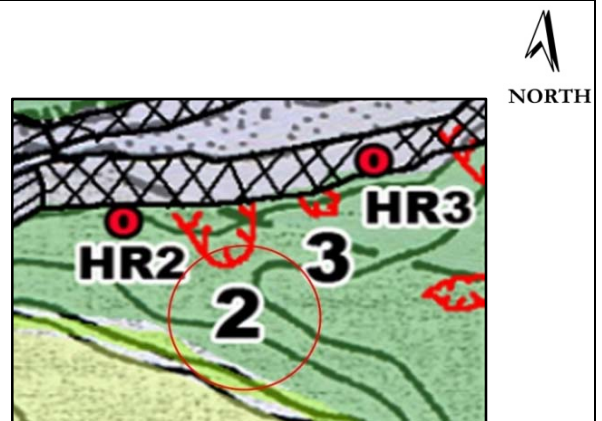
- Slope modification
- Gabion wall and jute netting , launching apron with grass vegetation
- Management of drainage, vegetated stone pitching

LANDSLIDE 2**Location**

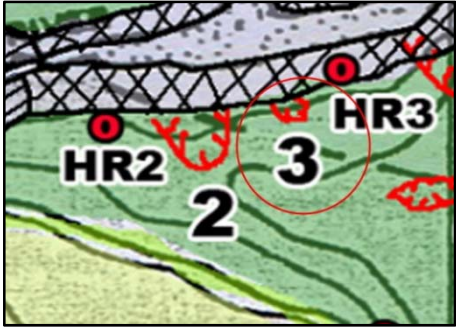

Left bank of Chameliya River (2 landslide)

Easting 449924 **Northing** 3277559 **Elevation** 767**Characteristics of slide**

Size (m²)	8 × 15 20 × 30
Geomorphology	Moderately steep
Geology	Colluvial
Formation	Lakharpata
Hydrology	Wet
Failure type	Collapse
Scale	Small
Nature	Debris
Dominant mechanism	Loose soil mass, road cutting
Hazard rating	Very high

**Proposed stabilization measures**

- Gabion wall or Crib wall
- Slope modification (< 30°)
- Grass plantation with jute netting

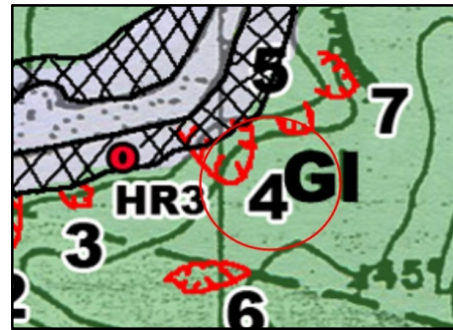
LANDSLIDE 3	
Location	
Left bank of Chameliya at road level near Salsena	
Easting	441167
Northing	3277794
Elevation	738
Characteristics of slide	
Size (m²)	25 × 20
Geomorphology	Moderate slope
Geology	Very weak and crushed phyllite
Formation	Galyang
Hydrology	Dry
Failure type	Rock mass failure
Scale	Small
Nature	Rock
Dominant mechanism	Poor rock mass, road cutting
Hazard rating	Very high
	
	
Proposed stabilization measures	
<ul style="list-style-type: none"> • Toe protection with stone masonry • Shotcrete with wire mesh and rock bolts 	

LANDSLIDE 4**Location**

Left bank of Chameliya River

Easting 450544 **Northing** 3277604 **Elevation** 759**Characteristics of slide**

Size (m²)	20 × 15
Geomorphology	Steep slope
Geology	Very weak rock mass in steep slope, seepage
Formation	Galyang
Hydrology	Wet (Seepage)
Failure type	Collapse
Scale	Small
Nature	Debris
Dominant mechanism	Steep slope, loose colluviums
Hazard rating	Very high

**Proposed stabilization measures**

- Gabion wall with jute netting grass vegetation

LANDSLIDE 5**Location**

Left bank of Chamtari River

Easting 451543 **Northing** 3277914 **Elevation** 695**Characteristics of slide**

Size (m²)	200 × 200
Geomorphology	Steep slope
Geology	Highly crushed phyllite/slate
Formation	Galyang
Hydrology	Wet
Failure type	Landslide
Scale	Large
Nature	Debris
Dominant mechanism	Steep slope, loose colluviums
Hazard rating	Very high

**Proposed stabilization measures**

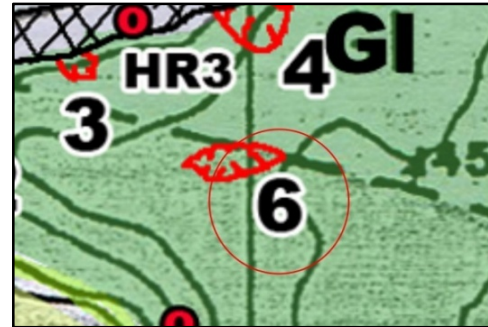
- Gabion wall at Toe
- Modification of slope (< 30°)
- Properly dressed and light grass vegetation or brush layering

LANDSLIDE 6**Location**

Left bank of Chameliya above road level near Jamadi

Easting 460611 **Northing** 3285399 **Elevation** 759**Characteristics of slide**

Size (m²)	50 × 25
Geomorphology	Moderate to steep slope
Geology	Highly jointed Rock masses
Formation	Lakharpata
Hydrology	Dry
Failure type	Rock fall
Scale	Small
Nature	Rock
Dominant mechanism	Steep slope, highly jointed rock mass
Hazard rating	Very high

**Proposed stabilization measures**

- Shotcreting at the crown
- Gabion wall with grass vegetation

LANDSLIDE 7**Location**

Right bank of Chadati Khola at road level

Easting 439415 **Northing** 3290272 **Elevation** 655**Characteristics of slide**

Size (m²)	30 × 40
Geomorphology	Moderate slope
Geology	Loose Colluviums
Formation	Galyang
Hydrology	Dry to damp
Failure type	Landslide
Scale	Small
Nature	Debris
Dominant mechanism	Loose soil
Hazard rating	Very high

**Proposed stabilization measures**

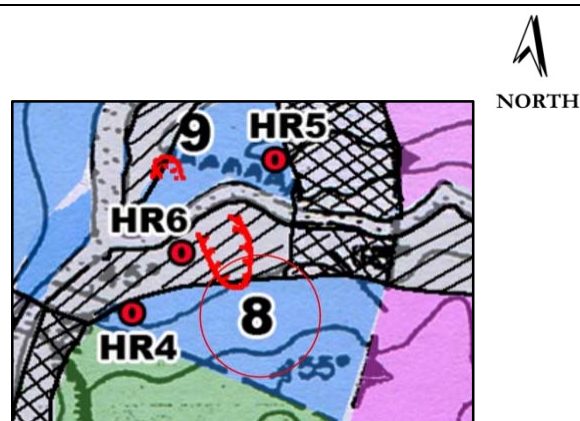
- Gabion wall with grass vegetation
- Vegetated stone pitching in gullies

LANDSLIDE 8**Location**

At Sittad, ward no. 04

Easting 452744 **Northing** 3279487 **Elevation** 656**Characteristics of slide**

Size (m²)	150 × 200
Geomorphology	Moderate to steep
Geology	Crushed rock masses with large boulders
Formation	Malekhu
Hydrology	Damp
Failure type	Landslide
Scale	Large
Nature	Debris
Dominant mechanism	Loose soil mass, toe cutting
Hazard rating	High

**Proposed stabilization measures**

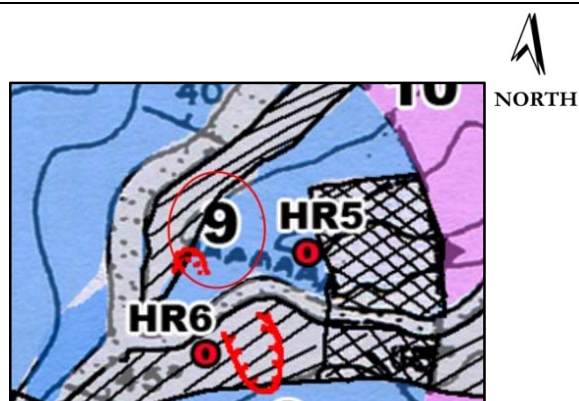
- Terraced gabion wall from bottom of river and stone masonry at toe
- Effective drainage
- Modification of slope (< 30°)
- Brush layering

LANDSLIDE 9**Location**

Right bank of Jamari Gad at Panjunaya Goth

Easting 442030 **Northing** 3293058 **Elevation** 697**Characteristics of slide**

Size (m²)	20 × 30
Geomorphology	Moderate slope
Geology	Colluviums
Formation	Malekhu
Hydrology	Dry
Failure type	Rock fall
Scale	Small
Nature	Rock
Dominant mechanism	Steep slope, highly jointed rock mass
Hazard rating	High

**Proposed stabilization measures**

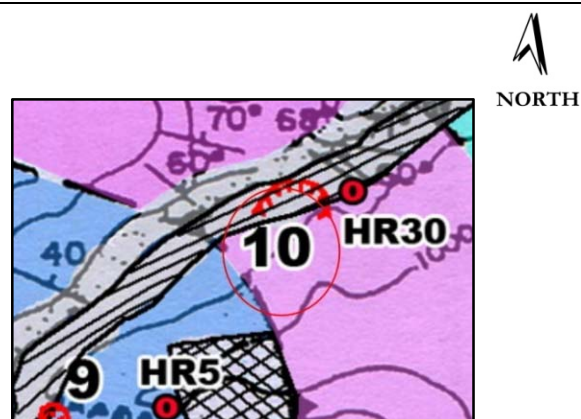
- Shotcreting at the crown
- Vegetated stone pitching in channel
- Gabion wall (Toe protection) or Tree plantation at Toe

LANDSLIDE 10**Location**

BANGA BAGAR, Left bank of Chameliya River

Easting 453147 **Northing** 3280720 **Elevation** 716**Characteristics of slide**

Size (m²)	300 × 600
Geomorphology	Moderate to steep slope
Geology	Highly crushed weak and fragile rock masses
Formation	Banku
Hydrology	Flowing water
Failure type	Debris flow
Scale	Large
Nature	Debris
Dominant mechanism	Crushed rock mass, poor drainage
Hazard rating	High

**Proposed stabilization measures**

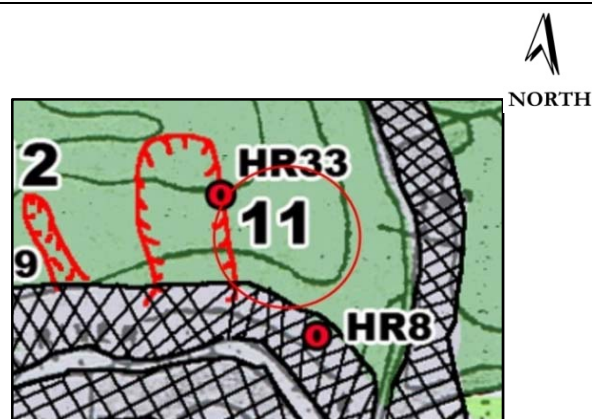
- Shotcrete at crown
- Terraced gabion wall from toe
- Water flow management
- Jute netting with grass plantation

LANDSLIDE 11**Location**

Right bank of Chameliya River, DETHALA

Easting 461630 **Northing** 3285536 **Elevation** 779**Characteristics of slide**

Size (m²)	300 × 300
Geomorphology	Steep slope
Geology	Highly crushed dolomite with phyllite
Formation	Galyang
Hydrology	Dry/ flowing water
Failure type	Collapse
Scale	Large
Nature	Debris
Dominant mechanism	Steep slope, Crushed rock mass and poor drainage
Hazard rating	Very high

**Proposed stabilization measures**

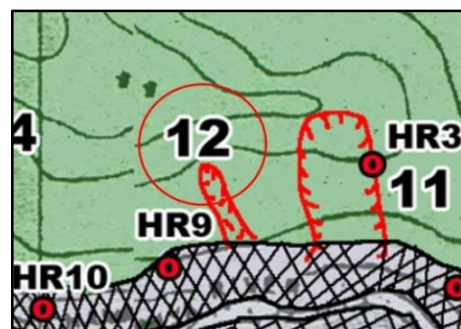
- Shotcrete at the crown
- Slope modification
- Terraced gabion wall
- Grass vegetation and water flow management

LANDSLIDE 12**Location**

Right bank of Chameliya River above road level before Luita

Easting 458874 **Northing** 3284987 **Elevation** 728**Characteristics of slide**

Size (m²)	5 × 40
Geomorphology	Moderate to steep slope
Geology	Loose and fractured rock masses
Formation	Galyang
Hydrology	Dry to damp
Failure type	Landslide
Scale	Small
Nature	Debris
Dominant mechanism	Steep slope, loose colluviums
Hazard rating	Very high

**Proposed stabilization measures**

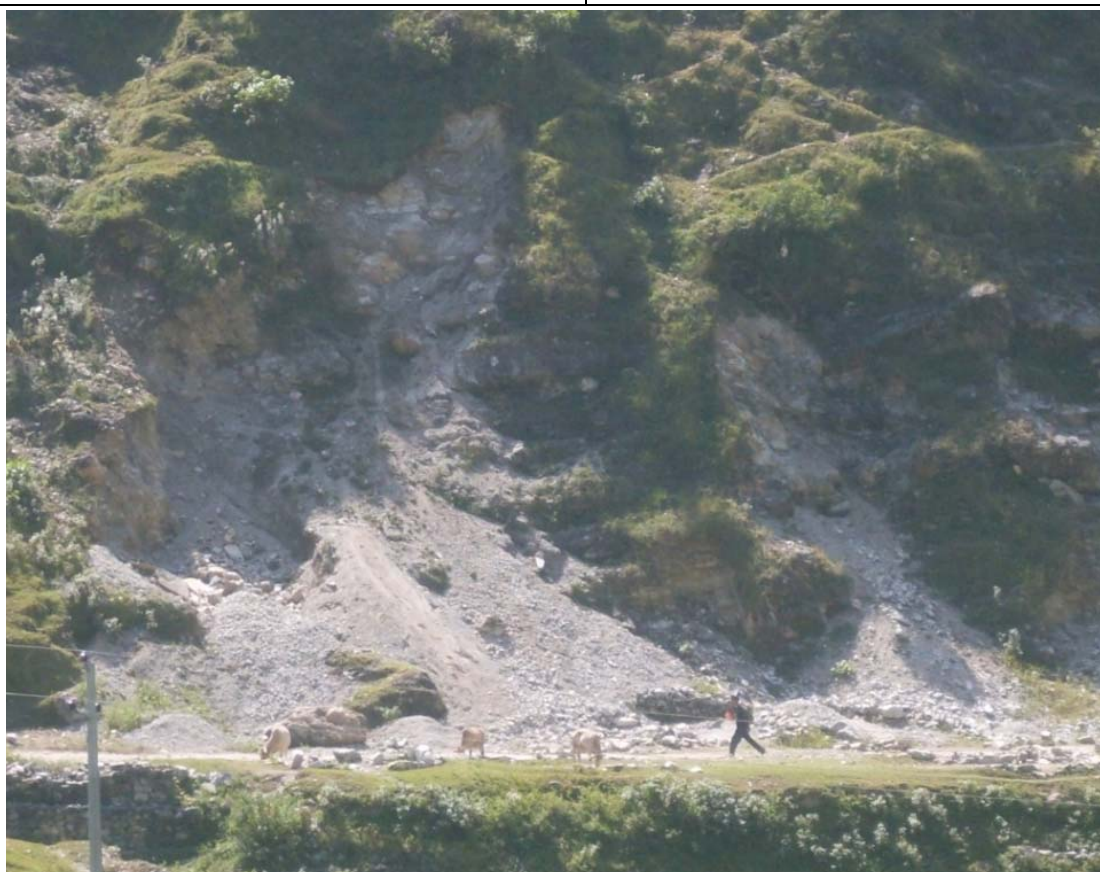
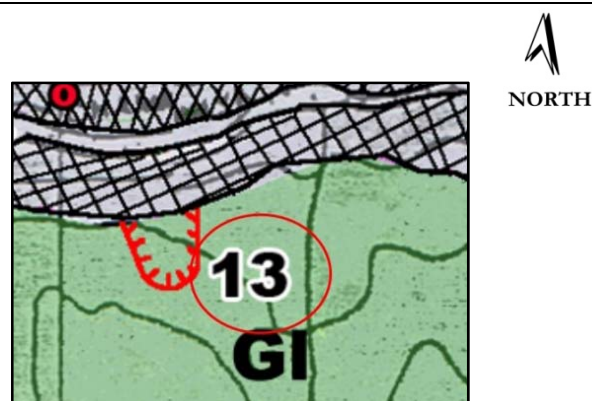
- Shotcreting at the crown
- Slope modification, terraced gabion wall with grass vegetation
- Check dam with bioengineering

LANDSLIDE 13**Location**

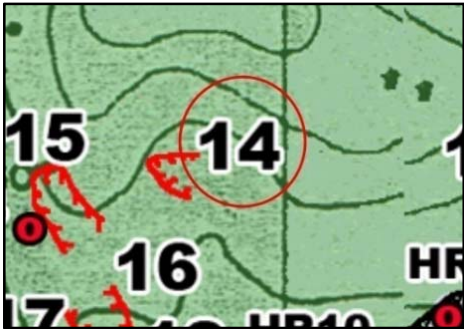

Opposite to Jagannath Lower Secondary School at main road

Easting 460001 **Northing** 3285133 **Elevation** 750**Characteristics of slide**

Size (m²)	50 × 20
Geomorphology	Steep to Moderate slope
Geology	Colluvium mixed with alluvium
Formation	Galyang
Hydrology	Damp
Failure type	Collapse
Scale	Small
Nature	Debris
Dominant mechanism	Steep slope, loose colluviums
Hazard rating	Very high

**Proposed stabilization measures**

- Shotcreting at crown
- Gabion wall at toe
- Slope modification (< 30°)
- Vegetated stone pitching in gullies

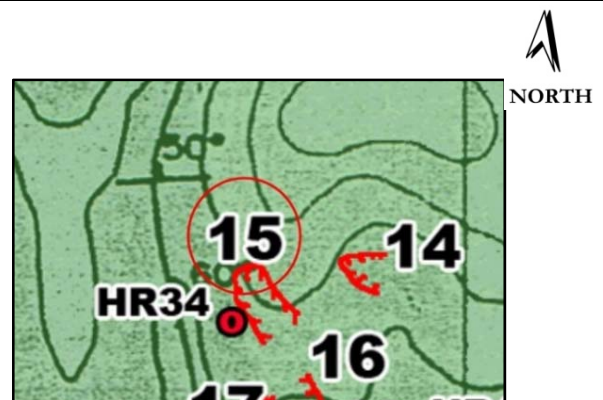
LANDSLIDE 14	
Location	
Right bank of Kuku Khola above Osap	
Easting 0	Northing 0 Elevation 0
Characteristics of slide	
Size (m ²)	25 × 30
Geomorphology	Moderate slope
Geology	Colluviums
Formation	Galyang
Hydrology	Damp
Failure type	Landslide
Scale	Small
Nature	Debris
Dominant mechanism	Steep slope, loose colluviums
Hazard rating	Very high
	
	
Proposed stabilization measures	
<ul style="list-style-type: none"> • Gabion wall at toe • Slope modification • Jute netting and grass vegetation 	

LANDSLIDE 15**Location**

Right bank of Chameliya River above OSAP

Easting 458913 **Northing** 3285369 **Elevation** 813**Characteristics of slide**

Size (m²)	150 × 300
Geomorphology	Moderate to steep slope
Geology	Highly crushed rock with boulders
Formation	Galyang
Hydrology	Dry
Failure type	Landslide
Scale	Large
Nature	Debris
Dominant mechanism	Steep slope, loose colluviums
Hazard rating	Very high

**Proposed stabilization measures**

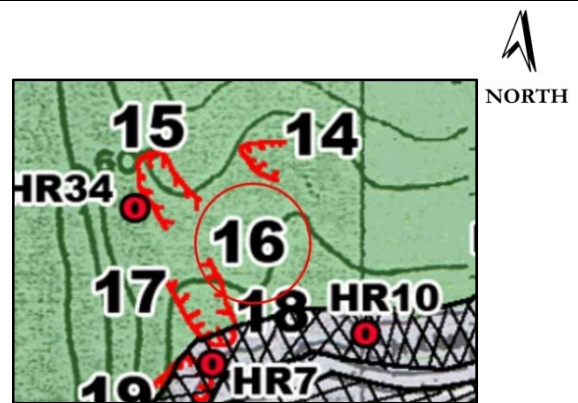
- Terraced gabion wall from toe
- Water management
- Ditch canal at top
- Slope modification
- Stone pitching (vegetated) in gully's
- Grass plantation in barren areas

LANDSLIDE 16**Location**

Right bank of Chameliya River at Osap

Easting 451870 **Northing** 3278070 **Elevation** 687**Characteristics of slide**

Size (m²)	5 × 50
Geomorphology	Moderate slope
Geology	Phyllite mixed with Colluvium
Formation	Galyang
Hydrology	Dry to damp
Failure type	Landslide
Scale	Small
Nature	Debris
Dominant mechanism	Steep slope, loose colluviums
Hazard rating	Very high

**Proposed stabilization measures**

- Tree plantation at toe
- Check dams (Brush wood)
- Grass vegetation in barren areas
- Vegetated stone pitching in channel

LANDSLIDE 17**Location**

Right bank of Chameliya River at Osap

Easting 458754 **Northing** 3284886 **Elevation** 732**Characteristics of slide**

Size (m²)	20 × 30
Geomorphology	Moderate slope
Geology	Loose rock piece
Formation	Galyang
Hydrology	Dry
Failure type	Rock fall
Scale	Small
Nature	Rock
Dominant mechanism	Loose rock mass, road cutting
Hazard rating	Very high

**Proposed stabilization measures**

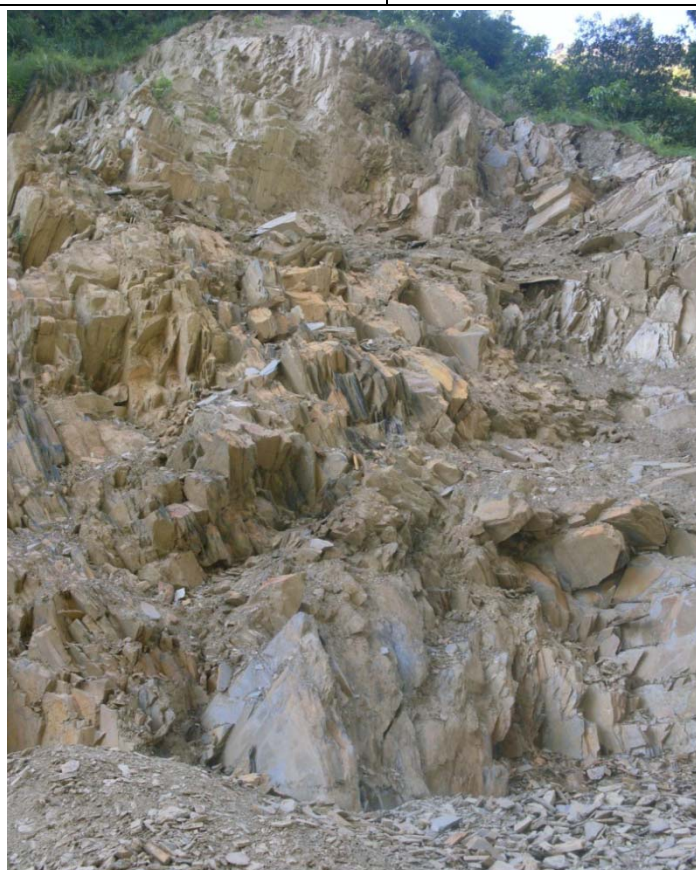
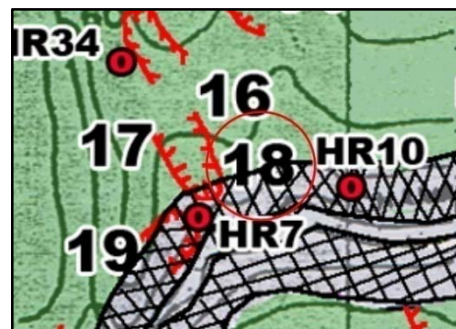
- Shotcreting with wire mesh
- Catch wall at toe

LANDSLIDE 18**Location**

Right bank of Chameliya River at Osap

Easting 444975 **Northing** 3297212 **Elevation** 696**Characteristics of slide**

Size (m²)	300 × 150
Geomorphology	Steep slope
Geology	Highly crushed and fractured rock masses
Formation	Galyang
Hydrology	Damp to seepage
Failure type	Rock fall
Scale	Medium
Nature	Rock
Dominant mechanism	Highly jointed rock mass, road cutting
Hazard rating	Very high

**Proposed stabilization measures**

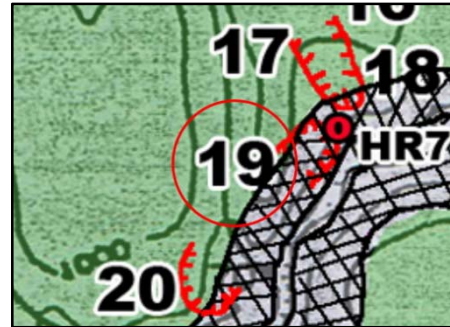
- Wire mesh with shotcrete
- Gabion wall/ Catch wall at toe

LANDSLIDE 19**Location**

Right bank of Chameliya River at Osap

Easting 445282 **Northing** 3297594 **Elevation** 710**Characteristics of slide**

Size (m²)	20 × 10
Geomorphology	Moderate slope
Geology	Colluvial
Formation	Galyang
Hydrology	Damp
Failure type	Collapse
Scale	Small
Nature	Debris
Dominant mechanism	Loose soil mass, road cutting
Hazard rating	Very high

**Proposed stabilization measures**

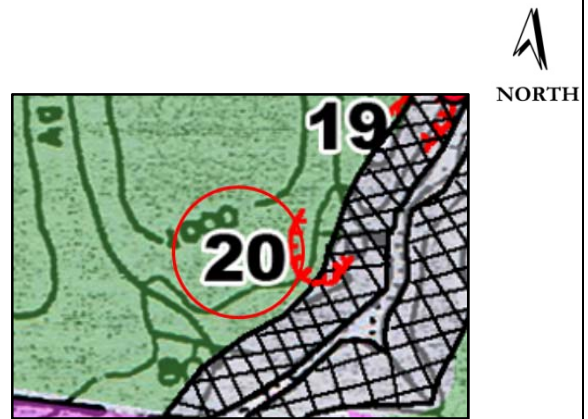
- Gabion wall/Stone masonry
- Slope modification
- Grass plantation

LANDSLIDE 20**Location**

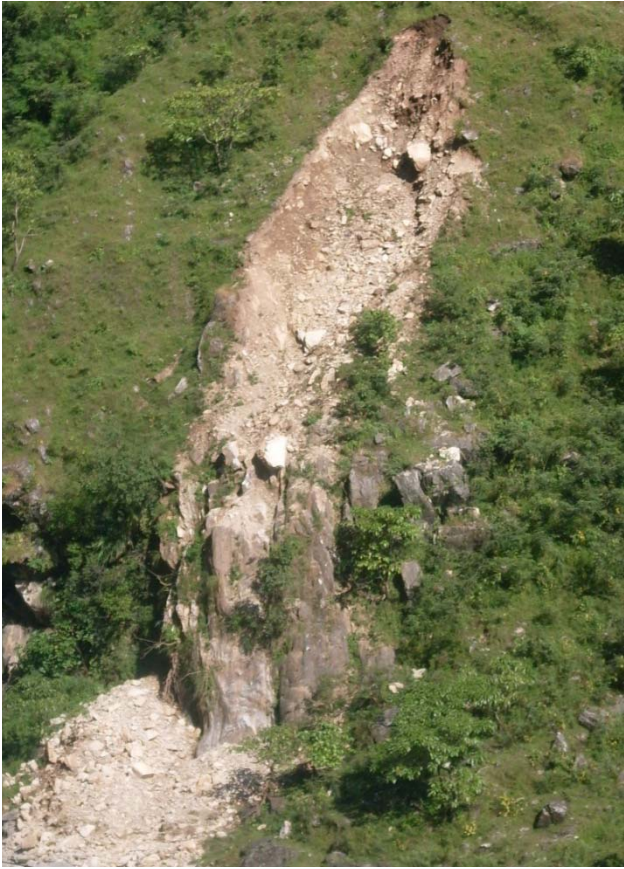
Right bank of Chameliya River at confluence with Ghatte Khola

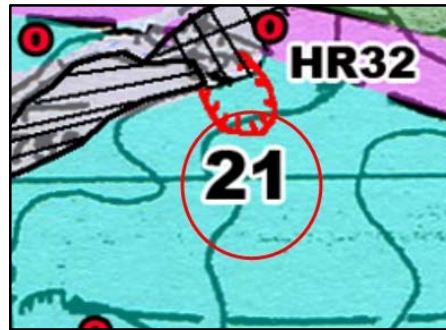
Easting 458092 **Northing** 3283916 **Elevation** 708**Characteristics of slide**

Size (m²)	30 × 15
Geomorphology	Gentle to moderate slope
Geology	Colluvium with alluvium loose masses
Formation	Galyang
Hydrology	Dry to damp
Failure type	Collapse
Scale	Small
Nature	Debris
Dominant mechanism	Loose alluviums, road cutting
Hazard rating	Very high

**Proposed stabilization measures**

- Drainage management
- Gabion wall/ toe protection
- Vegetated stone pitching in channels

LANDSLIDE 21	
Location	
Left bank of Chameliya River opposite to Agari Gad	
Easting	450734
Northing	3277651
Elevation	750
Characteristics of slide	
Size (m²)	5 × 30
Geomorphology	Steep slope
Geology	Colluvium with Very weak phyllite and quartzite rock
Formation	Kalikot
Hydrology	Dry to damp
Failure type	Collapse
Scale	Small
Nature	Debris
Dominant mechanism	Steep slope, loose soil mass
Hazard rating	Very high
	
Proposed stabilization measures	
<ul style="list-style-type: none"> • Toe protection • Gabion wall • Slope modification (< 30°) with grass vegetation 	

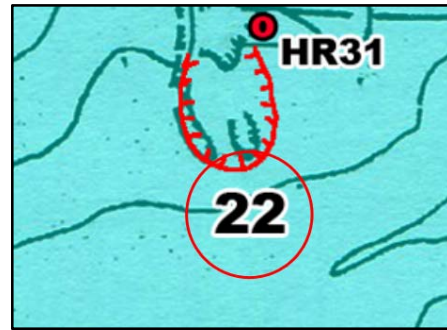


LANDSLIDE 22**Location**

Upstream of Magarau Khola, opposite to Gokuleshwor

Easting 456952 **Northing** 3381903 **Elevation** 824**Characteristics of slide**

Size (m²)	600 × 500
Geomorphology	Steep slope
Geology	Highly crushed disoriented rock schists/ quartzite
Formation	Kalikot
Hydrology	Flowing water
Failure type	Collapse
Scale	Large
Nature	Debris
Dominant mechanism	Crushed rock , loose soil mass, poor drainage
Hazard rating	High

**Proposed stabilization measures**

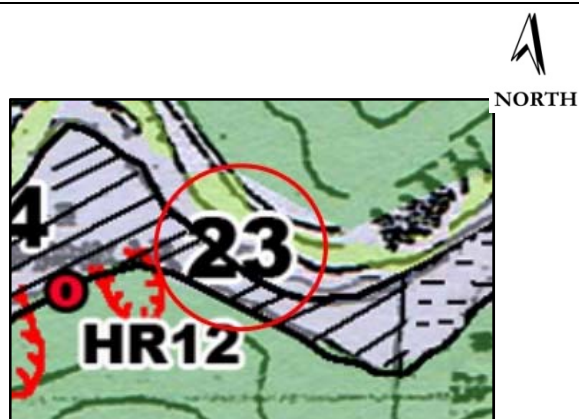
- Shotcreting with wire mesh at crown
- Gabion wall
- Water management
- Filling of cracks at crown
- Modification of steep slope (< 30°)
- Jute netting and grass vegetation

LANDSLIDE 23**Location**

Left bank of Mahakali River, Sarkar village

Easting 445461 **Northing** 3297772 **Elevation** 712**Characteristics of slide**

Size (m²)	15 × 7
Geomorphology	Moderate slope
Geology	Alluvium, loose gravels with sands and clays
Formation	Galyang
Hydrology	Wet
Failure type	Collapse
Scale	Small
Nature	Debris
Dominant mechanism	Loose alluvium, road cutting, poor drainage
Hazard rating	High

**Proposed stabilization measures**

- Effective drainage management
- Gabion wall at Toe with jute netting and grass vegetation

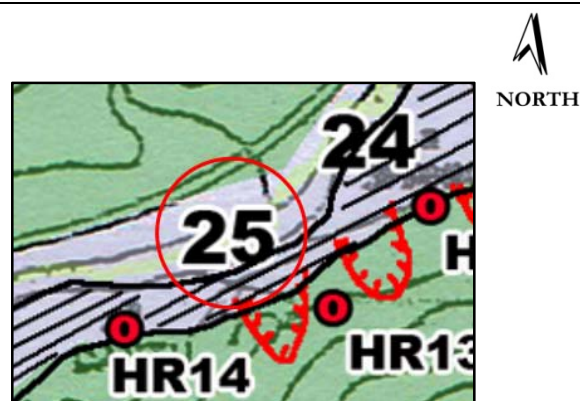
LANDSLIDE 24	
Location	
Left bank of Mahakali River, Sarkar village	
Easting	445152
Northing	3297321
Elevation	713
Characteristics of slide	
Size (m²)	15 × 50
Geomorphology	Moderate to steep , thick vegetation
Geology	Colluvial soil with silts and mud gravels
Formation	Galyang
Hydrology	Wet
Failure type	Collapse
Scale	Small
Nature	Debris
Dominant mechanism	Loose soil mass, road cutting
Hazard rating	High
	
	
Proposed stabilization measures	
<ul style="list-style-type: none"> • Modification of slope (< 30°) • Gabion wall at Toe • Grass vegetation with jute netting 	

LANDSLIDE 25**Location**

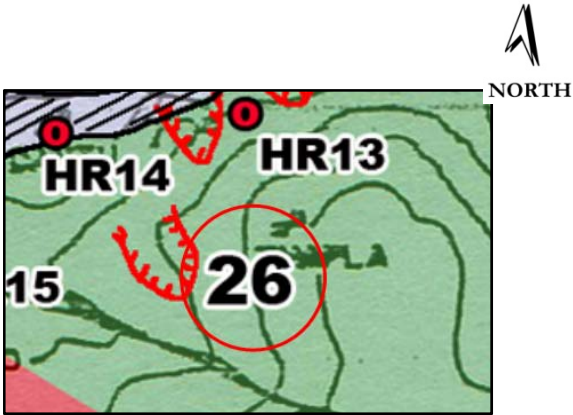

Left bank of Mahakali River at Dattu

Easting 451500 **Northing** 3277900 **Elevation** 710**Characteristics of slide**

Size (m²)	250 × 50
Geomorphology	Moderate to steep slope
Geology	Dolomite with slate rock masses
Formation	Galyang
Hydrology	Dry to wet
Failure type	Rock fall
Scale	Medium
Nature	Rock
Dominant mechanism	Steep slope, highly crushed rock, road cutting
Hazard rating	High

**Proposed stabilization measures**

- Shotcreting with wire mesh
- Gabion/ stone masonry/ Catch wall at toe
- Surface drainage

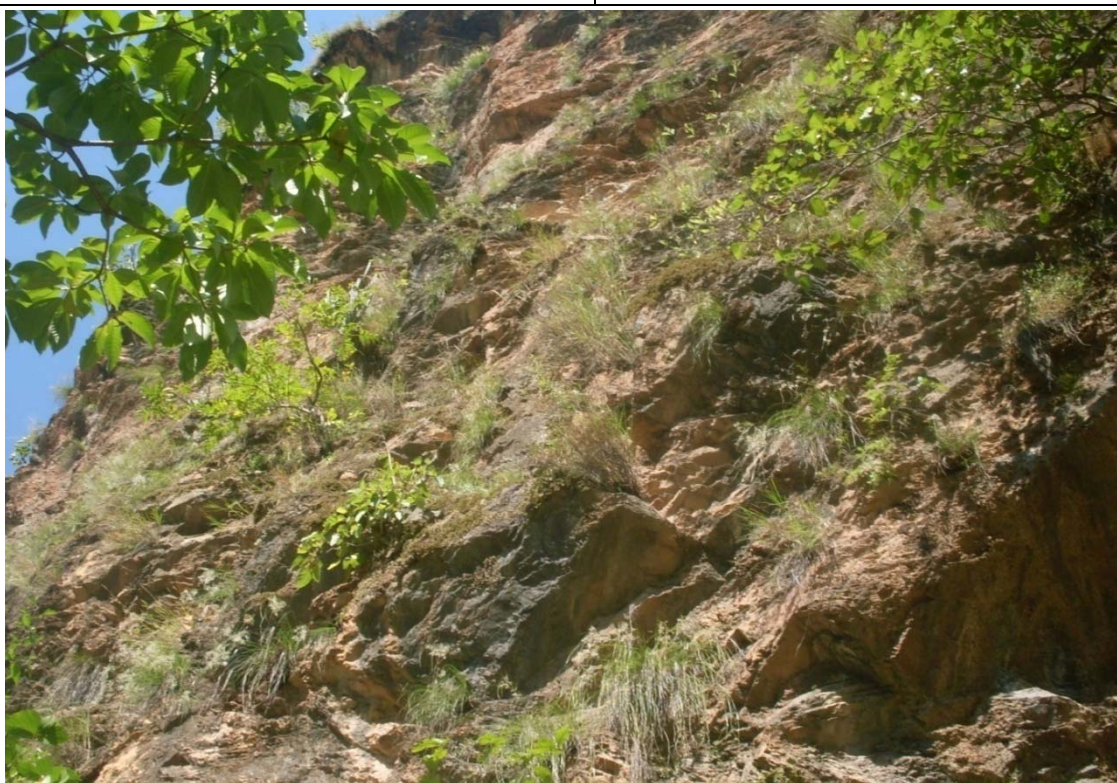
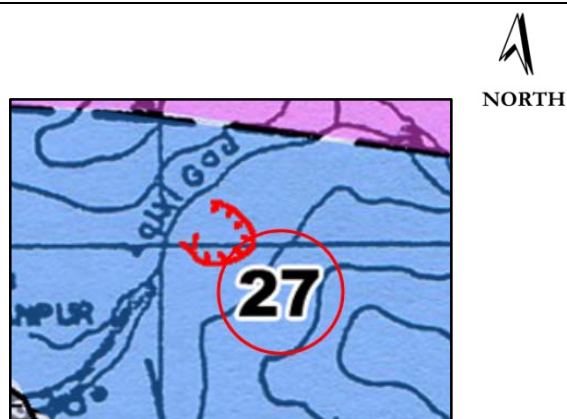
LANDSLIDE 26	
Location	
Left bank of Mahakali at Dattu	
Easting	444729
Northing	3297114
Elevation	701
Characteristics of slide	
Size (m²)	25 × 60
Geomorphology	Steep slope
Geology	Colluvium angular rock fragments with silt sand and clays
Formation	Galyang
Hydrology	Wet
Failure type	Collapse
Scale	Small
Nature	Debris
Dominant mechanism	Loose colluviums, poor drainage, road cutting
Hazard rating	High
	
	
Proposed stabilization measures	
<ul style="list-style-type: none"> • Effective drainage system • Gabion wall at Toe • Grass vegetation with jute netting 	

LANDSLIDE 27**Location**

Left bank of Lali Gad

Easting 443685 **Northing** 3281283 **Elevation** 707**Characteristics of slide**

Size (m²)	200 × 100
Geomorphology	Moderate to steep slope
Geology	Highly jointed and fractured rock mass (Dolomites)
Formation	Malekhu
Hydrology	Dry
Failure type	Rock fall
Scale	Large
Nature	Rock
Dominant mechanism	Steep slope, highly jointed rock mass
Hazard rating	Medium

**Proposed stabilization measures**

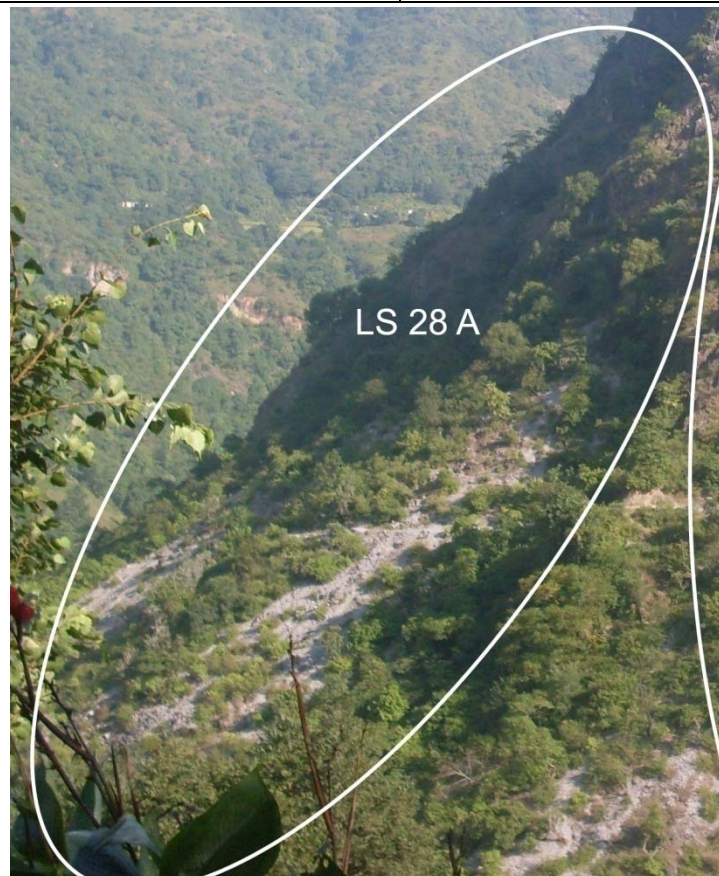
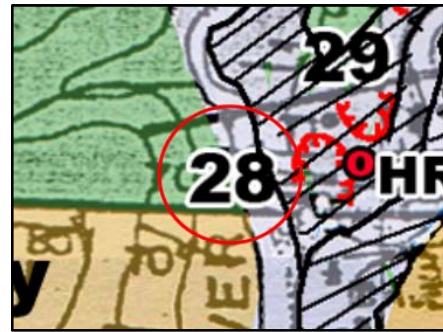
- Removing of overhangs
- Grass seeding
- Catch wall at toe

LANDSLIDE 28 A**Location**

At confluence of Mahakali and Chameliya River

Easting 443035 **Northing** 3276060 **Elevation** 509**Characteristics of slide**

Size (m²)	150 × 150
Geomorphology	Steep slope, cliff
Geology	Massive dolomite, highly fractured and jointed
Formation	Lakharpata
Hydrology	Dry
Failure type	Rock fall
Scale	Large
Nature	Rock
Dominant mechanism	Crushed highly jointed rock mass
Hazard rating	High

**Proposed stabilization measures**

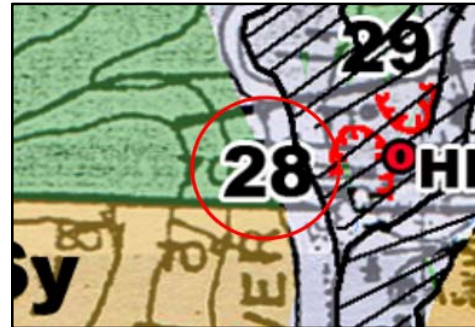
- Catch wall with tree vegetation at Toe
- Grass plantation at middle and upper part

LANDSLIDE 28 B**Location**

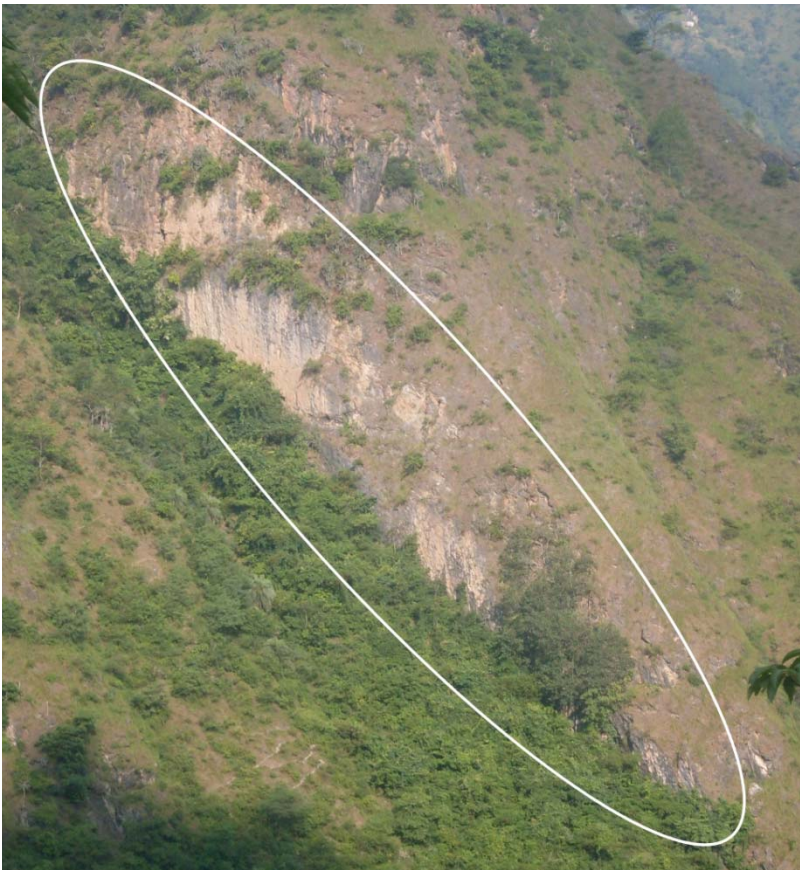
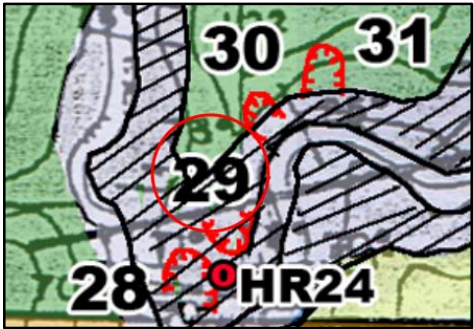
At confluence of Mahakali and Chameliya River

Easting 443175 **Northing** 3275968 **Elevation** 513**Characteristics of slide**

Size (m²)	200 × 100
Geomorphology	Moderate to steep slope
Geology	Loose crushed rocks
Formation	Lakharpata
Hydrology	Dry
Failure type	Rock fall
Scale	Large
Nature	Rock
Dominant mechanism	Crushed highly jointed rock mass
Hazard rating	High

**Proposed stabilization measures**

- Shotcreting at the crown
- Vegetated stone pitching in gully
- Tree plantation at Toe

LANDSLIDE 29	
Location	
Landslide at right bank of Chameliya River above Chameliya suspension bridge	
Easting	0
Northing	0
Elevation	0
Characteristics of slide	
Size (m²)	20 × 100
Geomorphology	Steep slope
Geology	Highly jointed dolomite
Formation	Lakharpata
Hydrology	Dry to damp
Failure type	Rock mass failure
Scale	Medium
Nature	Rock
Dominant mechanism	Highly crushed jointed rock mass
Hazard rating	High
	
	
Proposed stabilization measures	
<ul style="list-style-type: none"> • Dormant slide • Cross check dam • Vegetated stone pitching in channel 	

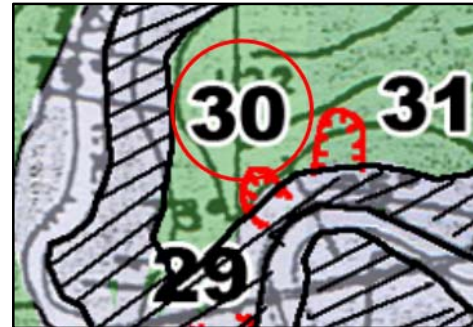
LANDSLIDE 30**Location**

Landslide at right bank of Chameliya River above Chameliya suspension bridge


Easting 0 Northing 0 Elevation 0

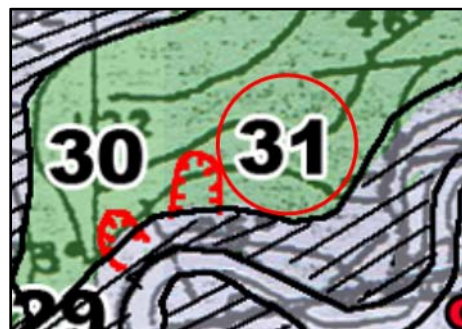
Characteristics of slide

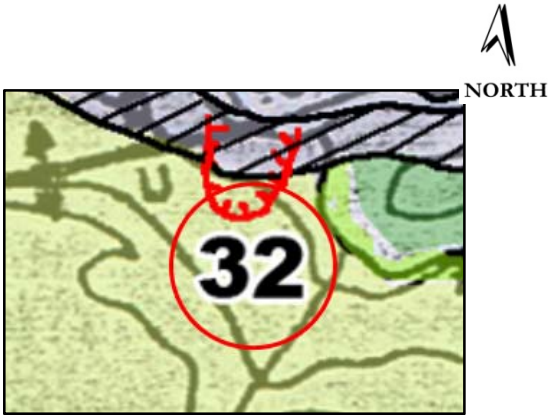

Size (m ²)	20 × 50
Geomorphology	Steep slope
Geology	Highly jointed dolomite
Formation	Lakharpata
Hydrology	Dry to damp
Failure type	Plane failure
Scale	Small
Nature	Rock
Dominant mechanism	Highly crushed jointed rock mass
Hazard rating	High

**Proposed stabilization measures**

- Dormant slide
- Cross check dam
- Vegetated stone pitching in channel

LANDSLIDE 31	
Location	
Landslide at right bank of Chameliya River above Chameliya suspension bridge	
Easting	0
Northing	0
Elevation	0
Characteristics of slide	
Size (m²)	100 × 3
Geomorphology	Steep slope
Geology	Highly jointed dolomite
Formation	Lakharpata
Hydrology	Dry to damp
Failure type	Landslide
Scale	Small
Nature	Rock
Dominant mechanism	Highly crushed jointed rock mass
Hazard rating	High
	
Proposed stabilization measures	
<ul style="list-style-type: none"> • Dormant slide • Cross check dam • Vegetated stone pitching in channel 	



LANDSLIDE 32	
Location	
At confluence of Dhik Gad and Chameliya River	
Easting	448596
Northing	3277469
Elevation	605
Characteristics of slide	
Size (m²)	50 × 50
Geomorphology	Steep slope
Geology	Colluvium, mainly rock pieces, old nearly stabilized
Formation	Lakharpata
Hydrology	Dry to damp
Failure type	Rock fall
Scale	Small
Nature	Rock
Dominant mechanism	Highly crushed loose rock mass
Hazard rating	High
	
	
Proposed stabilization measures	
<ul style="list-style-type: none"> • Slope modification • Gabion wall at bottom and brush layering • Water flow management 	

LANDSLIDE 33**Location**

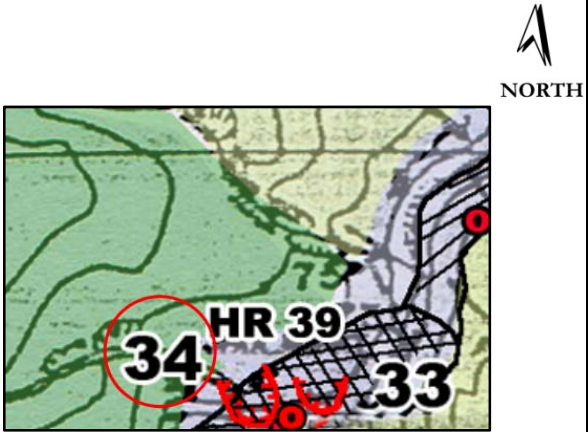

Left bank of Mahakali River at Jhulaghat

Easting 440481 **Northing** 3272013 **Elevation** 562**Characteristics of slide**

Size (m²)	150 × 25
Geomorphology	Moderate to steep slope
Geology	Highly crushed rock in loose condition
Formation	Lakharpata
Hydrology	Dry to damp
Failure type	Rock fall
Scale	Medium
Nature	Rock
Dominant mechanism	Steep slope, highly jointed crushed rock mass
Hazard rating	Very high

**Proposed stabilization measures**

- Vegetated stone pitching in channels
- Brush wood check dams

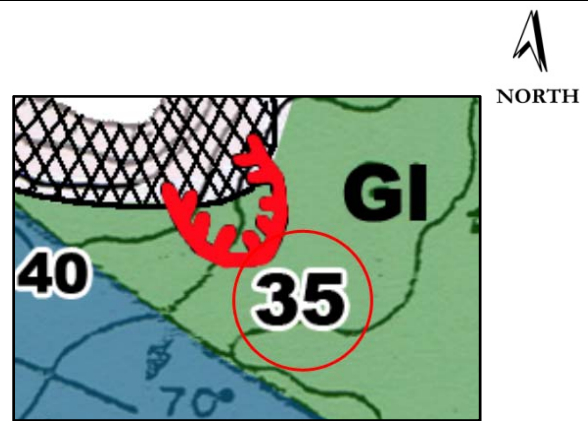
LANDSLIDE 34	
Location	
Left bank of Mahakali River at Jhulaghat	
Easting	440186
Northing	3272099
Elevation	574
Characteristics of slide	
Size (m²)	30 × 30
Geomorphology	Moderate slope
Geology	Colluvium deposits, nearly highly crushed phyllite slates thinly bedded
Formation	Galyang
Hydrology	Dry to damp
Failure type	Collapse
Scale	Small
Nature	Debris
Dominant mechanism	Loose colluviums, road cutting
Hazard rating	Very high
	
	
Proposed stabilization measures	
<ul style="list-style-type: none"> • Modification of the slope (< 30°) • Gabion wall at Toe • Grass plantation with jute netting 	

LANDSLIDE 35**Location**

Along newly cut road to Budda

Easting 439115 **Northing** 3270559 **Elevation** 730**Characteristics of slide**

Size (m²)	15 × 50
Geomorphology	Gentle to moderate slope
Geology	Colluvium, rock pieces in silt sandy matrix
Formation	Galyang
Hydrology	Dry to damp
Failure type	Collapse
Scale	Small
Nature	Debris
Dominant mechanism	Loose colluviums, road cutting
Hazard rating	Very high

**Proposed stabilization measures**

- Toe protection
- Gabion wall with grass plantation and slope modification

B.3 RATING SCHEME FOR LANDSLIDE HAZARD EVALUATION FACTOR

A landslide hazard zonation (LHZ) map for the reservoir fluctuation zone was prepared using an empirical approach that relates the investigation of landslides to existing slope conditions (Anbalagan, Chakraborty, & Kohli, 2008). This method uses a relative rating scheme, called the landslide hazard evaluation factor (LHEF), which quantifies the qualitative nature of field conditions through a rating of major inherent causative factors of slope instability, such as geology, slope geometry, relative relief, land use, land cover and hydrological conditions, with corrective parameters for external factors such as rainfall and seismicity (Table 1). The maximum LHEF rating values for different categories are determined based on their estimated significance in causing instabilities.

Table 1: Maximum LHEF rating for different causative factors

Causative factors		Max. LHEF rating
Inherent factors	Lithology	2.0
	Structure	2.0
	Slope morphometry	2.0
	Relative relief	1.0
	Land use and land cover	2.0
	Hydrogeological conditions	1.0
Total LHEF rating		10.0
Corrective parameters for external factors		1.0
Corrected LHEF rating		11.0

For a particular slope, the rating scheme yields a Total Estimated Hazard (TEHD) with a maximum value of 11. Based on the TEHD values, slope facets are categorized into five classes of relative hazard zones (Table 2)

Table 2: Landslide hazard zones based on corrected total estimated hazard (TEHD)

Hazard zone	Range of corrected TEHD	Hazard classification
I	$TEHD < 3.5$	Very low hazard (VLH)
II	$3.5 \leq TEHD < 5.0$	Low hazard (LH)
III	$5.0 \leq TEHD \leq 6.5$	Moderate hazard (MH)
IV	$6.5 < TEHD \leq 8.0$	High hazard (HH)
V	$TEHD > 8.0$	Very high hazard (VHH)

During field investigations, site-specific causative parameters were checked, analyzed and evaluated at 40 sites along Mahakali and Chameliya rivers to arrive at their TEHD rating. Field studies were carried out to collect the required data facet wise/ rock mass or soil types to estimate the total hazards of each studied sites. Based on the forty studied sites, three types of landslide hazard zones, ranging from medium to very high have been identified within the reservoir area along Chameliya and Mahakali rivers. The general procedure of the mapping technique is outlined in Figure 1.

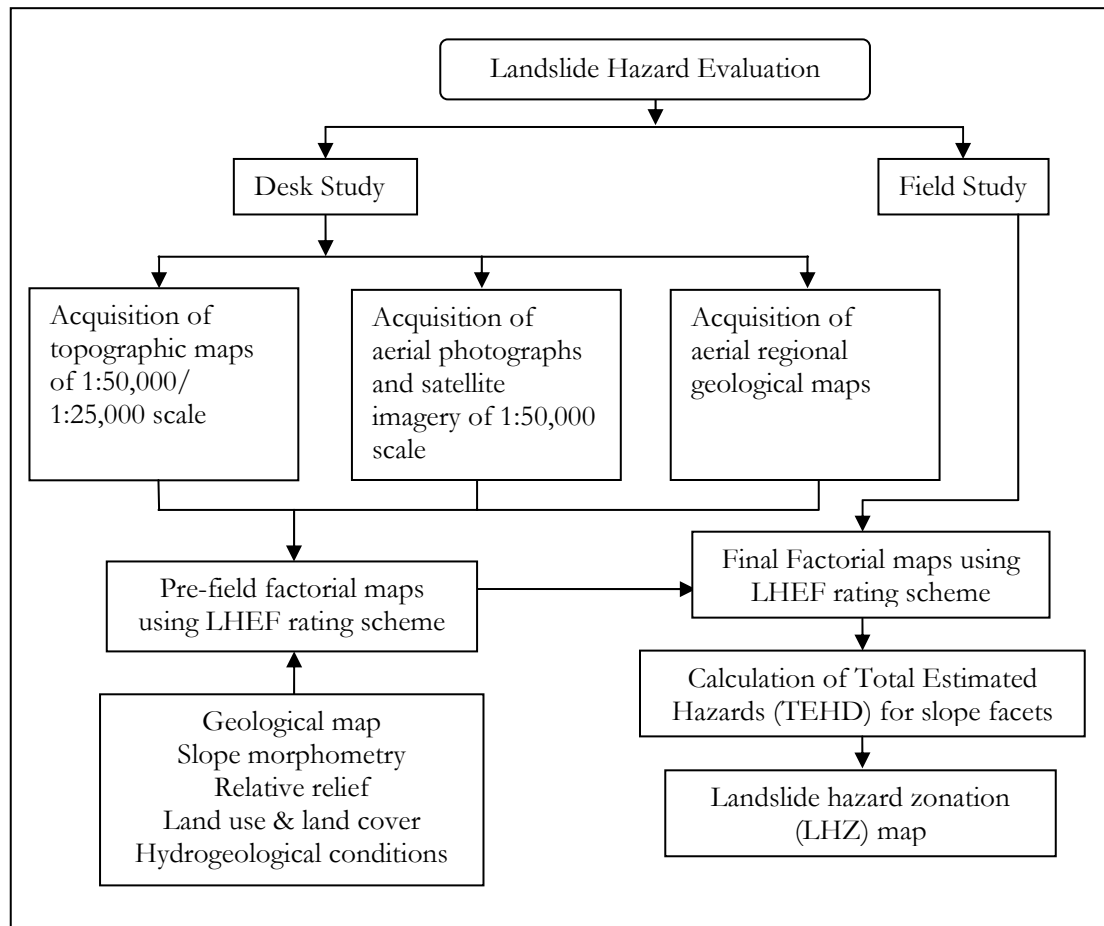


Figure 1: Procedure for landslide hazard mapping

Table 3: Rating for rock types

Category	Rock types	Rating
Type – I	Basalt, quartzite and massive limestone & dolomite	0.2
	Granite, gabbros and dolerite	0.3
	Granite gneiss and meta volcanic	0.4
Type – II	Well-cemented terrigenous sedimentary rocks (dominantly sandstone) with minor beds of clay stone and Gneissic rocks	1.0
	Poorly-cemented terrigenous sedimentary rocks (dominantly sandstone) with intercalations of clay or shale beds	1.3
Type – III	Well foliated gneiss	1.0
	Shale, slate, phyllite and other argillaceous rocks like siltstone, mud stone and clay stone	1.2
	Schistose rocks	1.4
	Shale with inter-bedded clayey rocks (silt stone, mud stone and etc.)	1.8
	Weathered shale and other argillaceous rocks, phyllite and schistose rocks	2.0

Table 4: Correction factors for weathering

Weathering condition	Description	Rock rating	
		Type – I	Type – II
Completely weathered	Rock totally decomposed/disintegrated to soil, no or minor existence of initial rock structure (<i>Correction factor C₁</i>)	C ₁ = 4.0	C ₁ = 1.5
Highly weathered	Rock totally discolored, discontinuity planes show weathering products, rock structure altered heavily with minor soil formation near surface (<i>Correction factor C₂</i>)	C ₂ = 3.5	C ₂ = 1.35
Moderately weathered	Rock prominently discolored with remnant isolated patches of fresh rock, weathering and alteration prominent along discontinuity planes, considerable alteration of rock structure (<i>Correction factor C₃</i>)	C ₃ = 3.0	C ₃ = 1.25
Slightly weathered	Rock partially discolored along discontinuity planes indicating weakening of rock mass, rock structure is slightly altered (<i>Correction factor C₄</i>)	C ₄ = 2.5	C ₄ = 1.15
Faintly weathered	Rock slightly discolored along discontinuity planes which may be moderately tight to open in nature, intake rock structure with or without minor surface staining (<i>Correction factor C₅</i>)	C ₅ = 2.0	C ₅ = 1.0

Table 5: Ratings for soil types

Description		Rating
Older well compacted fluvial fill material (Alluvial)		0.8
Clayey soil with naturally formed surface		1.0
Sandy soil with naturally formed surface (Alluvial)		1.4
Debris comprising mostly of rock pieces mixed with clayey or sandy soil	Older well compacted	1.2
	Younger loose material	2.0

Table 6: LHEF rating for relationship between structure and slope

Condition	Rating	Total rating of all conditions
Parallelism between slope and discontinuity	0.5	2.0
Relationship between slope inclination and dip/plunge of discontinuity	1.0	
Dip of discontinuity/plunge of wedge line	0.5	

Table 7: Rating for relationship of parallelism between slope and discontinuity

Category	Difference in angle of parallelism Plane: $ (\alpha_j - \alpha_s) $ Wedge: $ (\alpha_i - \alpha_s) $ Topple: $(\alpha_s + 160^\circ) \leq \alpha_j \leq (\alpha_s + 200^\circ)$	Rating	Slope condition
I	$> 30^\circ$	0.20	Very favorable
II	$21^\circ - 30^\circ$	0.25	Favorable
III	$11^\circ - 20^\circ$	0.30	Fair
IV	$6^\circ - 10^\circ$	0.40	Unfavorable
V	$\leq 5^\circ$	0.50	Very unfavorable

Where, α_j = Dip direction of discontinuity, α_i = Direction of plunge of the line of intersection of two discontinuity surfaces and α_s = Direction of slope inclination

Note: For slopes falling in category I in Table 7, the rating for structure as awarded in Table 8 and Table 9 will not be applicable and hence a rating of zero may be awarded.

Table 8: Ratings for relationship between dip/plunge of discontinuity and slope inclination

Category	Difference in angles Plane: $(\beta_j - \beta_s)$ Wedge: $(\beta_i - \beta_s)$	Rating	Sum of angles Topple: $(\beta_j + \beta_s)$	Rating	Slope condition
I	$> 10^\circ$	0.30	$\leq 110^\circ$	0.30	Very favorable
II	$0^\circ - 10^\circ$	0.50	$111^\circ - 130^\circ$	0.50	Favorable
III	0°	0.70	$131^\circ - 140^\circ$	0.70	Fair
IV	$0^\circ - (-10^\circ)$	0.80	$141^\circ - 160^\circ$	0.90	Unfavorable
V	$> (-10^\circ)$	1.00	$> 160^\circ$	1.00	Very unfavorable

Where β_j = Dip amount of discontinuity, β_i = amount of plunge of line of intersection of two discontinuity surfaces and β_s = amount of slope inclination

Table 9: Ratings for amount of dip of discontinuity

Category	Dip amount Plane: β_j and Wedge: β_i	Rating	Dip amount Topple: β_j	Rating	Slope condition
I	$< 15^\circ$	0.20	$< 50^\circ$	0.20	Very favorable
II	$16^\circ - 25^\circ$	0.25	$51^\circ - 60^\circ$	0.30	Favorable
III	$26^\circ - 35^\circ$	0.30	$61^\circ - 70^\circ$	0.40	Fair
IV	$36^\circ - 45^\circ$	0.40	$71^\circ - 80^\circ$	0.45	Unfavorable
V	$> 45^\circ$	0.50	$> 80^\circ$	0.50	Very unfavorable

Where β_j = Dip amount of discontinuity and β_i = amount of plunge of line of intersection of two discontinuity surfaces

Table 10: Ratings for depth of soil cover

Depth (m)	Rating	Probable mode of failure
≤ 5	0.65	Dominantly Talus
6 – 10	0.85	Talus and sometimes circular
11 – 15	1.30	Circular and sometimes Talus
16 – 20	1.50	Dominantly Circular
> 20	2.00	Dominantly Circular

Note: When depth of soil cover is ≤ 5 m, then put rating of 1 if the slope angle is more than 35° .

Table 11: Rating for slope morphometry

Slope type	Slope angle	Probable type of failure	Rating
Escarpment / Cliff	$> 65^\circ$	Falls and Topples	2.0
Very steep slope	$46^\circ - 65^\circ$	Falls and Topples	1.8
Steep slope	$36^\circ - 45^\circ$	Slides	1.6
Moderately steep slope	$26^\circ - 35^\circ$	Slides	1.3
Gentle slope	$16^\circ - 25^\circ$	Slides with creep movement	0.8
Very gentle slope	$< 15^\circ$	Slides with creep movement	0.5

Table 12: Ratings for relative relief

Relief classes	Relative relief (m)	Rating
Very low	< 50	0.3
Low	50 – 100	0.4
Medium	101 – 200	0.6
High	201 – 300	0.9
Very high	> 300	1.0

Table 13: Ratings for land use and land cover types

Land use and land cover types		Rating
Agricultural land or populated flat land ($\leq 15^\circ$)		0.65
Thickly vegetated forest area		0.80
Moderately vegetated area		1.20
Sparsely vegetated area with thin grass cover		1.50
Sparsely urbanized		1.20
Moderately urbanized		1.50
Heavily urbanized	With proper surface and/or subsurface drainage measures – no wet patches on slope	1.60
	Inadequate drainage – wet patches observed on slope	1.70
Barren land		1.80
Barren land with slope excavation (cut slopes for road construction, mining activities, etc)		2.00

Table 14: Ratings for external factors

Seismic zone	Rating	Average annual rainfall of the area (cm)	Rating
II	0.2	≤ 50	0.2
III	0.3	51 – 100	0.3
IV	0.4	101 – 150	0.4
V	0.5	> 150 or history of cloud burst	0.5

B.4 LANDSLIDE HAZARD RATING IN PROJECT AREA

S N	Location	Lithology		Structure		Slope morphometry	Relative relief (m)	Landuse and land cover	Hydrology	Rainfall	Seismicity	Ratings	Remarks
		Rocks	Soils	Relation of major joints/ bedding with slope	Soils (Thickness, m)								
HR 1	LB of Chameliya River at road level, Dhanthala E: 449907 N: 3277620 H: 748 m	Thinly bedded least stable Dolomite and Slate rock, faintly weathered		Fair		Moderately steep	~ 100	Sparsely vegetated with thin grass	Damp	VHI	Very high	7.4	HH, Lk Fm
	Ratings	1.5		1.3		1.3	0.6	1.5	0.2	1.0			
HR 2	LB of Chameliya River at road level E: 450544 N: 3277604 H: 759 m	Highly crushed phyllite with thinly bedded dolomite and limestone		Very favorable		Steep slope (36° – 45°)	~ 50	Thin grass, moderately vegetated	Wet	VHI	Very high	7	HH, Lk Fm
	Ratings	1.2		0.8		1.6	0.4	1.5	0.5	1.0			
HR 3	LB of Chamtari River at road level E: 451543 N: 3277914 H: 695 m	Highly crushed phyllite slate, weathered		Very unfavorable		> 45°	~ 100	Barren land for road construction	Wet	VHI	Very high	9.9	VHH, Gl Fm
	Ratings	2.0		2		1.8	0.6	2.0	0.5	1.0			
HR 4	Confluence of Jamadi and Chameliya river E: 452177 N: 3279220 H: 673 m	Thinly bedded dolomite, slate alteration, slightly weathered		Very favorable		Steep	~ 100	Moderately vegetated	Damp	VHI	Very high	6.25	MH, MI Fm
	Ratings	1.15		0.7		1.6	0.4	1.2	0.2	1.0			

S N	Location	Lithology		Structure		Slope morphometry	Relative relief (m)	Landuse and land cover	Hydrology	Rainfall	Seismicity	Ratings	Remarks
		Rocks	Soils	Relation of major joints/ bedding with slope	Soils (Thickness, m)								
HR 5	LB of Jamadi Khola E: 452567 N: 3279324 H: 665 m		Thick alluvium to colluvial soil sands with gravel		> 20	Steep to moderate	50 – 100	Moderately vegetated	Wet	VHI	Very high	8.1	VHH, MI Fm
	Ratings		1.4		2	1.6	0.4	1.2	0.5	1.0			
HR 6	RB of Panjunaya Gad at confluence with Chameliya River E: 452521 N: 3279809 H: 670 m		Alluvium and colluvial older compacts		> 30	Moderate to steep	50 – 100	Moderately vegetated	Damp	VHI	Very high	6.9	HH, MI Fm
	Ratings		0.8		2.0	1.3	0.4	1.2	0.2	1.0			
HR 7	Banga Bagar E: 453147 N: 3280720 H: 716 m	Highly jointed quartzite with phyllite		Favorable		Steep	50 – 100	Moderately vegetated	Flowing	VHI	Very high	6.9	HH, Bq Fm
	Ratings	0.7		1.0		1.6	0.4	1.2	1.0	1.0			
HR 8	Magarau Khola, opposite to Gokuleshwar	Highly weathered schists and quartzite		Favorable		Steep	100 – 200	Sparsely urbanized	Flowing	VHI	Very high	7.8	HH, Kk Fm
	Ratings	1.4		1.0		1.6	0.6	1.2	1.0	1.0			
HR 9	LB of Chameliya opposite to Agari Gad E: 450734 N: 3277651 H: 750 m	Highly jointed quartzite with phyllite interbeds		Favorable		Steep	100 – 200	Moderately vegetated	Damp	VHI	Very high	6.2	MH, Bq Fm
	Ratings	0.6		1.0		1.6	0.6	1.2	0.2	1.0			

S N	Location	Lithology		Structure		Slope morphometry	Relative relief (m)	Landuse and land cover	Hydrology	Rainfall	Seismicity	Ratings	Remarks
		Rocks	Soils	Relation of major joints/ bedding with slope	Soils (Thickness, m)								
HR 10	Downstream from confluence Nangada E: 461843 N: 3285435 H: 783 m		Debris comprising rock pieces, sand and clays		> 30	Moderately steep	200 – 300	Sparse vegetation with grass	Damp	VHI	Very high	8.5	VHH, Gl Fm
	Ratings		1.6	Favorable	2.0	1.3	0.9	1.5	0.2	1.0			
HR 11	RB of Chameliya, Devthala E: 461630 N: 3285536 H: 779 m	Slate with dolomites highly crushed		Favorable		Steep	100 – 200	Sparsely vegetated	Flowing	VHI	Very high	8.1	HH, Gl Fm
	Ratings	1.4		1.0		1.6	0.6	1.5	1.0	1.0			
HR 12	At road level before Luita E: 460912 N: 3285440 H: 765 m		Colluviums with local bed rocks, older compacted		< 5	Moderate	100 – 200	Sparse with thin grasses	Dry to flowing water	VHI	Very high	7.2	HH, Gl Fm
	Ratings		0.8		1.0	1.3	0.6	1.5	1.0	1.0			
HR 13	Luita, RB of Chameliya River E: 459995 N: 3285127 H: 744 m		Older alluvium (Bank erosion)		> 20	Very gentle slope	< 50	Moderately urbanized, Luita Village	Wet to flowing	VHI	Very high	6.9	HH, Gl Fm
	Ratings		0.8		2.0	0.5	0.3	1.5	0.8	1.0			
HR 14	RB of Chameliya River near Oshap E: 458783 N: 3284933 H: 726 m	Massive bedded grey dolomite, vertical slightly weathered		Very favorable		Cliff	50 – 100	Sparse vegetation	Dry	VHI	Very high	6.1	MH, Gl Fm
	Ratings	0.5		0.7		2.0	0.4	1.5	0.0	1.0			

S N	Location	Lithology		Structure		Slope morphometry	Relative relief (m)	Landuse and land cover	Hydrology	Rainfall	Seismicity	Ratings	Remarks
		Rocks	Soils	Relation of major joints/ bedding with slope	Soils (Thickness, m)								
HR 15	RB of Chameliya river above Osap E: 458913 N: 3285369 H: 813	Highly crushed talcosic dolomite		Fault zone highly favorable		Moderately steep	100 – 200	Sparsely vegetated	Damp	VHI	Very high	8.6	VHH, Gl Fm
	Ratings	2.0		2.0		1.3	0.6	1.5	0.2	1.0			
HR 16	Starting point of Darchula road from Gokuleshwar E: 456943 N: 3283277 H: 731 m	Phyllite, quartzite and schist		Very favorable		Moderate	50 – 100	Sparsely vegetated with thin grass cover	Damp	VHI	Very high	6.3	MH, Kk Fm
	Ratings	1.2		0.7		1.3	0.4	1.5	0.2	1.0			
HR 17	At Dhapa, RB of Mahakali River	Shale with quartzite		Favorable		Moderately steep	50 – 100	Moderately vegetated	Damp	VHI	Very high	6.1	MH, Sy Fm
	Ratings	1.0		1.0		1.3	0.4	1.2	0.2	1.0			
HR 18	LB of Mahakali river at Sarkar E: 445485 N: 3297920 H: 717 m		Alluvial soil loose with clay and sand gravel		16 – 20	Very gentle	≤ 50	Moderately vegetated urbanized	Wet	VHI	Very high	7.1	HH, Gl Fm
	Ratings		2.0		1.5	0.5	0.3	1.3	0.5	1.0			
HR 19	LB of Mahakali river at Sarkar E: 445282 N: 3297594 H: 710 m		Colluvial soil, loose rock fragments of slate, phyllite and dolomite		6 – 10	Moderate steep	50 – 100	Thickly vegetated	Wet	VHI	Very high	6.05	MH, Gl Fm
	Ratings		1.2		0.85	1.3	0.4	0.8	0.5	1.0			

S N	Location	Lithology		Structure		Slope morphometry	Relative relief (m)	Landuse and land cover	Hydrology	Rainfall	Seismicity	Ratings	Remarks
		Rocks	Soils	Relation of major joints/ bedding with slope	Soils (Thickness, m)								
HR 20	LB of Mahakali river at Dattu E: 444975 N: 3297212 H: 696 m	Bedded dolomite with rare inter coalitionist slate, highly folded and fractured		Very favorable		Steep slope	100 – 150	Sparsely vegetated	Flow of ground water	VHI	Very high	7.3	HH, Gl Fm
	Ratings	0.7		0.7		1.8	0.6	1.5	1.0	1.0			
HR 21	LB of Mahakali river, at Ghatte khola, Dattu E: 443517 N: 3296496 H: 761 m	Grey sand stone with rare shale highly jointed fractured		Very favorable		Very step to steep	50 – 100	Sparse vegetation	Dry to damp	VHI	Very high	6.5 5	MH, Sn Fm
	Ratings	1.35		0.7		1.6	0.4	1.5	0.0	1.0			
HR 22	LB of Mahakali river before Bet at road level E: 442742 N: 3295142 H: 699 m	Slate/shale with rare beds of meta and stones		Very favorable		Steep	100 – 200	Thick vegetation	Wet to inflow	VHI	Very high	6.7	HH, Gl Fm
	Ratings	1.2		0.7		1.6	0.6	0.8	0.8	1.0			
HR 23	RB of Bhartola Gad at confluence of Mahakali river E: 440033 N: 3293548 H: 641 m		Loose to compacted to older colluviums with signs of instabilities		15 – 20	Moderate to steep	150 – 200	Thickly vegetated	Wet, flow of ground water	VHI	Very high	7.2	HH, Gl Fm
	Ratings		1.2		1.5	1.3	0.6	0.8	0.8	1.0			
HR 24	LB of Mahakali River before Dinsi E: 442030 N: 3293058 H: 697 m	Dolomite massive, highly fractured		Favorable		Steep	150 – 200	Sparsely vegetated thin grass cover	Seepage to flowing	VHI	Very high	6.7	HH, MI Fm
	Ratings	0.2		1.0		1.6	0.6	1.5	0.8	1.0			

S N	Location	Lithology		Structure		Slope morphometry	Relative relief (m)	Landuse and land cover	Hydrology	Rainfall	Seismicity	Ratings	Remarks
		Rocks	Soils	Relation of major joints/ bedding with slope	Soils (Thickness, m)								
HR 25	At Dinsi village, road level E: 441021 N: 3292714 H: 740 m	Phyllite highly crushed foliated		Very favorable		Gentle to moderate	50 – 100	Moderate vegetated area	Wet	VHI	Very high	6.0 5	MH, MI Fm
	Ratings	1.2		0.75		1.0	0.4	1.2	0.5	1.0			
HR 26	Jolgibi, confluence opposite to Gori Ganga E: 439164 N: 3291917 H: 616 m		Colluvium with boulder, cobble with bed rocks		≤ 5	Moderate to steep	100	Thickly vegetated forest	Wet	VHI	Very high	5.8 5	MH, Bq Fm
	Ratings		1.2		0.65	1.3	0.4	0.8	0.5	1.0			
HR 27	Jolgibi from confluence of Gori Ganga E: 439097 N: 3291939 H: 617 m	Quartzite bedded to massive		Very favorable		Steep to moderate	50 – 100	Sparsely to moderate vegetated	Dry	VHI	Very high	5.0	MH, Bq Fm
	Ratings	0.4		0.7		1.3	0.4	1.2	0.0	1.0			
HR 28	100 m down to Radam Khola E: 441144 N: 3282820 H: 620 m	Highly fractured dolomite massive (Fresh)		Very favorable		Very steep slope	100	Very sparse vegetation	Dry	VHI	Very high	5.4	MH, MI Fm
	Ratings	0.2		0.7		1.8	0.4	1.3	0.0	1.0			
HR 29	Confluence of Tamali gad with Mahakali E: 443685 N: 3281283 N: 507 m	Thinly bedded lst/dolomite		Very favorable		Very steep	100	Sparse to moderate vegetation	Damp	VHI	Very high	6.0	MH, MI Fm
	Ratings	0.2		0.7		1.8	0.6	1.5	0.2	1.0			

S N	Location	Lithology		Structure		Slope morphometry	Relative relief (m)	Landuse and land cover	Hydrology	Rainfall	Seismicity	Ratings	Remarks
		Rocks	Soils	Relation of major joints / bedding with slope	Soils (Thickness, m)								
HR 30	LB of Mahakali at Garudami in between HR 23 and HR 24	Black slate shale		Favorable		Moderate steep	100 – 200	Moderately vegetated	Wet	VHI	Very high	6.8	HH, Gl Fm
	Ratings	1.2		1.0		1.3	0.6	1.2	0.5	1.0			
HR 31	Confluence of Mahakali and Chameliya river E: 442987 N: 3276130 H: 528 m	Massive to bedded dolomite highly fractured dome shaped stromatolite		Favorable		Steep	150 – 200	Moderately to sparse vegetation	Damp	VHI	Very high	5.9	MH, Lk Fm
	Ratings	0.2		1.0		1.6	0.6	1.3	0.2	1.0			
HR 32	LB of Chameliya in between Raktadi and Regan E: 444765 N: 3276539 H: 631 m	Massive fractured dolomite		Very favorable		Steep to moderate	300	Thickly vegetated forest area	Dry to wet	VHI	Very high	5.2	MH, Lk Fm
	Ratings	0.2		0.7		1.3	0.9	0.8	0.3	1.0			
HR 33	Before Jadabagar at suspension bridge over Chameliya		Colluvium, older		20 – 30	Moderate steep	100	Thick forest	Damp	VHI	Very high	6.5	MH, Lk Fm
	Ratings		0.8		2.0	1.3	0.4	0.8	0.2	1.0			
HR 34	Before Jadabagar E: 445686 N: 3277333 H: 596 m		Alluvium loose sand, gravels and silts		20 – 30	Very gentle slope	10 – 20	Thick vegetated area	Wet / Damp	VHI	Very high	6.4	MH, Lk Fm
	Ratings		1.4		2.0	0.5	0.3	0.8	0.4	1.0			

S N	Location	Lithology		Structure		Slope morphometry	Relative relief (m)	Landuse and land cover	Hydrology	Rainfall	Seismicity	Ratings	Remarks
		Rocks	Soils	Relation of major joints/ bedding with slope	Soils (Thickness, m)								
HR 35	LB of Mahakali river after Jabali at foot trail E: 442464 N: 3274104 H: 526 m	Slate black/ dolomite thickly bedded		Favorable		Steep	100	Sparse vegetation	Flow	VHI	Very high	7.9	HH, Sy Fm
	Ratings	1.2		1.0		1.8	0.4	1.5	1.0	1.0			
HR 36	LB of Mahakali before Jhulaghat after HR 28	Dolomite bedded highly jointed		Favorable		Steep	200 – 300	Moderately vegetated	Damp	VHI	Very high	6.5	MH, Mk Fm
	Ratings	0.6		1.0		1.6	0.9	1.2	0.2	1.0			
HR 37	LB of Mahakali at Jhulaghat	Thinly bedded lst and dolomite with slate		Favorable		Steep	200 – 300	Moderately vegetated	Damp	VHI	Very high	6.9	HH, Lk Fm
	Ratings	1.0		1.0		1.6	0.9	1.2	0.2	1.0			
HR 38	LB of Mahakali at Jhulaghat E: 440186 N: 3272099 H: 574 m	Dominantly slate and shale		Unfavorable		Steep	200 – 300	Moderately vegetated	Wet	VHI	Very high	8.5	VHH, Gl Fm
	Ratings	1.8		1.7		1.6	0.9	1.2	0.3	1.0			
HR 39	New road to Bodda before Jabalgada E: 439115 N: 3270559 H: 730 m		Colluvium with sand and silts		10 – 15	Gentle to moderate	100	Sparse vegetation	Dry to damp	VHI	Very high	6.8	HH, MI Fm
	Ratings		1.4		1.3	1.0	0.4	1.5	0.2	1.0			

S N	Location	Lithology		Structure		Slope morphometry	Relative relief (m)	Landuse and land cover	Hydrology	Rainfall	Seismicity	Ratings	Remarks
		Rocks	Soils	Relation of major joints / bedding with slope	Soils (Thickness, m)								
HR 40	LB of Mahakali at the confluence with Nilgarh Gad	Dolomite and Ist with slate		Favorable		Moderate	100 – 200	Sparsely vegetated	Damp	VHI	Very high	6.6	HH, Lk Fm
	Ratings	1.0		1.0		1.3	0.6	1.5	0.2	1.0			

Note:

RB: Right Bank
VHH: Very High Hazard
Gl: Galyang
Sy: Syanga


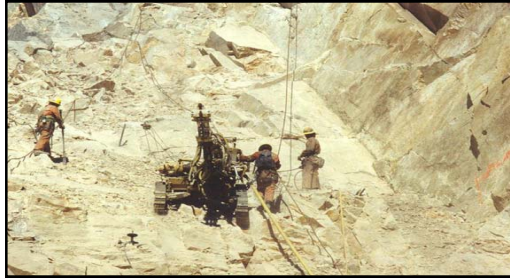



LB: Left Bank
E: East
Kk: Kalikot
Fm: Formation






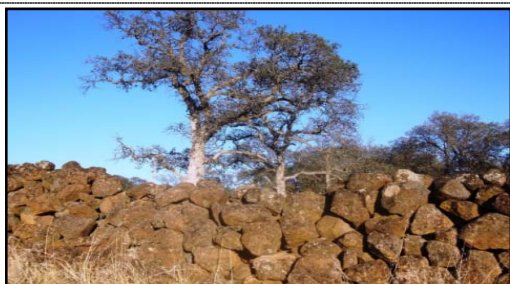
VHI: Very High Intensity
N: North
Bq: Banku




MH: Moderate Hazard
H: Height above Sea Level
Ml: Malekhu

HH: High Hazard
Lk: Lakharpata
Sn: Suntar






B.5 CIVIL ENGINEERING MEASURES FOR SLOPE STABILIZATION






S N	Mitigation measures	Description /Purpose	Photos
Slope Geometry Modification			
1	Hand/ Mechanical Scaling	Used to remove loose soils and rocks from unstable slopes via hand tools and/or mechanical equipment. Commonly used in conjunction with other stabilization methods.	
2	Trim Blasting	Used to remove overhanging rocky faces and protruding knobs and to modify the slope angle to improve rock fall trajectory and slope stability.	
Reinforcement			
Internal Stabilization			
3	Rock Bolts	Tensioned steel bars used to increase the normal force friction and shear resistance along discontinuities and potential failure surfaces of rock mass. Applied in a pattern or in a specific block.	
4	Rock Dowels	Untensioned steel bars installed to increase shear resistance and reinforce the block. Increase normal force friction once block movement occurs. Less visible than rock bolts.	
5	Shear Pins	Provide shear support at the leading edge of a dipping rock block or slab using grouted steel bars. Can easily be blended with surrounding rock by colored concrete.	





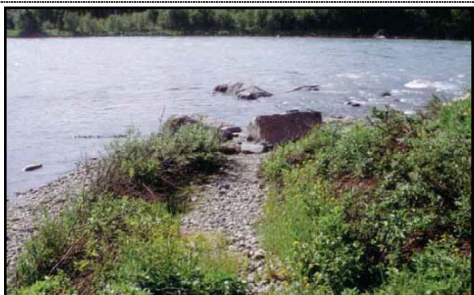
S N	Mitigation measures	Description /Purpose	Photos
6	Injectable Resin/Epoxy	Resin/epoxy injected into the rock mass through a borehole; travels along joints to add cohesion to discontinuities. Decreases the number of rock bolts or dowels needed in a rock slope. Great for aesthetics as it cannot be seen.	
External Stabilization			
7	Shotcrete	Pneumatically applied concrete requiring high velocity and proper application to consolidate. Primarily used to halt the ongoing loss of support caused by erosion and raveling. Drainage must be installed.	
Retaining Walls			
8	Stone Pitching	This technique involves interlocking large stones, with their flattest side up to create small irregular steps that blend into the landscape.	
9	Concrete Wall	A type of concrete throughout which small air bubbles are dispersed in order to increase its frost resistance: used for making roads	
10	Crib Wall	Crib walls are one of the oldest gravity wall systems, comprised of a series of stacked members creating hollow cells filled with soil or rock.	
11	Stone Masonry	Stonemasonry is the craft of shaping rough pieces of rock into accurate geometrical shapes, mostly simple, but some of considerable complexity, and then arranging the resulting stones, often together with mortar, to form structures	

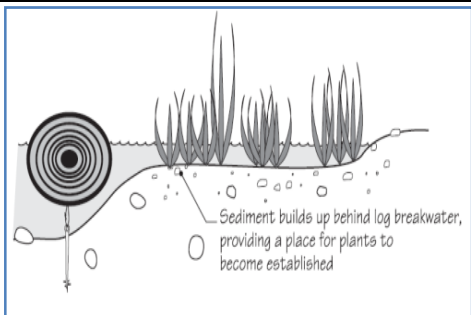


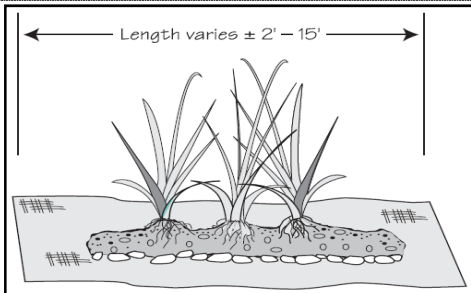
S N	Mitigation measures	Description /Purpose	Photos
12	Gabion Wall	A gabion wall is a retaining wall made of stacked stone-filled gabions tied together with wire. Gabion walls are usually battered (angled back towards the slope), or stepped back with the slope rather than stacked vertically.	
Drainage			
13	Weep Drains	Reduce water pressures within a slope using horizontal drains or adits. Commonly used in conjunction with other design elements. Good for aesthetics because drains are rarely visible.	
14	Check Dam	A check dam is a small barrier constructed of rock, gravel bags, sandbags, fiber rolls, or reusable products, placed across a constructed swale or drainage ditch. Check dams reduce the effective slope of the channel, thereby reducing the velocity of flowing water, allowing sediment to settle and reducing erosion.	


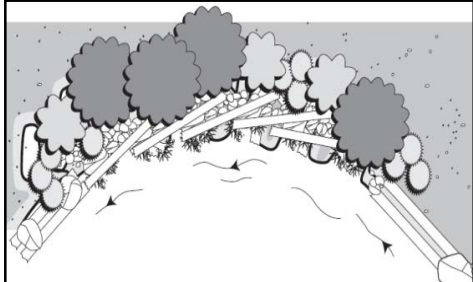
B.6 BIOENGINEERING MEASURES FOR SLOPE STABILIZATION

S N	Mitigation measures	Description/ Purpose	Figure/Sketch
1	Branch Packing	Branch packing is used to repair small, localized slumps and holes in stream banks. It consists of alternating layers of live branches and compacted backfill. Branches trap sediment that refills the localized slump or hole, while roots spread throughout the backfill and into the surrounding earth to form a unified mass.	
2	Brush Layering	Brush layering is the technique of laying cuttings on horizontal benches that follow the contour of either an existing or filled bank (slope). Branches serve as tensile inclusions or earth-reinforcing units to provide shallow stability of slopes.	
3	Brush Mattress	A brush mattress is a layer of dormant branches laid on and secured to a bank surface. It offers immediate bank coverage. This technique is also effective on lakeshores. Typically, it is combined with a toe stabilizing technique such as rock, root wads, live siltation, fascines, coconut fiber logs, or tree revetments. In this example, a fascine will be used with the mattress.	
4	Coconut Fiber Roll	A coconut fiber roll is used to protect a bank's toe and to define an edge. It is a cylindrical structure composed of coconut husk fibers bound together with twine woven from coconut fiber.	
5	Lakeshore Construction	A coconut fiber roll can function as a breakwater along a calm shallow lakeshore. In addition to reducing wave energy, this product can help contain substrate and encourage development of wetland communities.	

S N	Mitigation measures	Description/ Purpose	Figure/Sketch
6	Hay Bale Breakwater	Cylindrical hay bales, lined up parallel to the shore, are used in reservoirs and lakes to break wave action and to promote vegetative recovery of the shoreline.	
7	Joint Planting	Joint planting disguises riprap and may provide habitat. The plant roots help hold soil together under the rocks. It involves tamping live stakes into joints or open spaces between existing rocks or when rock is being placed on the slope face.	
8	Root Wad	Root wads armor a bank by keeping the current off the bank. They should be used in combination with other soil bioengineering techniques to stabilize a bank. Use them on lakeshores to combat wind- and wave-erosion.	
9	Jute-mat Log	This log can reinforce a stream bank without much site disturbance. Each log is 1 to 2 ft. in diameter and made out of coconut fiber mat or jute, straw, and lengths of branch cuttings. Logs are placed along the banks to provide armoring. They can vary in length from a few feet up to 100 ft.	
10	Live Cribwall	It consists of a boxlike interlocking arrangement of untreated log or timber members. The structure is filled with rock at the bottom and soil beginning at the ordinary high-water mark or bankfull level. Layers of live branch cuttings root inside the crib structure and extend into the slope. Once the live cuttings root and become established, vegetation gradually takes over the structural functions of the wood members.	

S N	Mitigation measures	Description/ Purpose	Figure/Sketch
11	Live Fascine/ Wattle	A fascine is a long bundle of branch cuttings bound together in a cylindrical structure. It should be placed in a shallow contour trench on a dry slope and at an angle on a wet slope to reduce erosion and shallow sliding.	
12	Trench Pack	Trench packs act to break the force of moving water, and trap sediment. They are deciduous branch cuttings placed vertically in trenches or holes. Plant cuttings should be selected from the same zone in which they will be planted, such as at stream's edge, on the bank, or on the floodplain.	
13	Live Post	Live posts form a permeable revetment. They reduce stream velocities and cause sediment deposition in the treated area. The roots help to stabilize a bank. Dormant posts are made of large cuttings installed in stream banks in square or triangular patterns. Unsuccessfully rooted posts at spacing of about 4 ft. can also provide some benefits by deflecting higher stream flows and trapping sediment.	
14	Live Stake	Live stakes create a living root mat that stabilizes the soil by reinforcing and binding soil particles together and by extracting excess soil moisture. Most willow species root rapidly and begin to dry out an excessively wet bank soon after installation. Live, rootable vegetative cuttings are inserted or tamped into the ground.	
15	Live Siltation	Live siltation is used to armor and revegetate the toe of a bank. It can be used on streams and lakeshores to combat wind and wave erosion. Plant live siltation perpendicular to the wind and waves. Dead and live branch cuttings are used to provide immediate and long-term stability, cover, and fish habitat. Cuttings are laid against the streamside edge of the trench. A layer of soil is packed around the cuttings. A layer of gravel, small rock, and soil fill the trench to hold the cuttings in place.	

S N	Mitigation measures	Description/ Purpose	Figure/Sketch
16	Log Breakwater	The log breakwater is used on lakes and reservoirs to reduce waves, deflect debris and ice, and trap sediment. It is 5 – 6 ft. wide. A breakwater is effective floating or tied to the lakebed. If tied to the bed, it will trap sediment more rapidly. In this case, the top of the logs should be at ordinary pool height. The installation technique is the same in either case. The breakwater is built with a series of log rafts. Stagger the logs in each raft. Then, when the rafts are strung end to end, the ends will mesh.	 <p>Sediment builds up behind log breakwater, providing a place for plants to become established</p>
17	Vegetated Geogrid	Vegetated geogrids are used to rebuild a bank. They are similar to the brush layering fill technique except that an erosion control fabric (geotextile) is wrapped around each soil lift. Live branch cuttings are laid between the layers.	
18	Plant Mat	A plant mat provides an instant swath of herbaceous ground cover in much the same way that unrolling sod does. Use this technique on lakeshores and on quiet stretches of streams. The mats are 2 – 3 inch thick nonwoven coconut fiber that are held together with organic latex and secured with a high tensile strength net backing. Herbaceous plants, such as sedges, and/or emergent aquatic plants are grown on a mat in a hydroponic setting, and then transported to the project site.	
19	Plant Roll	This technique introduces herbaceous vegetation to streambank and lakeshore sites while providing structural stability. Clumps of plants in sod are placed tightly in a sausage-like roll held together with burlap and twine. They are approximately 9 – 10 in. in diameter and can be 2 – 15 ft. long. They can be used alone or with other techniques, for example, at the base of a brush mattress instead of a live fascine.	 <p>Length varies ± 2' – 15'</p>

S N	Mitigation measures	Description/ Purpose	Figure/Sketch
20	Rooted Stock	Rooted stock provides instant leaf cover and habitat improvement. Rooted stock is a transplanted tree, woody shrub, or herbaceous plant with an established root system. It can be rooted cuttings balled with a burlap wrap, bare root, containerized plants, or sod or sedge harvested near the site and transplanted.	
21	Log Revetment	A log revetment is similar to a tree revetment. Generally, the branches are removed, and the logs are larger in diameter. Root wads and boulders can be incorporated into the design. The log revetments can be installed as previously described using deadman and cables.	
22	Tree and Log Revetment	A tree revetment creates an armored bank. It is constructed from whole trees (minus the root wad), cabled together and anchored to the bank. Log revetments are tree revetments with the branches removed. In certain instances, it may be necessary to remove some or all of the branches. This facilitates stacking the logs. It is always beneficial to leave the branches intact. Branches slow the rate of flow, catch sediment, and provide fish habitat.	