TA – 7984 NEP
September, 2014

Mainstreaming Climate Change Risk Management in Development

1 Main Consultancy Package (44768-012)

ROADS AND BRIDGES SECTOR

DoR

MUSTANG VULNERABILITY ASSESSMENT REPORT

Prepared by	ICEM – International Centre for Environmental Management
	METCON Consultants
	APTEC Consulting
Prepared for	Ministry of Science, Technology and Environment, Government of Nepal
	Environment Natural Resources and Agriculture Department, South Asia Department, Asian Development Bank
Version	A

TABLE OF CONTENTS

1 DISTRICT ASSETS/SYSTEM PRIORITIES 1
1.1 Briefing on Mustang District 1
1.2 Description of Priority System 2
2. VULNERABILITY ASSESSMENT METHOD 4
2.1 Summary of method/process 4
2.2 Interpretation of the climate vulnerability assessment methodology criteria for the Roads Sector 6
3. VULNERABILITY ASSESSMENT OF THE ASSET 9
3.1 Asset Description 9
3.2 Climate Change Threat to Infrastructures in Mustang District 14
3.3 Vulnerability Assessment Results 15
Table 8: Road damage at Marpha (km 72) (Asset 1) 15
Table 9: Road damage at Tukuche (km 65) (Asset 2) 16
3.4 Vulnerability Assessment Summary 17
Table 10: Road damage at Marpha (km 72) (Asset 1) 17
Table 11: Road damage at Tukuche (km 65) (Asset 2) 18

1 DISTRICT ASSETS/SYSTEM PRIORITIES

1.1 Briefing on Mustang District

Overall View of the District

Mustang district is located in Dhaulagiri zone of the Western Development Region of Nepal. It has borders with Tibet to the North, Manang to the East, Myagdi to the South and Dolpa to the West. The district has 16 VDCs, 9 Ilakas and 1 constituency area. The total area of the district is 3,573 sq. km having various types of topography. The lowest elevation point is 1,372 m and the highest elevation point is 8,167 m from the mean sea level. As a result of the elevation differences, the district has two different types of climate: sub-tropical from 1000-2000 m and temperate above 2000 m. Tourism and herbs are the main source of occupation and livelihood of the majority of the population. The total population of the district is 17,163 of which 9,017 are male and 8,146 are female (source: Nepal Population Report 2011, Ministry of Health and population, GoN). The headquarter of the district is Jomsom. It is located at the bank of Kali Gandaki River.

Major rivers in the district are; Kaligandaki, Lete, Yamkin, Marhang, Tukche etc.

Strategic Road Network in the District

The total strategic road network in Mustang District is 207 km. The main road of the district; from Pairothapla-Jomsom was constructed by the Nepal Army. At present this road is in the form of motorable track. Condition of the above road and other roads in the district is very poor. It is to be noted that Pairothapla-Jomsom-Ghoktan road section falls within the north-south road corridor (highway) linking India and China and is classified as future national highway.

There are only three strategic roads in the district. Their details are given in Table 1.

Table 1: Road Network in Mustang District.

S.N	Name of Road	Class	Ref No	Link Code	BT	GR	ER	Total	UC	PL	Remarks
1	Pairothapla-Jomsong	FRN	F042	F04209	0.00	0.00	59.00	59.00	0.00	0.00	All the roads are in form of earthen track. DOR is planning to upgrade them.
2	Jomsong-Ghoktang (China border)	FRN	F042	F04210	0.00	0.00	122.00	122.00	0.00	0.00	
	Kagbeni-Muktinath	FRO	F166	F16601	0.00	0.00	26.00	26.00	0.00	0.00	
				Total	0.00	0.00	207.00	207.00	0.00	0.00	

Source: Statistics of Strategic Road Network, SSRN 11/12, DOR

All the strategic roads and bridges in the district are managed by Pokhara Division of DoR. The division is mainly responsible for maintaining the Strategic Road Network (SRN). But it also carries out rehabilitation, upgrading and new construction of all types of strategic roads and bridges.

There are 35 nos. permanent staff in the Division with 1 Division Chief (SDE), 7 Engineers, 1 Account Officer, 1 Section Officer, 7 sub-engineers and the rest auxiliary staff.

Climatological Record

The climatological record and monthly rainfall of the district is presented in Table 1 and 2.

Table 2: Climatological Record of Mustang District

Location: Gurja Khani Latitude: 28^{o} 36' N; Longitude: 83^{o} 13E; Elevation: 2530 amsl (2008)

Air Temperature					Relative Humidity		Precipitation (mm)		No. of Rainy Days
Mean			Absolute Extreme		Observed at				
Max.	Min.	Daily	Max. & Date	Min. & Date	08:45 NST	17:45 NST	Total	Max. in 24 hrs. & Date	1:100
8.2			25.2/Aug.		67	80	2090	47/Sept	148

Source: Department of Hydrology and Meteorology

Table 3: Monthly Rainfall of Mustang District (mm)

Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
0	3.6	27.6	14.3	104.3	119.8	375.4	420	176.1	101.8	2	3.3

Source: Department of Hydrology and Meteorology (2009)

1.2 Criteria for Identifying Priority Assets/Systems for the Vulnerability Assessment

In the road sectors (both DoR and DoLIDAR) it is considered that the primary assets or systems are the road links joining important centres of population or production for example a feeder road joining a national highway to a district centre is considered as a system. The priority assets in that system are the parts or sections of the link which, if affected by an extreme weather event, would cause serious disruption to the movement of traffic on the link.

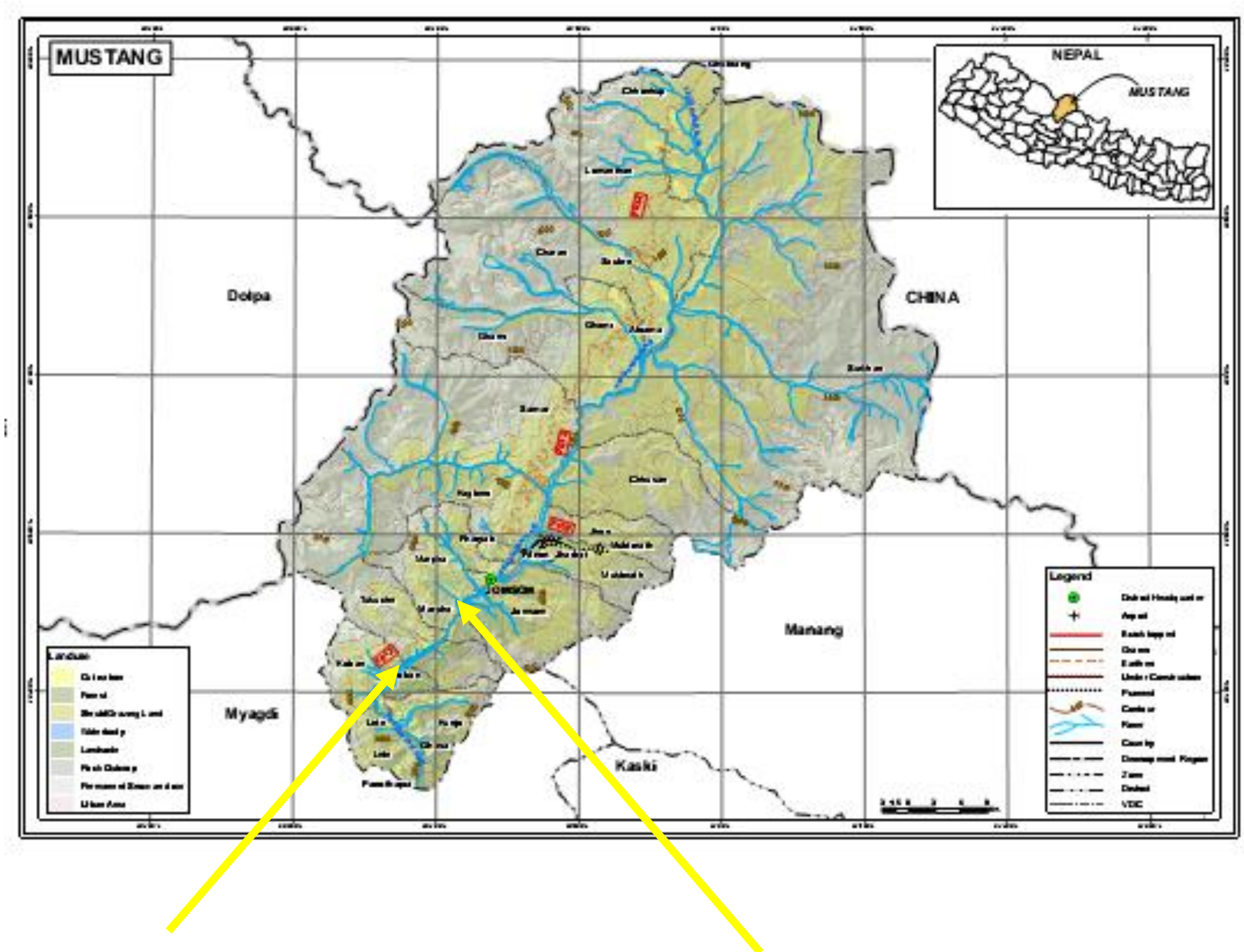
The key criteria for prioritisation include:

- Infrastructure of national strategic importance
- Infrastructure of district strategic importance
- Infrastructure that has been impacted by past extreme events
- Infrastructure located in areas prone to past extreme events

In each district the consultant in consultation with the division chief prepared final lists of the priority structures of the district. The list was prepared following the criteria provided in District Office Report.

1.2 Description of Priority System

In total five assets were covered in baseline report. Among them road damage at Marpha at km 72 (by Podkyu Khola) and road erosion at Tukuche (km 65), both along Pairothapla-Jomsom Road, are selected for vulnerability assessment and adaptation planning. The location of the assets is shown in Fig.1.



Road erosion at Tukuche (Asset 2) **Road damage at Marpha (Asset 1)**

Fig 1: Map of Mustang District showing asset locations

Road damage at Marpha (km 72) (Asset 1)

In July 2013 there was extensive rain at/ around Marpha area. The heavy rain caused flooding at Podkyu Khola and washed away about 150 long road sections at both sides of the khola. In the mean time the flood deposited large amount of debris at/around the road side (see photo). Due to such an incident vehicles are unable to cross the Khola from the original road track. At present they cross the Khola 200 m downstream. DoR is planning to construct a vented causeway across the khola.

Road erosion at Tukuche (km 65) (Asset 2)

About 40m long section of the Beni-Jomsom Road (motorable track) at km 65 was completely washed away in 2010. After the incident, DoR realigned the road at the hill side (at about 10m away from the previous road alignment). There is not any damage to realigned road section. However the river is still eroding this section and may damage the road in future.

2. VULNERABILITY ASSESSMENT METHOD

2.1Summary of method/process

The VA of the assets is carried out following the procedure as outlined below:

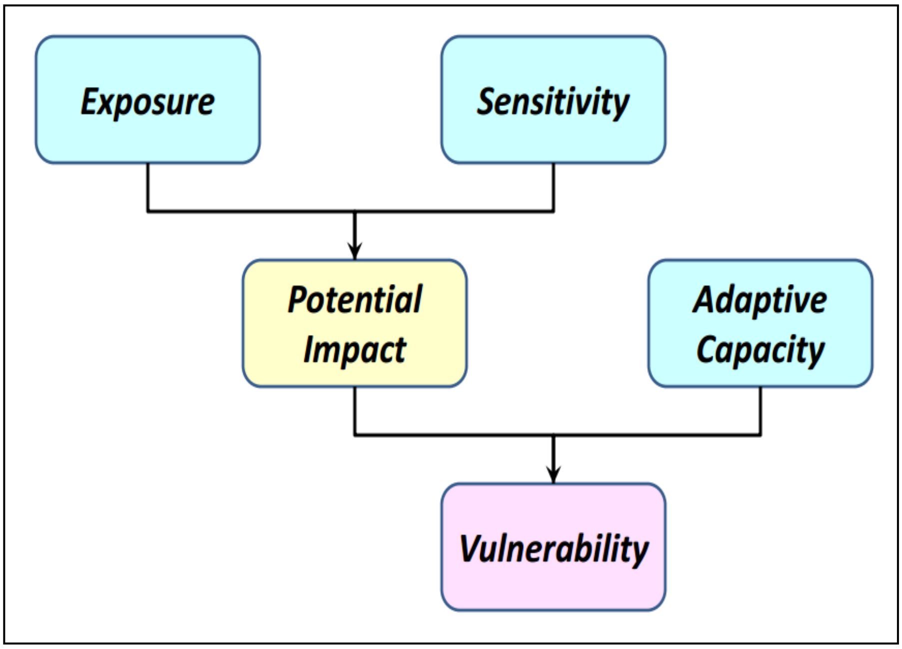


Fig 2: VA Process

There are two components in this phase

I. Assessing the impact of a climate threat on an asset and system; and
II. Defining the level of vulnerability of the asset and system to the projected threats.

Impact Assessment

The potential impact (or level of risk) is a function of the level of **exposure** to climate change induced threats and the **sensitivity** of the target asset or system to that exposure.

Exposure: exposure is the degree of climate stress on a particular asset. It is influenced by long-term changes in climate conditions and by changes in climate variability, including the magnitude and frequency of extreme events.

The following criteria influence exposure:

- Duration (e.g. hours or days of flooding)
- Location (e.g. distance from flood)
- Intensity (e.g. strength of rainfall, speed of flow)
- Magnitude (e.g. volume, flow or size of event)

Sensitivity: Sensitivity is the degree to which a system will be affected by, or be responsive to, climate change exposure.

The following variables affect infrastructure sensitivity:

i. Construction quality
ii. Levels of maintenance
iii. Protective system (e.g. river training wall to protect asset)
iv. Design (including safety margins)

A key tool in the process is the use of the **Climate Change Impacts Matrix** (Fig.2). The matrix is completed using descriptors for exposure and sensitivity, for example, 'very low' to 'very high'. If the exposure of a bridge to the threat of high flash floods is **High** (due to catchment area and topography) and its sensitivity to scour is **Very High** (due to soil type and foundation design) then the Matrix tells us that the **Impact** of the threat is **Very High**.

		Exposure of system to climate threat				
Sensitivity of system to climate threat		*Very Low*	*Low*	*Medium*	*High*	*Very High*
	Very High	*Medium*	*Medium*	*High*	*Very High*	*Very High*
	High	*Low*	*Medium*	*Medium*	*High*	*Very High*
	Medium	*Low*	*Medium*	*Medium*	*High*	*Very High*
	Low	*Low*	*Low*	*Medium*	*Medium*	*High*
	Very Low	*Very Low*	*Low*	*Low*	*Medium*	*High*

Fig.3: Impact Assessment Matrix

Vulnerability Assessment (VA)

A vulnerable system or asset is one that is sensitive to changes and extremes in climate and hydrology and one for which the ability to adapt is constrained. The vulnerability of an asset is therefore a function of the potential impact of changes in climate and the ability **(Adaptive Capacity)** of the responsible authority to respond to any possible impact.

The following variables affect the **adaptive capacity** of the responsible institution:

i. Institutional Strengths/Weaknesses
ii. Financial Resources
iii. Technical Capacity
iv. Ability to respond effectively to extreme events in the District

The Vulnerability of an asset is determined by applying the Impact value given by the Impacts matrix and the assessed value of adaptive capacity to the **Vulnerability Assessment Matrix** (Fig. 3).

This value of **Vulnerability** obtained (from Very High to Very Low) is then carried forward to the Adaptation Planning phase of the Climate Change Risk Management methodology

		Impact				
Adaptive Capacity		*Very Low* *Inconvenience (days)*	*Low* *Short disruption to system function (weeks)*	*Medium* *Medium term disruption to system function (months)*	*High* *Long term damage to system property or function (years)*	*Very High* *Loss of life, livelihood or system integrity*
	Very Low *Very limited institutional capacity and no access to technical or financial resources*	*Medium*	*Medium*	*High*	*Very High*	*Very High*
	Low *Limited institutional capacity and limited access to technical and financial resources*	*Low*	*Medium*	*Medium*	*High*	*Very High*
	Medium *Growing institutional capacity and access to technical or financial resources*	*Low*	*Medium*	*Medium*	*High*	*Very High*
	High *Sound institutional capacity and good access to technical and financial resources*	*Low*	*Low*	*Medium*	*Medium*	*High*
	Very High *Exceptional institutional capacity and abundant access to technical and financial resources*	*Very Low*	*Low*	*Low*	*Medium*	*High*

Fig 4: Vulnerability Assessment Matrix

2.2 Interpretation of the climate vulnerability assessment methodology criteria for the Roads Sector

In the highways sectors there are two major elements which make up a road link:

1) Road pavement & side drainage
2) Bridges and cross drainage structures

It is necessary to consider for both these elements their sensitivity and exposure to the various increased threats due to climate change.

Sensitivity

The following tables outline the sensitivity of the two road elements to various climate threats.

Table 3. Road pavement and side drains sensitivity to climate threats

CLIMATE THREAT	SENSITIVITY	IMPACT
Increased rainfall Increased intensity of rainfall	Depends on condition of existing pavement – a pavement in poor condition will have a High sensitivity	Damage to surface of pavement
Increased rainfall Increased intensity of rainfall	Side drains which are in good condition and well maintained will have a low sensitivity	Damage to side drains
Increased rainfall increases instability of hillside Increased intensity of rainfall increases instability of slope High flow in river scours base of hillside & causes landslide	A road across an hillside prone to landslides will have a Very High sensitivity A road above a river which is eroding the toe of the hillside will have a Very High Sensitivity	Landslide destroys road & side drains
Increased rainfall causes high monsoon flood Intense rainfall causes flash flood	A road constructed next to a river will have a Very High sensitivity	Road running along river valley damaged by adjacent river

Table 4. Cross road drainage sensitivity to climate threats

CLIMATE THREAT	SENSITIVITY	IMPACT
Increased rainfall causes riverine flooding	A road with adequate cross drainage structures for today's floods will have an increasing sensitivity as climate change takes effect	Road on embankment crossing flood plain washed out
Increased intensity of rainfall causes large flash flood	Design and condition of bridge foundations will cause sensitivity to vary from Medium to Very High	Bridge on river with small catchment area is damaged by flood
Increased intensity of rainfall increases size of flash flood	Design and condition of causeway slab and retaining walls will mean sensitivity will vary from Medium to Very High	Causeway for stream with small catchment area washed out by flood
Increased temperature variation from cold to hot season	The condition and design of the expansion joints & bearings will cause the sensitivity to vary from Low to High	Large Bridge over major river – damage to bearings & expansion joints
Increased rainfall causes high monsoon flood	The condition and design of the bridge piers and abutments will cause the sensitivity to vary from Low to Very High	Settlement or scour at pier or abutment

Exposure

The above tables illustrate examples of the sensitivity of various elements in the highway infrastructure to climate change. It shows that for both roads & bridges the major climate change threats are increased rainfall and intensity of rainfall which result in high monsoon floods, riverine floods and flash floods. For large bridges, very high temperature variations will be a threat to the viability of expansion joints and bearings.

The table below provides interpretation of exposure for different road and bridge assets to the climate threats identified for Mustang district. This general interpretation can be used along with consideration of the relative magnitude of the climate change threat at the target system site to assess the exposure of the assets of the target system.

The highway infrastructure in Mustang District will generally, depending also on upstream catchment area and topography, have a High or Very High Exposure to climate change.

Table 5. Interpretation of climate change threats and exposure for road and bridge assets

TYPE OF ASSET	CC THREAT	EFFECT OF THREAT	EXPOSURE
Large bridge on large river	Increase in max. temperature	Increase in expansion of deck – more stress on joints and bearings	Low to Medium
	Increase in wet season flow	Increased velocity of flow increases likelihood of scour to foundations	High to Very High
		Increased height of flood threatens stability of bridge deck and causes erosion of approach roads	Medium to Very High
		Increased sedimentation	Medium to Very

		reducing clearance under bridge	High
Smaller bridge on smaller river	Increasing risk & severity of flash floods during wet season	Increased velocity of flow increases likelihood of scour to foundations	Medium to Very High
		Increased height of flood threatens stability of bridge deck and causes erosion of approach roads	Medium to Very High
Pipe culverts & causeways on roads crossing watershed	On hill roads - increasing risk & severity of flash floods during wet season	Increased velocity of flow threatens to wash out pipe/ causeway & headwalls	High to Very High
	On flood plain roads - increase in wet season flow	Increase volume of flow threatens to wash out pipe/ causeway & headwalls	High to Very High
Hill road crossing watershed on sloping ground	Increasing risk of landslides	Road blocked or totally destroyed	Medium to Very High
Hill road running along valley bottom adjacent to river	Increasing wet season flow	Road eroded by height & high velocity of flow	High to Very High
	Increasing risk & severity of flash floods		
	Increasing risk of landslides	Road destroyed as erosion to toe of hillside causes landslide	
Road crossing flood plain	Increasing wet season flow and water levels	Road overtopped by flood water and pavement/ embankment destroyed	Medium to Very High

Impact

The impact of extreme weather event on an asset is a function of the Sensitivity and the Exposure and can be found by considering the Climate Change Impacts Matrix given in Fig. 2 and interpolating between the value of Sensitivity and the value of Exposure to give a value for Impact.

The value for Impact obtained by using the Impacts Matrix should be judged from a practical engineering point of view and if considered incorrect then the values used for Exposure and Sensitivity should be revisited. In particular, for road infrastructure, the value for sensitivity is very difficult to determine without carrying out detailed condition surveys for the particular asset under review. If sufficient design detail is unavailable, or the ground conditions difficult to judge, then an expert judgment of Sensitivity needs to be made and clear notes made justifying the decision.

Adaptive Capacity

Evaluating the Adaptive Capacity of the Department of Roads in a District is not a simple task. Baseline assessments including consultations and site visits have shown that the DRO which is responsible for strategic roads and bridges in the Mustang District has:

- Extensive experience in design and construction of roads and bridges;
- Sound financial resources;
- Sufficient trained and skilled man power available for design and construction of bridges;

- Adequate management system; and
- Good ability to respond promptly to disasters.

However in the baseline assessments (see Baseline Assessment Report for the Mustang District) for the district it was also observed:

a) Approved Budget funds are not released on time;
b) Programmes are not approved on time;
c) Very low bids are submitted by the contractors; and
d) Contractors receive mobilization advance but do not execute the work on time.

DoR has shown it is able to respond rapidly to emergencies where road links are disrupted. However the ability or preparedness of DoR to respond to possible future threats to the road infrastructure has yet to be demonstrated.

The above findings indicate that the Adaptive Capacity of the DoR Division offices is "High"

Vulnerability Scoring: Based on the impact and adaptive capacity assessments, the vulnerability of the asset against the climate change threats is estimated using the guiding Vulnerability Matrix as provided in Fig.4.

3. VULNERABILITY ASSESSMENT OF THE ASSET

3.1 Asset Description

Road damage at Marpha (km 72) (Asset 1)

The following table describes the important aspects of the asset.

Table 6: Salient features of the asset

Name of the Road	Beni-Jomsom
Road Category	National Highway
Service Provided by the Road	Connects all important places of the district and provides link to China.
Location of Asset	Km 72
Length of the affected road section.	About 150 m
Responsible Agency for repair/rehabilitation of the asset.	Pokhara Division of DoR
Major cause of the damage	Heavy rainfall in July 2013 which is unusual for that area.
Existing Condition of different components	Road: poor Major problem: - Road is completely washed away : - Podkyu Khola deposited large amount of debris at large area.

Fig. 4a: Upstream view of Podkyu Khola from its confluence with Kaligandaki River. Roads at both banks can also be seen on photo.

Fig. 4b: Timber bridge along the existing temporary crossing. Due to washing away of the road sections, temporary road crossing is built at about 200m downstream of the previous road alignment.

Fig. 4c: Photo of Podkyu Khola from the existing motorable crossing. According to the local people, the Khola washed away substantial road length at both sides due to heavy flood in July 2013. According to local people, there was continuous rain for three days, which is a rare incident in that area.

Road erosion at Tukuche (km 65) (Asset 2)

The following table describes the important aspects of the asset

Table 7: Salient Features of the Asset

Name of the Road	Beni-Jomsom
Road Category	National Highway
Service Provided by the Road	Connects all important places of the district and provides link to China.
Location of Asset	Km 65
Length of the affected road section.	About 40 m
Responsible Agency for repair/rehabilitation of the asset.	Pokhara Division of DoR
Major cause of the damage	Bank erosion by Kaligandaki River
Existing Condition of different components	Road: poor Major problem: - The river is still eroding the bank and may damage to realigned road. :

Fig. 5a: Washing away of road section due to heavy erosion. DoR has constructed a new motorable track at hill side. However the newly constructed road may be damaged if it is not protected.

Fig. 5b: Photo of damaged road from the river side. The newly constructed road is about 10m away from it.

.

Fig. 5c: Series of spurs are provided at about 60 m downstream from the damaged road to protect the bank from river erosion. About 1.5 km long right bank at this area is highly vulnerable to erosion.

Fig 5d: View of hill slope from river. The hill slope is very weak and is easily eroded by normal rainfall event. With increase in rainfall (due to climate change), the slope erosion will be extensive.

3.2 Climate Change Threat to Infrastructures in Mustang District

The study team prepared climate threat profile of Mustang District. The profile is presented in Annex 1 and its brief is presented below.

Threat due to Temperature Increase

As per the threat profiles, the average temperature increase in Mustang District will be 1.7^0 by 2050.

Adverse effect on the road and bridge assets due to above temperature rise will be nominal.

Threat due to Precipitation and Flood Increase

The threat profile indicated the following change on rainfall and flood patterns:

(i) Increasing number of extreme rainfall events – events that now occur every 10 years are projected to occur every 2 years

(ii) Increasing wet season flow on the Kali Gandaki River – peak monthly average flow in wet season will increase by up to 89%

(iii) Increasing flooding frequency of the Mustang River– the one in fifty year return period flow will increase by 78% (from 1006 m3/s to 1790 m3/s) at Mangla Ghat

The above findings show that there will substantial increase in frequency and magnitude of extreme discharge. Hence following aspects need serious consideration while designing road and bridge structures:

<u>Design life</u>: At present the important bridges are designed for 100 years return period and rural road bridges for 50 years return period. The drainage structures, in general are designed for 10, 20 or 25 years depending upon the importance of the roads. In order to accommodate the increased flood volumes, bridges as well as drainage structures should be designed for higher return periods. For example there will be a need to design important bridges for more than 200 years return period (instead of 100), rural road bridges for 100 years return period (instead of 50) and drainage structures for 50 years return period (instead of 25) to accommodate the increasing flood volumes.

<u>Invert level of bridges/culverts</u>: Due to increase in discharge, the high flood level (HFL) will increase. This will require increasing the invert level of bridges/culverts.

<u>Foundation depth of bridges/culverts</u>: The increased discharge will cause more scouring requiring more foundation depth.

<u>Size of drainage structures</u>: Sizes of both side drainage and cross drainage structures should be increased to accommodate increased flood volumes.

<u>Road pavement</u>: Roads lying in low land and adjacent to rivers will be highly affected by increased flood. The wetting of subgrade for longer duration will decrease its strength (CBR) requiring thicker road pavement.

3.3 Vulnerability Assessment Results

The following tables show the VA results of the assets.

Table 8: Road damage at Marpha (km 72) (Asset 1)

Climate Change Threats	Interpretation of threat	Exposure	Sensitivity	Impact Level	Impact Summary	Adaptive capacity	Vulnerability
Component 1: Road section near/at the Podkyu Khola.							
• Increasing intensity and duration of rainfall • Increasing number of extreme rainfall events • Increasing wet season flow.	Frequency and intensity of extreme event will increase.	VH[1]	M[2]	H	Road section at/near the khola will be washed away.	H[3]	H
Component 2: River banks of Podkyu Khola (where the roads are located very near to the river)							
• Increasing intensity and duration of rainfall • Increasing number of extreme rainfall events • Increasing wet season flow.	Erosion of both banks due to increase in wet season flow. .	H[4]	M[5]	H	Road sections located near the river will be damaged due to bank erosion.	H[3]	H
Component 3: Siltation							
• Increasing intensity and duration of rainfall • Increasing number of extreme rainfall events • Increasing wet season flow.	The probability of siltation will be higher.	H[6]	M[7]	H	Damage to road will be more frequent.	H[3]	H

Notes:

1. *The road alignment near/at the khola is highly exposed to river flow. With increase in flood volume the exposure will become very high.*
2. *The road will be closed for few days. The loss of lives and properties will be nominal.*
3. *The adaptive capacity of DoR Division Road Office is **High**; see section 2.2.4.*
4. *About 100m long stretch of road alignment at both banks is located very near to the river. Probability of bank erosion will be higher with increase in flood volume. The erosion may cause road damage.*
5. *The road will be closed for few days. The loss of lives and properties will be nominal.*
6. *The siltation which occurred in July 2013 was an extreme event. Frequency of such events will be more with increase in flood volume.*
7. *The road will be closed for few days. The loss of lives and properties will be nominal*

Table 9: Road damage at Tukuche (km 65) (Asset 2)

Climate Change Threats	Interpretation of threat	Exposure	Sensitivity	Impact Level	Impact Summary	Adaptive capacity	Vulnerability
Component 1: Road + River bank							
• Increasing intensity and duration of rainfall • Increasing number of extreme rainfall events • Increasing wet season flow.	The eroding capacity of Kaligandaki River will be higher with increase in wet season flow.	VH[1]	M[2]	H	The intensity and frequency of bank erosion will substantially increase. The road sections located near to the river will be damaged.	H[3]	H
Component 2: Hill slope							
• Increasing intensity and duration of rainfall • Increasing number of extreme rainfall events • Increasing slope erosion and landslide events.	Increase in intensity and duration of rainfall will cause slope erosion and landslides. As the slope is weak, the vulnerability will be much higher.	VH[4]	M[5]	H	The road will be damaged. The traffic will be closed for few days.	H[3]	H

Notes:

1. *The river bank is being eroded by present flood. With increase in flood volume the erosion process will be much higher.*
2. *The road will be closed for few days. The loss of lives and properties will be nominal.*
3. *The adaptive capacity of DoR Division Road Office is **High**; see section 2.2.4.*
4. *The hill slope is being eroded with normal rainfall. With increase in intensity and duration of rainfall, slope erosion will be very high. There is a high probability of big landslides at few locations.*
5. *The road will be closed for few days. The loss of lives and properties will be nominal.*

3.4 Vulnerability Assessment Summary

Table 10: Road damage at Marpha (km 72) (Asset 1)

THREAT	IMPACT	EXPOS.	SENSIT.	IMPACT	ADAPT. CAP.	VULN.	COMMENTS
• Increasing intensity and duration of rainfall • Increasing number of extreme rainfall events • Increasing wet season flow	Road section at/near the khola will be washed away.	**VH**	**M**	**H**	**H**	**H**	The increase in flood volume will damage to the road more frequently. DoR should provide sufficient drainage and retaining structures to protect the road.
• Increasing intensity and duration of rainfall • Increasing number of extreme rainfall events • Increasing wet season flow	Road sections located near the river will be damaged due to bank erosion.	**H**	**M**	**H**	**H**	**H**	The road alignment is very near to banks. As the banks are not protected, there is a high probability of road damage.
• Increasing intensity and duration of rainfall • Increasing number of	Damage to road section near the khola will be more frequent	**H**	**M**	**H**	**H**	**H**	The gradient of the Podkyu khola is high. It transports large amount of debris and damages the road even during normal flow. There are not any structures to lessen the

extreme rainfall events.							debris flow (check dams) and hence the road near/at the khola is highly vulnerable to siltation.

Table 11**: Road damage at Tukuche (km 65) (Asset 2)**

THREAT	IMPACT	EXPOS.	SENSIT.	IMPACT	ADAPT. CAP.	VULN.	COMMENTS
• Increasing intensity and frequency of extreme rainfall events. • Increasing wet season flow	The intensity and frequency of bank erosion will substantially increase. The road sections located near to the river will be damaged.	**VH**	**M**	**VH**	**H**	**H**	Kaligandaki River is extensively eroding about 1.5 km long section of right bank (where the road is located). Bank protection works are provided at few sections only. The sections (bank) including the asset which are not protected are highly vulnerable to river erosion.
• Increasing intensity and frequency of extreme rainfall events. • Increasing slope erosion and landslide events	The road will be damaged. The traffic will be closed for few days.	**H**	**M**	**H**	**H**	**H**	Due to weak geology, the hill slope is highly vulnerable to rainfall increase. Moreover the road lacks basic protection structurers.