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Mainstreaming Climate Change Risk Management in Development

1 Main Consultancy Package (44768-012)

Department of Roads

Dolakha District

VULNERABILITY ASSESSMENT REPORT

Prepared by	ICEM – International Centre for Environmental Management
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Prepared for	Ministry of Science, Technology and Environment, Government of Nepal
	Environment Natural Resources and Agriculture Department, South Asia Department, Asian Development Bank
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TABLE OF CONTENTS

1 DISTRICT ASSETS/SYSTEM PRIORITIES

1.1 Briefing on Sector in Dolakha District

1.1.1 Strategic Roads and Bridges in Dolakha District

Dolakha is a mountainous District of Janakpur Zone in the central Development Region. The district headquarter of Dolakha is Charikot which is located at a distance of 132 km from Kathmandu. The area and population of the district is 2,191 sq.km and204,229 (2001 census) respectively. The district extends from north to east consisting of 51VDCs and 1municipality.

There are 8 major roads in the district with a total length of 136 kilometers. DoR has planned to construct additional 109 km roads in the future. The total number of bridges in the district along strategic roads is 12 including Charnabati Bridge (the asset). Strategic roads and bridges in Dolkaha District are managed by CharikotDvision of DoR.

1.1.2 Charikot Division

Charikot Division is one of the 25 divisions of DoR and manages all strategic roads in Dolakha, Sindhupalchok and Ramechhap Districts in Central Development Region. The Office is responsible for 420.35 km of roads, of which, 256.83km are blacktop, 41.00 km are gravel and 112.10km are earthen. There are 34 nos. of permanent staff currently working under this Division with 1 Division Chief (SDE), 1 Senior Divisional Engineer (special), 1 Engineer, 1 Account Officer, 7 Engineers (special), 2 Sub Engineers, 1 Lab Technician, 2 Lab Assistants, 1 Store Keeper and rest auxiliary staff.

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 centers 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 TA 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.

1.3 Description of Priority System

Lamsongu to Jiri Road at Charnabati River at km 45.

Lamsongu-Jiri is the most important road in Dolakha and neighboring districts. It provides access to several districts of Central and Eastern Development Regions with Kathmandu. Construction of this road was started in 1976 with the assistance from the Government of Switzerland. In 1987, when the construction of this road was in its final stage about a 500 metre long section of the road including the bridge over the Charnabati Khola was washed away by a flash flood in 1987. This road section as well as bridge was reconstructed again by Swiss

Government. It is believed that the cost of rehabilitation and reconstruction of this road section (including bridge) was almost equal to the construction cost of the whole Lamsongu-Jiri Road. The road section as well as bridge at present seems to be in stable condition.

2 VULNERABILITY ASSESSMENT METHOD

2.1 Summary of method/process

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

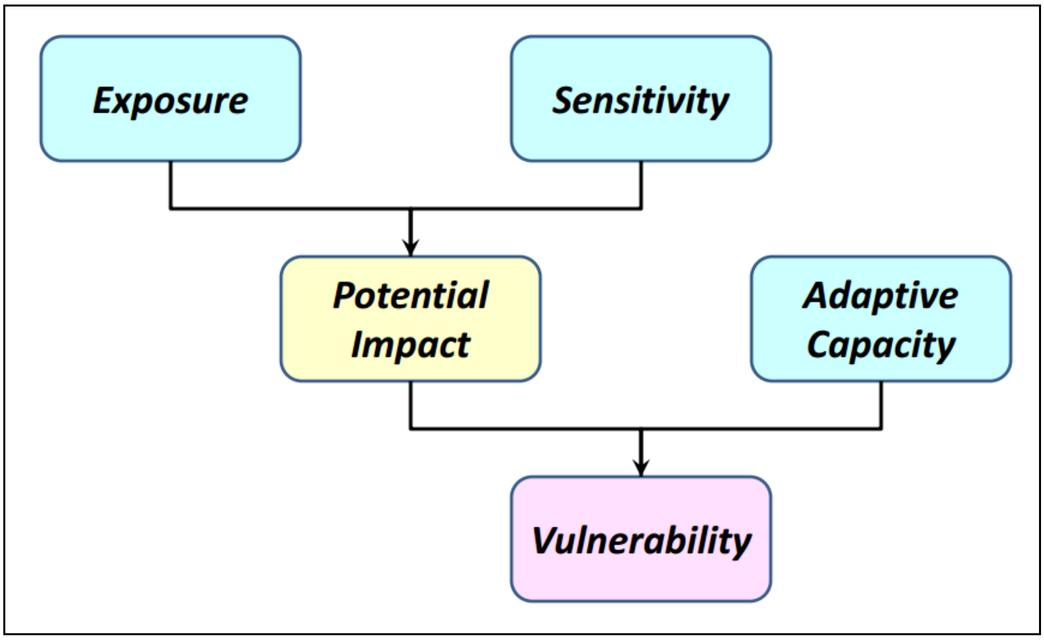


Fig 1: VA Process

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.

2.1.1 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.2: Impact Assessment Matrix

2.1.2 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

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. 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.

2.2.1 Sensitivity

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

Table 1. 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 2. 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	The condition and design of the expansion joints & bearings will	Large Bridge over major river – damage to bearings

CLIMATE THREAT	SENSITIVITY	IMPACT
season	cause the sensitivity to vary from Low to High	& 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

2.2.2 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 Climate Change Threat Profile for Dolakha District shows that the flood magnitude will increase in the range of between 16-41 % in 2040 and 40-57 % in 2060 for different return periods. It also indicates that the maximum average monthly flow in the Bagmati River at Chovar will occur about one month earlier, in mid July, and will be around 50% larger.

The table below provides interpretation of exposure for different road and bridge assets to the climate threats identified for Dolakha 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 Dolakha District will generally, depending also on upstream catchment area and topography, have a High or Very High Exposure to climate change.

Table 3. 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 reducing clearance under bridge	Medium to Very 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	On hill roads - increasing risk & severity of flash	Increased velocity of flow threatens to wash out pipe/ causeway & headwalls	High to Very High

watershed	floods during wet season		
	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

2.2.3 Impact

The impact on an 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

		Impact				
		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*
Adaptive Capacity	*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 3: Vulnerability AssessmentMatrix

2.2.4 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 Charikot Division Office of DoR which is responsibe for strategic roads and bridges in the Dolakaha 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 Dolakha 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.

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 Assessment Matrix provided in Fig. 3. as shown below:

3 VULNERABILITY ASSESSMENT OF THE CHARNABATI BRIDGE, LAMOSANGU-JIRI ROAD

3.1 Asset Description

Table 4 describes the important detail aspects of Lamsangu-Jiri Road and Charnabati Bridge site area. A full description of the asset is outlined in DoR Dolakha District Baseline Report. Fig. 4 provides a photo overview of the asset.

Table 4: Salient Features of the Lamosangu-Jiri Road and the Asset

Name of the Road	Lamosangu-Jiri
Road Category	Feeder Road (Major)
Service Provided by the Road	- Connects Sindhupalchowk, Dolakha and Ramechhap Districts with national road network system - Provides vehicular link to hilly areas of Central Development Region.
Responsible Agency	Charikot Division of DoR
Location of Asset	Km 35

Major Components of the Asset	Bailey Bridge (12.4 m) Approach Roads at either sides of the bridge, protection works (check dams, concrete aprons and side walls), bio-engineering works
Existing Condition of different components	Bailey bridge: good; Check Dams, Concrete Aprons & Side Walls: damaged at few locations because they were constructed long time ago; DoR is maintaining them. Bio-engineering: good

Fig. 4a: Charnabati Bridge and upstream side of the river.

Fig. 4b: Upstream side of the river from the bridge. Several drop structures as along with concrete aprons are constructed at upstream as well as downstream to lessen the velocity of the river.

FIG. 4C: Heavy bio-engineering works at the both banks of the river.

3.2 Climate Change Threat to Infrastructures in Dolakha District.

The climate change threat profiles for Dolakha District were prepared by the hydrological modeling teams. The threat profile is provided in Annex 3. The effect of climate change to the road and bridge Sector as implied by the threat profiles is outlined below.

3.2.1 Threat due to Temperature Increase

As per the threat profiles, the temperature increase scenario in DolakhaDistrict in 2060 will be as follows:

- The average increase in minimum temperature will be 2.2^0 C(with maximum increase of 3. 5^0 C in February and minimum increase of 1.0^0 C in May).
- The average increase in maximum temperature will be 1.7^0 C (with maximum increase of 4.0^0 C in February and minimum increase of 0.7^0 C in March).

Adverse effect on the asset due to above temperature rise will be nominal.

3.2.2 Threat due to Precipitation Increase

The threat profiles show that duration of extreme rainfall events with high intensity will occur more often than before. The following conclusions can be drawn from the threat profile:

- Duration of extreme rainfall events with high intensity will increase. For example for the ARI event the duration of 100 mm /h rainfall intensity which is 15 minutes at present will increase to 45 minutes in 2060; and.
- Floods with a return period of 2, 5, 10, 25, 50, 100 and 200 will increase in volume by 57, 57, 56, 50, 47, 43 and 40 percentages respectively.

The above findings show that there will substantial increase in frequency and magnitude of extreme discharge. Hence the 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,

20or 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 may be a need to design important bridges for 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.

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

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

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

Road pavement: 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 table below presents the vulnerability assessment for the components of the bridge and approach roads for Charnabati River on Lamsonguto Jiri Road. The analysis found that the most vulnerable component is the bioengineering and drainage works on downstream left bank. This component is ranked as very highly vulnerable predominantly due to very high exposure to increasing intensity and volume of precipitation.

Table 5. Vulnerability assessment for bridge and approach roads for Charanabati River crossing on Lamsonga to Jiri Road

Climate change threats	Interpretation of threat	Exposure	Sensitivity	Impact Level	Impact Summary	Adaptive capacity	Vulnerability
Component 1: 12.4 metre Bailey Bridge across Charnabati River							
• Increasing wet season flow • Increasing risk & severity of flash floods	• Increased threat to stability of bridge abutments due to possibility of scour undermining footings	VH[1]	M[2]	VH	• The impact of the failure of an abutment is very high as the road would be closed for a considerable time	H[5]	H
	• Very high flood level may overtop bridge and remove structure from the abutments	H[3]	H[4]	H	• The loss of the bridge deck would not be as serious as the destruction of an abutment	H	M
Component 2: Check Dams, Concrete Aprons & Side Walls							
• Increasing wet season flow • Increasing risk & severity of flash floods	• Threat of damage to previously built protection works from increased flows	VH	VH[6]	VH	• The stability of all the protection work may be affected by the failure of one element	H[8]	H
	• Threat of progressive collapse of protection works after failure of one element	VH	M[7]	VH		H[8]	H
Component 3: Bio Engineering and Drainage works to earlier landslide area on downstream left bank							

• Increasing intensity of rainfall • Increasing number of extreme rainfall events	• Increased possibility of failure of both sub-surface and surface water drainage works • Increased likelihood of landslides which destroy approach road	VH VH	M[9] M[9]	VH VH	• The ability of the bio-engineering & drainage work to reduce the likelihood of landslides will be affected by the threats from CC	M[10] M[10]	VH VH
Component 4: Retaining Walls constructed to stabilise landslides on downstream right bank							
• Increasing wet season flow • Increasing risk & severity of flash floods	• Increased likelihood of erosion on downstream right bank with consequent increase in size and frequency of landslides • Possibility of landslides blocking flow of river and causing erosion on left bank with threat of landslide affecting approach road	M[11] M[11]	VH[12] L[13]	H M	• There is a very high probability that there will be more landslides on the right bank hillside which will damage the newly built track but are unlikely to affect the bridge and approach roads	H[14] H[14]	M M

NOTES: (the Impact Assessment Matrix tool is provided in Annex 1 and the Vulnerability Assessment Matrix tool is provided in Annex 2)

1. *The exposure is very high because an extreme event occurred in the past and CC will increase the probability of a more extreme event occurring*
2. *The sensitivity is medium because the abutments are well designed and constructed*
3. *The exposure is high rather than very high because the threat of such an event is reduced by the extensive upstream protection & flood dissipation works*
4. *The sensitivity of the Bailey Bridge is high as the bridge bearings are not designed to withstand such an event*
5. *The Adaptive Capacity of DoR is considered to be high although this may change as the threats from CC increase. It is clear that DoR has some emergency funds available for extreme events which disrupt roads but it is unclear whether the Adaptive Capacity for less urgent work is as high.*
6. *A concrete apron upstream of the bridge is already badly cracked and is likely to break up under extreme flows. Some of the tetrapods constructed at the end of the protection works have been displaced; any further displacement may affect the stability of the protection works below the landslide prone area*
7. *The likelihood of progressive collapse is less because the design & construction is of high quality*
8. *DoR reconstructed a damaged check dam before the 2013 rainy season and it has withstood the subsequent high flows*

9. *The bio-engineering drainage works were well constructed but the design did not take into consideration the increased threat imposed by CC*
10. *The ability of DoR to maintain and adapt the bio-engineering and drainage works is not as high as for simpler engineering tasks*
11. *The increase in the possibility of landslides will not affect the bridge or road unless a major landslide takes place (see 13 below)*
12. *There have already been some minor landslides caused by the construction of a road across the hill slope and the ability of the retaining walls to restrict further landslides is limited thus the sensitivity is very high*
13. *The slope of the hillside is not high and the likelihood of a large landslide is not great thus the sensitivity is low*
14. *It is not clear which authority is responsible for this work, DoR or DWIDP, so the adaptive capacity may be less than noted*

3.3 Asset Vulnerability Summary

The table below provides a summary of the vulnerability assessment for the components of the bridge and approach roads for Charnabati River on Lamsonga to Jiri Road. The analysis found that the impacts to which the crossing was ranked very high vulnerability was the failure of bioengineering and drainage works on the downstream left bank and landslide on the left bank destroying the approach road.

Table 6. Summary of vulnerability assessment for bridge and approach roads for Charanabati River crossing on Lamsonga to Jiri Road

THREAT	IMPACT	EXPOSURE	SENSITIVITY	IMPACT	ADAPTIVE CAPACITY	VULN.	COMMENTS
Increasing wet season flow	Bridge Destroyed by abutment collapse	VH	M	VH	H	H	The sensitivity of the structures which make up this asset is very difficult to ascertain as detailed design drawings are not available. The condition of the structure is also uncertain so it is necessary to carry out further investigations before the value for sensitivity is confirmed
Increasing high flood level	Bridge Deck removed by high flood	H	H	H	H	M	
Increasing wet season flow and flash floods	Damage to protection works i.e. apron slab	VH	VH	VH	H	H	The fact that there has already been some damage caused to the check dams and aprons indicates that there is some vulnerability to high flows. The threat from increased flows due to CC therefore reinforces the need for continuing assessment of the condition of the structures and where necessary prompt action being taken to rectify any damage
Increasing wet season flow and flash floods	Progressive collapse of protection works	VH	M	VH	H	H	
Increasing intensity and frequency of extreme rainfall	Bio Engineering & drainage works fail	VH	M	VH	H	VH	The effectiveness of bio-engineering work increases with time as the planting becomes more established. However the drainage works require constant

events							attention and the sub surface drains may become less effective with time so it is necessary to monitor the condition of the drains and ensure that the main carrier drains do not become damaged or blocked
Increasing occurrence of landslide	Landslide on left bank destroys approach road	**VH**	**M**	**VH**	**H**	**VH**	
Increasing occurrence of landslide	Landslide on right bank damages retaining walls	**M**	**VH**	**H**	**H**	**M**	The instability of the downstream right bank does not affect the bridge or road in the short term but if the erosion is not controlled the landslides could progress up the hillside and affect the approach road on that side. Also any blockages to the river would have a detrimental effect to the left bank & hillside and in time to the approach road above
Increasing occurrence of landslide	Large landslide on right bank blocks river and affects left bank	**M**	**L**	**M**	**H**	**M**	

ANNEX 1 SITE VULNERABILITY ASSESSMENT SHEET

CC THREATS	DESCRIPTION OF THREATS
Change and shift in regular climate Increase/decrease in temperature Increase/decrease in precipitation Increase/decrease in flow **Change and shift in events** Riverine flooding Extreme localised pooling/flooding Flash floods River bed scouring +Bank erosion Landslides	•

EXPOSURE	**SCORE VL TO VH**
SENSITIVITY SCORE VL TO VH	
IMPACT VH	**SCORE VL TO**
ADAPTIVE CAPACITY VL TO VH	**SCORE**
VULNERABILITY SCORE: VL TO VH	

ANNEX 2 VULNERABILITY ASSESSMENT COMPARISON TABLE

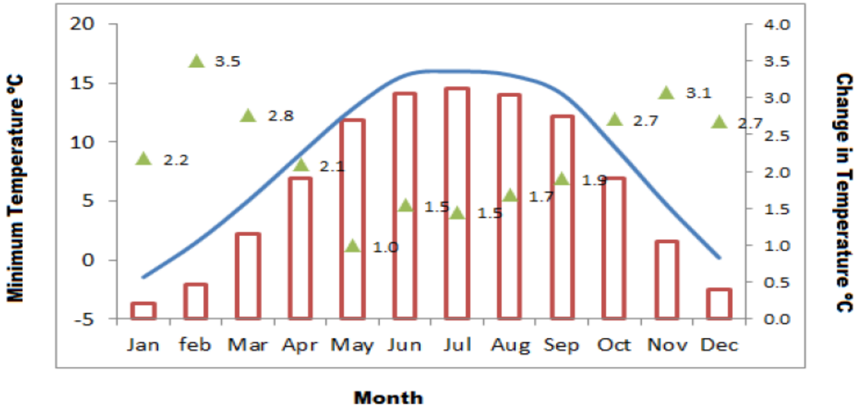
Asset:

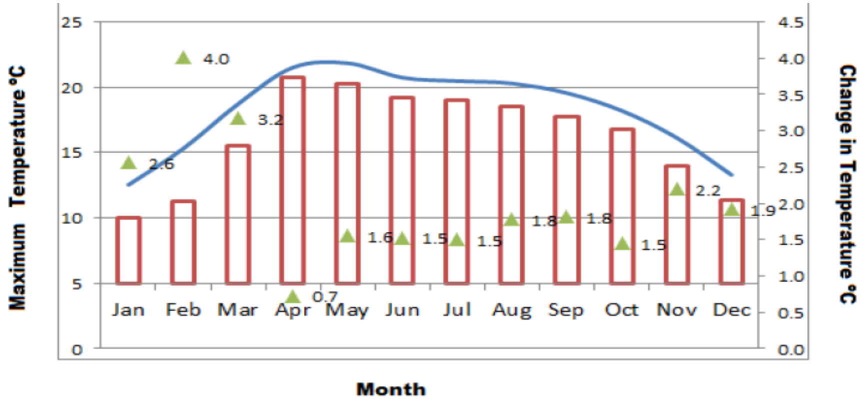
CC Threats	**Interpretation of threat**	**Exposure**	**Sensitivity**	**Impact Level**	**Impact Summary**	**Adaptive capacity**	**Vulnerability**
Component 1							
	•				•		
Component 2							
	•				•		
Component 3							
	•				•		

NOTES:

Max/Min temperature
(Charikot, Dolakha)

Month	Change in Minimum Monthly Temperature °C (2060)	Change in Maximum Monthly Temperature °C (2060)
Jan	+2.1	+2.6
Feb	+3.5	+4.0
Mar	+2.8	+3.2
Apr	+2.1	+0.7
May	+1.0	+1.6
Jun	+1.5	+1.5
Jul	+1.5	+1.5
Aug	+1.7	+1.8
Sep	+1.9	+1.8
Oct	+2.7	+1.5
Nov	+3.1	+1.2
Dec	+2.7	+1.9





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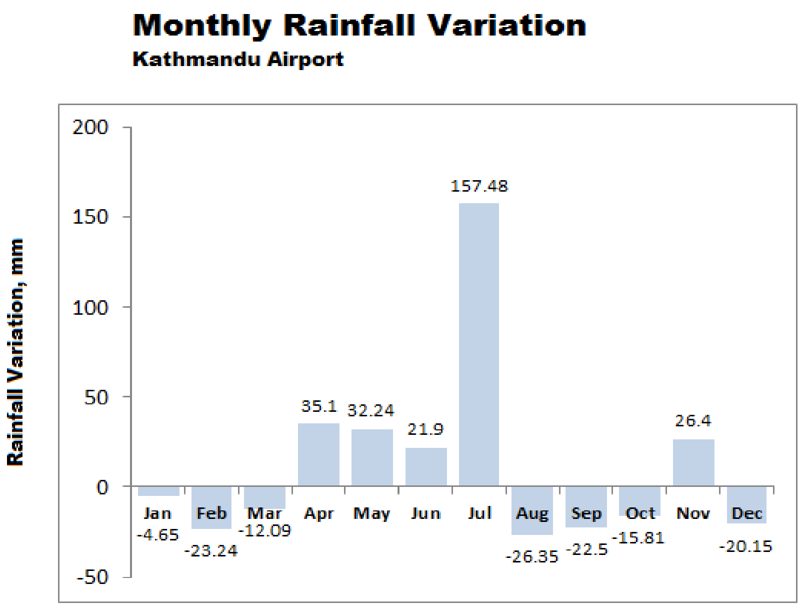
Seasonal changes in rainfall



Kathmandu Airport				
Month	Monthly rainfall,mm BL	Projected Rainfall 2060, mm	Change in Rainfall, mm	% change
Jan	34	29	-5	-14
Feb	47	24	-23	-49
Mar	57	45	-12	-21
Apr	72	107	35	49
May	211	243	32	15
Jun	344	366	22	6
Jul	326	484	157	48
Aug	337	311	-26	-8
Sep	305	282	-23	-7
Oct	148	132	-16	-11
Nov	56	83	26	47
Dec	65	45	-20	-31

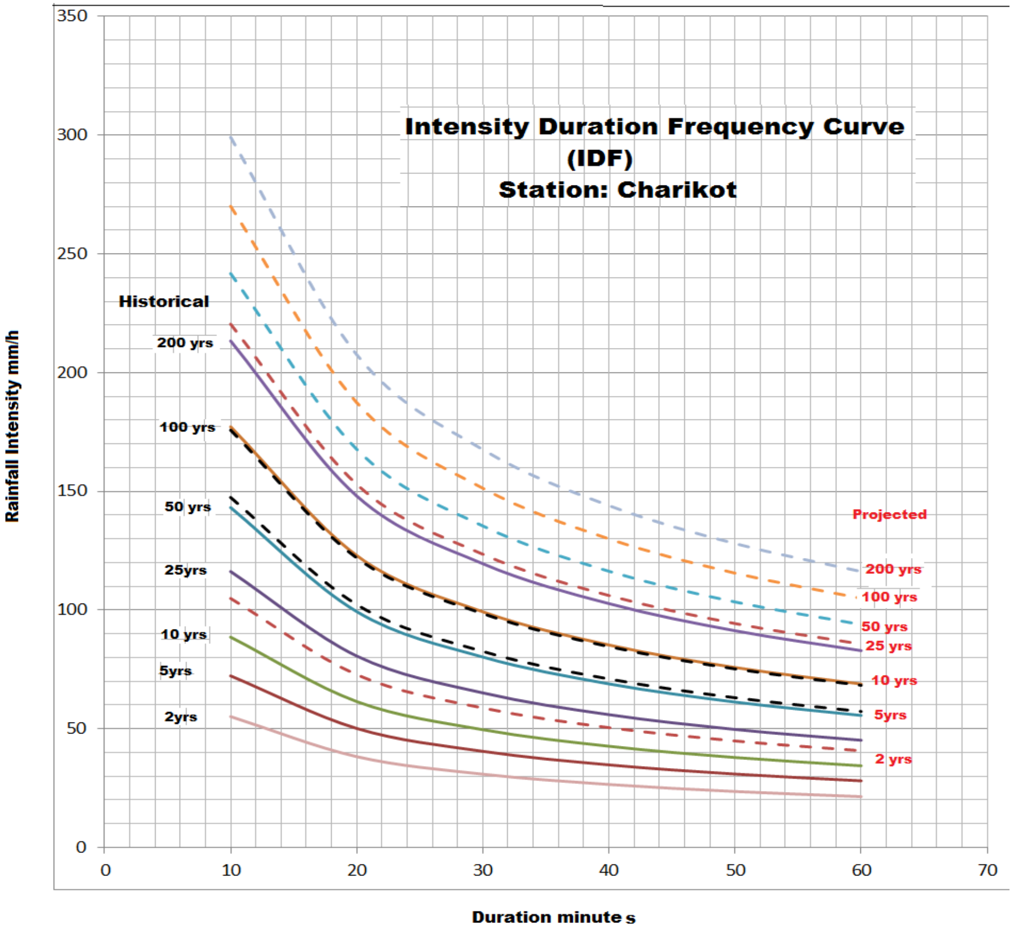
- Greatest increase end of dry/start of wet season
- Decrease end of wet season/start of dry

icem

Change in IDF curves
Charikot

- Intensity of rainfall events are increasing
- Increases are more pronounced for extreme rainfall

Charikot	
Return Period Years	% change
2	90
5	104
10	98
25	84
50	69
100	52
200	36



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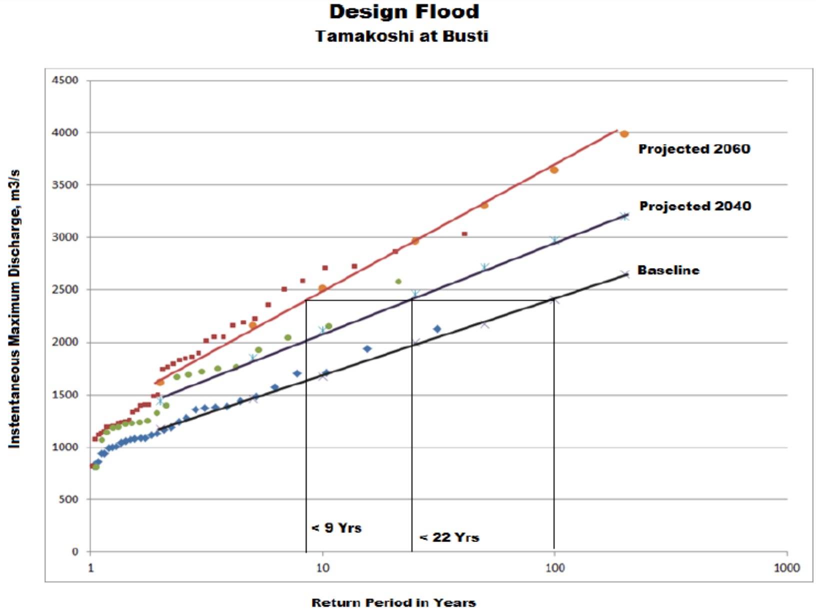
Flood return periods

Return Period	Design Flood BL M3/s	Design Flood 2040 M3/s	Design Flood 2060 M3/s	%Δ 2040	%Δ 2060
2	799	1125	1254	+41	+57
5	1080	1474	1697	+36	+57
10	1280	1711	1998	+34	+56
25	1589	2019	2388	+27	+50
50	1825	2254	2683	+24	+47
100	2090	2492	2983	+19	+43
200	2350	2735	3289	+16	+40



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