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Department of Roads

Kathmandu District

VULNERABILITY ASSESSMENT REPORT

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TABLE OF CONTENTS

1 DISTRICT ASSETS/SYSTEM PRIORITIES

1.1 Briefing on Sector in Kathmandu District

1.1.1 Overall View of the District

Kathmandu District is located in the valley and hills of Bagmati Zone, Central Development Region. The district covers an area of 395 km^2 and is the most densely populated district of Nepal with a population of 1,740,977 (as per 20011 census). The district consists of 57 VDC, 1 metropolitan city and one municipality. The district's headquarters is Kathmandu Metropolitan City (KMC), also the capital of Nepal. KMC occupies 2592.7 hectares, or 48.88% of the total area of the district. The road area also occupies a significant land area (386.52 hectare). Being a capital city, KMC is also a major economic as well as education center of the country.

1.1.2 Division Road Office, Kathmandu

Division Road Office (DRO), Kathmandu is responsible for all strategic and important city roads in Kathmandu District. The Office is responsible for 229.99 km of roads, of which, 169.39 km are blacktop, 25.40 km are gravel and 36.20 km are earthen. DoR plans to construct a further 88.1 km of strategic roads in the district. In total 60 bridges are constructed along the above roads. In addition to above, the Office is widening/upgrading several roads in the district. A majority of the roads and bridges in the district are located in the valleys made by the above rivers and hence they are vulnerable mainly to river flooding.

The DRO is headed by Senior Divisional Engineer. It has a provision of 7 Engineers and 18 sub-engineers. As the division is also widening several roads in the valley more than 8 engineers and 15 sub-engineers are deputed temporarily. Beside, the technical staff, the other working personnel in the division are accountants, administrative officers, drivers, peons etc.

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 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

Considering the prioritisation criteria following road and bridge are selected for VA and AP in consultation with Kathmandu DRO:

1. Road Widening on Nagdhunga-Pipalmod Road Section
2. Bagmati Bridge along Arniko Highway at Tinkune

1.3.1 Road Widening on Nagdhunga-Pipalmod Road Section

At present DoR is widening 100 m length of road at km 14 between Nagduhunga - Pipilmod section. This road section lies on Tribhuban Rajpath (TRP). TRP is the first highway of Nepal and was constructed between 1954 and 1957 with the assistance of Government of India. The total length of this highway is 189 km of which 14.46 km section from Tripureswor to Pipalmod falls under the Jurisdiction of DRO Kathmandu.

The Thankot – Naubise road section where the asset is located is the busiest (excluding city roads) and most important road section of Nepal. The annual average daily traffic (AADT) on the road in 2012 was 4,891. Due to high number of vehicles, steep longitudinal gradient and insufficient road width, there used to be frequent traffic jams on this section. In order to lessen the traffic problem, GON gave top priority to this road and rehabilitated/upgraded this section in 1980, 1999 and 2007.

As present, DoR is widening/upgrading a 100m long road section near Pipalbod to lessen the traffic congestions. The estimated cost of widening/upgrading works is 25 million rupees.

1.3.2 Bagmati Bridge along Arniko Highway at Tinkune

The bridge (or the asset) lies at km 2+390 along Arniko Highway. The highway links Kathmandu with China and its total length is 113 km. The highway including all the bridges was built with the assistance of Government of China and was completed in 1968. **The bridge is located on the busiest road in Kathmandu and hence it has very high importance**.

The bridge has 5 spans and its total length is 90m. The superstructure and substructures of the bridge is RCC. The foundation of the bridge is adopted of RCC piles. As per the prevailing market rates, the cost of the bridge is estimated to be 200 million rupees.

When the bridge was constructed, the pile cap level was flush with the river bed level and the piles of all foundations were buried under the ground. At present piles of all foundations are exposed by 2-3m due to heavy scouring which is caused by encroachment of waterway and extensive sand mining. The scouring is endangering the bridge stability and there is a high probability of foundation failure. It is to be noted that bridges across the Bagmati River at Thapathali and Sinamangal collapsed in the past due to heavy scouring.

2 VULNERABILITY ASSESSMENT METHOD

2.1 Summary of method/process

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

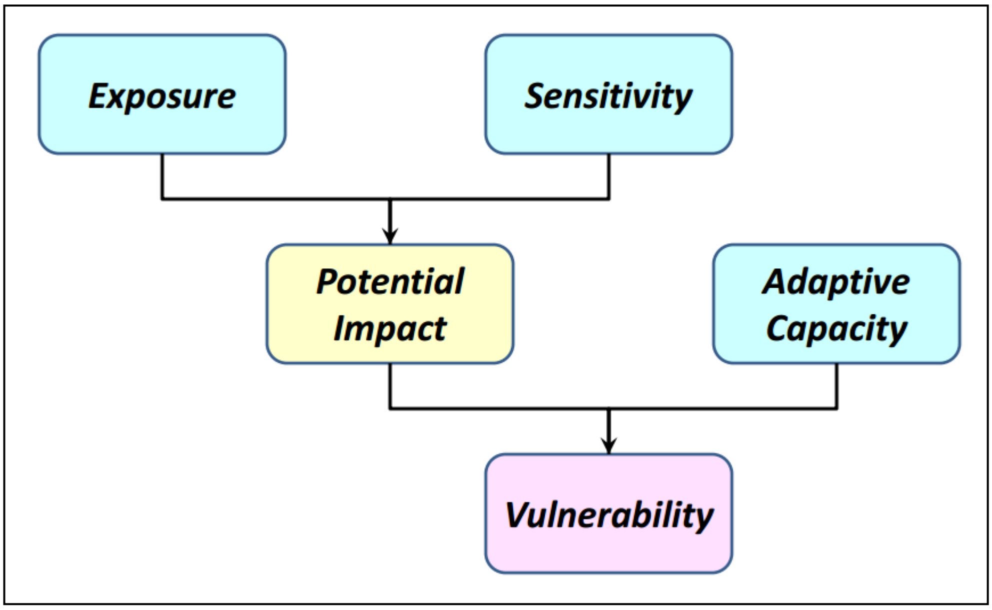

Fig 1: VA Process

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

		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 3: 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) 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 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

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 table below provides interpretation of exposure for different road and bridge assets to the climate threats identified for Kathmandu 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 Kathmandu 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 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

2.2.3 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.

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 DRO which is responsible for strategic roads and bridges in the Kathmandu 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 Kathmandu 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.3.

3 VULNERABILITY ASSESSMENT OF THE ASSET

3.1 Asset Description

3.1.1 Road Widening on Nagdhunga-Pipalmod Road Section

The following table describes the important aspects of Tribhuban Rajpath (TRP).and Nagdhunga-Pipalmod Road section.

Table 4: Salient Features of the Tribhuban Rajpath (TRP) and the Asset

Name of the Road	Tribhuban Rajpath (TRP).
Road Category	National Highway
Service Provided by the Road	-Connects Kathmandu with other parts of the country and India. - Majority of goods and passengers coming to Kathmandu should pass through Thankot-Naubise Section of TRP.
Responsible Agency	Kathmandu Division of DoR
Location of Asset	Km 14
Major Components of the Asset	Road pavement, side drains, breast wall and bio-engineering
Existing Condition of different components	Road pavement: good; Side drains: good Retaining walls: good

Fig. 4a: Widening works of the road at end section (towards Naubise side). Due to steep gradient and insufficient road width, the traffic is frequently jammed for long period. In order to solve the problem, DoR is widening about 100m section where the problem is severe.

Fig. 4b: Starting point of widening (towards Kathmandu side). Most of the road section is widened by excavating hill side and providing stone masonry breast wall.

Fig. 4c: Breast wall and bio-engineering works are provided at majority of the one Pipalmod-Nagdhunga Road Section. These measures were adopted on different periods in the past.

3.1.2 Bagmati Bridge along Arniko Highway

The following table describes the important aspects of the asset

Table 5: Salient Features of the Arniko Highway and the Asset

Name of the Road	Arniko Highway.
Road Category	National Highway
Service Provided by the Road	- Connects Kathmandu with China and several districts in Central Development Region; - Links various places inside the KMC
Responsible Agency	Kathmandu Division of DoR
Location of Asset	km 2+390 of Arniko Highway. The bridge is located along the busiest road of Kathmandu City and hence is very important.
Major Components of the Asset	Superstructure, substructure and foundation of the bridge and approach roads and bank protection works
Existing Condition of different components	Superstructure and substructure: good; Foundation: Poor; about 3m length of piles are exposed; may collapse if appropriate measures are not adopted; Bank protection works: Poor; damaged at several locations; Approach road: Good.

5a: General view of the bridge from upstream. It is a RCC T beam bridge on pile foundation. The bridge has 5 spans and its total length is 90m

5 b: Exposure of pile foundation due to extensive scouring. The field observation showed that the river has scoured about 3-4 m from pile cap level. The major causes of scouring are heavy encroachment of waterway and extensive sand mining in the past. The climate change effect will accelerate the scouring process.

5c: View of river at immediate downstream from the bridge. The width of the river is heavily encroached and is confined to 10-15m by constructing walls at both banks.

3.2 Climate Change Threat to Infrastructures in Kathmandu District

The climate change threat profiles for Kathmandu District were prepared by the hydrological modeling teams. The threat profile is provided in Annex 3. The effects 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 average temperature increase in Kathmandu District by 2060 will be up to 1.85^0.

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

3.2.2 Threat due to Precipitation and Flood Increase

The threat profile findings are as follows:

- Increasing number of extreme rainfall events – events that now occur every 5 years are projected to occur every 2 years;
- Increasing wet season flow on the Bagmati River – peak monthly average flow in wet season will increase by up to 68%

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:

Design life: 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 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 following tables show the VA results of the assets.

Table 6: Vulnerability Analysis of Nagdhunga- Pipalmod Road Section (Asset 1)

Climate Change Threats	Interpretation of threat	Exposure	Sensitivity	Impact Level	Impact Summary	Adaptive capacity	Vulnerability
Component 1: Road Pavement							
• Increasing intensity and duration of rainfall • Increasing number of extreme rainfall events	Increase in intensity and duration of rainfall will weaken the sub grade consequently accelerating the pavement damage	M[1]	M[2]	M	The sensitivity to increase precipitation will be medium as the road section is blacktopped and the drainage management is adequate.	H[3]	M
Component 2: Retaining Walls							
• Increasing intensity and duration of rainfall • Increasing number of extreme rainfall events	Increased possibility of both hill side and valley side slopes failure and damage to wall.	M[4]	M[5]	M	The height of the hill slopes is low. Hence the horizontal pressure due to increased moisture content at the backfill will be medium.	H[3]	M
Component 3: Bio-engineering							
• Increasing intensity and duration of rainfall • Increase in surface water	Increased accumulation of surface water will cause landslides/slips damaging the bio-engineering works.	M[6]	L[7]	M	The length of hill and valley slopes at both sides of the road is not high. Due to this, less water will be accumulated at the hill slopes and its damaging capacity will not be high.	H[3]	M

1. *The exposure of road pavement will be medium due to increasing intensity and duration of rainfall as the pavement surface is asphalt or concrete. These surfaces do not allow the rainfall to penetrate to the subgrade*.
2. *The road pavement is sensitive to precipitation. As adequate drainage structures are provided, the increased precipitation will have medium effect.*
3. *The adaptive capacity of DoR Division Road Office is* ***High****; see section 2.2.4.*
4. *The slope height behind the wall is low and hence will not cause large horizontal pressure.*
5. *The wall is constructed of stone masonry in cement mortar and its quality is good.*
6. *The bio-engineering has medium exposure to increased rainfall intensity because the amount of surface water which causes the landslides will not be high.*
7. *The bio-engineering works have already withstood several rainy seasons. Effect on them due to climate change will be low.*

Table 7: Vulnerability Analysis of Bagmati Bridge along Arniko Highway (Asset 2)

Climate Change Threats	Interpretation of threat	Exposure	Sensitivity	Impact Level	Impact Summary	Adaptive capacity	Vulnerability
Component 1: Pile Foundation							
Increasing intensity and duration of rainfall; Increasing number of extreme rainfall events; Increasing risk and severity of flash floods	The increase in flood due to climate change effect will cause more scour depth. Further increase in scour depth may cause collapse to the bridge. Such incidents have already occured on Bagmati Bridges at other locations.	VH[1]	VH[2]	VH	Sensitivity of the bridge is very high as the piles are already exposed. Similarly, the impact bridge failure will also be very high as the asset is located on one of the busiest roads of Kathmandu.	H[3]	H
Component 2: Abutments and Piers							

• Increasing intensity and duration of rainfall; • Increasing number of extreme rainfall events; Increasing risk and severity of flash floods	Increased flood will cause additional water current force on piers and abutments	VH[4]	L[5]	H	The sensitivity of the piers and abutments is low because they are constructed of RCC and their section is heavy. The river does not carry big boulders and trees.	H[3]	M
Component 2: Bank Protection Wall							
• Increasing intensity and duration of rainfall; • Increasing number of extreme rainfall events; • Increasing risk and severity of flash floods	The bank protection walls along the Bagmati River have collapsed several times in the past due to scour. Increased flood due to climate change will aggravate the scour making the walls further vulnerable.	VH[6]	VH[7]	VH	Bank protection walls are frequently damaged in the past. The sensitivity of the walls is very high due to poor design and construction.	H[3]	H

1. *As per the climate change threat profile, the peak monthly season flow will increase by 68 %. Such increase will cause further scouring. Moreover, the increased flood volume is restricted by constructing bank protection walls at both banks.*
2. *The sensitivity is very high as 2-3 m top section of piles are already exposed. The condition of the pile is also not good as reinforcements are exposed and they are heavily corroded.*
3. *The adaptive capacity of DoR Division Road Office is High; see section 2.2.4.*

Note: The VA matrix shows that the vulnerability is "High". In actual the vulnerability of the pile foundation to the climate change effect is 'Very High" due to extreme importance of the asset.

4. Abutments and piers of the bridge are directly hit by the water current.
5. Generally the RCC abutments and piers do not get damaged by water current forces which do not carry large boulders and trees;

6. The bank protection walls were frequently damaged in the past. With increase in flood volumes and the restricted waterway the failure rate will be more.
7. *The quality of walls is not good. Moreover, they are not designed to take care of the scour (shallow foundation depth and without launching apron)*

Remarks: VA analysis of superstructure and approach roads is not carried. Climate change effect on them will be nominal

3.4 Vulnerability Assessment Summary

The vulnerability assessment summary of both the assets is provided in the following tables:

Table 8: Vulnerability Assessment Summary of Nagdhunga- Pipalmod Road Section (Asset 1)

THREAT	IMPACT	EXPOS.	SENSIT.	IMPACT	ADAPT. CAP.	VULN.	COMMENTS
Increasing intensity and frequency of extreme rainfall events.	Damage to road pavement due to increased rainfall.	**M**	**M**	**M**	**H**	**M**	The road surface is provided of asphalt or concrete. Such pavement does not allow the surface water to penetrate up to the subgrade. Moreover the water management is also good as adequate drainage structures are provided.
Increasing intensity and frequency of extreme rainfall events Increasing occurrence of landslide	Damage to retaining walls.	**M**	**M**	**M**	**H**	**M**	The height of slope is low and the quality of walls is good.
Increasing intensity and frequency of extreme rainfall events Increasing occurrence of landslide	Damage to bio-engineering works	**M**	**L**	**M**	**H**	**M**	The damaging capacity of the surface water will not be high due to low slope height. As a result, there will be little damages at the existing bio-engineering works.

Table 9: Vulnerability Assessment Summary of Bagmati Bridge along Arniko Highway (Asset 2)

THREAT	IMPACT	EXPOS.	SENSIT.	IMPACT	ADAPT. CAP.	VULN.	COMMENTS
Increasing intensity and frequency of extreme rainfall events. Increasing wet season flow	Foundation failure (bridge collapse) due to scouring	**VH**	**VH**	**VH**	**H**	**H**	The VA matrix shows that the vulnerability is "High". But in actual, the vulnerability is "Very High" due to extreme importance of the bridge.
Increasing intensity and frequency of extreme rainfall events. Increasing wet season flow	Damage to abutments and piers due to water current	**VH**	**L**	**M**	**H**	**M**	Although the piers and abutments are directly hit by the water current, substantial damage to them is not envisaged as the river does not carry big boulders and trees.
Increasing intensity and frequency of extreme rainfall events. Increasing wet season flow	Damage to bank protection walls	**VH**	**VH**	**VH**	**H**	**H**	The walls were damaged several times in the past. With to climate change effect, their sensitivity will further increase.

ANNEX 1 SITE VULNERABILITY ASSESSMENT SHEET

ANNEX 2 VULNERABILITY ASSESSMENT COMPARISON TABLE

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ANNEX 3 CLIMATE CHANGE THREAT PROFILE (NOT ATTACHED)