TA7984-NEP: MAINSTREAMING CLIMATE CHANGE RISK MANAGEMENT IN DEVELOPMENT

1 Main Consultancy Package (44768-012)

STRATEGIC ROAD NETWORK

Sector Adaptation Plan Framework for Guidelines:
Synthesis Report on Adaptation to Climate Change

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Pilot Program for Climate Resilience - PPCR3, Mainstreaming Climate Change in Development

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MoSTE Guide	Climate Change Vulnerability Assessment and Adaptation Planning Methodology for Infrastructure Development in Nepal
Climate Change Risk Management Framework for Infrastructure Sectors in Nepal	A Guide for developing and implementing Sector Adaptation Plans for Action - SAPAs

EXECUTIVE SUMMARY

INTRODUCTION

The objective of this report is to set out the procedures that have been undertaken as part of the project in order to identify those elements of the roads infrastructure which are particularly susceptible to Climate Change threats. The report will also recommend interventions into selected guidelines and policies so that the risks imposed by Climate Change are reduced.

Studies were carried out in eight Districts to provide a baseline of data regarding the existing institutional capacity of DoR and the condition of the existing road network. In addition, examples of infrastructure assets which had suffered under past weather events were identified and examined.

Climate Profiles setting out the Climate Change Threat to each of the eight Districts were drawn up by the modelling team and then used as a basis of determining the possible future threats to the identified assets.

Having identified the possible threats to the existing assets from Climate Change the vulnerability of the assets was determined and adaptations to combat the risk from the threats proposed with recommendations as to their urgency and priority,

In conclusion the report recommends which guidelines, standards and policies should be reformed so that the road infrastructure of Nepal has increased resilience to climate variability and climate change.

ROAD SECTOR IN NEPAL

Since the founding of the Department of Roads in 1970 there has been a rapid expansion of the road network which has resulted in average growth in the network of 4% a year since 1970 to the present. More recently there has been a doubling of the length of the Strategic Road Network (SRN) from under 5,000km in 2001 to almost 11,000km in 2012. This rapidly increasing workload, together with a lack of a commensurate increase in the capacity of the Department has inevitably led to difficulties in the management, construction and maintenance of the road network. Budgets are poorly managed, design is sometimes not to the required standard, contracts are awarded to inexperienced contractors who submit bids which are too low, contracts frequently over-run with construction quality poor and there is a large maintenance backlog. The lack of records of design and as-built drawings for bridges and other important structures makes the assessment of the resilience of such structures very difficult**.**

THREAT TO ROAD SECTOR FROM CLIMATE CHANGE

Studies done by the National & International Hydrological Modelling TA Team in consultation with Department of Hydrology and Meteorology (DHM) show that climate change induced threats would affect differently people living in various regions in Nepal, their socio-economic development, biological diversity and other sectors. The results of such climate change induced threats are increased risks of floods, landslides, glacier outbursts, drought and other natural calamities.

The Strategic Road Network in Nepal is highly vulnerable to climate change. Geomorphological systems are dynamic, natural systems are already stressed so that even relatively minor weather events can cause major disturbances. The very nature of the SRN which reaches all parts of Nepal inevitably means that many sections of road cross rivers and streams which are prone to floods and hillsides which are unstable.

The climate change THREATS to the SRN are determined through an analysis of past extreme events and trends and through climate modelling and downscaling of future climate and hydrology against various scenarios.

BASELINE STUDY

The TA team recommended a geographic approach to identifying case studies whilst ensuring that the locations identified allow the case studies to cover the issues raised by each sector. During the Orientation Workshop the TA team consulted with the sector focal points and counterparts to prepare criteria for identifying the case study locations and subsequently identified six case study districts based on the criteria. The case study locations were chosen to ensure sufficient coverage of sector infrastructure and climate change issues and to represent the diverse ecological, infrastructure, climate, climate hazard and population density of Nepal.

Following the selection exercise conducted by sector Focal Points and the national team, and based on the priorities set under the NAPA and subsequent national vulnerability assessment studies, the case study assessments would be undertaken in the vulnerable districts of: (i) Mugu (ii) Dolakha (iii) Accham; (iv) Kathmandu Valley; (v) Banke; and (vi) Chitwan. Subsequently Mugu was dropped and replaced by Mustang with Panchthar and Achham added in order to broaden the extent of the baseline studies.

The Consultant's National Roads and Bridges Engineer visited all the Districts, met the Divisional and District Engineers and with their assistance drew up Baseline Reports which describe the road network and set out the resources available in the District. The Reports also highlight the trends and some of the issues affecting the management of the roads infrastructure.

Several road infrastructure locations were selected with the help of the Division and District Officers which illustrated the effects of previous severe weather events. Included were some examples of adaptation plans which had been implemented after severe weather related events.

VULNERABILTY ASSESSMENT & ADAPTATION PLANNING

The climate change vulnerability and adaptation process has been used at the case study level. It is a flexible process and set of tools which can be applied to sectors, areas and communities down to specific infrastructure level. It is applicable to varying assessment scales from localized projects to settlements up to city size, and to larger spatial planning units such as watersheds and provinces. The methodology combines international best-practice in climate change science and hydrological modelling with best-practice in a number of rapid assessment methodologies such as Strategic Environmental Assessment, life-cycle analysis, socio-economic analysis, energy efficiency audits, risk management and participatory planning. In this project the CAM process will be integrated with existing methods in Nepal and shaped and adjusted by national teams and stakeholders to suit local conditions.

In the Roads Sector the CAM methodology has been used to identify those sections of the road infrastructure which are vulnerable to particular climate change threats and to assess the degree of vulnerability. The methodology then sets out the possible adaptation actions that can be implemented to reduce the identified vulnerabilities together with a prioritisation process which generates a timetable for carrying out the adaptations.

The methodology for carrying out this process is set out in Section 7 of the report.

TYPICAL CLIMATE THREATS AND IMPACTS FOR THE ROAD SECTOR

Climate Threat Profiles have been produced by the modelling team for each District and each Sector. These Profiles set out the specific threats likely to occur in each District.

They identify the major threats to the road network as being:

- Increased total rainfall causing increased riverine floods and increase in average river levels
- Increase in number and intensity of storms causing increased frequency and intensity of rainfall
- Increase in intensity of rainfall causing increase in flash floods and debris flows

- Increase in the likelihood of Glacial Lake Outburst Floods (GLOF)due to increased ice melt and increased rainfall
- As a result of the increase in total rainfall and in the intensity of rainfall an increase in the number of landslides

This report sets out examples of the effect of the above threats on existing sections of the road network together with the corresponding Vulnerability Assessment and Adaptation Planning options.

CONCLUSION

The report recommends:

- In the short to medium term the elimination of the maintenance deficit must be considered the top priority.
- Reconstruction of an existing element in the road infrastructure should only be contemplated if there is strong evidence of likely failure of the element.
- Vulnerability Assessments should be carried out along the most important road links in order to determine which sections are most vulnerable to extreme weather events
- Increase the technical and physical capability of the Department to respond to disruption caused by severe weather events

REFORMS TO GUIDELINES AND POLICIES

The following Guidelines and Policies were identified during roundtable discussions as possible entry points for Mainstreaming Climate Change Risk Management into the procedures of DoR.

- Management procedures of DoR
- Project Implementation Plan
- Annual Road Maintenance Plan (ARMP)
- Highway Management Information System
- Environmental Management Guidelines
- Design Standards
- Project Designs

Recommendations are given as to how these Guidelines and Policies can be modified so that the Mainstreaming of Climate Change Risk Management into the procedures of DoR can commence.

ACRONYMS

AADT	: Average Annual Daily Traffic
ADB	: Asian Development Bank
ARMP	: Annual Road Maintenance Plan
AP	: Adaptation Planning
CC	: Climate Change
DDC	: District Development Committee
DoI	: Department of Irrigation
DoLIDAR	:Department of Local Infrastructure and Agricultural Roads
DoR	: Department of Roads
DoT	: Department of Transport
DR	: District Roads
DWIDP	: Department of Water Induced Disaster Project
DWSS	: Department of Water Supply and Sewerage
EIA	: Environment Impact Assessment
ESMF	: Environmental and Social management Frameworks
FR	: Feeder Roads
HFL	: Highest Flood Level
HMIS	: Highway Management Infromation System
HRD	: Human Resource Development
IEE	: Initial Environment Evaluation
MOLD	: Ministry of Local Development
MoPIT	: Ministry of Physical Infrastructure and Transport
MRM	: Mahendra Raj Marga
NEA	: Nepal Electricity Authority
NH	: National Highways
NMRM	: Naubise Mugling Raj Marga
NSET	: Nepal Society for Earthquake Engineering
NT	: Nepal Telecom
PRM	: Prithvi Raj Marga
PWD	: Public Works Department
RTO	: Road Transport Organization
SDE	: Senior Divisional Engineer
SED	: Strengthened Equipment Division
SRN	: Strategic Road Network
TRP	:Tribhuban Rajpath
UNDP	: United Nations Development Project
UR	: Urban Roads
VA	: Vulnerability Assessment
VCDPF	:Vulnerable Community Development Policy Framework
VDC	: Village Development Committee
vpd	: Vehicle per Day
VR	: Village Roads

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1 INTRODUCTION

This synthesis report was prepared as part of the TA – 7984 NEP: *Mainstreaming Climate Change Risk Management in Development Project* supported by ADB with funding from the Climate Investment Fund (CIF), and implemented by the Ministry of Science, Technology and Environment (MOSTE) in partnership with ICEM – International Centre for Environmental Management.

The project involves line departments working together with MOSTE in eight districts to develop and test a vulnerability assessment and adaptation planning approach tailored for their needs. The aim is to distil the lessons of the district experience into reforms at national level for planning and managing more resilient infrastructure. The national agencies are those concerned with infrastructure development throughout Nepal such as irrigation, roads and bridges, water induced disasters, urban planning and water supply and sanitation systems (Figure 1).

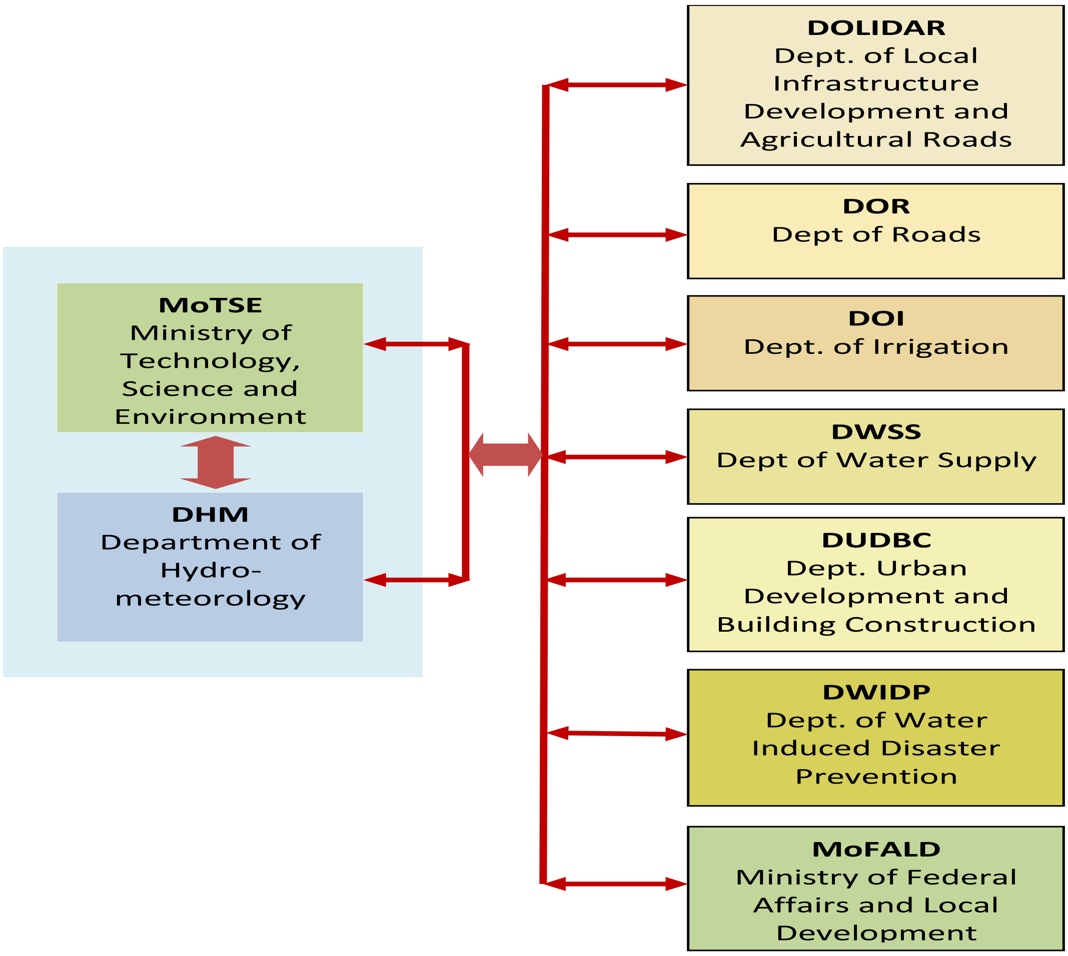

Figure 1: TA – 7984 NEP infrastructure sector department partners

A core group of technical staff from each of the departments participated in working sessions and missions to the eight districts of Kathmandu, Dolakha, Achham, Banke, Myagdi, Chitwan, Panchthar and Mustang (Figure 2) where vulnerability assessments and adaptation planning exercises were conducted for existing strategic infrastructure assets. The target districts were identified by core group members to reflect the diverse ecological zones of the country and varying environmental and social conditions in which infrastructure is built. The district assessments were supported by climate change threat analysis and hydrological modelling at each case study location.

The core group comprised of some 30 members from 9 government agencies with each agency having a wider range of staff involved in the process of setting and implementing reform priorities with support from the project team (Figure 3). Sector focal points on the core group have a key role in promoting the climate change mainstreaming in their departments so that the design and management of existing and planned infrastructure progressively adjusts to become more resilient to the most significant projected changes and their associated potential impacts.

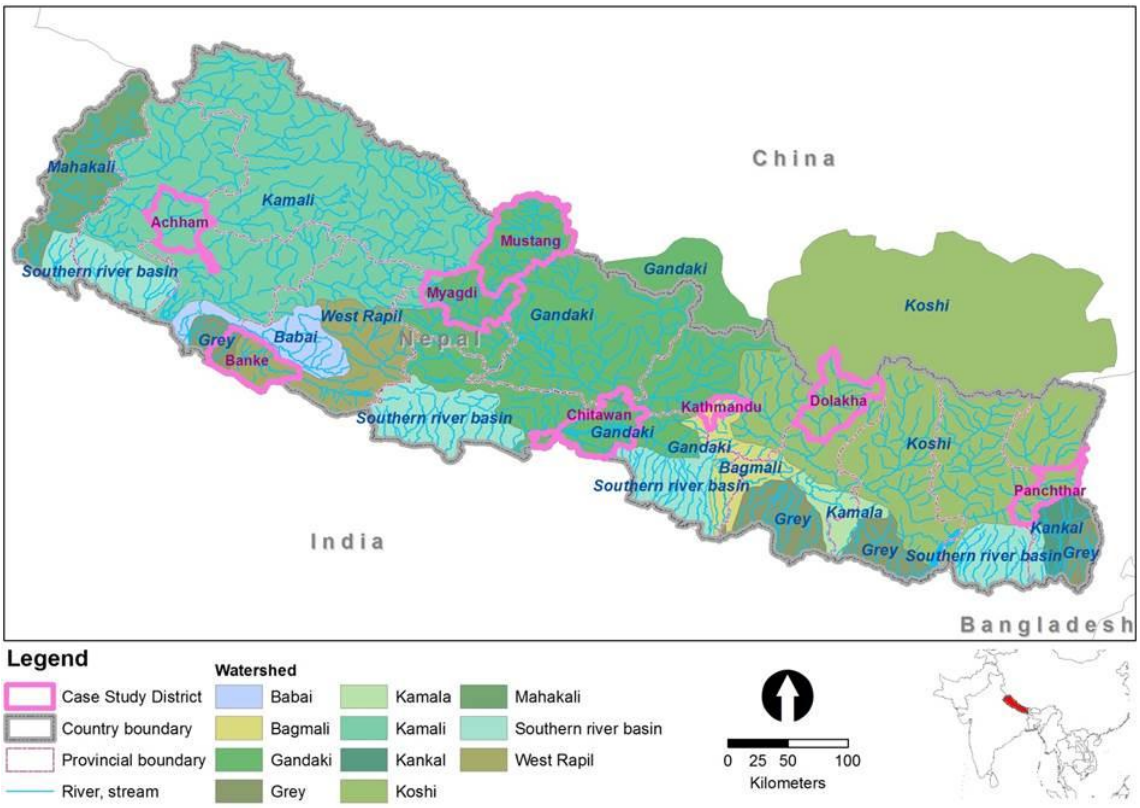

Figure 2: Target districts for developing an approach to infrastructure vulnerability assessment and adaptation planning

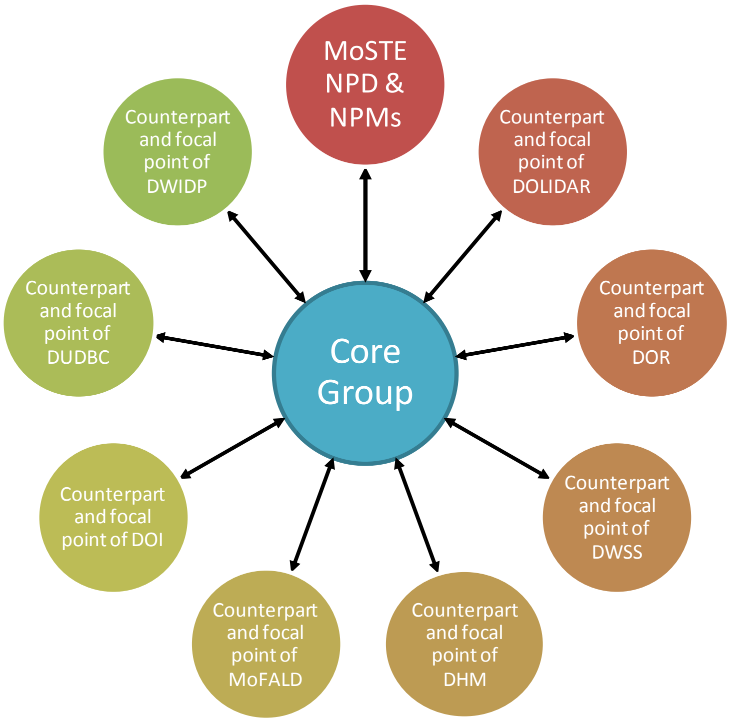

Figure 3: Infrastructure sector department climate change core group

Through the project, a "climate change risk management system" (CCRS) has been developed based on the district and international experience. The CCRS includes tools to facilitate climate change vulnerability assessment and adaptation planning and a dedicated process for the development of *sector adaptation plans for action* (SAPAs) that complement Nepal's existing climate change planning framework consisting of the National Adaptation Plan for Action (NAPA) and Local Adaptation Plans for Action (LAPAs).

The district case studies inform a sector vulnerability assessment and adaptation planning process that demonstrates the elements of a future SAPA process including the shape of SAPA reports (in the form of sector synthesis reports). The end result of this process is a sector oriented review of climate change vulnerability of key assets and a sector adaptation plan identifying the policy, procedures and structural reform priorities for building resilience in the sector and its infrastructure. The *sector synthesis reports* are being used as the basis for a sector specific training of government staff at the national and district levels on how to give effect to the reforms identified using the SAPA process and to apply the vulnerability assessment and adaptation planning tools developed by the core group and project team.

This Strategic Road Network Synthesis Report was prepared with DoR and involved a program of consultations in the districts and with the sector core group members and departmental officials. That process culminated in a national workshop at which government roads experts presented and discussed the synthesis conclusions and reform priorities. The government staff closely involved in the Strategic Road Network consultations and in the preparation and commentary on this report and the various linked sector district reports, climate change threat assessments and institutional analyses are listed in Annex V.

2 BACKGROUND

1.1 ROAD SECTOR IN NEPAL

The development of roads in Nepal gained momentum after Democracy arrived in 1951. In the early periods, roads were constructed by different government agencies such as Public Works Department (PWD), Road Transport Organization (RTO) etc. In order to develop the road network in a planned way, the Government of Nepal (GoN) established the Department of Roads (DoR) in 1970. DoR was responsible for planning, construction and maintenance of all type of roads until the establishment of Department of Local Infrastructure and Agricultural Roads (DoLIDAR) in 2001. After 2001, DoR was made responsible for the Strategic Road Network (SRN) only. The growth of SRN from the period from 1970 to 2010 is given in Table 1.

Table 1: Growth of Strategic Road Network

Year	Total SRN (km)	Growth Rate in %
1970	2166	Average growth rate is for the whole period is 4%.
1975	2517	
1980	3570	
1985	3835	
1990	3933	
1994	4254	
1998	4740	
2002	4861	
2004	7535	
2010	10,835	

Source: Priority Investment Plan for the year 1970-2004 and DoR for 2004-2010

In spite of GoN giving high priority to the road sector, Nepal's road network is one of the least developed among the SAARC countries. This is one of the main reasons for poor growth of other sectors such as industry, agriculture, hydropower etc. The poor road network is also hindering the effective and comprehensive participation of the rural population in the country's economic growth process. As well as a poor network, the condition of existing roads is also far from satisfactory due to lack of maintenance and rehabilitation.

1.2 CLASSIFICATION OF ROADS

GoN classified the roads in following five categories and published in Road Classifications (Second Revision), 2050 (1992).

(i) National Highways (NH);
(ii) Feeder Roads (FR); FRs are further classified into FR (major) and FR (minor);
(iii) District Roads (DR);
(iv) Urban Road (UR);
(v) Village Roads (VR)

For effective management of road network in the country and to make the best use of available resources, GoN/DoR further classified the roads in four classes on the basis of functional and administrative importance as defined below.

(a) The Strategic Road Network (SRN) - comprising NH and FRs.
(b) The District Transport Network- comprising District Roads, Main Tracks and Main Trails.

(c) The Urban Road Network – comprising all non-strategic within the municipal boundaries.

(d) The Village Transport Network – includes short non-through roads, tracks and local trails linking single villages to the District Transport Network.

The Department of Roads has responsibility for the Strategic Road Network (SRN).

The District and Village Roads are being implemented/managed by a consortium of DDC/VDC/MOFALD and DoLIDAR.

Urban Roads are the responsibility of the respective municipalities.

1.3 LENGTH OF SRN ACCORDING TO THEIR TYPES AND DEVELOPMENT REGIONS

The existing designated SRN comprises approx 11,636 km of open and operational National Highways and Feeder Roads. The distribution of SRN according to their categories, surface types and location wise is given in Table 2 and 3.

Table 2: Length of SRN with its Pavement Types& Regions (in Kilometres)

Development Regions	Type of Roads				Road Category					Total SRN
	BT	GR	ER	Total	NH	FRN	FRO	MH	PR	
Eastern	1156	353	1060	2570	797	1180	28	429	136	2570
Central	1827	632	714	3173	876	1888	137	61	211	3173
Western	1032	169	1050	2250	478	1385	194	142	50	2250
Mid-Western	871	513	924	2308	735	948	216	309	100	2308
Far-Western	687	220	425	1334	525	627	0.00	87	94	1334
Total in Nepal	5574	1888	4174	11636	3411	6029	575	1028	592	11636

Source: Statistics of SRN, 2011/12; DoR

Table 3: Length of Strategic Road Network as per Terrain

Description	Hills	Terai	Total
Roads (km)	7507	4129	11636

Source: Statistics of SRN, 2011/12; DoR

A map of the Strategic Road Network is given in Annex 1.

1.4 ORGANISATIONAL STRUCTURE OF DOR

DoR is responsible for all the SRN and associated bridges. The department manages the works through: Five Regional Offices, 25 Maintenance Division Offices, Road Projects, ADB Directorate, Postal Road Directorate and Bridge Project.

The department is headed by a Director General. There are 4 Deputy Director General (DDG) reporting directly to the DG. DoR is responsible to the Ministry of Physical Infrastructure & Transport (MOPIT).

1.5 STRATEGIES AND PLANS

Based on the overall transport policy, DoR has prepared: (i) DoR Strategy, 1995 (MOPIT/DoR); (ii) Bridge Policy and Strategy, (MOPIT/DoR) 2004 and (iii) HRD Policy and Strategy, (MOPIT/DoR) 2002.

The strategies and policies of above documents are summarized below.

Objectives of the Strategies

- Increase policy level awareness;
- Prepare network planning;
- Establish direction of donors;
- Improve maintenance operations and management;
- Prepare needs based budget;
- Improve plant management.

Main Strategies

- Introduce Network Planning
- Support and promote the use of local expertise and materials for road construction;
- Maximise the benefits of these resources through the use of stage construction for new roads (design for present needs and upgrade only when justified by actual demand);
- Put the present roads in the Strategic Network into a maintainable condition;
- Execute planned maintenance***;***
- Initiate the development of National Standards for road construction and maintenance;
- Put the DOR Heavy Equipment Divisions on more commercial lines;

1.6 DESIGN STANDARDS

Nepal Road Standard-2070 is the latest publication on design of road, bridges and allied structures. It supersedes all the previous design standards. It is divided into two main parts:

Part A: Roads and Part B: Bridges.

Major aspects covered in Part A are: Road classification, Traffic Characteristics, Capacity and Level of Service, Terrain Classification, Design Speed, Sight Distance, Horizontal Alignment, Vertical Alignment, Road Cross Section Elements, Traffic Signs and safety, Miscellaneous Road Appurtenances (Guard Rails and Safety Barriers, Road Humps, Bicycle Tracks, Pedestrian Facilities, Bus Lay Bys, Curbs, Road Lighting, Road Drainage), Access Control, Pavement, Road Intersections, Structures, Maintenance, Aesthetics and Landscape Design, Roadside Arboriculture, Environmental Consideration, Roadside Service Facilities

Part B (Bridges) covers the following aspects:

Bridge Structure, Bridge Highway Loading (IRC and ASHTO), Clearances (vertical and horizontal) Bridge Classification, Minimum Vertical Clearance above HFL, Kerbs and Safety Kerbs (bridge barriers), Carriageway Drainage, Material Specification etc.

1.7 INSTITUTIONAL ISSUES

The following governance issues are highlighted by the Baseline Studies:

- Delays in approving and releasing budgets
- Delays in approving programmes
- Inexperienced contractors who submit low bids which are unrealistic
- Contracts not started or completed on time
- Insufficient technical staff
- Many roads which are not part of the SRN become the responsibility of DoR because of influence from influential individuals or organizations
- Backlog of maintenance

3 NATURAL HAZARDS IN NEPAL AND THEIR EFFECTS ON THE ROAD SECTOR

Nepal is one of the countries most vulnerable to natural hazards. Because of its topographical variation and geological characteristics, together with torrential rain during the monsoon season, the country frequently experiences several types of hazards such as landslides, debris flows, floods and earthquakes. These phenomena cause loss of life of several hundred people as well as loss of properties worth millions of rupees every year. Besides the above, they also pose severe threats to physical infrastructure, and disrupt social and economic development. Their impacts are worsened by: (a) poor economic condition (people as well as country) (b) lack of awareness and preparedness and (c) absence of measures for mitigating their impacts. The major natural disasters being experienced in Nepal are given in table 4.

Table 4: Types of natural hazards in Nepal and their effect on road sector

S.No.	Types of Hazard	Prevalence	Effect on Road Sector
1	Earthquake	Whole Nepal lies on high-hazard earthquake zone	High; several roads and bridges were damaged in the past.
2	Flood (inundation, bank cutting and sediment deposition)	Terai, Middle Hills	Very high; Several roads and bridges are damaged every year causing heavy loss of lives and properties.
3	Landslides	Hills and Mountain,	Very high. Causes severe damage roads, bridges and properties.
4	Debris Flow	Hills and Mountain,	Medium; Instances of debris flow in the past is low. Debris flow totally washed away bridge at Larcha (along Arniko Highway), Beni-Jomsom Road at Marpha (Mustang) etc.
5	Glacier Lakes Outburst Floods (GLOF)	Higher Himalaya; its effect will reach to Higher Mountains, and middle Hill regions.	Large scale damage to roads and bridges by GLOF is not recorded.
6	Avalanche	Higher Himalaya	None
7	Fire (forest)	Forest of Hills and Terai	Very low
8	Drought	All over the country	Vulnerability to roads and bridges will reduce.

4 BASELINE STUDIES

4.1 SELECTION OF DISTRICTS

In total eight districts were selected to assess the climate change effect on road sector. One of the major criterions for their selection was their degree of vulnerability to natural hazards. The list of the districts including details such as location, terrain and type of hazards is given in **table 5**.

Table 5: List of Districts and Frequently Occurring Natural Hazards

S. No.	District	Location (Development Regions/ Zone)	Terrain	Frequently Occurring Natural Hazards
1	Panchthar	Eastern/Koshi	Hills and Mountains	Landslides, floods, fire, debris flow , drought
2	Dolakha	Central/Janakpur	Mountains	Landslides, floods, debris flow drought, GLOF
3	Kathmandu	Central/Bagmati	Valley and mountains	Landslides, floods, fire, drought
4	Chitwan	Central/Narayani	Terai, Chure,	Landslides, floods, debris flow, fire, drought
5	Myagdi	Western/Dhaulagiri	Mountains	Landslides, floods, debris flow drought
7	Banke	Mid Western/Rapti	Terai	Floods, fire, drought
8	Achham	Far Western/ Seti	Mountains	Landslides, floods, debris flow, drought

4.2 SELECTION OF ASSETS

In general assets (mostly roads and bridges) were selected in all districts for Asset Baseline Report and Adaptation Audit Report. The key criteria for selection included:

- 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
- At least one planned infrastructure

Beside above, following aspects were also considered:

- Suggestions of DoR's Division Chief;
- Different type of structures are covered;
- Different types of problems faced by roads and bridges are covered;

The final list of assets and the reasons for their inclusion is given in **Table 6**.

Table 6: List of Assets

Districts/ Responsible Division of DoR	Assets		
	Name (or type of works)	**Type**	**Reasons for inclusion**
Panchthar/ Ilam	Barpa Landslide	Road	Example of successful adaptation measure. One of the most problematic sites of Panchthar-Phidim Road Section in the past. At present it is almost stabilized after construction of breast walls and bio-engineering works.
	Amarpur Landslide	Road	Example of manmade disaster. During pavement construction, the contractor excavated roadside hill slope for gravels and crushed stones. The excavation made the hill slope very unstable causing frequent landslides and road closures.
	Kabeli Bridge Mechi Highway; at 60kilometer from Phidim.	Bridge	Appropriate selection of site and type of bridge.
	Hengwa Khola Bridge; Mechi Highway; at 9 kilometer from Phidim	Bridge	Improper selection of bridge type. The gradient of the river at the bridge site is very high and transport boulders. The boulders hit the piers and may cause damage. With CC effect, the boulder impact will increase. Piers should be avoided at rivers which transport boulders.
	Tamor Bridgeway; 10 kilometer from Phidim	Bridge	Newly constructed bridge at the border between Panchthar and Dhankuta Districts. It is the longest bridge of the district. There is high possibility of landslides at both approach roads due to heavy excavation. The landslides may damage bridge.
Dolakha/ Charikot	Protection structures at Charnabati Bridge site	Road and Bridge	This is one of the most expensive protection works along Lamosngu-Jiri Road. Most probably such expensive works are not constructed for protection of roads and bridges in other parts of the country as well.
	Rehabilitation/reconstruction of road.	Road	DoR successfully rehabilitated/ reconstructed 150m long section of this road which had totally collapsed by landslide in the first week of August in 2011.
	Tamakoshi Bridge	Major Bridge	One of the largest and very important bridges in the district.
	Dholi Khola Bridge (Under construction)	Medium bridge	This is a unique case of damage. During the construction of bridge, large amount of debris was deposited at/around the bridge site. The construction activities are stopped after this incident.
	Crossing structure	Culvert	Example of vulnerability of smaller structures to natural hazards.
Kathmandu	Road widening	Road	This is the busiest section of all the roads (excluding city roads) in Nepal. At present DOR is widening a small section where the traffic jam is very high.
	Bagmati Bridge	Bridge	The bridge is very highly vulnerable to damage due to heavy scouring.

	Bagmati Bridge	Bridge	Example of bridge damage due to heavy encroachment and extensive sand mining.
Chitwan	Lothar Bridge	Bridge	To show an example of exceptionally heavy siltation at/around the bridge. At present the vertical clearance at the bridge is 2.5m which was 8m in 1977 (during construction).
	Riu Khola Bridges	Bridge	The river is overflowing and damaging surrounding areas even after the construction of two bridges.
	Approach Road of Sauraha Bridge	Road	Flood washed away approach road and houses at left bank in 2003. The main cause of damage was substantial restriction of waterway. DOR constructed very short bridge (in comparison to the waterway width) to save the cost.
	Landslide Protection works	Road and Bridge	Several check dams are constructed at upstream to protect road and bridges from debris, which is unique and successful.
	Slab bridge across Badarmudhe Khola	Slab Bridge	To show the example of: - change of hydrological regime within short period and; - poor design and construction.
Myagdi	Road damage at Bhirkate.	Road	The road was damaged due to deposition of the large amount of debris by Sunari Khola in July 2012. It is one of the most vulnerable location on to Beni-Jomsom Road.
	Timure Bhir (landslide)	Road	About 50 meter of road section was completely washed away by the landslide. DoR realigned the road at this location.
	Under construction bridge across Kaligandaki River	Mediu m Bridge	After construction of abutments of bridge across Kaligandaki River at Bhirkate, the river washed away right bank requiring longer bridge than originally designed. Example of designing shorter bridge than required by site condition.
	Kaligandaki River Bridge.	Major Bridge	Example of different types of protection measures at/around the bridge and vulnerability of Beni Bazaar due to its proximity with Kaligandaki River.
	Under construction bridge across Lasti Khola	Mediu m Bridge	The contractor was redyeing for concreting of superstructure. Suddenly a flash flood washed away falsework, formorks and reinforcements.
Mustang	Road section damaged by Podkyu Khola at Marpha	Road	Example of an extreme event. In July 2013 there was extensive rain at/ around Marpha area which was a very rare event in that area. The rain caused heavy flooding and debris flow. The flood washed away about 250m long road sections. Such incident will be more with CC and hence requires proper study.
	Road section eroded by Kaligandaki River at Tukuche	Road	About 1.5 kilometer of road is located very near to Kaligandaki River. The river is extensively eroding the right bank and at one location it has washed away 40m long road section. This issue is very important as substantial road length falls under this threat. With CC

			effect this threat will aggravate and hence is included for this study.
	Road damaged by landslides near Lete Khola	Road	The road sections at both sides of Lete Khola are frequently blocked due to landslides. Because of weak geology along considerable road length, blockage of traffic by landslides is common. Such incident will more frequent after CC effect if the issue is not properly addressed.
Banke	Structures to protect MRM from river erosion.	Dykes	Dyke is constructed to protect the road from increase in flood level due to intake construction. Construction quality of the dyke is good. This type of structures is rare in the country.
	Road rehabilitation works	Miscella neous	Example of severe damage to road by flood. During high flood Rapti River frequently damages/destroys the left approach road. The river overflows to several villages at southern part of the district causing heavy loss of lives and properties.
	Crossing structure along	Culvert	Example of poor maintenance
	Crossing structure along MRM.	RCC Bridge	Example of adequate adaptation measure. Bridge was constructed as the existing causeway was not sufficient to pass the river discharge.
	Rapti River Bridge	Steel Bridge	To show example of traditional protection works for bridge and river banks
Achham	River bank erosion by Budhiganga River causing high vulnerability to road.	Road	On Asadh 20 (mid june) the Budhiganga River severely damaged about 60m long section of the road and is endangering the stability of 200m long section at the same location. If the road will be washed away, the road link of Bajura District with National Road Networks will be cut off. The problem is very critical.
	Landslide	Road	Typical landslide causing damage and closure of road.
	Landslide at km 14+500 along Sanfebagar-Martadi Road	Road	It is one of the biggest landslides along Sanfebagar-Martadi Road. The landslide is causing serious damage to road and obstructing traffic at frequent interval.
	Motorable Bridge across Budhiganga River	Bridge	Due to extensive erosion, the reinforcements of the lower portion of one pier of the bridge are exposed. If the problem is not corrected timely, the repair cost could be very high. Example of poor maintenance.

4.3 DAMAGE ASSESSMENT OF ASSETS AND POSSIBLE ADAPTATION MEASURES

Damage assessment was done of all the above mentioned assets. Assessment was done by:

- Conducting field verification
- Collecting information from the respective DoR Divisions.
- Interviewing local people
- Studying drawings if available etc.

While selecting the assets, one of the criteria was that they are affected/damaged by some kind of natural hazard. The main reason for it is to figure out the probable additional damages on them by climate change effect. In several cases, DOR has already provided adaptation measures. These measures will be very useful for adapting measures on roads and bridges due to climate change effect and hence they are considered as an important part of the study.

5 CLIMATE CHANGE THREATS TO ROAD SECTOR

5.1 TYPICAL CLIMATE THREATS FOR THE ROAD SECTOR

Several studies have assessed and documented the impacts of climate change on road sector in developed countries. As such studies have not been carried out in Nepal experience from developed countries was used to inform the assessment presented in this report. The findings from of the studies conducted in developed countries especially on road sector are summarized in Table 5.

Table 5: Road Infrastructures, Potential Impacts, and Design Parameters

Climate Event	Potential Impacts	Vulnerability to Roads and Bridges	Mitigation Measures	
			General	**Specific**
Temperature	Temperature increase can cause pavement deterioration due to liquidation of bitumen.	Moderate	Use stiff bitumen to withstand additional heat.	Include additional clauses in the Specifications.
Rainfall	Increased rainfall intensity will create: - More floods affecting drainage structures, bridges, road pavement, driving condition and visibility. - Increase in HFL, waterways, scouring of bridge foundation etc. - Will trigger more landslides and mudslides in mountainous roads causing frequent road blocks	High	Review (and revise if required) the current practice of: - Calculating return period, design discharge, high flood level, clearance above high flood level, length of waterway, water current force etc. - Design methodology of slope protection works (retaining and breast walls), subsurface drains, catch drains etc. - Design of pavement including selection of appropriate type of base and sub-base, materials -Increase road surface camber for quick removal of surface water. -Increase frequency of periodic maintenance.	Revise the road and bridge design parameters conducting consultation with the departmental staffs, designers, hydrologists, meteorologists and CC specialists. Avoid landslide areas as much as possible. Revise the landslide design parameters with consultation with other concerned agencies.
Storms and storm surges	Rainfall and winds associated with storm/cyclone can create flooding, inundation of embankments, and affect road transport.	Moderate; heavy storms are rare in Nepal.	Increase the capacity of side drains, cross drains, road embankment height etc.	Find out the probable increase in rainfall and design the structures accordingly. For this, involvement of DHM and prominent hydrologists of the country is very important.

This experience was later synthesised with climate threat modelling conducted specifically for the project. The modelling methodology and findings are discussed briefly below.

5.2 CLIMATE THREAT PROFILE MODELLING

District-level climate threat profiles were prepared to assess future climate change impacts on irrigation systems relying on localised projections of future climate change for the period 2040-2060 compared to a baseline of 1980-2000. Monitoring data and results from the regional dynamic downscaling model PRECIS (Providing Regional Climate Scenarios for Impact Studies) were used for the climate projections. The monitoring data was projected using climate change statistics (averages, variability/variance, number of dry days and extreme values) from the PRECIS results and then interpolated with orographic adjustment into the high resolution grids necessary for development of district-level models. This procedure can be described as combined dynamic/statistical downscaling.

The results of the downscaling were incorporated into the IWRM basin-wide hydrological model which computed changes in temperature, precipitation amounts and intensities, river discharges and flood amounts and runoff for every 120 x 120m grid cell in each district. Hydrological and other processes were computed in each grid cell and the grid cells were connected through mass transport above ground (e.g. rivers and overland flow) and through the soil (e.g. groundwater flow). The model grid was constructed by combining together soil, land use, topography and river networks. Observed and projected meteorological data as well as water utilisation and infrastructure were added to the model together with the grid.

Despite the limitations in data coverage and quality and time available for model calibration the model represented quite well the hydrological characteristics within each of the target districts. Based on calibration results using historical events, modelling could also be deemed reliable in representing changes caused by climate change scenarios.

The findings of the climate threat profiles are summarized in the following sections.

5.3 THREAT DUE TO TEMPERATURE INCREASE

The increase in maximum temperature in all districts for 2040-2060 is given in table 6.

Table 6: Increase in Maximum Temperature in 2040-2060 due to Climate Change Effect.

Increase in maximum temperature (^{0}C)	Districts							
	Panchthar	Dolakha	Kathmandu	Chitwan	Myagdi	Mustang	Banke	Achham
	1.6	1.7	1.85	1.66	1.7	1.7	2.15	1.5

It is considered that the adverse effect on road and bridge infrastructure due to above temperature rises will be nominal.

5.4 THREAT DUE TO PRECIPITATION AND FLOOD INCREASE

The climate change effect will increase the rainfall intensity and duration and will also increase the flow volume in the rivers. The change of rainfall and flow increase pattern in all districts is given in T**able 7**.

Table 7: Increase of Rainfall and Flood due to Climate Change

Districts	Increasing intensity of rainfall events	Increasing number of extreme rainfall events; Frequency of occurrence		Increasing wet season (peak monthly average) flow	Increasing risk and severity of flash floods during wet season	Remarks
		1980-2000	2040-2060			
Panchthar	Yes	every 20 years	every 2 years	up to 170 % (Tamor River)	Yes	Average number of dry days in January will increase from 6.3 to 6.9 days
Dolakha	Yes	every 100 years	every 52 years	up to 140 % at Tamakoshi River in Busti.	Yes	
Kathmandu	Yes	every 5 years	every 2 years	up to 68% (Bagmati River)	Yes	pooling will increase by up to 220mm; irrigation demand will increase by up to 980mm
Chitwan	Yes	every 6 years	every 2 years	up to 36% (Rapti River)	Yes	
Myagdi	Yes	every 10 years	every 2 years	up to 89% (Kaligandaki River)	Yes	The flood frequency of Myagdi River at Mulaghat will increase by 78 %
Mustang	Yes	every 60 years	every 2 years	up to 257% (Kaligandaki River)	Yes	The average number dry days in June is increasing from 5.5 to almost 7 days
Banke	Yes	every 50 years	every 35 years	up to 5% (West Rapti River)	Yes	
Achham	Yes	every 50 years (Benighat)	every 30 years (Benighat)	up to 36% (West Rapti River)	Yes	The peak flow will shift from July to August

5.5 KEY CLIMATE CHANGE THREATS TO ROADS INFRASTRUCTURE

The above findings show that there will substantial increase in the number of extreme rainfall events and in the frequency and magnitude of extreme river flows. 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 minor 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.

BRIDGE DESIGN: Design of bridges should endeavour to make the structure more resilient to over topping by high floods. Abutments and piers should have piled rather than open foundations wherever possible to reduce the risk of failure from scour.

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 increased foundation depth.

SIZE OF DRAINAGE STRUCTURES: Sizes of both side drainage and cross drainage structures should be increased to accommodate increased flood volumes.

FREQUENCY OF DRAINAGE STRUCTURES: In addition to assessing whether to increase the size of cross drainage structures it will be necessary to consider whether additional structures will be more beneficial or more cost effective.

ROADS ADJACENT TO RIVERS: Roads lying in low land and adjacent to rivers will be highly affected by increased flood flows. Additional protection works to resist erosion and scour will be required

ROADS CROSSING FLOOD PLAINS ON EMBANKMENT: Roads on embankment crossing the flood plains of the larger rivers will require additional cross-drainage structures to allow for the increased flows predicted due to Climate Change. The construction of submersible roads at a low level for roads crossing flood plains is a possible option that should be investigated. These would have the additional advantage of not impeding flood flows across flood plains.

REVIEW OF SPECIFICATIONS: Specifications for materials and mixes used in drainage structures and road pavements should be reviewed in order to increase their resilience to the impact of increased rainfall, increased flows and greater temperature variations.

6 CLIMATE RELATED IMPACTS ON EXISTING ROAD INFRASTRUCTURE

6.1 CLIMATE CHANGE IMPACTS ON KEY ROAD INFRASTRUCTURE ASSETS

A selection from the assets visited during the baseline studies is given below to illustrate the effects on existing infrastructure of weather events similar to those predicted to become more severe because of climate change. The chosen assets are described below.

Asset	Weather Related Threat	Damage/Adaptation
ASSET I		
Sanfebagar to Martadi Road Achham District	Rainfall on unstable slope above road	Landslide cut road
 *General view of the landslide*	 *The condition of road at the landslide area is very poor*	
ASSET II		
Nepalgunj to Bagouda Road Banke District	High riverine flood on Rapti River floodplain	Road embankment cut at approach to bridge across Rapti River
 *Rapti River has washed away a section of approach road to bridge across river*	 *Triple cell and double cell PC were constructed to discharge the overflow from Rapti River. Damage to the road shows that these structures are not sufficient during high flood*	

<table>
<tr><th>Asset</th><th colspan="2">Weather Related Threat</th><th>Damage/Adaptation</th></tr>
<tr><td colspan="4">ASSET III</td></tr>
<tr><td>Bridge across Bagmati River at Tinkune Kathmandu District</td><td colspan="2">High flow in Bagmati River</td><td>Scour of river bed exposing piled foundations of central pier</td></tr>
<tr><td colspan="2">
View of the bridge from upstream</td><td colspan="2">
Exposure of pile foundation due to extensive scouring of river bed.</td></tr>
<tr><td colspan="4">ASSET IV</td></tr>
<tr><td>Sanfebagar to Martadi Road Achham District</td><td colspan="2">High Flow in Budhiganga River</td><td>Road running along bank of river eroded by high flood</td></tr>
<tr><td colspan="2">
View of the road section from Sanfebagar side</td><td colspan="2">
Bank protection work has failed</td></tr>
</table>

Asset	Weather Related Threat	Damage/Adaptation
ASSET V		
Bridge across Lothar River on East – West Highway Chitwan District	High Flow/Flash Flood in Lothar River causes debris flow	Debris flow causes bed level to rise threatening bridge from future high flows
 *Extensive siltation at the bridge site. The bed level has risen by 6m in 35 years*	 *Excavation of river bed materials downstream of bridge. The speed of excavation is very slow*	
ASSET VI		
Charnabati Bridge on Tamakoshi to Jiri Road Dolakha District	Intense rainfall in catchment above road causes flash flood	Flash flood washed away bridge and caused landslide which cut approach road to bridge. Adaptation of extensive river training work and bio-engineering carried out
 *Several drop structures, bank protection walls, bed protection works, cross drainage structures & tetrapods provided*	 *Beside structures heavy bio-engineering works are also provided at both banks of the river*	

Asset	Weather Related Threat	Damage/Adaptation
ASSET VII		
Mugling to Narayanghat Road Chitwan District	Rainfall on unstable slope above road	Heavy rainfall caused landslide which blocked road. Check dams & retaining walls constructed to stabilize hillside above road.

Series of check dams/retaining walls. Tthe check dam start at the road and extend about 150m up the gulley caused by the stream

Stone masonry breast wall at foot of slope. Substantial amount of water is emerging from weep holes indicating that slope remains very wet

7 VULNERABILITY ASSESSMENT

7.1 SUMMARY OF METHOD/PROCESS

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

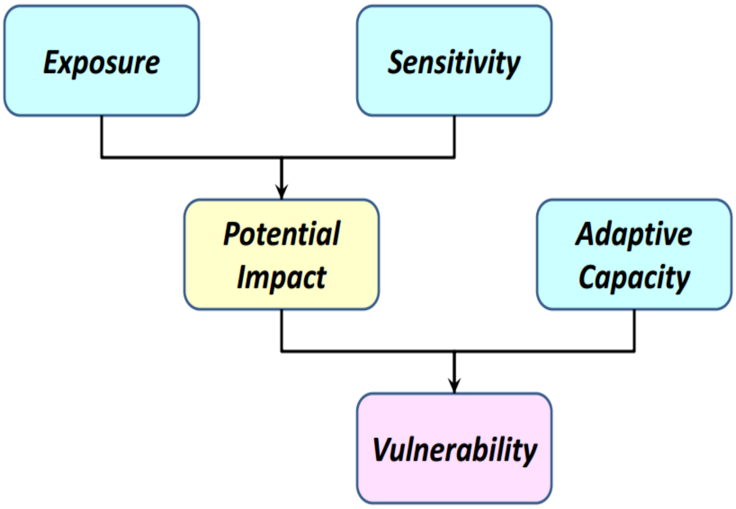

Figure 4: Vulnerability Assessment Process

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** (Figure 5). 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				
		Very Low	*Low*	*Medium*	*High*	*Very High*
Sensitivity of system to climate threat	*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*

Figure 5: 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** (Figure 6).

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				
		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 6: Vulnerability Assessment Matrix

7.2 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.

SENSITIVITY

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

Table 10: 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 (the threat/exposure is High/V. High so the impact is H/VH)
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 (threat is H/VH but for well maintained drains the sensitivity is medium so the impact is M/VH
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 (the threat is V/VH and the sensitivity is H/VH so the impact is VH)

Climate Threat	Sensitivity	Impact
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 (Threat of high flood or flash flood is M/H and sensitivity is VH so impact is VH)

Table 11: 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 (the threat of flood is H/VH but sensitivity is dependent on adequacy of cross drainage and can vary from M to VH so impact is M to VH)
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 (the threat of flash flood on river with small catchment is M/H and the sensitivity can vary from m to VH depending on condition so impact casn vary from M to H)
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 (as above)
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 (the threat is M/H and the sensitivity L to H so the impact is M?H
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 (threat is H/VH and sensitivity L to VH so impact is L to VH depending on condition

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 Banke 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 Banke District will generally, depending also on upstream catchment area and topography, have a High or Very High Exposure to climate change.

Table 12: Interpretation of climate change threats and exposure for road and bridge assets

Type of Asset	Climate Change 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

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. 3 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 Nepalgunj Division of DoR which is responsible for strategic roads and bridges in the Banke 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 Banke 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.

7.3 VULNERABILITY ASSESSMENT OF ASSETS

SELECTION OF ASSETS

In general five assets were covered in each district in baseline report. Out of five, two assets, which are in more vulnerable condition, are selected for VA and AP in all districts except Dolakha. In Dolakha, only one asset is selected. Their list is given in Table 13.

Table 13. List of Assets for Vulnerability Assessment

Districts	Assets	Risks/Vulnerability
Panchthar	Landslide at Amarpur	It is located along Mechi Highway at a distance of 49 kilometer from Phidim (towards Taplejung side). During pavement construction, the contractor excavated roadside hill slope for gravels and crushed stones. After excavation, the hill slope became highly unstable resulting frequent landslides and road closure.
	Hengwa Khola Bridge.	It is a multi span bridge along Mechi Highway and is located at a distance of 9 kilometer from Phidim (towards Taplejung side). The gradient of the river at the bridge site is high. There is high vulnerability to damage of the bridge pier by boulder impact during high flood.
Dolakha	Charnabati Bridge and	Several large scale structures are constructed for protection

Districts	Assets	Risks/Vulnerability
	approach roads.	of bridge and approach roads. This is one of the most expensive protection works along Lamosngu-Jiri Road. Such expensive works are not constructed for protection of roads and bridges in other parts of the country as well.
Kathmandu	Road Widening on Nagdhunga-Pipalmod Road Section	Road section between Nagdhunga and Pipalmod (total length of widening=1.89 km). This is the busiest section of all the roads (excluding city roads) in Nepal. DoR has upgraded this road section several times in the past. At present DoR is widening above road section where the traffic jam is very high.
	Bagmati Bridge along Arniko Highway at Tinkune	The bridge was constructed in seventies by Chinese Government. It is multi-span RCC bridge on pile foundation. Due to heavy scouring, about 2-3 m top sections of the pile are exposed at all piers. If appropriate measures are not adopted timely, the bridge may collapse any time.
Chitwan	Lothar Bridge	Due to heavy siltation, the vertical clearance of the bridge which was 8m during construction in 1977 is reduced to 2.5m. The bridge may be washed away if timely appropriate measures are not adopted.
	Landslide Protection works at Mauri	Landslide Protection works at the hill slope of Narayanghat-Mugling Road near Mauri Bridge. Several check dams are constructed at upstream to protect road and bridges from debris, which is unique and successful.
Myagdi	Beni-Pairothapla Road Section at Bhirkate (km 17*)*	The road was severely by Kaligandaki River. In July 2012, Sunari Khola which joins the river at km 17, deposited large amount of debris at right bank. Due to this, the river change its course towards left bank and severely damaged the road. At present DOR is rehabilitating this road section.
	Under construction bridge across Lasti Khola	The contractor had erected all the formworks and had placed all the reinforcements and was ready to concrete the superstructure within few days. In the mean time an instantaneous flood washed away all the formworks and reinforcements
Mustang	Road damage at Marpha (km 72).	In July 2013 there was extensive rain at/ around Marpha area. The heavy rain caused flooding in Podkyu Khola. The flood washed away the road as well as deposited large amount of debris. The incident was very unique because high rainfall is rare in Marpha area. Such incident will be more with CC and should be properly studied.
	Road erosion at Tukuche (km *65)*	About 1.5 kilometer of Beni-Jomsom Road is located very near to right bank of Kaligandaki River. The river is extensively eroding the bank and at one location it has washed away 40m long road section. This issue is very important as substantial road length falls under this threat. With climate change this threat will aggravate.
Banke	Nepalgunj-Baghouda Road	About 500 m long section of approach road at left bank of Rapti Bridge was severely damaged by flood. Although DoR constructed several cross drainage structures to protect the road, the damaging effect is still not controlled.
	Dyke at Agaiya	Department of Irrigation has constructed an intake at Rapti River for Sikta Irrigation Project at Agaiya, a small settlement along MRM. The project constructed about 300 m dyke at right bank to protect the road from increased water level.

Districts	Assets	Risks/Vulnerability
Achham	Landslide at Tashi (km 9+920)	The hill slope of the road is very fragile. Due to this, landslides and road closure are common. The hill slope can be stabilized if appropriate measures (breast wall, drainage management, bio-engineering etc,) are adopted.
	Road erosion at km 11+ 900	There was a heavy flood on Budhiganga River on June 2013. The flood severely damaged about 60m long section of the road and is endangering the stability of 200m long section at the same location. If appropriate measures are not adopted timely, substantial road length will be washed away and will deprive Bajura District of road link.

VULNERABILITY ASSESSMENT OF ASSETS

In total vulnerability assessment of 15 assets in all eight districts was carried out. Out of them 3 assets are located in terai, 2 in higher mountain/lower Himalaya (Mustang), 2 in Kathmandu Valley and the rest in mountains. The vulnerability assessment summary of the assets is presented in Annex III.

8 ADAPTATION PLANNING FOR TYPICAL ASSETS

8.1 OBJECTIVES

The main objectives of the adaptation planning are:

- To provide DoR with a methodology for identifying elements which are susceptible to the increasing threat of extreme weather events caused by climate change within the system;
- To identify which particular threats may affect different elements within the system;
- To provide a means of prioritising which are the most sensitive elements to any particular threat; and
- To provide a programme for monitoring and maintaining the system so that vulnerable elements are identified in time for action to be taken before serious damage occurs.

8.2 ADAPTATION PLANNING PROCESS

The Adaptation Planning process is defining adaptation priorities and plans for the most vulnerable assets and areas based on VA. The major aspects considered in the AP are presented below.

SIGNIFICANCE OF IMPACTS

Significance of the impact is assessed according to the degree of likelihood and seriousness as given in Table 14.

Table 14: Significance of Impacts

		Seriousness of Impact				
Likelihood of impact happening		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

Very High = Extreme impact requiring immediate action;
High = High impact requiring additional research or some immediate action;
Medium = Moderate impact that are likely to benefit from adaptation measures;
Low or Very Low = Low impact that can be dealt with as and when they happen or they are considered acceptable should they happen.

LIKELIHOOD

Likelihood is the chances of an impact occurring and resulting threat due to the particular impact.

For the purpose of the study, likelihood of impact occurring is classified in the following five categories:

Very Low: < 25 %;
Low: 25-50 %;
Medium: 50-75 %
High: 75-90 %

Very High: 90-100%

SERIOUSNESS

Following criteria are major influencing factor for deriving the degree of seriousness.

- Loss of life
- Loss of property – i.e. destruction of property
- Damage to property
- Loss of productivity and income
- Impeding of function

ADAPTATION PRIORITIES

Adaptation priorities are fixed according to feasibility of action and effectiveness in dealing with impact and are assessed as per following table.

Table 15: Assessment of adaptation priorities.

		Effectiveness in Dealing with Impact				
Feasibility of Action		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

FEASIBILITY OF ADAPTATION OPTIONS

The major factors for assessing the feasibility of options are:

- Is the action technically feasible without additional R&D or does action requiring some development?
- What is the time required to implement – can it be implemented immediately or does it require long surveys and design time
- What is its cost – how expensive is the measure? Is government budget available?
- What are the capacities of community/user group (e.g. commitment, labor, materials)?
- What are the capacities of government to support the action (e.g. skills, institutional arrangements, equipment)?

EFFECTIVENESS

The degree of effectiveness of the adaptation options is found out as outlined in Table 16.

Table 16: Factors that influence the effectiveness of Adaptation Options

	Effectiveness in Dealing with Impact				
	Very Low	Low	Medium	High	Very High
Can the impact be avoided completely?	Not at all		Partially		Yes
To what extent will deal with impact?	< 25 %	25- 50 %	25- 50 %	25- 50 %	100 %
How long will the adaptation measures last?	1 year	2 years	2-10 years	10-20 years	Permanent

8.3 PRIORITIZATION AND PHASING OF WORKS

Prioritization is one of the very important aspects of adaptation planning. In general prioritization is done according to the followings:

- Loss of lives (The works which can save lives should get highest priority);
- Traffic closure (Traffic closure especially on busy or important roads should be avoided by carrying out repair/rehabilitation/reconstruction of damaged works);
- Saving high reconstruction cost (If minor remedial works can save substantial reconstruction cost, such works should also get high priority);
- Repair and maintenance of road drainage structures;
- Bank protection works (which are protecting lives and properties) etc.

After work prioritization is fixed, the works should be carried out in different phases. For the purpose of this study the work phasing is divided into the followings:

- Regular (R); throughout the year
- Immediate (I); generally within 6 months
- Short (S), medium (M) or long term (L) (2, 5, 10, 15 years or more)

Following the above procedures, a selection of the types of adaptation responses recommended for different types of assets identified in this report is summarized in Table 17. A detailed assessment of the adaptation options for the selected assets is presented in Annex IV.

Table 17: Summary of Adaptation Options for Different Assets

Asset	Physical Threat	Component	Climate Threat*	Impact	Adaptation options
Sanfebagar to Martadi Road at Tashi ACHHAM	**Instability of hillside**	**Hill Slope**	IIDR INRE ILE	The intensity and frequency of slope erosion and landslides events will substantially increase.	Construct 3m high breast walls; provide surface drains and bio-engineering.

Asset	Physical Threat	Component	Climate Threat*	Impact	Adaptation options
		Road	IIDR INRE IDRW	Higher moisture content at sub-grade for longer duration causes pavement failure.	Repair and clean side drains. Provide additional measures to drain off the water from the road. Reconstruct road pavement after completing slope stabilization measures.
Nepalgunj to Baghouda Road BANKE	**Road embankment eroded & road cut**	**Road embankment**	IIDR INRE IWSF	The road embankment collapsed at several occasions in the past during high flood. The increase in flood will accelerate this process.	Reconstruct road embankment and provide stone rip rap or gabion mattress at upstream side.
		Bank protection works	IIDR INRE IWSF	Bank protection works were frequently damaged by the flood in the past. With increase in flood the damage will be more severe and frequent.	Repair/reconstruct the damaged walls providing adequate scour protection measures
		Cross Drainage Structures	IIDR INRE IWSF	Existing cross drainage structures are not sufficient to pass the current discharge during high flow. With increased flow, this problem will become more severe and probability of damage to those structures will be high	• Complete construction of cross drainage structures (Baily Bridge, concrete causeway, pipe culvert). • Repair/new construction of bank protection works
Bagmati Bridge on Arniko Highway, Tinkune KATHMANDU	Failure of Bridge	**Pile Foundation**	IIDR INRE IWSF	Foundation failure due to increase in scour depth	Issue of directives (focusing on encroachment and sand mining) and placement of watchman to prevent further scouring and provide scour checking structures around the pile foundation.
		Bank Protection Wall	IIDR INRE IWSF	Failure of wall due to increase in	Repair/reconstruct the damaged walls

Asset	Physical Threat	Component	Climate Threat*	Impact	Adaptation options
				scouring and water current.	providing adequate scour protection measures.
Sanfebagar to Martadi Road ACHHAM	Erosion of road by river Budhiganga	**River Bank**	IIDR INRE ILE	Bank erosion will be more severe due to increase in wet season flood volume.	Construct spurs, groynes etc. to divert the flow towards left bank (away from the road)
		Road	IIDR INRE IDRW	Higher moisture content at sub-grade for longer duration causes pavement failure.	Repair and clean side drains. Provide additional measures to drain off the water from the road if required. Reconstruct road pavement after completing slope stabilization measures.
		Retaining walls	IIDR INRE ILE	Bank erosion will be more severe causing more damage to walls due to increase in wet season flood volume.	Construct spurs, groynes etc. to divert the flow towards left bank (away from the road)
Lothar Bridge on East – West Highway CHITWAN	**Failure of bridge due to sedimentation due to debris flow**	**Bridge Superstructure**	IIDR INRE IWSF	Additional siltation may cause bridge collapse.	Clear debris (siltation) from the bridge site. Adopt measures to reduce land erosion at catchment area by constructing check dams, bio-engineering and discouraging cultivation.
		Bank protection works	IIDR INRE IWSF	Frequency and magnitude of damage to bank protection works will be more.	Repair/reconstruct the damaged walls providing adequate scour protection measures
		Landslide/Land Erosion at Catchment	IIDR INRE IDRW	Siltation process is still very active due to land erosion at catchment areas. If it is not controlled, increasing rainfall trend will accelerate the process.	Construct check dams, plant trees and discourage cultivation.
Charnabati Bridge & Approach Roads on Takakoshi – Jiri Road DOLAKHA	**Failure of bridge and approach roads**	**Bailey Bridge across Charnabati Khola.**	IIDR INRE IWSF	Destruction of an abutment & failure of bridge	1. Carry out detailed condition survey of bridge & abutments 2. Carry out any repair works found by condition survey 3. Carry out condition

Asset	Physical Threat	Component	Climate Threat*	Impact	Adaptation options
					survey after every rainy season
		Check Dams, Concrete Aprons & Side Walls	IIDR INRE IWSF	Failure of cracked concrete apron slab Consequent failure of check dam & progressive further failures downstream	1. Reconstruct cracked apron slab 2. Condition survey to all protection works after every rainy season 3. Carry out works as identified by condition survey
		Bio Engineering and Drainage works on downstream left bank	IIDR INRE IWSF ILE	-Damage or blockage to surface water drainage system -Damage or blockage to sub-surface drainage system	1. Carry out detailed condition survey of drainage system 2. Carry out works required as identified by condition survey
Mugling to Narayanghat Road at Mauri CHITWAN	**Road cut by landslide**	**Hill slope**	IIDR INRE ILE	The debris behind the check walls have already started to overtop. If further erosion occurs, large amount of debris will move to the road.	Clear the debris
		Gabion check dams	IIDR INRE ILE	Land erosion has started to occur at several other locations.	Provide check walls, surface and sub-surface drains and bio-engineering at the whole slope.
		Mauri Bridge and Narayanghat-Mugling Road	IIDR INRE ILE	The local people are cultivating at the top of hill slope. With increase in rainfall, more water will penetrate through the cultivated land and will increase the moisture content of the whole slope. This may cause collapse of the road side breast walls.	Encourage the local people to shift the cropping pattern (encourage plantation which require less water).

***Abbreviation used in tables**

IIDR = Increase in intensity and duration of rainfall
INRE = Increasing number of rainfall events
IWSF = Increasing wet season flow
ILE = Increasing landslide events
IDRW = Increasing duration of road pavement wetting

9 CONCLUSIONS

9.1 BASELINE REPORTS

- **Condition of Existing Strategic Road Network Infrastructure**

The visit by the Project Road & Bridge Engineer to all eight Districts allowed a fairly comprehensive survey of the condition of the SRN infrastructure to be carried out. **Annex III** gives a summary of his findings.

His observations confirm that the overall condition of the SRN network is poor with a significant backlog of and periodic maintenance and rehabilitation. A road network where there is a backlog of maintenance (or maintenance deficit) is more susceptible to damage from any weather event. The infrastructure is therefore Vulnerable to the threats of severe weather predicted by the Climate Threat Profiles. Any work to reduce the maintenance deficit will reduce the vulnerability of the road network and is therefore an Adaptation.

- **Annual Road Maintenance Plan**

The introduction of the requirement that all 25 Divisions of DoR draw up an Annual Road Maintenance Plan (ARMP) should enable the maintenance of the SRN to be better managed. It is important that the ARMP addresses the issue of prioritising the SRN in each Division and District so that the maintenance deficit is first addressed on the most important roads.

- **Institutional Issues**

The comments entered as Issues in the Baseline Reports were provided by officers in the Districts. It is clear from these comments that Governance is a major problem.

  - Budgets are insufficient and not provided on time
  - Programmes are not approved on time
  - Resources are diverted from managing and maintaining the SRN to construct roads which are not the direct responsibility of DoR
  - Limited technical capacity
  - Inexperienced contractors who submit low bids and do not complete the work on time and to the required quality
  - There is a very limited amount of information kept about the design and construction of bridges, retaining wall, cross-drainage etc and without this information it is extremely difficult to assess the vulnerability of such structures to extreme weather conditions.

The capacity for DoR in the Divisional and District Offices to manage and maintain the SRN effectively and to respond to critical events is severely limited by the difficulties set out above. The increasing risk of severe disruption to the road network because of extreme weather events brought about by Climate Change makes the strengthening of the capacity of these offices a prime objective.

9.2 CLIMATE THREAT PROFILES

The Climate Threat Profiles predict that extreme weather events will become more frequent and more severe in all the eight Districts considered. The magnitude of these events will vary from District to District and also within each District.

9.3 VULNERABILITY ASSESSMENT REPORTS

The Vulnerability Assessments carried out on the selected assets in the eight Districts show that they all have a high or very vulnerability to extreme weather events. These events may be increased rainfall, more frequent storms with greater intensity rainfall or high river flows caused be increased rainfall over the catchment area upstream.

However, the limitations in predicting accurately the magnitude and likelihood of an extreme event at a particular location mean that in the short term it is not possible to assess the vulnerability of any asset with any confidence.

9.4 ADAPTATION PLANNING REPORTS

The Adaptation actions set out in the Adaptation Planning matrices completed for the selected assets are nearly all actions which can be classified as work to be carried out under either routine, periodic maintenance or rehabilitation programmes.

With the limited resources available at District level the Adaptation Planning process should be used to prioritise the maintenance interventions.

9.5 COMMENT

- The poor condition of the fabric of the road network makes it vulnerable to damage and failure from relatively minor weather events. Efforts to improve the condition of the roads will have an immediately beneficial effect in that it will reduce the likelihood of damage from all weather events and reduce the cost of transporting goods and people by increasing traffic speed and reducing wear and tear on vehicles.
    - **In the short to medium term the elimination of the maintenance (adaptation) deficit must be considered the top priority.**
- The lack of the necessary information to allow more precise determination of the sensitivity of an asset together with the uncertainty over the likelihood and magnitude of any climate related threat means that making a commitment to major expenditure on a single intervention is very risky[1].
    - **Reconstruction or costly protection of an existing element in the road infrastructure should only be contemplated if there is strong evidence of likely failure of the element.**
- The extensive nature of the SRN is that it extends over the whole country in a network of roads linking centres of habitation or production which makes it particularly vulnerable to any extreme weather event. The cutting of a road link at any place along its length disrupts the whole link and causes hardship and economic loss to the communities at both ends of the link. At present, it is not possible to predict where along a link an event may occur which will disrupt the link because: 1. It is not possible to predict where along a link a weather event will take place; 2. The information regarding which are the most vulnerable sections of the link is not available.
    - **Vulnerability Assessments should be carried out along the most important road links in order to determine which sections are most vulnerable to extreme weather events[1]**
- In the short to medium term it must be accepted that severe weather events will disrupt the SRN without warning at locations which cannot be predicted. It is therefore necessary to increase the ability to respond to major disruption caused be extreme weather events.
    - **Increase the technical and physical capability of the Department to respond to disruption caused by severe weather events**

1 Ref. Road Vulnerability Map as proposed in Fig 2 on page 20 of ADB publication “Climate Proofing ADB investments in the Transport Sector: Initial Experience”.

10 REFORMS ON SECTOR ISSUES

10.1 ROUNDTABLE DISCUSSIONS

During roundtable discussions the following areas were identified as possible entry points for mainstreaming climate resilience into DoR activities:

- Management procedures of DoR
- Project Implementation Plan
- Annual Road Maintenance Plan (ARMP)
- Highway Management Information System
- Environmental Management Guidelines
- Design Standards
- Project Designs

10.2 PROPOSED REFORMS

1. Institutional

1.1. Nepal Road Sector Assessment Study

1.1.1. In paragraph 12, Safeguards, a clause stating that the possible risks associated with the threats from Climate Change should be assessed in all areas of DoR's responsibility.

2. Policies & Plans

2.1. Project Implementation Plan

2.2. Annual Road Maintenance Plan (ARMP)

2.2.1. Prioritisation of Maintenance Procedures???

2.2.2. Records of Road Closures

Collate existing procedure to record road closures so that, over time, those sections of road which are more vulnerable to extreme events ("hot spots") are identified.

2.3. Highway Management Information System (HMIS)

2.3.1. Condition Surveys

Increase the scope of the surveys to include more details about condition of structures, stability of slopes above and below road and commence to include vulnerability assessment of sections of road which are considered to be at risk.

3. Guidelines, Standards & Manuals

3.1. Environmental Management Guidelines (Geo-Environment Unit 1999)

3.1.1. paragraph 2.1 Scope, amend Clause 6 to "provision of suitable drainage facilities utilising discharge to natural drainage channels in conjunction with erosion protection features *having taken into account the predicted increase in extreme rainfall events over the liftime of the project due to Climate Change"*

3.2. Environmental Assessment

3.2.1. Initial Environmental Examination (IEE)

In the Terms of Reference issued to the Consultant drawing up the IEE include:

- In section titled "Objectives" amend the following paragraphs:
  - document key physical, *meteorological,* biological, socio-economic and cultural baseline conditions of the project area
  - identify, predict and assess the adverse and beneficial environmental impacts of the project, *having taken into consideration the effects of Climate*

Change, in terms of magnitude, extent and duration during the project construction phase including operation phase

3.2.2. Environmental Impact Assessment (EIA)

In the Terms of Reference issued to the Consultant drawing up the EIA include:

- Amend the paragraph setting our the Rationality for Conducting EIA to:
  - The rationality for conducting EIA is to determine whether the implementation of the project will result in adverse environmental impacts such as the triggering of landslides, soil erosion and depletion of existing forest condition, displacement of local people etc. *having taken into account the effects of Climate Change as calculated by DHM*
- In the Scope for the Preparation of the Report under Adverse Issues:
  - Para. APC3 Physical Impacts due to slope instability, landslide, erosion of hill slopes along road alignment *taking into account the increase in total rainfall and the intensity of rainfall due to Climate Change*
  - Para. APC4 Impacts of River flow regime and river environment *taking into account the increased flows brought about by Climate Change as calculated by DHM*

3.2.3. Design Standards

Latest prediction of climate change effects obtained from DHM and used in assessing:

- Bridges
  - Location
  - Maximum flood discharge for a given return period
  - Type of Depth of Foundation
  - Total Span & Number of Piers
  - Bridge Deck Level
  - River training works at approaches to bridge
- Roads
  - Alignment
  - Cross Drainage
  - Side Drainage
    - In Nepal Road Standards (2070) paragraph 13.8 Road Drainage sub-section h, amend clause to read "For calculating design discharge on roadside drains following return periods should be taken. *The intensity of rainfall should be found using the latest rainfall return period curves allowing for the effects of Climate Change as provided by DHM"*
  - Retaining Walls & Toe Walls
  - Stability of roads crossing unstable ground
  - Extent of bio-engineering required

3.2.4. Project Design

In preparing designs for new projects the increased threats brought about by Climate Change as calculated by DHM should be taken into account when assessing:

- Stability of slopes
- Design of cross drainage
- Design of side drains

1 Ref. Road Vulnerability Map as proposed in Fig 2 on page 20 of ADB publication "Climate Proofing ADB investments in the Transport Sector: Initial Experience".

- Viability of road alignments constructed along river valleys adjacent to rivers subject to flash floods
- Road embankments constructed across flood plains

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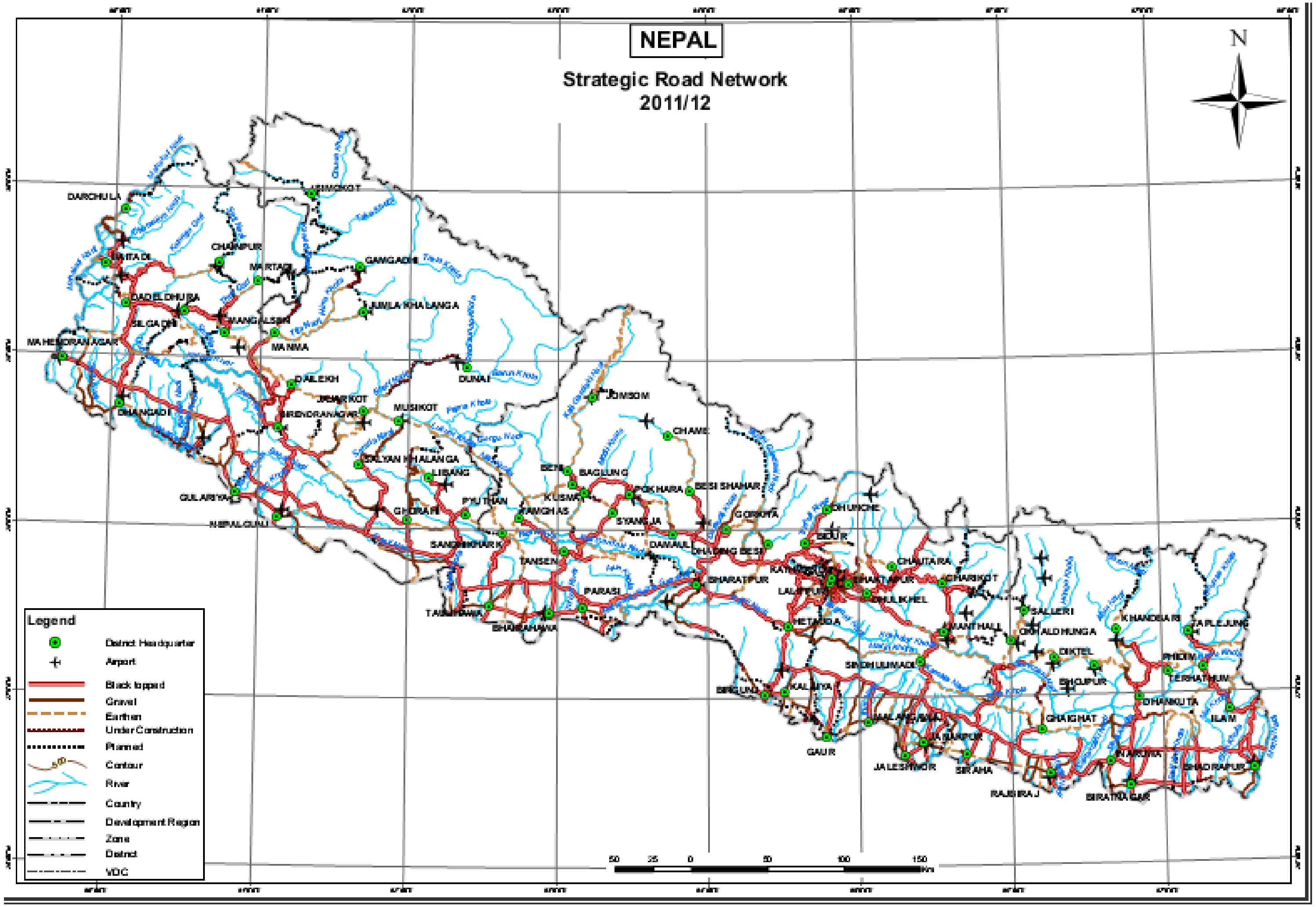
1 Ref. Road Vulnerability Map as proposed in Fig 2 on page 20 of ADB publication "Climate Proofing ADB investments in the Transport Sector: Initial Experience".

ANNEX I: MAP OF STRATEGIC ROAD NETWORK



ANNEX II: CONDITION OF EXISTING SRN INFRASTRUCTURE

1. Condition of Existing Infrastructures

During the visit by the National Roads and Bridges Engineer the following observations can be made regarding the resilience of the Strategic Road Network Infrastructure in the project districts.

1.1 General Observations; applicable to all districts.

- Roadside drains are inadequate, extensively damaged and poorly maintained;
- Cross road drainages structures are inadequate, extensively damaged and poorly maintained;
- Much of the road network is constructed across steep slope which are prone to landslides in hill areas.
- Several road sections in terai area are located at flood prone areas and are frequently damaged by flood;
- The road pavements are in poor condition making them liable to further damage under severe weather condition;
- The records of the condition of existing infrastructure are inadequate making planning of periodic or emergency maintenance difficult;
- The design drawings of road, bridges and structures are not available making assessment of their long term stability difficult to determine;
- Condition of several district roads is very poor. Due to absence of basic structures (cross drainages, retaining wall, gravelling etc.), the roads are not passable during rainy season. In some instances, the road is blocked by landslides for a quite long time as the DDCs are not able to clear them due shortage of fund.

1.2 Specific Observations

Strategic Roads

District	Findings/Observations
Panchthar	DoR has not still not stabilized old landslides; • DoR has still not adopted adequate measures to stabilize the Amarpur Lanslide (along Mechi Highway) which occurred about four years ago. It is still in vulnerable condition.
	Gabion bank protection works at bridge sites are damaged; • Gabion bank protection works at Kabeli and Hewa Khola Bridge sites are damaged at several locations.
	Extreme flooding may damage Hewa Khola Bridge pier; • DoR has constructed minor pier protection works to protect the pier of Hewa Bridge. These works are not sufficient to protect the bridge from big flood.
	Tamor Bridge may be damaged if there will be heavy landslide at right approach road; • The right bank at the Tamor River near the bridge site is steep and in close proximity to the bridge. While constructing approach road, huge cutting is made at this location. If the cut slope fails, there is a high probability of bridge damage.

District	Findings/Observations
Kathmandu	There is heavy encroachment and sand mining at all bridge sites. These activities caused heavy scouring of bridge foundations; • The Bagmati Bridge at Tinkune collapsed due to heavy scouring. • The other bridge at Tinkune is also suffering from extensive scouring. The bed level of the river is scoured by about 3-4m. The foundation piles are exposed and eroded. Pile reinforcements are visible and they are corroded. The bridge may collapse any time if protection measures are not adopted timely.
	The bridge bearings are in poor condition;
Chitwan	Bridges in the district are undergoing heavy siltation. It is endangering the bridge stability and causing river overflow at several locations. • Heavy siltation at the Lothar Bridge site is endangering the stability of the structure. • The overflow at Riu Khola Bridge site frequently damages the left approach road.
	The debris at the back of check dams have started to overtop the walls. The debris are not cleaned for a long period; • At the hill slope near Mauri Bridge DoR/DWIDP has constructed several gabion check dams to protect the road from landslides. At present the check dams are overtopped by debris. If appropriate measures are not taken, the debris will slide to road side causing traffic blockage.
	Several rivers in the district are changing their regime/course; • The Badarmudhe Khola in Madi is changing its course very rapidly. The Khola, at present, does not flow through the bridge but along the left bank.
Myagdi	Kaligandaki River has washed away the Beni-Jomsom Road at several locations; • Beni-Jomsom Road which is the only strategic road in the district was severely damaged by Kaligandki River at Bhirkate (km 17) and Timure Bhir (km 16).
	Incidence of flash floods has become more frequent in the past few years; • The flash flood in June 2013, washed away formworks and reinforcements of the under construction bridge across Lasti Khola.
Mustang	There is substantial increase in rainfall intensity and duration in the last few years; • About 250 m long road section at km 72 was washed away by the heavy flooding in Podkyu Khola in July 2013. The flood also deposited large amount of debris at the road side and surrounding areas.
	Kaligandaki River is eroding the Beni-Jomsom Road at several locations; • Kaligandaki River washed away 40m long road section at Tukuche (km 65) and has eroded at several other locations.

District	Findings/Observations
Banke	Rapti River is causing heavy damage at frequent interval; • About 20m long section of approach road of Rapti Bridge along Nepalgunj-Bagauda Road was totally washed away by 2012 flood. The flood also severely damaged adjacent road sections; • The Rapti River is extensively eroding the left bank near the Rapti Bridge and has damaged protection works;
	The condition of almost all drainage structures is poor due to lack of maintenance; • The culvert at km 8+050 of Nepalgunj-Guleria Road is suffering from deterioration of substructures and scouring. This is the result of inadequate maintenance. The condition other structures is also similar.
Achham	Budhi Ganga River is extensively eroding the right bank where the Sanfebagar-Martadi Road is located; • About 200m long road section of Sanfebagar-Martadi Road at km 12 is highly vulnerable to erosion by Budhigandaki River. Out of 200m, the condition of 60m long section is very critical. If appropriate measures are not adopted, the river will wash away the above road section;
	The landslides frequently block the Sangebagar-Martadi Road; • Landslides at km 9+920 and 14+500 along of Sanfebagar-Martadi Road along Sanfebagar –Mangalsen Road are frequently blocking the traffic. The measures which were adopted to prevent the landslides are inadequate;
	Budhiganga River is eroding the concrete pier of motorable bridge at Sanfebagar; • Due to extensive erosion, the reinforcements of the lower portion of one pier of the Budhiganga Bridge at Sanfebagar are exposed. If the problem is not corrected timely, the repair cost could be very high.

ANNEX III: VULNERABILITY ASSESSMENT OF ASSETS

The matrix below sets out the Vulnerability interpretation process for the selected assets.

Abbreviation used in tables

IIDR = Increase in intensity and duration of rainfall
IWSF = Increasing wet season flow
IDRW = Increasing duration of road pavement wetting
INRE = Increasing number of rainfall events
ILE = Increasing landslide events
VL = Very low; M = Medium; L = Low; H = High; VH = Very High

Asset	Physical Threat	Components	Climate Threat	Interpretation of Threat	Exposure.	Sensitivity.	Impact	Adaptive. Capacity	Vulnerability	Comments
I **Sanfebagar to Martadi Road ACHHAM**	**Instability of hillside**	**Hill Slope**	IIDR INRE ILE	Intensity and frequency of landslides will increase.	VH[1]	VH[2]	VH	H[3]	H	The hill slope can be stabilized by constructing breast wall, drainage structures and bio-engineering.
		Road	IIDR INRE IDRW	Weakening of the sub-grade due accumulation of water for longer period.	H[4]	M[5]	H	H[3]	M	Additional drainage structures (side drains and cross drains) should be provided.
		Retaining walls	IIDR INRE ILE	Pore pressure and flood impact at bank protection wall will increase.	VH[6]	VH[7]	VH	H[3]	H	The bank protection walls are in very poor state. They will fail if adequate measures are not adopted.
1. *Exposure of (fragile) hill slope is very high to increase in rainfall intensity and duration.* 2. *The scale of landslide will be high. The road will be closed for few days. There will some loss of lives and properties. .* 3. *The adaptive capacity of DoR Division Road Office is **High**; see section 2.2.4.* 4. *The exposure of damaged road (pavement completely destroyed) to increased rainfall will be high.* 5. *The road will be severely damaged but it will not be closed. Vehicles will face difficulty to pass through the damage section. Reconstruction cost could be high.* 6. *The retaining walls are located very near to river course. Hence it is very highly exposed to increased flood.* 7. *The quality of wall is not good. Moreover, scour protection measures are not provided. Reconstruction cost could be high.*										
II	**Failure of Road Embankm**	**Road embankm ent**	IIDR INRE IWSF	Threat to previously built embankment from increased flows.	VH[1]	VH[2]	VH	H[3]	H	The road embankment is located at very near to the river. It was damaged several times in the past. The scale of

Nepalgunj to Baghouda Road BANKE	**ent**									damage due to 2012 flood was very high.
		Bank protection walls	IIDR INRE IWSF	Higher possibility of failure of bank protection works from increased flows.	VH[4]	VH[5]	VH	H[3]	H	The exposure of the bank protection works is very high as they are located very near to the water current. The protection works were damaged several times in the past.
		Cross drainage structures	IIDR INRE IWSF	Higher probability of damage of cross drainage structures due to increase in flood volume.	VH[6]	H[7]	VH	H[3]	H	Existing cross drainage structures are not sufficient to pass the water during high flood and hence they are highly vulnerable to increased flood volume.
1. *The road embankment is located at highly vulnerable to flood. It was washed away several times in the past.* 2. *The embankment is not protected (by gabions or stone rip rap). The embankment collapse will cause road closure in rainy season and will affect large number of people residing at the southern parts of the district.* 3. *The adaptive capacity of DoR Division Road Office is **High**; see section 2.2.4.* 4. *Bank protection works are very near to the main river course. They were damaged several times in the past;* 5. *Bank protection works are constructed without proper design. Similarly, launching aprons are not provided in many cases.* 6. *Cross drainage structures are directly affected by the flood.* 7. *The quality of structures is good but their capacity is inadequate.*										
III **Bagmati Bridge on Arniko Highway, Tinkune KATHMANDU**	Failure of Bridge	**Pile Foundation**	IIDR INRE IWSF	Scouring effect will increase. It may cause bridge collapse. Bagmati Bridges at other two locations have already collapsed.	VH[1]	VH[2]	VH	H[3]	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.
		Abutments and Piers	IIDR INRE IWSF	Increased flood will cause additional water impact on piers and abutments	VH[4]	L[5]	H	H[3]	M	Substantial damage to abutments and piers is not envisaged as the river does not carry big boulders and trees.
		Bank Protection Wall	IIDR INRE IWSF	Damage to gabion protection walls are common. Increased flood will aggravate the scour making the walls further vulnerable.	VH[6]	VH[7]	VH	H[3]	H	Most of the bank protection walls in Nepal are constructed without scour protection measures. Similarly, their quality is also not maintained. These are the main reasons of for damage/ failure of gabion bank protection walls.
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.*										

<table>
<tr><td colspan="11">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.
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)</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td rowspan="2">IV

Sanfebagar to Martadi Road ACHHAM</td><td rowspan="2">Erosion of road by river Budhiganga</td><td>Embankment & protection walls</td><td>IIDR INRE IWSF</td><td>Erosion will be substantially higher with increase in flood volume.</td><td>VH[1]</td><td>H[2]</td><td>VH</td><td>H[3]</td><td>H</td><td>The walls have started to fail at many locations because they are constructed without scour protection measures. Moreover their quality is also not good.</td></tr>
<tr><td>Road</td><td>IIDR INRE IWSF</td><td>Probability of washing away of road will be higher.</td><td>M[4]</td><td>VH[5]</td><td>VH</td><td>H[3]</td><td>H</td><td>If the protection walls fail the road will be washed away.</td></tr>
<tr><td colspan="11">1. The right bank (where the road is located) was being eroded by the river in the past. With the shift of the river towards it, exposure of bank erosion / walls has substantially increased.
2. Banks and retaining walls are in very critical state at some locations. The quality of walls is not good.
3. The adaptive capacity of DoR Division Road Office is High; see section 2.2.4.
4. Exposure of road to increase in flood volume will be medium as it is protected by walls.
5. The sensitivity is very high because it is the only road providing link to eastern part of Achham District and whole Bajura District.</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td rowspan="3">V

Lothar Bridge on East – West Highway CHITWAN</td><td rowspan="3">Failure of bridge due to sedimentation due to debris flow</td><td>Bridge Superstructure</td><td>IIDR INRE IWSF</td><td>Overtopping of bridge by flash flood.</td><td>VH[1]</td><td>VH[2]</td><td>VH</td><td>H[3]</td><td>H</td><td>The vertical clearance of the bridge has reduced to 2.5 m from 8m in 35 years due to heavy siltation. The bridge may collapse with further siltation. Although the "Vulnerability Assessment Matrix" shows that the vulnerability is only "high" but in actual the vulnerability of the bridge is "catastrophic" due to its location.</td></tr>
<tr><td>Bank protection works</td><td>IIDR INRE IWSF</td><td>Damage to bank protection works will be more.</td><td>VH[4]</td><td>H[5]</td><td>VH</td><td>H[3]</td><td>H</td><td>The exposure of the bank protection works is very high as they are located very near to the water current.</td></tr>
<tr><td>Approach Roads</td><td>IIDR INRE IDRW</td><td>Probability of damage to approach roads will increase.</td><td>M[6]</td><td>H[7]</td><td>M</td><td>H[3]</td><td>M</td><td>Some sections of approach roads located near the river bank will be</td></tr>
</table>

										washed away. The road can be rebuilt within short time.

1. *The vertical clearance of the bridge has reduced to 2.5m from 8m in the last 35 years due to heavy siltation. The flood of 1993 and 2003 overtopped the bridge. With increase in flood, the damaging capacity of the river will substantially increase which may wash away the bridge. Several bridges in Nepal are washed away by flood.*
2. *Although the construction quality is very good, the sensitivity of bridge has become very high due to heavy siltation. As the bridge is located along the most important section of the national highway its sensitivity is further increased.*
3. *The adaptive capacity of DoR Division Road Office is **High**; see section 2.2.4.*
4. *Bank protection works are very near to the main river course. They were damaged several times in the past;*
5. *Some bank protection works are properly designed (especially the dyke at right bank of downstream side) and some are constructed without considering the hydrological parameters such as scour depth (launching aprons are not provided at many locations), width of waterway during high flood, HFL etc. The quality of bank protection works at some locations is good whereas it is poor at several instances. Hence the sensitivity is considered as medium.*
6. *Bank protection works are constructed at both sides of the river. The river will damage/wash away approach roads in extreme flood condition only. .*
7. *The quality of approach road is good. But its sensitivity is considered high due to its importance.*

VI **Charnabati Bridge & Approach Roads on Takakoshi – Jiri Road DOLAKHA**	**Failure of bridge and approach roads**	**Bailey Bridge across Charnabati River**	IIDR INRE IWSF	Scour around the abutments will be more. Very high flood level may overtop bridge and wash away superstructures.	VH[1] H[3]	M[2] H[4]	VH H	H[5] H	H H	Previously constructed bridge has already collapsed. The existing bridge is also highly vulnerable to scour and overtopping.
		Check Dams, Concrete Aprons & Side Walls	IIDR INRE IWSF	Threat of damage to previously built protection works from increased flows Threat of progressive collapse of protection works after failure of one element.	VH VH	VH[6] M[7]	VH VH	H[8] H	H H	Almost all the protection structures were constructed more than 25 years ago. Many structures are failing and DOR is rehabilitating them. Hence all the protection works should be continuously assessed to save them from increased rainfall and flood.
		Bio Engineering and Drainage works on downstream left bank	IIDR INRE IWSF ILE	Increased possibility of failure of drainage works. Increased likelihood of landslides which destroy approach roads.	VH VH	M[8] M[9]	VH VH	M[10] M	VH VH	The effectiveness of bio-engineering work increases with time as the planting becomes more established. However the drainage works especially sub-surface drains require constant attention they may become less effective with time.
		Retaining Walls at right bank	IIDR INRE ILE	Increased likelihood of erosion and landslide on downstream right bank.	M[11]	VH[12]	H	H[14]	M	If the erosion is not controlled the landslides could progress up the hillside and affect the approach roads on that

				Possibility of landslides blocking flow of river and causing erosion on left bank.	M[11]	L[13]	M	H[14]	M	side.

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*

VII **Mugling to Narayanghat Road at Mauri CHITWAN**	**Road cut by landslide**	**Hill slope**	IIDR INRE ILE	Intensity and frequency of landslides will increase.	VH[1]	VH[2]	VH	H[3]	H	Size and frequency of landslides will be higher causing road closer for longer duration.
		Gabion check dams	IIDR INRE ILE	Pore pressure on check dams will increase. The increase in landslide events will also cause more impact damage to check dams.	VH[4]	H[5]	VH	H[3]	H	The gabion check dams are retaining huge amount of debris. If they collapse, all the retained debris will move to the road causing damage and closure.
		Mauri Bridge and Narayanghat- Mugling Road	IIDR INRE ILE	Larger and more frequent landslides will cause more damage to road and bridge.	VH[6]	VH[7]	VH	H	H	Road closure will be more frequent. Road rehabilitation cost may increase substantially.

1. *The area lies in very high rainfall intensity area. The rainfall intensity recorded at this location in 1993 is one of the highest ever recorded in Nepal. The slope is steep and unstable. The road was closed at several instances in the past due to landslides.*

2. *The slope is protected by constructing series of gabion check dams. But it is still very prone to landslide due to steep slope. The slope failure will cause traffic closure which is not permitted due to its extreme importance.*
3. *The adaptive capacity of DoR Division Road Office is High; see section 2.2.4.*
4. *The check dams are located on high landslide prone area.*
5. *The quality of wall is good but it is already overtopped by debris causing substantial increase in back pressure. Damage to check dams will cause movement of debris and road closure.*
6. *The road and bridge is located along very high landslide area.*
7. *The quality of road and bridge is good. But it will be heavily damaged by the probable landslide. The damage will cause road closure which is least desired on such highway. The reconstruction cost of the road and bridge will be high.*

ANNEX IV: ADAPTATION PLANNING FOR ASSETS

Asset	Physical Threat	Component	Climate Threat	Impact	Significance			Adaptation options	Priority adaptation			Adaptation phases
					Likelihood	Seriousness	Significance		Feasibility	Effectiveness	Priority	Regular (R) Immediate (I), Short (S), medium (M) long term (L)
I Sanfebagar to Martadi Road at Tashi ACHHAM	**Instability of hillside**	**Hill Slope**	IIDR INRE ILE	The intensity and frequency of slope erosion and landslides events will substantially increase.	VH[1]	VH[2]	VH[3]	Construct 3m high breast walls; provide surface drains and bio-engineering.	H[4]	H[5]	H[6]	S[7]
		Road	IIDR INRE IDRW	Higher moisture content at sub-grade for longer duration causes pavement failure.	H[8]	H[9]	H[10]	Repair and clean side drains. Provide additional measures to drain off the water from the road. Reconstruct road pavement after completing slope stabilization measures.	H[11]	H[12]	H[13]	R & S[14]

2. The asset lies in the high rainfall area.
2. The landslides can be heavy. There will be loss of lives and properties. Traffic will be closed for several days/months.
3. As per matrix.
4. The breast wall, water management and bio-engineering are highly feasible as they can prevent heavy landslides and lessen road closure.
5. The measures are highly effective to reduce the surface erosion/landslides.
6. As per matrix.
7. The work should be completed within short period (1-2 years).
8. Road pavement has totally failed. At present it is in the form of earthen track. Hence it is highly exposed to increased rainfall.
9. The pavement strength is very weak. Extensive rain may cause traffic closure for few hour/days.
10. As per matrix.
11. Drainage management and new pavement will ensure smooth traffic flow..
12. The effectiveness of drainage management and pavement will be high. However, these works should be carried out after landslide stabilization measures.

13. *As per matrix.*
14. *The drains should be regularly cleaned. If necessary additional drainage structures and pavement should be constructed within short period (1-2 years)*

II **Nepalgunj to Baghouda Road BANKE**	**Road embankment eroded & road cut**	**Road embankment**	IIDR INRE IWSF	The road embankment collapsed at several occasions in the past during high flood. The increase in flood will accelerate this process.	VH[1]	VH[2]	VH[3]	Reconstruct road embankment and provide stone rip rap or gabion mattress at upstream side.	VH[4]	VH[5]	VH[6]	**I[7]**
		Bank protection works	IIDR INRE IWSF	Bank protection works were frequently damaged by the flood in the past. With increase in flood the damage will be more severe and frequent.	VH[8]	VH[9]	VH[10]	Repair/reconstruct the damaged walls providing adequate scour protection measures	VH[11]	VH[12]	H[13]	**I &S[14]**
		Cross Drainage Structures	IIDR INRE IWSF	Existing cross drainage structures are not sufficient to pass the current discharge during high flow. With increased flow, this problem will become more severe and probability of damage to those structures will be high	VH[15]	H[16]	H[17]	• Complete construction of cross drainage structures (Baily Bridge, concrete causeway, pipe culvert). • Repair/new construction of bank protection works	H[18]	H[19]	H[20]	**S[21]**

1. *The road embankment lies in highly vulnerable area and collapsed several times in the past.*
2. *The road will be closed. The farmers cannot sell their goods in the market.*
3. *As per matrix.*
4. *It is very essential.*
5. *It will open the Nepalgunj-Bagauda Road which is the only road to large number of people.*
6. *As per matrix.*
7. *The work should be completed as soon as possible.*
8. *Bank protection walls have collapsed at several locations in the past*
9. *There will be severe damage to roads, cultivated land and houses. Probability of loss of lives is also high.*
10. *As per matrix.*

11. *It is highly feasible. Repair/reconstruction of bank protection works will save lot of several types of properties as well as lives. .*
12. *This will be highly effective to protect properties and the Nepalgunj-Bagauda Road.*
13. *As per matrix.*
14. *Some of the works should be done immediately and some within short period of time.*
15. *Damage to cross drainage structures were frequent in the past. With climate change effect, the exposure will increase.*
16. *There will be some property loss. The road may be closed for short duration.*
17. *As per matrix.*
18. *Cost of cross drainage structures will be less in comparison to the damage done by the river in their absence.*

III **Bagmati Bridge on Arniko Highway, Tinkune KATHMANDU**	Failure of Bridge	**Pile Foundation**	IIDR INRE IWSF	Foundation failure due to increase in scour depth	VH[1]	VH[2]	VH[3]	Issue of directives (focusing on encroachment and sand mining) and placement of watchman to prevent further scouring and provide scour checking structures around the pile foundation.	VH[4]	VH[5]	VH[6]	**I[7]**
		Bank Protection Wall	IIDR INRE IWSF	Failure of wall due to increase in scouring and water current.	VH[8]	H[9]	H[10]	Repair/reconstruct the damaged walls providing adequate scour protection measures.	VH[11]	VH[12]	H[13]	**I & R [14]**

1. *The bridge is in very critical condition. There is high chance of bridge failure if there will be more scour due to climate change effect.*
2. *Cost of bridge reconstruction and traffic management will be very high. There may be loss of lives if the bridge fails suddenly.*
3. *The bridge lies on the busiest road of Kathmandu city.*
4. *It is highly feasible. Cost of water scour protection measures will be very low in comparison to consequences due to bridge failure.*
5. *It is very highly effective.*
6. *The adaptation measures should be immediately started.*
7. *Scour protection measures should be started immediately.*
8. *Bank protection walls have collapsed at several locations in the past*
9. *There may be damage to roads and buildings. Probability of loss of lives is nominal*
10. *The reconstruction works will save buildings and roads located near the river.*
11. *It is highly feasible. Repair/reconstruction of walls will be low in comparison to the rehabilitation/repair cost of the damaged properties.*
12. *The repair/reconstruction works are the only option and it will be highly effective.*
13. *The priority for reconstruction of damaged walls is high but not important as scour protection works.*

14. *The damaged walls which are located on sensitive areas (which may cause substantial property loss) should be repaired/reconstructed immediately. Walls constructed on less sensitive areas should be covered by regular maintenance works.*

IV **Sanfebagar to Martadi Road ACHHAM**	Erosion of road by river Budhiganga	**River Bank**	IIDR INRE ILE	Bank erosion will be more severe due to increase in wet season flood volume.	VH[1]	VH[2]	VH[3]	Construct spurs, groynes etc. to divert the flow towards left bank (away from the road)	H[4]	H[5]	H[6]	S[7]
		Road	IIDR INRE IDRW	Higher moisture content at sub-grade for longer duration causes pavement failure.	H[15]	H[16]	H[17]	Repair and clean side drains. Provide additional measures to drain off the water from the road if required. Reconstruct road pavement after completing slope stabilization measures.	H[18]	H[19]	H[20]	R & S[21]
		Retaining walls	IIDR INRE ILE	Bank erosion will be more severe causing more damage to walls due to increase in wet season flood volume.	VH[8]	VH[9]	VH[10]	Construct spurs, groynes etc. to divert the flow towards left bank (away from the road)	H[11]	H[12]	H1 3	S[14]

1. *Likelihood of bank erosion is high very due to increase in flood volume.*
2. *The road will collapse. Traffic will be closed for several days/months. There will be loss of lives and properties.*
3. *As per matrix.*
4. *The cost of protection measures is less in comparison to the loss due to road collapse.*
5. *The proposed measure will be highly effective to protect the road as it will deflect the river away from the road side.*
6. *As per matrix.*
7. *The protection measure should be constructed within short period.*
8. *The bank protection walls are very near to main river course. Hence their exposure is high.*
9. *The quality of walls is poor (see photo). The road section will be washed away if the walls collapse.*
10. *As per matrix*
11. *Repair works especially of gabion walls are highly feasible. It will lengthen their lives and will save considerable amount of money.*
12. *Repair work is always highly effective.*
13. *As per matrix*

14. *Repair works should be carried out on regular basis.*
15. *The road is black topped. Its exposure to higher rainfall will be medium.*
16. *The road pavement will fail. Traffic will not be closed. Loss of lives and properties will be nominal.*
17. *As per matrix*
18. *Management/improvement of water management is always highly feasible because it saves road rehabilitation/reconstruction cost which can be very high.*
19. *It is a highly effective option for road protection*
20. *As per matrix*
21. *The drainage management/construction should be completed within short period and should be regularly monitored*

V **Lothar Bridge on East – West Highway CHITWAN**	**Failure of bridge due to sedimentation due to debris flow**	**Bridge Superstructure**	IIDR INRE IWSF	Additional siltation may cause bridge collapse.	VH[1]	VH[2]	VH[3]	Clear debris (siltation) from the bridge site. Adopt measures to reduce land erosion at catchment area by constructing check dams, bio-engineering and discouraging cultivation.	VH[4]	H[5]	VH[6]	**I[7]**
		Bank protection works	IIDR INRE IWSF	Frequency and magnitude of damage to bank protection works will be more.	VH[8]	H[9]	VH[10]	Repair/reconstruct the damaged walls providing adequate scour protection measures	H[11]	H[12]	H[13]	**I. S & R[14]**
		Landslide/Land Erosion at Catchment	IIDR INRE IDRW	Siltation process is still very active due to land erosion at catchment areas. If it is not controlled, increasing rainfall trend will accelerate the process.	VH[15]	VH[16]	VH[17]	Construct check dams, plant trees and discourage cultivation.	VH[18]	VH[19]	VH[20]	**I &L[21]**

1. *The vertical clearance is very little. The flood already overtopped the bridge in 1993 and 2003 which indicate that the likelihood of the impact is very high.*
2. *The traffic on the most important highway of the country will be disrupted for several days. This will create havoc.*
3. *As per matrix.*
4. *It is very essential (more than feasible).*
5. *It will work for short term but for long term adequate measures should be adopted at the whole catchment areas.*

6. *As per matrix.*
7. *The work should be completed as soon as possible.*
8. *Bank protection walls have collapsed at several locations in the past and the events will increase further.*
9. *There will be damage to roads, cultivated land and house including loss of lives and properties.*
10. *As per matrix.*
11. *It is feasible. Repair/reconstruction of bank protection will protect adjoining areas.*
12. *This will be effective to protect lives and properties.*
13. *As per matrix.*
14. *The works should be done continuously (immediate, short term, long term and on regular basis) as there is large number of bank protection works.*
15. *Landslides and land erosion process will increase considerably.*
16. *Large amount of debris will be deposited at the bridge site which may cause bridge collapse.*
17. *As per matrix.*
18. *It will be highly feasible. It will protect bridge and the whole catchment area.*
19. *The measures are highly effective and are being adopted in several parts of the country.*
20. *As per matrix.*
21. *The works should be started immediately. But it will take long period.*

VI **Charnabati Bridge & Approach Roads on Takakoshi – Jiri Road DOLAKHA**	**Failure of bridge and approach roads**	**Bailey Bridge across Charnabati Khola.**	IIDR INRE IWSF	Destruction of an abutment & failure of bridge	H[1]	VH[2]	VH[3]	4. Carry out detailed condition survey of bridge & abutments 5. Carry out any repair works found by condition survey 6. Carry out condition survey after every rainy season	VH[4] VH VH	H[5] H H	VH[6] VH H	**I[7]** **S** **R**
		Check Dams, Concrete Aprons & Side Walls	IIDR INRE IWSF	Failure of cracked concrete apron slab Consequent failure of check dam & progressive further failures downstream	VH[8] M[12]	H[9] VH[13]	M[10] VH[14]	4. Reconstruct cracked apron slab 5. Condition survey to all protection works after every rainy season 6. Carry out works as identified by	VH[11] VH H	VH H H	VH H H	**I** **R[15]** **R**

								condition survey				
		Bio Engineering and Drainage works on downstream left bank	IIDR INRE IWSF ILE	-Damage or blockage to surface water drainage system -Damage or blockage to sub-surface drainage system	VH[16] H	VH[17] VH	VH[18] VH	3. Carry out detailed condition survey of drainage system 4. Carry out works required as identified by condition survey	H H	VH H	H H	**R[19]** **R[19]**

1. *The detailed condition of the bridge abutments is not known so the threat from increasing flood levels and flash floods is high*
2. *The failure of an abutment would lead to the failure of the bridge*
3. *The failure of the bridge would have serious consequences for the district of Dolakha and adjacent districts for a considerable period of time*
4. *The implementation of regular condition surveys is feasible*
5. *Keeping records of the condition of structures on a regular basis makes it possible to make a judgement of the sensitivity of a structure to extreme events due to CC possible*
6. *The collection of information about the condition of highway structures is high priority as it makes it possible to assess & prioritise maintenance and rehabilitation work*
7. *Condition surveys of bridges and supporting structures should be carried out after every rainy season*
8. *An apron slab upstream of the bridge has cracked badly with water flowing underneath. It is probable that it will fail completely under a relatively small flood*
9. *The failure of the apron slab is of itself not very serious but the consequences may be serious in the event of an extreme flood event*
10. *The significance is not high in the short term but the failure of the apron slab increases the sensitivity of the protection works lower downstream*
11. *The reconstruction of the damaged slab is urgent in order to reduce the likelihood of a cascade of failures if there should be an extreme weather event*
12. *The likelihood of a cascade failure following the failure of the apron slab is not high unless there is an extreme rainfall event*
13. *The consequences of a cascade failure are very high as the stability of the whole system would be in doubt*
14. *The failure of the system would be highly significant for the road link between Kathmandu and Charikot*
15. *Regular monitoring of the condition of the protection works and subsequent necessary repair work will reduce the likelihood of failure of the system*
16. *It is probable that there will be damage to the drainage system under the impact of severe weather events*
17. *A blockage of damage to the drainage system could cause serious damage and erosion to the bio engineering works*
18. *Any damage to the drainage or bio engineering works would increase the possibility of landslides causing damage to the hillside and progressing to damage the road*
19. *Regular monitoring of the condition of the bio engineering works and regular maintenance or rectification of damage will increase the resilience of the system to extreme weather events*

VII **Mugling to Narayanghat Road at Mauri**	**Road cut by landslide**	**Hill slope**	IIDR INRE ILE	The debris behind the check walls have already started to overtop. If further erosion occurs, large amount of debris will move to the road.	H[1]	H[2]	H[3]	Clear the debris	VH[4]	H[5]	VH[6]	**I &R[7]**

CHITWAN		**Gabion check dams**	IIDR INRE ILE	Land erosion has started to occur at several other locations.	H[8]	H[9]	H[10]	Provide check walls, surface and sub-surface drains and bio-engineering at the whole slope.	H[11]	H[12]	H[13]	**S &L[14]**
		Mauri Bridge and Narayanghat - Mugling Road	IIDR INRE ILE	The local people are cultivating at the top of hill slope. With increase in rainfall, more water will penetrate through the cultivated land and will increase the moisture content of the whole slope. This may cause collapse of the road side breast walls.	M[15]	H[16]	H[17]	Encourage the local people to shift the cropping pattern (encourage plantation which require less water).	H[18]	H[19]	H[3]	**S & L[25]**

1. *The debris has already started to overtop the walls at several locations. With further increase of land erosion, large amount of debris will move to the road.*
2. *The event will damage the road and close the traffic.*
3. *As per matrix.*
4. *Removal of debris will be highly feasible in comparison to consequence due to road closure and road repair cost*
5. *It is one of the effective methods to prevent the debris movement.*
6. *As per adaption priority matrix.*
7. *The works should be carried out immediately and on regular basis.*
8. *Due to loose slope there is high probability of land erosion at new areas.*
9. *The land erosion could be serious if controlling measures are not adopted timely.*
10. *As per adaption priority matrix.*
11. *The measure will be feasible in a longer period.*
12. *It is highly effective method and is being adopted at several landslide prone areas of the country.*
13. *As per matrix*
14. *The whole works may take long period.*
15. *The quality of road side breast walls is good and hence they may collapse only if the pore pressure increases substantially.*
16. *The road will closed for few hours/days depending upon the magnitude of slope failure. The reconstruction cost of the wall will be high.*
17. *As per matrix*
18. *This could be highly feasible if the local people are convinced.*
19. *It will protect from large scale damage*

20. As per matrix
21. These works should be started immediately but it may take long period.

ANNEX V: LIST OF GOVERNMENT OFFICIALS PARTICIPATING IN TIFFIN TALK & ROUND TABLE MEETINGS

No.	Name	Position/Organization
1	Mr. Arjun Jung Thapa	DDG, Planning
2	Mr. Keshab K. Sharma	DDG, DoR
3	Er. Meera Joshi	Environmental Expert, DoR
4	Ms. Pramila Bajracharya	Project Co ordinator/ RIP
5	Mr. Ganesh Kumar Gautam	SDE, BP,DoR
6	Mr. Rakesh Maharjan	Engineer. DoR
7	Mr. Ajaya Muli	Project Co-ordinator
8	Mr. Rabi Bhushan Jha	MD, BEAM consultant
9	Mr. Shyam Bikram	SDE, DoR
10	MR. Umesh B. Shrestha	SDE, DoR
11	Mr. Ghan Shyam Gautam	Unit Chief, RSSDU, DoR
12	Mr. Krishna B. Thapa	Engineer, RTU, DoR
13	Mr. Purna Shrestha	SDE, DoR
14	Mr. Shiva Raj Adhiakri	SDE, DoR
15	Mr. Naresh Shakya	SDE,DoR
16	Mr. Bijendra Bade Shrestha	SDE, DoR
17	Mr. Akhanda Sharma	SDE, MoSTE
18	Mr. Dipak Shrestha	SDE, BP, DoR
19	Mr. Shiva Prasad Nepal	SDE, DoR
20	Mr.Ghana Shyam Gautam	SDE, DoR

No.	Name	Position/Organization
21	Mr. Shuva Raj Neupane	Engineer , DoR
22	Mr. Ghana Shyam Gautam	SDE, DoR
23	Mr. Laxmi Datta Bhatta	SDE, Dotr
24	Mr. Niranjan Thapa	Engineer, DoR
25	Mr. Shiva Prasad Nepal	SDE, DoR
26	Mr. Shuva Raj Neupane	Engineer, DoR

ANNEX VI: ISSUES RAISED AT 22/23 SEP WORKSHOP WITH RESPONSES

Issues raised in Sept 22 - 23 presentation (DoR/DOLIDAR)

Raised by	Issues	Response
Mr. ……Shah, SE, DUDBC	At several roads of Kathmandu City, traffic is disturbed due to excessive accumulation of water or for any other reasons. Can some system be installed so that the road users could get the information beforehand?	Traffic management is the responsibility of the Department of Transport and Kathmandu Traffic Police
Mr. Akhanda Sharma, NPM	Condition of assts is explained using parameters such as exposure, sensitivity, likelihood etc and their degree (VH, H, M, L and VL). The consultants need to discuss in detail with the related departments to agree on using the above terminology for VA and AP.	The relative values of the parameters used in the VA & AP assessments are part of the ongoing discussions with DoR and DoLIDAR
	Effect of CC will not be same for road pavement, retaining wall, bridge etc. Hence they should be dealt separately.	The VA & AP analysis should be carried out for all the different elements in the Strategic and Rural Road Networks
	Bridge sector should be addressed separately.	Agreed.
	Synthesis Report does not include the effect of CC on snowfall, fog, visibility etc.	The Climate Threat Profiles do not provide sufficient information for these effects to be included in the threat analysis
	Planning/developing training package should be provided in detail.	Training packages/modules are part of the next phase of the Project
Mr. Madan Manandhar, Director, METCON	Social aspects are missing in VA and AP.	Social vulnerabilities will be addressed for relevant assets
Mr. Suraj Pokharel, DG, Department of Environment	Can we prepare separate typical design of structures considering CC effect?	As the threats from CC become more accurately defined so designs can be modified to make structures more resilient

ANNEX VII: BIBLIOGRAPHY

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