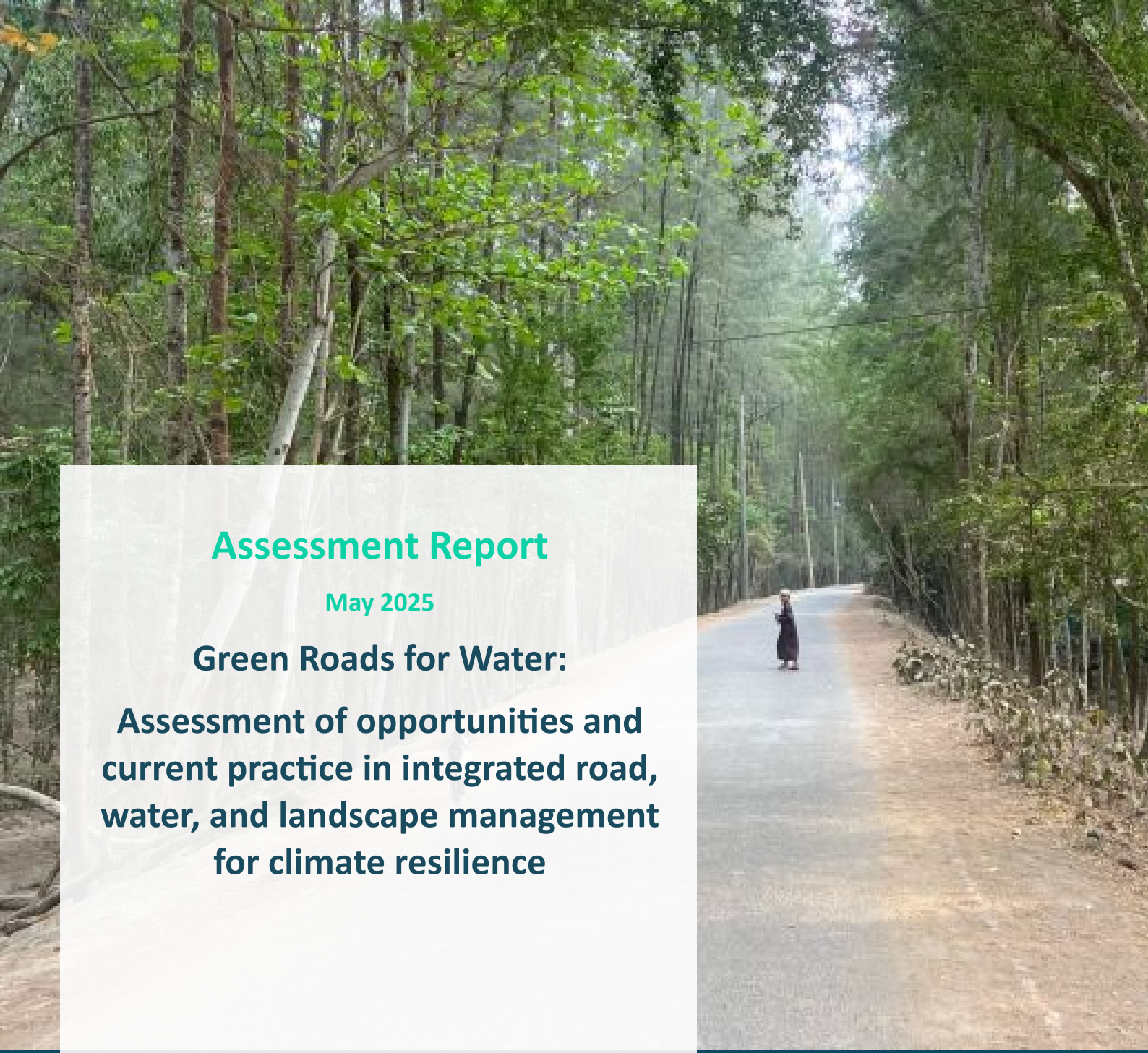

Assessment Report

May 2025

Green Roads for Water:

Assessment of opportunities and current practice in integrated road, water, and landscape management for climate resilience

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Overview

This report is prepared as part of the "***Consultancy Services for Increasing Resilience of Rural Infrastructure and Local Communities through Green Roads Concept***". This assignment is undertaken for the Local Government Engineering Department (LGED) in Bangladesh and the World Bank, and aims to set the foundation for systematically integrating water management and climate resilience in road development. This assessment serves as the main input for the forthcoming country-specific Guidance Note on Green Roads for Water.

The report explores the opportunities with LGED to systematically make roads instruments of water management in different parts of the country whilst at the same time preserving and even improving the transport functions of roads, by embracing the concept of **Green Roads for Water (GR4W)**. The report provides a comprehensive assessment of how rural roads can be leveraged for integrated water and landscape management to strengthen climate resilience. The report elaborates on the benefits of integrating water management functions with road infrastructure:

1. It will create productive water-related assets, supporting agriculture, forestry and fish production and enhancing flood resilience.
2. It will reduce damage to local areas and water bodies, in particular reduce water logging.
3. It will reduce maintenance costs and down-time of roads.

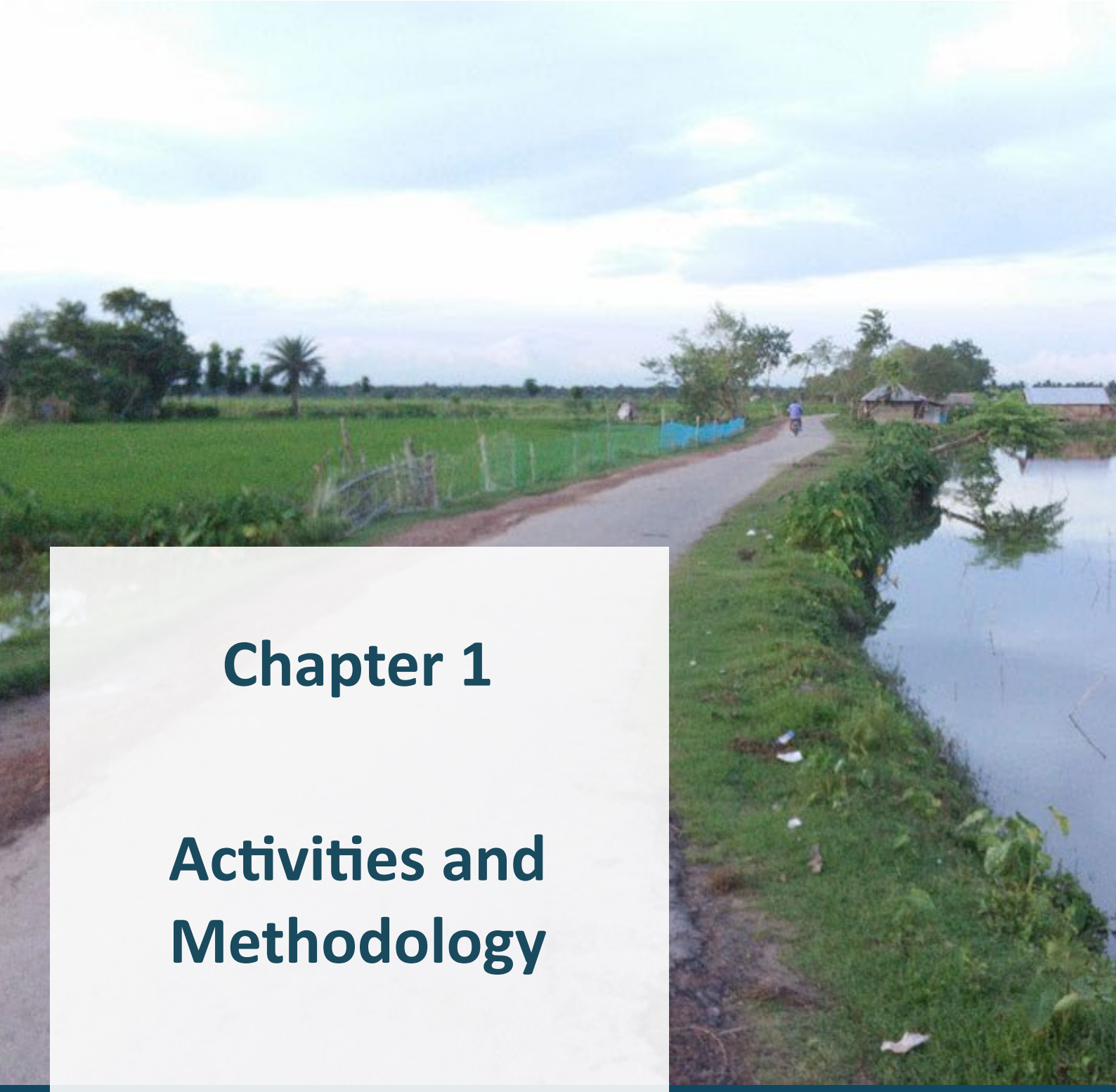
The present report builds on the earlier prepared and reviewed assessment report. This was based, amongst others, on field visits to five different hotspot areas in Bangladesh and local consultations and workshops. The current report is further elaborated with new findings, literature reviews and detailed analysis.

The report first describes the approach and methods used in the assessment of LGED's current road, water and landscape management and climate resilient practices (Chapter 1). Chapter 2 subsequently concentrates on current procedures in road planning, construction, budgeting, and the involvement of labour contracting societies (LCS) and summarizes the observations to improve these working methods.

In Chapter 3, the general elements of road development are addressed, and the opportunities to improve water management functions therein. It discusses road networks, road embankments/shoulders, roadside vegetation, cross drainage, bridges, and pavement and construction materials.

Chapter 4 dives into the specific situations for the five geographical zones in Bangladesh: (1) the Coastal Zone, (2) the Barind and Drought Prone Areas, (3) the Haor and Flash Flood Areas, (4) the Chattogram Hill Tracts, and (5) the Flood Plains and Estuaries. These zones coincide with the hotspot areas of the Bangladesh Delta Plan. This way, the scope for Green Roads for Water activities in the different parts of the country are discussed with each zone having unique challenges and opportunities.

The report ends with a discussion of the next steps in the development of the country specific Guidance Note for Green Roads for Water (Chapter 5). The annexes bring together the base material for the assessment, in particular an overview of the meetings, consultations and workshops that have taken place for the assessment (Annex 1), the deep dive guide used in the field visits (Annex 2), the area specific assessments (Annex 3), the policy and document review (Annex 4) and a number of case studies/blogs (Annex 5). The annexes also include components for the next outputs of the assignment – for review and feedback: initial generic road cross-sections (Annex 6), the template for the roadside forestry component of the guidance note (Annex 7) and examples for training material development (Annex 8).



Chapter 1

Activities and Methodology

1 Activities and methodology

1.1 Background and objective of the study

Rural roads in Bangladesh are of critical importance for the growth of Bangladesh's rural and national economy and for the welfare of its citizens. However, besides connecting people and places, roads also fragment the landscape and interrupt the natural flow of water – which is pivotal to consider everywhere, but especially in a riverine deltaic country such as Bangladesh, with numerous crisscrossing rivers and canals and discharging huge water and sediments. Currently, the impact of roads on area hydrology is an often-neglected aspect of road design in Bangladesh.

In Bangladesh, however, there are few interventions that have such an impact on water management as the construction of roads. Whereas Bangladesh has one of the highest population densities, it also has one of the highest road densities in the world – at 164 meters per square kilometre[1]. At present, the effect of roads on water management is often negative. Road construction undermines local water management: roads may, for instance, cause water logging, uncontrolled flooding, accelerated erosion or the silting of tidal rivers. Road infrastructure in Bangladesh currently frequently impedes the flow of flood water, drainage and creates waterlogging, affecting land use and the soil's capacity to absorb rain during high rainfall and flood events. Those issues are currently being dealt with, but suboptimal – as cross-drainage structures are often insufficient or too narrow, bridge sills are too high, and borrow pits are neglected as possible stormwater storages. These negative impacts, however, can be avoided, and instead, positive impacts can be created with roads.

Currently, major opportunities in connecting roads and water management are being missed, leading to a variety of problems in different regions of Bangladesh, including substantial drainage-related problems and higher flood risks. There is considerable scope for an integrated approach in which roads can become instruments for water management and flood/climate resilience by using the **"Green Roads for Water"** concept. Combining road development with water management has a great potential to bring multiple benefits, including less waterlogging, less road damage and improved access to facilities, improved agricultural and aquacultural production, more comprehensive watershed management, and improved livelihood opportunities for local communities. It should be noted that Green Roads for Water is not just about interventions on the road itself.

The approach encompasses interventions on both sides of the road, upstream and downstream, as well as within the broader landscape of which the road is a constituent part. With this concept, we consider not only the road itself but also the people, landscape characteristics, and assets in its vicinity. These include natural and physical features such as roadside tree planting, converted borrow pits, storage ponds, and water diversion structures, as well as socio-economic elements like roadside agricultural fields and ghers, roadside businesses and facilities, and livelihoods tied to activities near roads. Central to the integrated approach of the Green Roads for Water concept is local participation, where the voices of roadside communities and the priorities of local governments inform and shape road development and maintenance.

In 2021, the World Bank published Green Roads for Water guidelines (van Steenbergen et al., 2021), which provide strategies to use roads for beneficial water management tailored to diverse landscapes and climates, including watershed areas, semiarid climates, coastal lowlands, mountainous areas, and floodplain. In this assignment, those guidelines are taken to the next level with more detailed

[1] *Asian Transport Observatory (2024), Asian Development Bank (https://asiantransportobservatory.com/)*

guidelines for the local circumstances in Bangladesh. The current study, funded by World Bank, started on March 07, 2025, and is foreseen to conclude by June 30, 2025.

In line with this background, the **goal** of this assignment is to provide technical advice and capacity strengthening to the LGED on the implementation of the green roads for water concept and, overall, nature-based solutions (NBS) for the purpose of the integration of climate change adaptation and resilience in rural roads and water management in Bangladesh's rural areas. It is aimed to build knowledge on integrating climate change adaptation, NBS and water management in the design, construction and maintenance of rural roads and bridges in Bangladesh.

In line with this overarching goal, the assignment has three distinct specific **objectives**. These objectives are to be achieved following the implementation of GR4W and NBS in LGED and following capacity strengthening within LGED.

1. Reducing damage to rural road infrastructure (including bridges, culverts, embankments and other structures) and provide a cost-effective approach to address the effects of climate change;
2. Reducing direct and indirect damage due to flooding, limited drainage capacity, erosion, sedimentation, among others, in the surrounding areas of rural roads;
3. Suggesting innovative use of assets for water harvesting and increased flood protection to mitigate risks to rural roads.

Capacity strengthening is omnipresent within the assignment, contributing to mainstreaming the use of the green roads for water concept and nature-based solutions to strengthen the climate resilience of rural road infrastructure and local communities living along rural roads. Overall, this assignment will bring a major contribution to climate resilience in Bangladesh - not only for the road infrastructure, but also for the surrounding areas as well. Equipping the extensive road network that LGED is the custodian of with Green Roads for Water measures will have a massive impact on climate resilience in Bangladesh, as LGED roads penetrate even the remotest part of the country.

1.2 Overview of the road network and types of roads

Bangladesh has roughly 442,401 km of total road length network, with an average road length of approximately 0,13 meters/capita (Table 2) – indicating the possible massive contribution of Green Roads for Water to climate resilience in the country. The different types of roads in Bangladesh, their definition, and the ownership and responsibility are outlined in Table 1 below.

Table 1 Road Network Classification with Definition (Source: Planning Guidelines for Rural Road Master Plan, LGED GIS Unit, 2010)

#	Type	Definition	Ownership and responsibility
1	National Highway	Highways connecting National capital with Divisional HQs or sea ports or land ports or Asian Highway	RHD (Roads and Highways Department)
2	Regional Highway	Highways connecting District HQs or main river or land ports or with each other not connected by national Highways.	RHD
3	Zila Road	Roads connecting District HQ/s with Upazila HQ/s or connecting one Upazila HQ to another Upazila HQ by a single main connection with National/Regional Highway, through shortest distance/ route.	RHD
4	Upazila Road (UZR)	Roads connecting Upazila HQ/s with Growth Center/s or one Growth Center with another Growth Center by a single main connection or connecting Growth Center to Higher Road System, through shortest distance/route. (Former Feeder Road Type-B)	LGED/LGI
5	Union Road (UNR)	Roads connecting union HQ/s with Upazila HQs, Growth Centers or local markets or with each other. (Former Rural Road Class-1 (R1)	LGED/LGI

6	Village Road (VR)	a) Roads connecting Villages with Union HQs, local markets, farms and ghats or with each other. (Former Rural Road Class-2 (R2) b) Roads within a Village. (Former Rural Road Class-3 (R3)	LGED/LGI

Most roads are rural roads (94%). 9.5% of the rural road network comprises Upazila Roads and 11.2% comprises Union Roads[2]. There are 164.81 km of culverts and bridges[3]. According to the latest updates of the Asian Transport Observatory[4], which is continuously being updated collection of national-level indicators on the transport sector of Asia and the Pacific, the majority of Bangladesh's roads (63%) are unpaved, with a smaller part (37 %) paved (figures from 2017). In Table 2, some of the main parameters from the Asian Transport Outlook are given.

Bangladesh has made progress in improving rural accessibility, with a rural access index of 77.3% in 2019. This indicates the portion of the population that lives within 2 kilometres of an all-weather road. It is understood that with the road network being already dense, the priority in Bangladesh is on upgrading existing (unpaved) roads rather than constructing new roads.

Most of the unpaved roads in the country are in rural areas, resulting in urban and rural gap in access to services (ADB, 2020) and a long traveling time (ranging from 60 to 120 minutes) to cities by the population (see Table 2). This affects the healthcare system by limiting the accessibility of medical staff, emergency services, and the delivery of medical supplies (Aliyev, 2020).

Road safety is also a severe issue and has therefore even been integrated within the United Nations (UN) Sustainable Development Goals (SDG) – specifically, SDG 3 Good Health and Wellbeing, which includes a target of reducing road fatalities and serious injuries by 50% by 2030. Universal principles of standards setting, compliance, and accountability are essential to supporting the safety of the communities living on Bangladesh's rural roads (World Bank, 2023). The Rural Road Safety Action Plan 2023-30 emphasises the need for a "safe system" approach that rests on three simple ideas: 1) Death and serious injury are ethically unacceptable outcomes of road use, 2) The road traffic system should prevent crashes in the first place, and protect users from injury if a crash does occur, 3) There are physical limits to the forces which the human body can sustain without severe casualty. This Rural Road Safety Action Plan focuses particularly on the safety needs of vulnerable road users – the old and the young, pedestrians, bicyclists, and other low powered vehicles plying Bangladesh's rural roads.

Unfortunately, the estimated rate of road fatalities in Bangladesh per 100,000 population has been increasing over the past decade, reaching 15.3 in 2019 because of poor road conditions, reckless driving, and inadequate signage, especially in the rural areas (Table 2), making the Rural Road Safety Action Plan 2023-30 a very timely and relevant matter.

Table 2 Bangladesh Road Infrastructure/Access & Connectivity/Safety Status from the Asian Transport Outlook Database[5]

Indicator Name	Indicator Code	Indicator Sources	Value/Years			
			2015	2017	2019	2020
Road Length Total	INF-TTI-005(9)	International Road Federation (IRF)	372443 km	375427 km	416311 km	442401 km

[2] As per LGED's latest data provided.
[3] As per LGED website information.
[4] Asian Transport Observatory (2024), Asian Development Bank (https://asiantransportobservatory.com/)
[5] It should be noted that this overview includes data from both roads from LGED and RHD, and that the data provided therefore may not always reflect the rural context.

Road Density	INF-TTI-008(5)	Country Official Statistics	164 meters / km^2	164 meters / km^2	N/A	N/A
Road Length/ Capita	INF-TTI-009(5)		0,13 meters / capita	0,134 meters / capita	N/A	N/A
Paved Road	INF-TTI-010(3)	International Road Federation (IRF)	33.46 %	36.66 %	N/A	N/A
Unpaved Road	INF-TTI-011(3)		66.54 %	63.34 %	N/A	N/A
Road Quality (Perception)	INF-TTI-012	World Economic Forum (WEF)	2.8823 Value (1-7)	3,07 Value (1-7)	3,22 Value (1-7)	N/A
Rural Access Index	ACC-RAC-001(2)	World Bank (WB)	N/A	N/A	77,3 %	N/A
Travel time to cities by population	ACC-UAC-001	D.J Weiss et al.	60 mins by 98.1 % 90mins by 99.3 % 120mins by 99.5 %	N/A	N/A	N/A
Healthcare Accessibility	ACC-NRC-001	D.J Weiss et al.	N/A	N/A	Driving for 30 mins by 7.77 % Driving for 60 mins by 1.4 %	N/A
Road Connectivity Index	ACC-NRC-004	World Economic Forum (WEF)	N/A	N/A	54,47 out of the score of 100	N/A
Road Traffic Crash Fatalities	RSA-RSI-001(1)	World Health Organization (WHO)	N/A	15.6 deaths per 100,000 population	15.3 deaths per 100,000 population	N/A

1.3 Methodology

The overall methodology of the assignment and its associated activities are described in this chapter. It has been divided into four work packages, which are: A) Inception, B) Review of practice and theory, C) Guideline development, and D) Training of Trainers to CReLIC. This report is the outcome of the work package B, as outlined also in Figure 1 below.

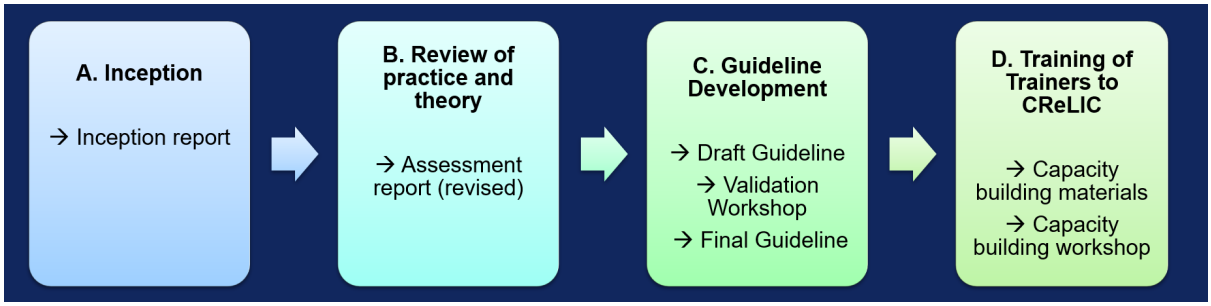


Figure 1 Work packages and deliverables as outlined in the inception report, guiding the execution of the project

By executing the methodology, we take stock of current challenges and improved practices in Bangladesh, validate these in stakeholder meetings and expert discussion and translate these in guidance notes but also in recommendations for changes in standard documents such as BOQs and adjustments to existing guidelines. This way, we will for the first time ever comprehensively bring together the main binding climate resilience practices for the road sector and suggest adjustments to closely related regulations and practices. The current report describes the first two steps in the assignment, serving as the basis for the third and fourth step. The methodology is elaborated upon below.

The assignment builds on the earlier developed and reviewed assessment report, assessing current policies, regulations, and practices in Bangladesh related to road infrastructure and climate resilience. A review of key documents, provided by LGED, CReLIC, and partly available online, was pivotal in this regard, and will be conducted iteratively in the development of the guidelines as more documents will be shared and reviewed. Those documents, together with stakeholder consultations, interviews with key experts, and validation field visits, bring the main issues and challenges to the surface, as well as the current recommended practices.

The **validation field visits**, to be conducted in May 2025, will follow up on the already conducted deep dive field visits in the Coastal Zone, Barind and Drought Prone Areas, Haor and Flash Flood Areas, Chattogram Hill Tracts, and Rivers Systems and Estuaries. These regions each have to deal with different water and climate resilience challenges, which are elaborated upon in this report. In each region, several districts and LGED offices have been visited to make an inventory of the challenges and practices in road building and road maintenance. Specific districts and road stretches to be transect-surveyed were decided upon in consultation with LGED engineers from the respective districts. The deep dives were also used to solicit stakeholder opinions and experiences related to green roads for water, nature-based solutions, and roadside tree planting. Specific attention was paid to, amongst others, the deterioration and failure analysis of roads due to the effect of various localized climate-induced disasters. In Annex 4, the deep dive guide is provided, which has been used to conduct surveys of the roads and solicit opinions and views. More engagements, with LGED, Forestry Department, BWDB, and others are foreseen in the near future, to better understand current practice in road planning/development and road asset management, cooperation between departments, good and bad experiences, application and applicability of guidelines and policies.

Between the start of the project and the submission of this report, several meetings have taken place, apart from the weekly MetaMeta-ADSL team meetings. Prior to the confirmation of Mr. Sabur as focal person in LGED on 9 April 2025, the team has kept in close contact with World Bank. The team has organised a joint meeting with LGED and World Bank on 15 April 2025, to discuss approaches, methods, timelines, collaborations and expectations. These engagements will intensify in the coming months, with in-person engagements in Dhaka and in the validation field visits.

1.4 Rethinking roads for DRR

Bangladesh is among the most vulnerable countries to climate change. According to the Global Climate Risk Index 2020, it ranked seventh globally in terms of climate impact during the period 2000–2019[6]. The country incurs estimated average annual disaster-related losses of around US$3 billion, equivalent to approximately 1–2% of its GDP[7]. By mid-century, climate change is likely to cost Bangladesh a further 2% of GDP on top of its baseline losses to climate hazards, a figure which potentially rises to 9% of GDP by the end of the century if mitigation action is not increased[8]. According to the GCA's national infrastructure stress test of Bangladesh, 95% of the road network is exposed to at least one type of climate hazard

The country is highly exposed to extreme weather events, including cyclones, floods, storm surges, and both coastal and riverine erosion. These climate-related disasters threaten to derail economic and social progress, particularly in rural areas.

Rural roads play a critical role in disaster preparedness, response, and recovery. They function as lifelines, enabling safe evacuation, facilitating the delivery of emergency services, and supporting the distribution of relief aid. However, rural road infrastructure is particularly vulnerable to the impacts of natural disasters. Flooding, flash floods in plains, landslides in hilly regions, and cyclones in coastal areas can wash out or severely damage road embankments and surfaces. This damage often cuts off access to markets, schools, and healthcare facilities, forcing rural communities to adopt coping strategies—such as selling land and assets[9]—that deepen their vulnerability and reduce resilience.

During and after disasters, rural roads become not only unpassable and unreliable, but even dangerous for rural people who try to use them as shelters from flooding or flashfloods or to seek social and economic recovery assistance in the aftermath of disasters. Other damages to rural roads during natural disasters include damages of concrete structures due to increased salinity in coastal districts, intense rainfall damaging road surface and side slopes due to rain cuts and wave actions (especially in Haor area), increased temperature leading to weakening of asphalt surface, and the falling of trees/branches on road and thus blocking transportation or rescue efforts during heavy rain or cyclone.

To improve resilience, road infrastructure planning must go beyond pavement and surface design. Other key considerations include the underlying embankment, provision of sufficient openings for passage of water through bridges and other structures to manage high water level and floods, the management and maintenance of road embankments, the management of borrow pits, and the multifunctional use of road environments—for instance, planting fruit- or timber-producing trees, vegetables, or medicinal plants on embankment slopes, and utilizing borrow pits as retention ponds for aquaculture, irrigation, or farming.

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[6] *Global Climate Risk Index 2020. Germanwatch. https://germanwatch.org/sites/germanwatch.org/files/20-2-01e%20Global%20Climate%20Risk%20Index%202020_14.pdf*

[7] *UNISDR (2014). PreventionWeb: Basic country statistics and indicators. URL: www.preventionweb.net/countries*

[8] *Ahmed, M., Suphachalasai, S. (2014). Assessing the costs of climate change and adaptation in South Asia. ADB.*

[9] *USAID/Bangladesh Comprehensive Risk and Resilience Assessment. September 2016. https://www.usaid.gov/sites/default/files/documents/1861/BNG_resilience_assessment_report_4Apr2017_final.pdf*

The strategic planning and construction of road infrastructure can significantly enhance disaster resilience, particularly in areas prone to floods, where proper drainage can mitigate water-related hazards. In the deep dive fields visits, it has been indicated by multiple LGED engineers that the increasing frequency of natural disasters further increases the need for climate-resilient infrastructure.

In coastal regions, roads can serve dual purposes by acting as protective embankments—if properly designed and managed. Raised roadways can function as flood barriers or cyclone shelters, and integrated drainage systems can help mitigate related risks. A systematic, integrated approach to road planning and design offers a cost-effective pathway to enhance both flood resilience and agricultural productivity, while also extending the operational lifespan of the infrastructure.

1.5 Integrating Locally Led Adaptation into road developments

Over the last two decades, the Bangladesh government's focus on national climate change adaptation policies has gradually shifted from 'community engagement' to 'enhancing community resilience and promoting local leadership', paving the path for the integration of Locally Led Adaptation into the day-to-day reality. This also applies to the road sector. In this regard, it is worth noting that the National Adaptation Plan (2023-2050) (2022), elaborates on the need to acknowledge Locally Led Adaptation as essential to catalyze effective, equitable, and transparent adaptation solutions based on local priorities and realities.

When road developments are tailored to these local priorities and realities, including bio-physical and socio-economic circumstance, the benefits gained by road development – particularly when embracing Green Roads for Water – have the potential to go far beyond transport-related benefits. Hence, engaging communities living in the hinterland in planning, design, and even O&M of roads, can have far-reaching knock-on effects in various sectors. This way, one will not only maximize benefits such as improved mobility and access to essential services but also enhancing water management by better managing road runoff and making it available for various purposes, such as agriculture and groundwater recharge.

1.6 Capturing the gains of Green Roads for Water in different areas in Bangladesh

The table below (Table 3) is a snapshot of the priority practices as they emerged from the field assessment and the document review, for the different zones in Bangladesh. In the upcoming field visits we will further validate and assess priority improvements in planning and design. In the subsequent chapters, we respectively discuss the observation on improved procedures, adjustments to the designs and the priorities for each of the five zones in Bangladesh.

The different zones have different water management challenges, mainly depending on their geographical, hydrological, and land use features, as also described in the National Adaptation Plan. These are often related to the climate stresses, as outlined in Figure 2.

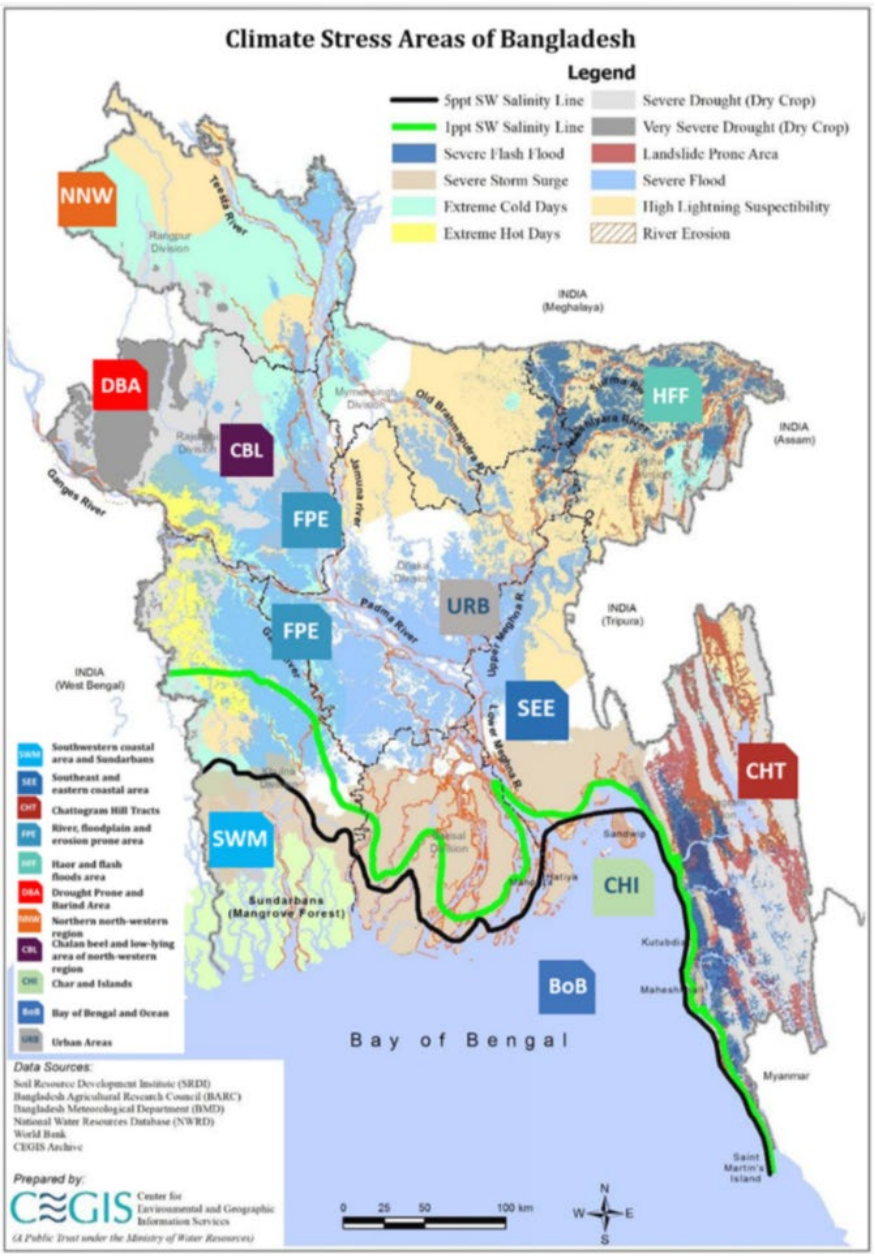


Figure 2 Climate Stress Areas of Bangladesh (National Adaptation Plan, 2022)

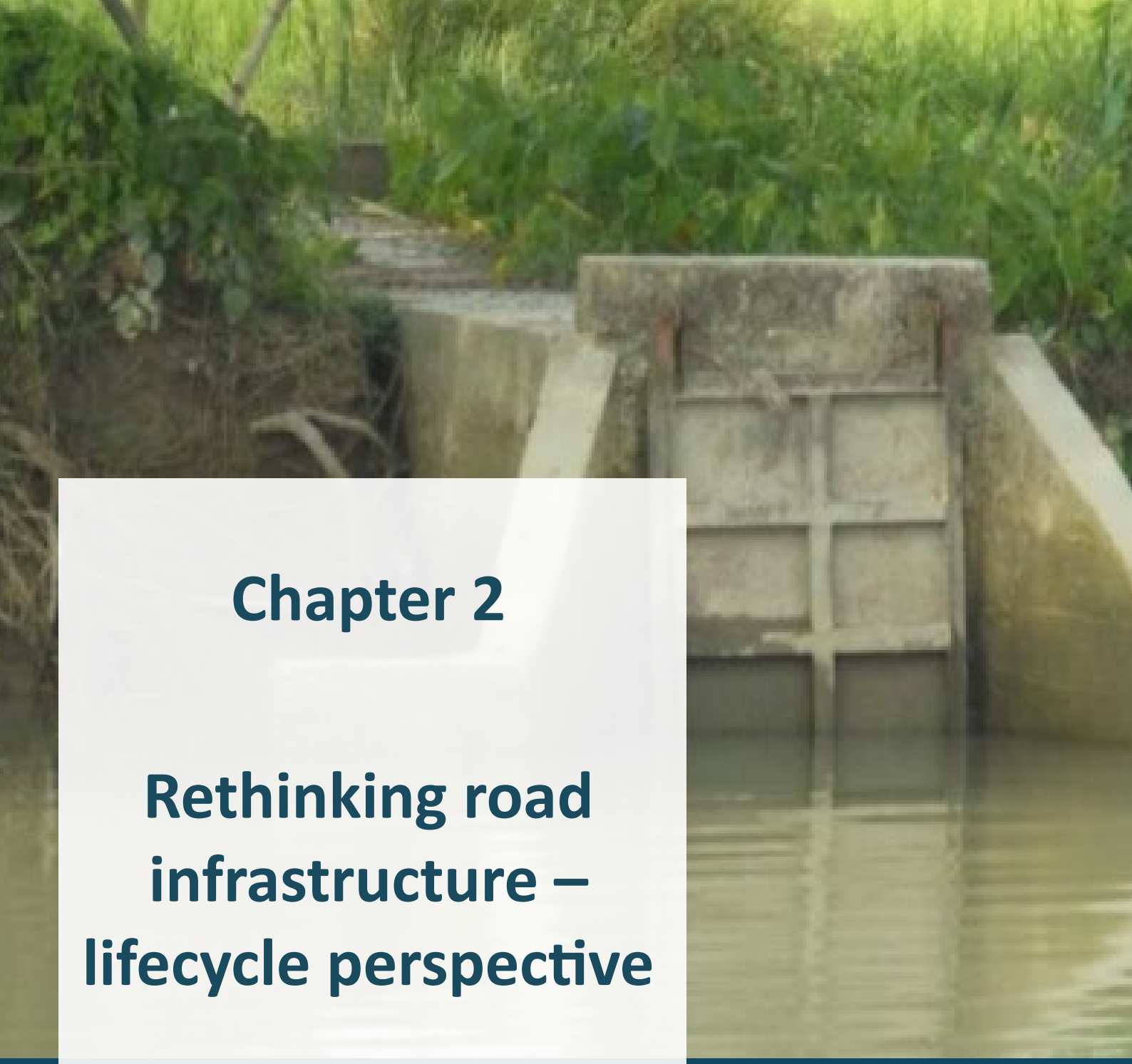
To start with, the Coastal Zone suffers from river floods, siltation of rivers, water logging, increasing salinity, rising sea levels, and storm surges. Also, riverbank erosion and rainfall variability (including droughts) put livelihoods in the region under pressure. The Barind and Drought Prone Areas suffer from drought, but also increasingly from heatwaves and periods of extreme colds, as also flash floods. The Haors and Flash Flood Areas have to deal with increasing rainfall and discharge variability, as well as erosion and cyclonic storm surges. The Chattogram Hill Tracts, on the other hand, have to deal with severe erosion and landslides induced by rainfall variability and flash floods. Lastly, the River Systems and Estuaries have to deal with, amongst other things, river floods, storm surges, rainfall, and discharge variability. At Chars and Islands, in the River Systems and Estuaries zone, the severe erosion, further challenges water management and livelihoods in general. Addressing the water management challenges can result in significant water management gains, summarised in Table 3.

Table 3 Zone and water management gains

Zone	Water management gains
1. Coastal zone	- Improved flood protection - Water level control for agriculture - Avoid siltation of tidal rivers - Avoid water logging - Road-side vegetation for multiple uses
2. Barind and Drought Prone Areas	- Water retention and harvesting - Road-side vegetation for multiple uses
3. Haors and Flash Flood Areas	- Controlled flood recession - Improved flood preparedness - Improved/ protected fish movement - Road-side vegetation for multiple uses
4. Chattogram Hill Tracts	- Water retention and harvesting - Slope protection - Road-side vegetation for multiple uses
5. River Systems and Estuaries	- Flood management/compartmentalization - Improved flood preparedness - Improved/ protected fish movement - Road-side vegetation for multiple uses

For the gains to materialize, adjustments are required in the designs of roads by LGED, as well as retrofitting on existing roads and revitalization of the road-side vegetation programs. The introduction of GR4W would also benefit from modification in the way road programs are implemented and managed.

This assessment report subsequently discusses (1) preferred adjustment in current planning, budgeting, and implementation procedures – see chapter 2; (2) suggested adjustment to main features of the road systems so as to optimize water management and reduce damage (chapter 3); and (3) opportunities for introducing Green Roads for Water in different parts of Bangladesh (chapter 4).



Chapter 2

Rethinking road infrastructure – lifecycle perspective

2. Rethinking road infrastructure – lifecycle perspective

Apart from developing better practices in the different zones of Bangladesh, there is also a need to reconsider the road planning and construction processes. A lifecycle perspective is recommended, whereby:

- The total functionality of the roads is taken into consideration, including the effect of roads on the landscape of which they are part and vice versa.
- Decisions are not made piece-meal but are based on the total life-cycle of the road, including after care and asset management – with investment decisions optimizing the costs and benefits of the road over the entire lifetime of the road.

In the current road-building processes, there is often little attention to the multiple benefits of roads beyond the primary transport function. Related to this, there is often insufficient coordination with other sectors, including with the organizations with mandates in water management.

In addition, there are also several administrative practices that stand in the way of optimizing the beneficial use of roads for water management or that may even cause negative effects. There is scope to improve the procedures and working methods in:

- Planning and budgeting (section 2.1)
- Preparation and implementation (section 2.2)
- Coordination with others (section 2.3)
- Aftercare and asset management (section 2.4)

As part of the assessment current procedures and working methods were reviewed. Improvements were identified, discussed below.

2.1 Improving processes in planning and budgeting

The following changes were assessed to improve the planning and development of new roads.

Planning roads with due cognizance of the natural topography and hydrology. When roads are planned, including smaller roads and paths, the local topography should be observed. Large parts of Bangladesh have very low gradients. In these areas roads are very vulnerable to floods – as e.g. demonstrated in Figure 3 for RHD roads. At the same time, the roads can be used to manage the floods.

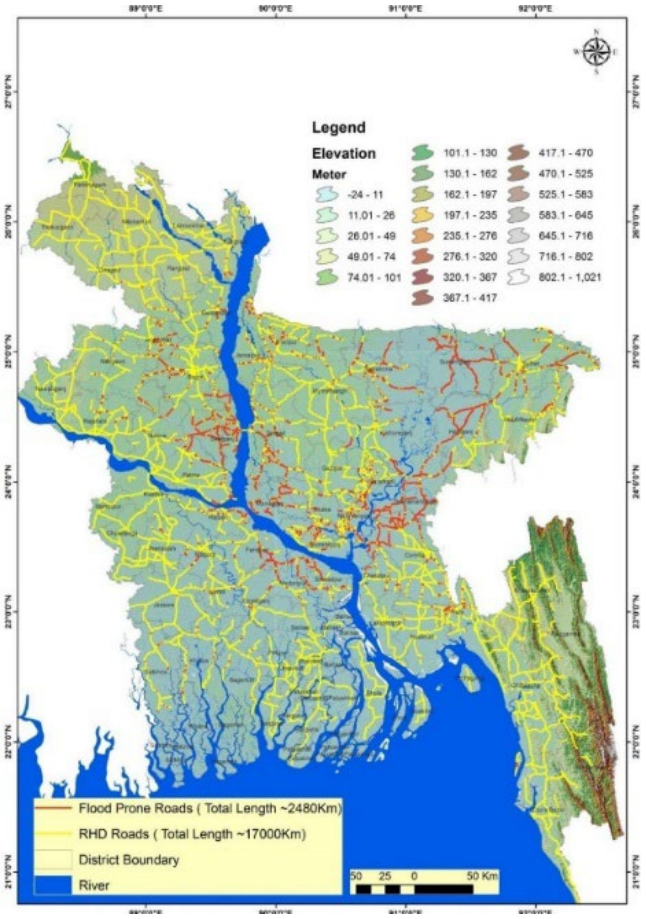


Figure 3 Flood vulnerability of roads of Bangladesh with respect to elevation (Mamun et al., 2017)

It is, hence, important to plan the roads so that they can for instance compartmentalize areas, which helps in flood management, or follow the contours so that roads and (gated) culverts can help the water level management. The same is true in the haors where even slightly elevated submersible roads can help to control flood recession and contribute to prolonged soil moisture. The compartmentalization at different levels can also help to slow peak rainfall runoff by storing it behind the road embankments before it overflows onto the next stretch of land. Modelling and survey tools, as elaborated upon in Box 1, can also be helpful in here. This process slows the velocity of water, reduces erosion and siltation, and leads to more groundwater recharge, and can ensure that areas that areas that need to remain dry, remain dry. Water can be retained longer in relatively higher areas that may serve as storage for lower areas or be used for the cultivation of rice or for aquaculture in the wet season. It should be noted that overflow of water over an embankment may cause scouring and erosion. In these circumstance, controlled overflows from a designated overflow point and controlled cross-drainage structures are recommended. An elaboration on flood modelling is provided in Box 1.

Make use of opportunities in land use planning. Ideally the development of roads is part of land and water use planning. In several projects this process has started for instance in the development of polder plans under several programs[10]. The interest in such local and spatial plans was positive as it allowed a larger perspective to be developed and shared by different parties operating in the same area. It would for instance ensure road development and upgrading aligns with topography and hydrology.

There are also legal openings. Flood control zone can be specified by referring to the boundaries of the mouza (village) map. Delineation of flood-free zones is of utmost importance in planning the road network. According to Article 25 of the Bangladesh Water Act, the Economic Commission may *declare any wetland as a flood control zone to ensure easy passage of the flow of flood water. To protect flood control zones, the Executive Committee may impose prohibitions or conditions on any activity that obstructs or diverts the water flow through such zones.* The BWDB should delineate this flood-free zone and this should be aligned in the planning/upgrading of road networks.

Current practice is that land grabbing and encroachment in the flood-free zones are a constant threat in Bangladesh, and land zoning is affected by this. Though there are several provisions that make it possible to start the process, further commitment/enforcement from the national government would be helpful.

Construct all roads with cross drainage from the beginning. A practice was observed whereby roads are constructed without (sufficient) cross drainage in the first place – sometimes caused by funding constraints.

The next step is then to wait for problems to occur, which may then be solved subsequently by the placement of culverts and bridges that were omitted earlier. It is understood that this is done as the initial budget may not suffice for the investment in the new road and cross drainage structures. However, in the meantime, huge losses are incurred to the adjacent farms as the land becomes waterlogged. This loss is a multiple of the investment in the delayed cross drainage. It is recommended to always construct all roads with cross drainage from the beginning. It is also recommended to prioritize investment in improved cross drainage over the construction or upgrading of roads.

[10] As for instance in the Blue Gold Programme, that ran till 2021.

Figure 4 Damage to road (left) and inadequate construction material (right)

Mainstream roadside vegetation. The benefits of roadside vegetation are multiple if done well (see Chapter 3). These benefits concern the stabilization of the road shoulders, their productive use, road safety, pollution control, improved local climate and the management of biodiversity. Chapter 3 also discusses negative effects of unplanned roadside plantation, including road safety, moisturising, and shading of pavement.

Figure 5 Road side vegetation on the shoulders of the road

At present, a rough estimate is that 30% of the rural roads are forested, whereas the others are barren. This proportion should go up, and special programs may be started along existing roads. Whereas in the major roads, owned by the RHD, the road verges are owned by the RHD, this is not the case with the roads under LGED. It is a precondition that ownership and community management of the rural roads are addressed, making use of the Social Forestry Rules. It is recommended to build in adequate time in road planning to secure the roadside verges for common beneficial use and to sharpen the guidelines on roadside vegetation.

Changing the choices in construction material. When considering climate resilience and improved water management in a more holistic manner, it should also be considered that roads have an enormous footprint in the extraction of construction materials, equivalent to 30-40% of all construction materials[11]. In Asia, in fact, the demand for construction materials increased by 64% over the last decade, whereas globally, this was 17%. There is a huge need to reduce this (carbon) footprint to mitigate climate change and reach targets including those of the Paris Agreement in 2015. Section 3.6 elaborates further on pavement and construction materials.

Budgeting. For each of the above-mentioned topics (adequate planning roads of with due cognizance of the natural topography and hydrology, making use of opportunities in land use planning, directly including cross drainage, mainstreaming roadside vegetation, and changing preferred construction material), budgeting is an important factor to consider. Too often, it is observed that actual design and construction are not aligned with the long-term importance of the road infrastructure in a changing climate. Increasingly working with a 'life cycle' approach, whereby long-term reliability of the infrastructure is served, and overall maintenance costs are reduced, albeit at maybe higher initial investment costs, is a promising avenue for improved budgeting. This finding is not only relevant for road infrastructure, but also for water infrastructure of Bangladesh (van Steenbergen et al., 2023). Additionally, incorporating circular economy principles in material selection and project design can help close resource loops, reduce waste, and enhance the sustainability of road infrastructure throughout its life cycle.

[11] https://www.aggbusiness.com/node/94340

Box 1: Flood modelling – Importance from planning onwards

In flood-prone and hydrologically sensitive regions, such as the coastal zones, haors and flash flood zones, and river systems and estuarine regions, flood modelling is a critical component of road design. To ensure climate-resilient infrastructure and maintain the natural hydrological balance, roads in these areas must often be constructed at elevated levels. This protects the road from flood damage and creates the scope for the road to positively contribute to flood management. Comprehensive flood modelling is essential to determine appropriate road elevations and to guide the design of cross-drainage structures, including bridges and culverts. This modelling helps finalize the height and width of such structures, ensuring adequate water flow and avoiding waterlogging or disruption to the surrounding watersheds.

To ensure that Green Roads for Water infrastructure offers a long-term, climate-resilient, integrated and sustainable solution, the application of flood models is essential. These models must be used to assess and verify the performance of proposed road systems under varying hydrological conditions. The modeling outcomes will aid in identifying flood-prone areas, supporting informed decision-making and prioritization.

Considering different scenarios

Flood modeling data can be used to determine the hydraulic capacity of road structures, ensuring that they are designed to maintain water balance and support the long-term performance and resilience of the infrastructure under varying flood conditions. Three flood modeling scenarios must be considered to simulate both current and future hydrological conditions. These include:

- **S1 – Existing Conditions**: This scenario represents the current situation, based on field surveys of existing infrastructure, terrain data, and observed land use/land cover. It serves as the baseline for comparison.
- **S2 – Do-Nothing Scenario**: This scenario assumes that no additional interventions are undertaken. However, it incorporates the projected impacts of climate change (e.g., increased rainfall intensity) and continued urban or rural development leading to increased runoff. This helps in understanding the potential future conditions if no interventions are implemented.
- **S3 – Proposed Plan/Interventions**: This scenario includes the proposed road infrastructure and associated green interventions. It evaluates the effectiveness of planned projects by comparing flooding extents and depths against those in the "do-nothing" scenario (S2). The goal is to quantify the benefits of the proposed design in terms of flood reduction.

By modeling and comparing these three scenarios, project designers can better understand flood behavior and optimize the placement and design of green road interventions, ensuring resilience and functionality under both current and anticipated future climate conditions.

Flood risk and opportunities assessments – key considerations

Flood risk assessment can be useful in ensuring climate-resilient and sustainable road infrastructure – at planning, design and implementation phase. The following are key considerations in this regard:

- **Flood Screening and Scenario Analysis**: Conduct flood screening using different return periods to assess flood impacts under S2 and S3 scenarios as outlined above. This screening should identify flood-prone areas and determine which return periods pose the highest risk, including potential for frequent inundation, significant damage, and submergence of the proposed road alignments.
- **Integration into Planning and Design**: The results of the flood screening must inform every stage of the project lifecycle. Given Bangladesh's vulnerability to both riverine and coastal flooding, coastal flood risks must be evaluated and integrated throughout planning, design, and construction.
- **Elevation and Freeboard Consideration**: Road embankments must be constructed above historical flood levels, with an additional freeboard to accommodate future sea-level rise and climate uncertainty. It is worthwhile considering applying this standard to set return periods of floods, and to adjust as needed based on regional risk assessments.
- **Cross-Drainage Design**: The height and width of cross-drainage structures (e.g., culverts, bridges) must be finalized using the findings of the flood risk assessment. Structures should be designed to – amongst others - ensure unobstructed water flow, prevent waterlogging, and avoid disruption to surrounding ecosystems and communities and also optimize the scope for flood retention and compartimentalization.

2.2 Preparation and implementation

Several factors affect the smooth preparation and implementation of integrated green road development. The following changes are assessed to affect the preparation and implementation of road construction.

Addressing the availability of land for roads and road shoulders. A recurrent complaint is that there is inadequate space for the road shoulders. Given the high population density and the intense land use, acquiring land for road development is a tedious process. The availability of land is required to make sure that roadside slope design can be as per design for the soil type of type of road. For roads that are likely to be upgraded, a wider road shoulder is preferred. The acquisition of the road verges may require a longer period in road development. At present the ownership of the road shoulders on extensive lengths of LGED roads is unclear. Land has been made available for the road construction to go ahead, but the status and ownership of the land is unclear. It is recommended that better processes are considered that allow better control over the road shoulders.

Gaining ownership of the road and road shoulder through land acquisition processes is furthermore challenged due to the huge cost considerations, especially when looking at the total length of rural roads. However, gradually ownership of land up to shoulder and side slopes has been transferring from the current owners to the Government through land survey and settlement process conducted by the Department of Land Records and Survey under Ministry of Land. Nevertheless, that transferring process is lengthy and time consuming.

Reviewing the sourcing of material from borrow pits. Borrow pits ideally have a dual function, sourcing material for road construction and maintenance, but also serving as a place for water storage, collecting excess water and making it available in times of stress. This requires careful consideration of where the borrow pits are placed, who owns them, and who will later operate them. A common practice is to use strips of land along the roads, collecting excess water from fields. Another practice is for borrow pits to be converted for water storage and fish cultivations. Ideally, this is planned in the road process. Apart from the excavation of borrow pits, sourcing of earthwork material, also for the widening of roads, is increasingly done through dredging of silt and sands from adjacent rivers and canals. In parallel to this development, the extent to which borrow pits are present and developed, has been shrinking.

Timing of road development/improvement activities. Insufficient road quality may occur as roads are developed or improved during the rainy season when working conditions are challenging. Execution of works in the monsoon season happens mainly due to poor planning, late procurement process and compulsion obligation prior to closing of projects. Construction is often delayed in the rainy season, which hampers the construction process. In such cases, compaction of the road may become a challenge as the soil is saturated with water, reducing the stability and sustainability of the structure.

It is proposed to fund road development and upgrading outside the monsoon season by considering multi-year projects. In this regard it is promising that the online Integrated Budget and Accounting System (iBAS) has been introduced in Bangladesh, which disburses funds on a quarterly basis taking away the problems that come up with annual disbursements. This helps to realise LGED's intention to have planning, designing, budgeting, and procurement done in the monsoon season, followed by implementation of the works soon after the monsoon. iBAS in principle is making fund disbursement more efficient in public spending: funds availability has become possible year-round. It also allows for easier multi-year funding, which has earlier been practiced by LGED in several cases of maintenance programming and project planning.

2.3 Coordination

Coordination with multiple stakeholders is essential for the integrated development of roads. The following critical issues were oberved to improve coordination in road development, upgrading and maintenance.

Strengthen coordination between LGED and water organizations (BWDB (for roads cum embankments owned by BWDB), WARPO, WMOs). This is particularly critical where the road is combined with flood management functions and the long-term development of the road, the carpeting of roads, its height and the slope protection should be aligned with flood protection functions. When LGED paves an embankment, height and width are not always according to the standard road design criteria. This may also lead to the carpeting of an embankment before it is raised to safe standard levels. Moreover, the quality of carpeting of embankment roads is sometimes not adequate (Figure 6). This results in rapid degradation of the road and later also leads to the deterioration of the embankment

Figure 6 Inadequate carpeting

Lack of communication between BWDB and LGED may result in extended time needed by BWDB to approve LGED's plans for developing an embankment road.. The coordination mechanism between LGED and BWDB, only relevant for roads cum embankments owned by BWDB, was in place through a signed MoU between LGED and BWDB at the central level for paving BWDB embankment. Local-level officials, in many cases, were not authorized to sign the MoU. This mechanism may be strengthened by establishing coordination committees at the district level with, more authority given to local-level officials.

It is proposed that embankment paving plans are streamlined and that design heights for embankments and embankment roads adopted by LGED and BWDB are harmonised, following the BWDB guidelines. The road templates and construction materials used for pavement should also comply to the minimum requirements in the LGED guidelines. Before starting the implementation, LGED should wait until BWDB reshapes the embankment in accordance with the guidelines' specifications. Afterwards, BWDB can give clearance (No objection certificate-NOC) to LGED to pave the embankment. Monitoring by BWDB is needed for embankment roads implemented by LGED.

Improve coordination between LGED, LGIs and local communities in road construction, upgrading and maintenance. LGED should involve local communities in the whole process (survey and implementation) of road improvement and cross-drainage structures. Local people are the users of the infrastructure, and their participation in the whole process is essential for them to understand the connection between road and water management. Moreover, it is a way to validate the collected data and address land acquisition challenges. The engagement should be done systematically, meaning that the discussions are open and representative, preferably with the engagement of LGIs. Discussion should be with the different stakeholder groups (farmers, fishermen, business people, teachers, among others) and use participatory planning techniques such as joint mapping.

Under various programs, Water Management Organizations have come into existence in the water systems in Bangladesh., including the Water Management Cooperative Societies, promoted under LGED. Other WMOs are registered either under the Participatory Water Management Rules of 2014. These WMOs have a significant role to play in improved water management, flood defence, and flood response. The different organizations working with these WMOs should be encouraged to strengthen

their activities in this field, and special service providers should be encouraged to work with WMOs in improved water management. There need to be regulations that encourage the WMGs/WMCA to follow and accomplish O&M guidelines related to their responsibilities (filling potholes, rat holes, side slope protection, clearing culverts of garbage).

Cooperation between LGED and NGOs. Some rural roads are constructed by NGOs. It is recommended to ensure effective cooperation among government offices (LGED, UP) and NGOs working on a rural road and water construction/improvement and maintenance, as well as cross drainage structures, and that improved design guidelines are followed by these actors as well if needed taking help of experienced design engineers.

Strengthen coordination between LGED and DDM. Some rural roads and bridges are being improved/constructed by another GoB agency, namely the Department of Disaster Management (DDM). However, coordination between the LGED and DDM remains limited. Strengthening inter-agency collaboration could also help ensure that rural road infrastructure better supports disaster management objectives. Additionally, roads built by DDM are often of lower quality (often earthen roads) compared to those constructed by LGED, resulting in LGED frequently having to upgrade or rehabilitate DDM-constructed segments. Improved coordination and communication between the two agencies could enhance the overall efficiency, quality, and effectiveness of infrastructure development efforts.

Vetting of bridge and culvert design by BWDB in sensitive areas. A special case where (inter-agency) coordination is required concerns the vetting of bridge and culvert design. The construction of bridges and culverts can interfere with the hydrology of the areas upstream and downstream. There are several critical interfaces. The first is the drainage congestion that occurs when bridges and culverts are under-dimensioned or where bridge sills and culverts are placed too high above the bed level of the river or khal. This will pond up the water and lead to drainage congestion, affecting the productivity of the land and leading also to unhealthy conditions related to the stagnant water. A special case is that of tidal rivers. When bridges across these tidal rivers are constructed too narrow, the sediment balance in these tidal rivers is affected, leading to a dramatic shifting of sediment loads in these rivers, affecting the normal drainage in large areas. The result can be devastating – with the productive use of large areas negatively affected. It is proposed that the design of bridges follow adjusted guidelines to avoid drainage congestion (bridge sills) or river sedimentation (narrow bridges) and that bridges and culverts are vetted by the engineering staff of the BWDB. A special water and sedimentation checklist may be developed for this purpose.

Figure 7 Left: Silted sluice, Right: Silted bridge

2.4 Aftercare and asset management

The management of the enormous portfolio of road assets by the LGED, in excess of 300,000 kilometre provides many benefits to optimize road development and water management.

The following are the recommendations to improve aftercare and asset management and improve the functions of Green Roads for Water Management.

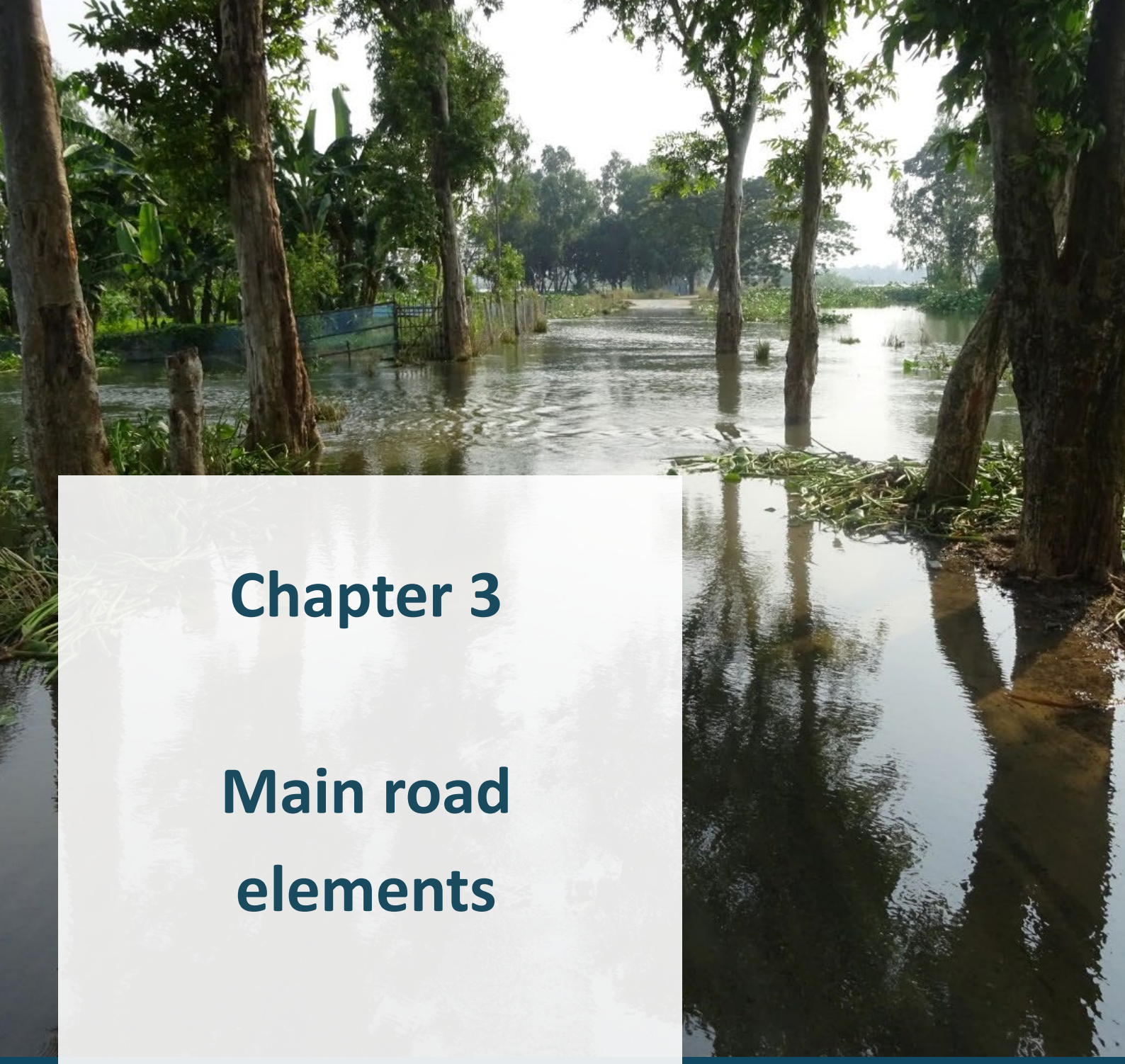
Engage local community organizations in maintenance and avoiding disruption. Roads and related drainage structures need very regular maintenance for their upkeep and also to ensure unhampered water flow. Currently, many pipes, culverts, and sluice openings are silted, damaged, or blocked (Figure 7). The high amount of sediments deposited through runoff is often related to the inconsiderate location of the road and drainage structures. Furthermore, local communities also obstruct the drainage structures for aquaculture or to create retention areas for irrigation. Thus, the khal's capacity to store water decreases due to siltation, leading to drainage congestion. The Bangladesh Water Act stipulates that no one can stop, obstruct, or divert water flow without permission. If this happens, the Executive Committee (EC) of WARPO may impose any restriction by issuing a protection order. It is recommended that local communities, especially where formalized in a WMO, are explicitly made responsible for these small but vital repairs.

Consider engaging Labour Contracting Societies (LCS) on long-term basis in road maintenance. Unlike in other countries, there is no permanent arrangement for local road maintenance. There is a long history of engaging LCS on relatively smaller, labour-intensive works, but this is almost always on one-time contracts. LCS should be engaged in this in multi-year contracts. Currently, earthen roads are mainly constructed/maintained by the PIO (project implementation office). Surveys are carried out to identify the road problems, which are repaired based on the available funds. However, more effort is needed at the local level for routine maintenance of roads and water structures. Routine maintenance should include the same tasks as the LCS have:

Figure 8 Pothole on road

- Ensure side slope
- Repair holes
- Drain water puddles
- Remove bushes and plants
- Remove vegetation that block the culverts or pipes
- Remove vegetation that damages roads
- Clean debris of outlet/inlet
- Turfing on the side slope
- Stockpile dry land on the side of the road for the monsoon

Figure 9 Damage to road carpeting



Chapter 3

Main road elements

3 Main road elements

In this chapter, we will discuss the main elements of road development and the optimization of their impact on water management. We will discuss subsequently the alignment of the road networks (3.1), the road shoulders and embankments (3.2), roadside vegetation (3.3), cross drainage (3.4), bridges (3.5), and pavement and construction materials (3.6).

3.1 Overall road network elements

The road network is a major part of the densely populated landscapes in Bangladesh, particularly with the prevailing high road densities. The location and orientation of the roads, as well as the position and capacity of the cross drainage, have a significant effect on the surface run-off. Roads can guide, direct, and retain water over the landscape.

In a deltaic country like Bangladesh, road alignment is particularly critical. The natural flow of water generally follows a north-to-south direction, toward the Bay of Bengal. Consequently, roads aligned in an east–west direction are more susceptible to flooding, as they often act as barriers to natural water flow. Therefore, careful hydrological planning and design – amongst other regarding bridges, culverts, and causeways which may be need more on this type of roads - is especially essential for east–west road alignments to minimize flood risk and maintain natural drainage of (rural) landscapes.

Road networks also are of essence during flood events, providing escape routes and shelters. These functions should be optimized – in the construction of new roads and in the upgrading of existing roads, for instance, in changing submersible roads to all-weather roads.

The impact of the road network on surface hydrology differs with the geography of the country. Based on the deep dive field visits, the following potential major impacts of the road network on water management were observed that may be optimized:

Table 4 Impact of road network on water management

Zone	Effect of road network	
1. Coastal zone	Contribute to flood protection	Coastal embankments as roads: harmonize flood protection and transport functions
	Contribute to flood preparedness and recovery	Make roads at higher elevation (for instance, by using excavated sediment) in flood-prone high-risk areas and include widened sections as flood shelters
	Reduce water logging	Follow drainage lines and provide adequate cross-drainage
	Improve water control in irrigated crop areas	Position (minor) roads on the contour lines and equip culverts with gates
	Avoid sedimentation of rivers	Ensure adequate cross drainage and wide enough bridges so as not to disturb the sedimentation process, particularly in the tidal rivers
2. Barind and Drought Prone Areas	Use roads for water harvesting	Roads at slight elevation, guiding run-off to overflow areas to recharge zones and water storages
	Use roads for water storage	Construct water retention structures and local mini-dams using road bodies

3. Haors and Flash Flood Areas	Control flood recession	Roads at slight elevation, including controlled overflow sections to slow down and direct recession flows and feed into wetlands or shallow reservoirs
	Contribute to flood preparedness and recovery	Make roads at higher elevation (for instance, by using excavated sediment) in flood-prone high-risk areas and include widened sections as flood shelter
	Improve/protect fish movement	Provide sufficient and well-located culverts of appropriate design to guide and facilitate fish movement
4. Chattogram Hill Tracts	Use roads for water harvesting	Develop roads at mid-slope hills to maximize water retention and water harvesting potential
		Develop water retention structures alongside roads
		Use road profile and roadside drainage to collect water
	Stabilize hill slides and control erosion	Use bio-engineering or seed spraying
		Control erosion by baffle structures
		Avoid water accumulation in landslide-prone areas
5. River Systems and Estuaries	Mitigate floods	Road networks to steer and compartmentalize floods by controlling the pattern of flood run-off.
	Contribute to flood preparedness and recovery	Make roads at higher elevation (for instance, by using excavated sediment) in flood-prone high-risk areas and include widened sections as flood shelter

3.2 Road shoulders and embankments

Road shoulders and embankments are essential parts of the road, and their design differs with the geography where the road is placed and its class and functions. In the deep dive surveys, it was observed that often the road embankments are too narrow and too steep. This jeopardizes the stability of the road as well as the traffic safety.

Underneath this issue is the (unclear) ownership of the road shoulders along a large part of the rural roads in Bangladesh – whether individual or community property or belonging to the local government (see Chapter 2). This also explains why not all roadsides are vegetated.

Figure 10 Shoulder wall to keep shoulder in place (partly successful)

The preferred methods for side slope protection (BUET, 2018) are given in Table 5. Due to the land constraints, it is not always possible to maintain these guidelines. In this case, it is important that additional stabilizing measures are introduced on the road embankments in particular, mini-benches and shoulder walls (Figure 10). There are also other slope protection methods currently being used by LGED such as concrete palisading and block works, as also observed in the field visits (Figure 87).

Table 5 Method and User Preferences of Side Slope Protection (BUET, 2018)

Method No.	Method Name	Preferable Scenarios	Preferable Side Slope Ratio (V : H)
01	Slope Protection work with Long Routed Grass* Turfing	General Road Embankments	1 : 2
02	Slope Protection work for High Embankment (Above 4.5 m) with Long Rooted Grass*	High Embankments, Haor Areas / Coastal Areas	1 : 1.75
03	Slope Protection Work with Grass Turfing & Geo-Jute on Slope for Sandy Soil with Long Rooted Grass	Sandy Soil	1 : 2
04	Slope Protection Work with Grass Turfing, Geo-Jute & Geo-Bags on Slope for Clayey Soil	Clayey Soil	1 : 1.5
05	Slope Protection work with Long Rooted Grass* Turfing & Geo-Jute on Slope for Hilly Areas	Hilly Areas	1 : 2
06	Temporary Slope Protection work with Gunny Bagged Rip-Rap and Geo-Textile	Haor Areas / Coastal Areas	1 : 2
07	Slope Protection work with Gabions	Haor Areas / Coastal Areas	1 : 2
08	Slope Protection work with Long Rooted Grass*, Vegetation, Block and Gabions	Haor Areas / Coastal Areas	1 : 2
09	Slope Protection work with Masonry Brick and Pre-Cast Gabions	General Road Embankments	1 : 2
***A good example of long rooted grass that is being used for this purpose in Bangladesh is Vetiver Grass (local name: Binna)**			

It should be noted that the preferable side slope ratio cannot always be reached due to practical reasons, including the challenges related to acquiring roadside land. Therefore, innovative measures such as structural measures for slope protection, may be also recommended to roadside slopes within 1:1.5. The guideline of Climate Resilient Road Development (2019), developed by BUET, has outlined some techniques on limiting roadside slope. This will be reflected upon in the forthcoming guidance note.

Side slope protection is also facilitated by timely repair of the road embankment in case of erosion or flood damage. This requires the ready availability of borrow areas for soil. A good practice observed in several areas are the multi-purpose roadside ponds/ trenches, that can be used to collect access drainage water and serve as a water storage. Deeper ponds/ trenches can be used for fish cultivation or aquatic crops.

In the hill tracts, road embankments differ from the low-lying plains; here, an important requirement is to prevent unstable roadsides that would affect the water retaining capacity of the landscape, cause local springs to lose their discharge, cause erosion and sedimentation of water bodies and increase the risk of disruptive landslides and landslips affecting the road bodies itself. Bioengineering is an appropriate practice for roads in hill tracts. Useful manuals for these have been developed, as well as training packages. These are partly summarized in Annex 2.

An important consideration in designing roads and road embankments is the height of the road embankment. Following also from section 3.1, this may follow from the water management functions of the road and the desire to make the road all-weather, for example:

- Having slightly elevated roads in the haors in order to influence the retreating inundation and to control soil moisture in the recession areas.
- Having heightened roads in flood-prone areas, such as the lower sections in the coastal polders, to contribute to flood preparedness.

3.3 Roadside vegetation

Roadside vegetation is an essential part of the road bodies and serves several functions that need to be optimized. These are listed in the table below:

Table 6 Functions and factors to consider for roadside vegetation including explanation / elaboration

Function	Explanation / Elaboration
Productive use	Define productive use (timber, fruits, fodder, fuelwood) against preferably extended lifespan to avoid regular replanting
Protection of road surface	Prefer deep-rooted over broad-rooted species that may interfere with the road surface
Stabilizing road embankments	Combination of roadside grasses (vetiver and others) and tree species to minimize erosion of embankments
Protecting submersible roads	Appropriate species that reduce eroding effects on submersible roads and that are adjusted to flooding conditions
Improved micro-climate	Tree planting to reduce exposure to desiccation and heat extremes
Dust control	Double-layered partly open vegetation (especially on level roads) to allow dust capture Tree planting in road sections that are perpendicular to the prevailing wind directions
Pollution control	Use of bio-accumulator species in pollution-sensitive areas
Promoting biodiversity	Selective mowing and removal of biomass to enhance species diversity. Connecting to landscape hedges to create biological corridors
Carbon sequestration	Careful selection of maturing species and wide vegetation
Road safety	Avoid tree planting in high-speed sections (>60 kilometres/hour) Support visibility (no tree planting in inner bends)
Beautification and comfort	Provide shade and space where there is much pedestrian movement

Apart from the wide scope of benefits that roadside vegetation can provide, there can also be negative effects of (unplanned) roadside plantation. Therefore, to avoid negative shade and moisture effects, it is important to consider tree height in shade-sensitive areas (direction of sunset) in case of farmland not to obstruct essential sunlight, leading to prolonged moisture retention on the road's surface. This condition can hasten the deterioration of bituminous pavements, diminish skid resistance in rigid pavements, and compromise road durability and safety. Well-planned planting and proper maintenance of roadside vegetation can prevent and limit such negative effects.

In comparison to other countries, Bangladesh has promoted roadside vegetation more systematically, making it part of the intensive land use. The preferred tree species (e.g., Figure 11) and planting methods are described in several guidelines issued by LGED, as listed below. These will be reviewed in the light of the above, validation field visits, and further consultations (see Annex 8).

Also, though Bangladesh has made much progress in roadside vegetation, there are large road sections where there is no roadside vegetation. A rough estimate of the order of magnitude is 70% of the roadsides not being vegetated. Particularly on level roads, the coverage of roadside vegetation can vastly expand. There is scope to expand the coverage of roadside vegetation in close consultation with the land-owning communities.

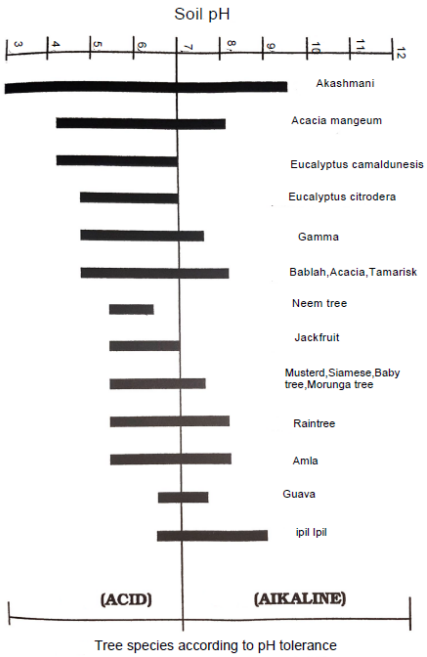


Figure 11 Tree species selection based on soil quality

In elevated roads, the embankment protection by roadside vegetation may complemented with clay cladding, especially when the road bodies are made of sandy silt, silty sand or non-plastic silt. In selected areas, embankments may also be stabilized by mini terracing and the use of vetiver grass.

Figure 12 The use of vetiver grass for slope stabilization

The management of the roadside vegetation is essential for its quality and sustainability. Here, the good practice is to apply the Social Forestry Rules. While initially established in 2004, the rules were amended/revised in May 2011. There have, however, not been any changes to the in 2004 established agreements among beneficiaries and other organisations. In general, positive observations are being made regarding the planted trees under the Social Forestry Rules, as beneficiaries benefit from the agreements.

Figure 13 Roadside vegetation providing ample benefits

The key characteristics of social forestry are summarised below.

- To use the road embankments and protect the roads from encroachment, social forestry groups are given custody of designated sections of the road embankments. The Forestry Department, with these SFGs, clears the road embankments and plants a mixture of trees. Forest Department invests in a first rotation of trees, provides necessary convening and technical expertise, and engages and organizes local communities for roadside tree planting.
- The SFGs take care of the road sections under a tripartite agreement they sign with the Forest Department, the LGED that owns the roadside land and the local government, the Union Parishad. Each community participant (family) enters a 10-year MoU with the Forest Department, which details the participant's credentials, a particular section of right of way, tree species for planting, management plan, conditions for harvesting and benefits sharing.
- Under this agreement, the SFGs have the usufruct of the roadside forestry, i.e., the tree twigs and branches, obtained from pruning, thinning, and other maintenance of the plantations. Besides, the SFGs are allowed some cropping of, for instance, papaya, ladyfingers or pigeon peas.
- The Forest Department harvests the trees (usually after a 10-year rotation period), sells the timber at auctions, and shares sell proceeds with the beneficiaries according to the Social Forestry Rule 2004. Here is the formula: Forest Department: 10%, LGEDt: 20%, Social Forestry Group: 55%, Union Parishad: 5%, and Tree Farming Fund 10% (for new planting after the first rotation).
- After the trees are harvested at the instigation of the Forest Department, a new cycle starts. In the meantime, the Social Forestry Groups protect the roadsides against encroachment by shops and houses, as common on most other roads.

Figure 14 Well-managed and vegetated shoulder

3.4 Cross-drainage

Cross-drainage is a vital feature in Green Roads for Water. The location and capacity of the cross-drainage on roads affect the extent of water logging surrounding the road. Yet, this water logging also undermines the stability of the road and the cross-drainage structures (see picture). Similarly, cross drainage (or the lack thereof) affects flooding patterns and the removal of heavy rainfall. In turn, floods also affect roads, culverts, and bridges, as this is where flood water accumulates. Roads and cross drainage can also be used to alter flooding patterns, as explained in section 3.1.

Figure 15 Due to shortage of cross drainage, water weakens the vulnerable section near the culvert and bridges, causing the roads to be undermined.

Also particularly in sedimentation prone rivers, as in the tidal area in South-West Bangladesh, bridges – particularly when they are ill-placed and too narrow – may affect the sediment stability in the river, causing the sediment loads to shift and disturb the delicate drainage pattern in such low-lying areas, see Box 2.

Provisions on road drainage in current manuals are relatively limited in scope. The rural road manual (2019) does call for the construction of longitudinal and transverse drains but does give little detail and does not take into account the impact of (the lack of adequate) road drainage on water logging or river sedimentation for instance. The limited detailing of longitudinal and transverse drains in current manuals hinders precise implementation.

In designing cross-drainage, the following is required:

- Cross-drainage should be adequate to deal with the regular drainage coefficient of the area. Water logging is to be avoided.
- Cross-drainage should be self-clearing. Siltation should be avoided by having adequate clearance and velocity of the flow, the latter of which is the function of the slope of the cross-drainage structure.
- Similarly, the cross-drainage structure should not be blocked by garbage and flotsam. This is a function of the maintenance being done but also of the dimensions and design of the culverts.

There are two important additional functions of cross drainage structure that may optimize the functionality of cross drainage, respectively, in the fishery and in irrigation.

For fishery, it is important that culverts allow fish passage. Many culverts have been historically undersized, set high in the channel, or formed a waterfall at its outlet, forming a barrier to fish and other aquatic organisms' movement. This has effectively fragmented the stream reaches where fish can live, reducing their overall population. By using stream simulation concepts, the culvert width matches the channel bank's full width, and a natural channel bottom is preserved or built into the structure. This avoids that either the flow is too fast, the flow is too shallow, the jump is too high, or

there is no resting pool. Key design considerations in a stream simulation design are that the culvert width matches or is wider than the natural channel bank full width (bank full is the flow level that occurs roughly every two years). Also, the stream channel through the culvert mimics or duplicates the condition in the stream reaches upstream and downstream of the crossing. The slope and elevation of the culvert match that of the stream channel, and the material placed through the culvert matches the natural channel material, typically with sand, gravel, and boulders.

Another function of culverts is that by having them gated, they can serve to control water levels, particularly for rice cultivation. With new rice varieties requiring water level control and drainage in different stages of crop growth, local roads and gated culverts are, in many cases, able to offer this opportunity, provided that the roads follow the contour lines or are high enough in low gradient areas to create rice-growing basins. The gates on these culverts and pipes may come in different forms – from corrugated iron sheets to properly constructed structures with a slide frame.

Figure 16 Left: Box culvert with slot for gate, Middle: Gated culvert, Right: Causeway

In the forthcoming guidance note, we will comment on the types and designs of culverts currently in use and to be in use when fully incorporating the Green Roads for Water concept for further improvement to retain water.

In addition to culverts, causeways (Figure 16, Right) play a vital role in cross-drainage management for rural roads in Bangladesh. Causeways are low-level road segments designed to be overtopped during floods, allowing water to flow freely across the roadway. These submersible stretches are particularly common in areas prone to flash floods, where bridges and culverts alone are often insufficient to handle the high volumes of rapidly flowing water. Without such provisions, roads in these regions are at high risk of being washed away. Causeways are generally more cost-effective and quicker to construct than elevated road sections. However, they are exposed to strong water turbulence, which can lead to structural damage or displacement. Therefore, regular inspection and maintenance are essential to ensure their durability and performance.

3.5 Bridges

Figure 18 Bridge being reconstructed with more drainage potential

Figure 17 Protection of river banks and abutment of bridge using vegetative measures

As with culverts and pipes, bridges are essential in cross drainage. As they are placed over larger streams, their effect on local hydrology, if not designed properly, can be substantial. For example, rivers may be in danger of silting up if bridges are too narrow, with the ponding of water causing the bedload to become unstable (see Box 2).

Despite their importance, however, bridge and culvert are often the most neglected components of the road maintenance program. Bridges are designed using design criteria that have been calculated from historical climate data under the assumption that the average and extreme conditions of the past will represent conditions over the future lifespan of the structure. In the context of climate change, these designs will need to be reassessed and updated to reflect changing climate – and hence water – risks. This is underlined by the IPDC who identify bridges as one of the infrastructures most at risk due to climate change. Climate change is likely to impact bridge infrastructure assets through modification in the pattern of extreme climatic events, which includes storms and storm surge, floods, and drought; or through gradual changes in seasonal or annual patterns of temperature, solar radiation, precipitation, and sea level rise.[12]

Both small and large bridges are affected by climate change very similarly, although small bridges are generally much weaker and therefore more susceptible to climate change. Since small bridges are typically designed and built with local labor or materials, they are often subjected to lower standards, requirements, lower quality of construction and materials. For large bridges, a major climate change risk is an increase in intensity and frequency of heavy rainfall, which can result in greater flooding and scouring around bridge foundations. Large bridges, especially those that span several hundred meters over a large water body, are very vulnerable to river flooding (if located inland) or storm surges and waves (if located in the coastal area).[12]

In designing bridges, the following is important with respect to Green Roads for Water:

- Bridge sills should not impede drainage and should be set deep enough.
- Bridges should be wide enough to prevent water ponding that can unsettle river sediment loads. If necessary, bridges should be reconstructed to have adequate drainage capacity, in sensitive rivers with limited flows, as in the Southwest.
- Bridge clearance should be high enough to allow boat movement.
- Nature-based solutions, such as riverbank plantation, may be used to stabilize the embankment of local rivers and streams, avoid bank erosion and direct flows to the centre of the stream. Plantation can also be used to protect the abutments of bridges.

Riverbank plantation has not yet been widely practiced in Bangladesh, although LGED and LGIs have been adopting plantation in their canal digging projects under limited scale. To some extent, local people do such a plantation, but in most cases, it grows naturally. Currently, there is a very limited public investment policy on riverbank plantations. Attracting public investment for riverbank plantations is therefore important. Entry points for gaining more public interest and investment

[12] Draft Guidelines for the Planning, Design and Implementation of Climate Resilient Rural Bridges has been drafted by WB supported 'Supporting Rural Bridge Program (SuPRB)

include raising awareness, demonstrating economic benefits, and highlighting the alignment with (inter)national priorities. Demonstrating riverbank plantation as a nature-based solution that addresses climate change adaptation, mitigation, and biodiversity challenges but that is also economically viable will help to raise public investment. Applying and contextualising the rules of roadside social forestry for riverbank plantation may be an interesting avenue which will be explore in the forthcoming guidelines.

Box 2: Choking Bridges[13]

It is a river but without water. Instead of water, there is silt, silt from bank to bank. The Sholmari River is one of the many tidal rivers in the Bangladesh South West coastal belt. In all these rivers, there is a very fine balance between water coming in with the tides from the sea with sediments, and the sediments are pushed downwards with the upstream flow, which has been reduced ever since India diverted more water upstream with the construction of Farakka Barrage in 1975.

The Sholmari River is now dead; besides less upstream flow, the other culprit is the Batiaghata bridge that restricted and choked the river. To save on costs, the bridge was made narrower than the river width and the bridge span length was kept small, which increased the number of piers. A large number of piers in the river changes the river's hydro-morphodynamical condition, which increases the sedimentation in the river. In other words, the construction of the bridge set in motion a chain reaction that totally destroyed the river. With the changing morphology, the inland reach of the tides also affected, further disturbing the river.

The end result is a dead river full of sediment – blocking the removal of water from the adjacent land, where cultivation becomes impossible and habitation difficult. This is a high tragedy. As the land cannot drain into the blocked river, water logging becomes widespread, and farming systems and residential areas are destroyed, including Beel Dakatia. The area of the 23 small and major beels that are affected, was approximately 1,500 hectares. An estimated 2,500,000 crores worth of agricultural and fishery products are produced annually in the aforementioned region. These areas are at risk of experiencing significant inundation due to the siltation in the Sholmari River. Several thousand already poor people may have to pick up their belongings and go nowhere.

The Sholmari River is not the only river killed by bridges; there are more examples in almost all rivers in the Southwest Region. Over the last 40 to 50 years, infilled channels have added around 90 km^2 of new land, or about 2 ^{km2} every year. The loss of tidal waterways accounts for a 60% reduction in total channel length over the region's 3000 km^2 of poldered terrain, or roughly two-thirds of the region's navigable waterways over the last 40 years. It all speaks for making a strong connection between building roads and bridges, managing water and silt, and, where possible, going for mutually beneficial effects. It speaks for counting in local hydrology whilst developing infrastructure. It speaks for not working in isolation but in combining forces between road and water agencies.

Pictures illustrating the siltation problems in in the Bangladesh South West coastal belt. This box has also been published as a blog on TheWaterChannel.

[13] *This blog has been largely based on the PhD dissertation by Saif Uddin, Mohammad (2022).*

3.6 Pavement and construction materials

As Bangladesh experiences increasing climate variability marked by intense rainfall, rising temperatures, salinity intrusion, and periodic flooding, its road infrastructure must evolve to withstand these environmental pressures while minimizing ecological footprints. In this context, the adoption of green pavement technologies is critical for achieving sustainable, low-carbon, and climate-resilient road development. The adoption of such pavement and construction materials aligns with the concept of Green Roads for Water, as it helps reduce water-related damage to roads and make roads instead instruments for water management. The design and material selection for road pavements are not only central to ensuring structural durability but also to enhancing climate resilience, reducing lifecycle emissions, and supporting environmentally sustainable water management practices.

Phasing out red bricks

Phasing out red bricks in road construction is a vital step toward these goals. Traditional red bricks, predominantly produced in fixed chimney kilns, contribute significantly to greenhouse gas (GHG) emissions, particularly carbon dioxide and black carbon, which are potent accelerators of global warming. These kilns rely heavily on coal and biomass fuels, leading to high carbon emissions, deforestation, and local air pollution. Beyond emissions, red brick production consumes fertile topsoil, causing long-term degradation of agricultural productivity and ecosystem health. Furthermore, red brick pavements and subgrades are structurally vulnerable to climate-related hazards such as prolonged inundation, intense rainfall, and thermal fluctuations, all of which are becoming more frequent and severe in Bangladesh due to climate change.

In Bangladesh, the government opted – amongst others - for the most efficient alternative to red bricks – hollow cement blocks that require no burning of fossil fuel but sunlight only. It started promoting this from 2019 onwards, when it issued a circular to implement hundred percent use of hollow blocks by 2025[14]. Because of the Covid-19 pandemic, this deadline has moved to the 2028-29 fiscal year.[15]

The use of those more climate-friendly concrete blocks has been made mandatory for construction, repair, and renovation works (buildings, herringbone bond roads, type-B rural roads) under a law of 2013. It should be noted however – in spite of the presence of this viable option - that industry insiders reported only 5% had been achieved so far. Meanwhile, brick kilns continue to thrive and expand. The transition to concrete blocks, hence, needs to accelerate. An estimate needs to be made of the current capacity to produce concrete blocks. The technology and designs also need to be shared more widely, and LGED may systematically phase out the use of red bricks and ultimately ban these.

Transitioning to sustainable and innovative alternatives

Transitioning to more sustainable alternatives such as Polymer Modified Bitumen (PmB), Reclaimed Asphalt Pavement (RAP), Waste Expanded Polystyrene (WEP), Warm Mix Asphalt (WMA), geosynthetics, permeable pavements, and industrial by-products like Fly Ash presents a strategic, climate-smart solution. It should be noted that these materials should not be treated as silver bullets, but instead as promising options in specific situations and have potential to be applied at scale In the guidelines, we will elaborate on the extent to which they are ready to be applied or scale or whether they are at a lower readiness level. The materials described in this section embody the principles of circular economy and offer reduced environmental footprints while maintaining or enhancing engineering performance.

[14] https://www.tbsnews.net/features/panorama/hollow-promise-hollow-blocks-2025-567982
[15] https://www.dhakatribune.com/bangladesh/328956/what-bangladesh-is-doing-to-shift-to-%E2%80%98green

These innovative technologies offer superior load-bearing capacity, resilience to erosion, and adaptability to moisture and thermal stress, making them particularly suitable for Bangladesh's diverse geo-climatic zones. Their integration into road development aligns with Bangladesh's commitments under the Paris Agreement, the Sustainable Development Goals (SDGs), and national strategies, which prioritize low-emission, resource-efficient, and climate-resilient infrastructure.

Polymer Modified Bitumen (PmB)

Polymer Modified Bitumen (PmB) is typically used on road pavements, particularly those that are intended to withstand extreme weather conditions such as the stagnation of water. In flood-prone and high-rainfall areas of Bangladesh, PmB is especially valuable as it reduces rutting, cracking, and moisture-induced damage, extending the service life of the pavement. Its superior binding properties also contribute to better adhesion between aggregates, which is critical in maintaining pavement integrity during water infiltration. The use of PmB aligns with the principles of Green Roads for Water by minimizing maintenance needs, reducing life-cycle costs, and enhancing climate resilience.

In addition, a warm and cold mix PmB is laid at lower temperatures. This means that PmB can be applied to road surfaces using special mixing techniques, warm and cold mix, that allow the bitumen to be produced and laid down at lower temperatures compared to traditional hot mix asphalt. Warm and cold mix technologies are alternatives to the traditional hot mix method, which typically requires high temperatures (around 150–180°C). This helps in cutting down the production of greenhouse gases and the overall consumption of fuel while producing and laying it. When considering a lifetime of 10 years for conventional bitumen, a road surface using PmB will last, at least, 11 years (10% more) for equal Global Warming Potential.

Reclaimed Asphalt Pavement (RAP)

Reclaimed Asphalt Pavement (RAP) involves milling and reusing existing bituminous layers, reducing the need for virgin aggregates and binder. RAP has a proven ability to enhance pavement stiffness and fatigue life due to the aged binder's higher viscosity. From a climate adaptation perspective, RAP pavements demonstrate superior rut resistance and thermal cracking control, which are critical under Bangladesh's temperature extremes and monsoon cycles. Laboratory studies show that up to 30–40% RAP content can be effectively blended with virgin materials without compromising performance. RAP also reduces life cycle greenhouse gas (GHG) emissions by up to 20%, aligning with low-carbon construction goals. Furthermore, its use in base and binder courses is particularly advantageous in regions prone to seasonal flooding, where quick rehabilitation and cost-efficiency are essential.

Waste Expanded Polystyrene (WEP)

Waste Expanded Polystyrene (WEP), typically derived from consumer packaging waste, serves as a lightweight bitumen modifier. When shredded and incorporated into hot bituminous mixtures (typically at 1–4% by weight of binder), WEP enhances rheological properties of asphalt, such as softening point, elasticity, and temperature susceptibility. Its use improves resistance to rutting in hot climates and mitigates thermal cracking. WEP-modified bitumen also exhibits improved moisture resistance (higher retained stability values), making it particularly beneficial in saline and waterlogged zones such as the coastal belt. Environmentally, this technology diverts polystyrene waste from landfills and incineration, thus reducing environmental toxicity and microplastic leakage.

Warm Mix Asphalt (WMA)

Warm Mix Asphalt (WMA) technology allows asphalt to be produced and placed at temperatures 20–40°C lower than conventional Hot Mix Asphalt (HMA). This temperature reduction leads to substantial environmental benefits, including 20–30% lower fuel consumption and up to 25% reduction in CO_2 and NOx emissions. Moreover, WMA improves workability and compaction in humid conditions, which is advantageous during monsoon transitions when conventional asphalt struggles with moisture-induced damage. Technically, WMA can incorporate up to 50% RAP, further enhancing sustainability. It also

minimizes oxidative aging of the binder during production, thereby increasing pavement longevity and reducing maintenance frequency.

Geosynthetics

Geosynthetics, including geotextiles, geogrids, geocells, and geomembranes, are increasingly used for subgrade stabilization, separation, filtration, and drainage. These synthetic polymer-based materials significantly improve the performance of pavements constructed over weak subgrades common in Bangladesh's deltaic floodplains. Geogrids and geocells, in particular, enhance load distribution and prevent differential settlement in areas prone to flooding or seismic activity. Studies have demonstrated that incorporating geosynthetics can reduce aggregate thickness requirements by 25–50%, lower construction costs, and extend pavement service life by 2–3 times. In hilly and erosion-prone areas like the Chattogram Hill Tracts, geosynthetics also help manage surface runoff and reduce landslide risks, making them essential for climate-resilient design.

Permeable Pavements

Permeable Pavements are particularly effective in managing surface water runoff, promoting groundwater recharge, and reducing the risk of localized flooding. These pavements allow water to percolate through the surface into a structured sub-base, slowing down runoff and reducing the load on adjacent drainage systems. In rural and peri-urban areas, the implementation of permeable pavements alongside roads can serve dual purposes, supporting transportation needs while functioning as a water management solution. They are especially useful in areas with moderate traffic volume, such non-motorized transport lanes.

Fly Ash and Ground Granulated Blast Furnace Slag (GGBFS)

Fly Ash and other industrial byproducts, such as Ground Granulated Blast Furnace Slag (GGBFS), have shown significant potential as sub-base stabilizers and partial cement replacements. Class F fly ash, rich in alumina and silica, reacts pozzolanically with lime and water to form cementitious compounds that enhance subgrade strength, reduce permeability, and resist sulfate attack. In soft and expansive clay soils prevalent in riverine zones, fly ash stabilization improves California Bearing Ratio (CBR) by up to 100–150%, reduces shrink-swell behavior, and controls plasticity. From a climate mitigation perspective, every ton of cement replaced with fly ash prevents approximately 0.9 tons of CO_2 emissions. Utilizing fly ash in road layers thus supports both material circularity and climate-smart construction, particularly in peri-urban zones where rapid urbanization is leading to increased road demand.

Successful application of these technologies requires site-specific assessments including soil profiles, hydrological data, traffic loads, and climate risk. Material availability, especially RAP, fly ash, and WEP should also be considered to ensure cost-effectiveness and environmental sustainability. Site-specific user preference of PmB, RAP, WEP, WMA, geosynthetics, permeable pavements, and fly ash are given below. The table below provides an overview of promising options for the different pavement types across the different regions in Bangladesh, which will be elaborated upon further in the guidance note.

Table 7 Zone and pavement types (promising options), and reasoning behind selection

Zone	Pavement Type – Promising options	Reasons
Coastal Zone	PmB + RAP + Geosynthetics	Resistant to saline moisture, erosion control, and structural durability under humidity
Barind and Drought Prone Zone	WEP-Modified Asphalt + Permeable Pavements	Handles high heat, promotes groundwater recharge, utilizes plastic waste
Haors and Flash Flood Zones	PmB + RAP + Geosynthetics	Withstands submersion and drying cycles, improves drainage, increases flexibility
Chattogram Hill Tracks	WMA + PmB + Geosynthetics + Permeable Shoulders	Slope stabilization, workability on steep terrain, erosion control

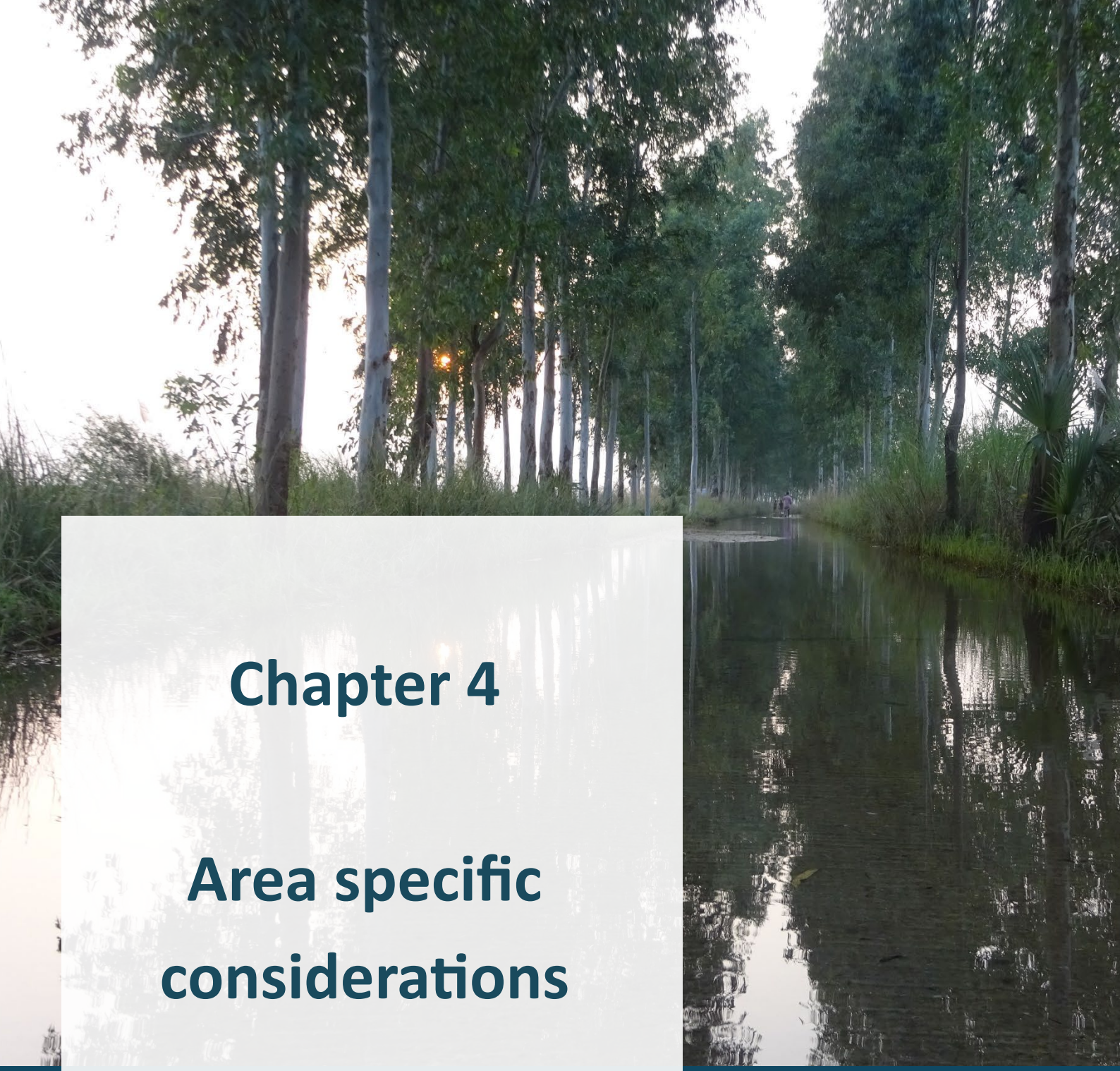
River Systems and Estuaries	Combination of PmB (main lanes) + Permeable Pavements (shoulders) + Fly Ash in base	Resilient to waterlogging, promotes drainage, minimizes settlement and carbon footprint

In addition to the options discussed above, it is also important to consider the findings from the report "Climate Resilient Rural Road Construction and Development of Pilots" (TRL, 2024), which places particular emphasis on alternative pavement and construction materials. These findings are summarized and contextualized in the table below (Table 8). The forthcoming guidelines will integrate these insights alongside the previously presented options to support more water-resilient and climate-resilient rural road development.

Table 8 Pavement types, design conditions, rationale, environnemental impacts, social impacts, zone references

Sl.	Pavement Types	Design Conditions	Rationale for Selection	Environmental Impacts	Social Impacts	Zone References
Surface Layer Types						
1	Rigid Pavement with Recycled Aggregate (Concrete Slab)	Moderate climate, salinity, soft soil	High resilience to climate impacts, dual function as strength and wearing surface, recycled materials support circular economy	Low emissions, reduced raw material extraction;	Requires proper handling of recycled materials; promotes local sourcing and reduces waste	Coastal Zone, and River Systems and Estuaries
2	Uni-block Pavement (Interlocking Concrete Blocks)	Salinity, soft soil, river erosion	Flexible and modular, performs well over strong base (e.g., ETB); local production possible; easily replaceable blocks	Lower environmental impact when locally produced;	Safe for communities; minimal long-term maintenance	Coastal Zone, and River Systems and Estuaries
3	Asphalt Wearing Course	Used as benchmark under varying conditions	Represents conventional LGED practice; facilitates comparative analysis with innovative materials	Bitumen fumes during application;	Moderate maintenance; well-understood performance	Can be used in all zones as final surface layer
4	Double Surface Dressing	Moderate climate with less flooding/salinity	Highly flexible, suitable for high deflection; resistant to cracking and affordable; used successfully in UK	Low carbon footprint;	Requires skilled application; minor dust generation	Chattogram Hill Tracts
5	Hot Sand Asphalt	High rainfall, flooding	Impermeable, heat-resistant, suitable for moisture-heavy environments	High-temperature handling risks;	Good performance in water-logged areas	Haors and Flash Flood Zones, and River Systems and Estuaries
6	Steel Slag Asphalt Concrete (Steel Slug)	High temperature region	Durable under heat, improves rutting resistance	Utilizes industrial waste;	Must test for leaching; promotes recycling	Barind and Drought-Prone Zone

7	Reclaimed Asphalt Pavement (RAP)	Dry, drought-prone, high temp	Reduces virgin material use; effective reuse of existing pavement	Lower carbon footprint;	Supports sustainability; performance depends on quality of reclaimed material	Barind and Drought-Prone Zone
Base Layer Type						
8	Demolition Waste	Moderate to high moisture and salinity	Locally abundant; repurposes urban rubble; strong interlocking properties	Potential dust and debris; mitigation through dust suppression	Supports circular economy; minimal land disruption	Coastal Zone, Flash Flood Zones, and River Systems and Estuaries
9	Steel Slag (Unbound)	Soft soil, salinity, and high-temperature zones	High bearing capacity; angular particles improve stability	Potential heavy metal leaching; requires leachate testing	Industrial byproduct reuse; potential concerns over safety awareness	Coastal Zone, and River Systems and Estuaries
10	Emulsion Treated Base (ETB)	High salinity, moisture-prone soils	Impermeable, durable in wet conditions; made with local fine sand	Requires careful handling during mixing to avoid chemical exposure	Labor-intensive; promotes local employment with training	Coastal Zone, and River Systems and Estuaries
11	Cement Treated Base (CTB)	Moderate moisture and soft sand-based soils	Strengthens local fine sand; resilient and high load-bearing	Emissions from cement; offset by use of Pozzolanic variants	Capacity building in new construction techniques	River Systems and Estuaries
12	Reclaimed Asphalt Pavement (RAP)	Hot and dry climate, moderate traffic	Reuses road waste; high stiffness and thermal resilience	Minimal if sourced and laid properly	Reduces raw material demand; supports sustainability goals	Barind and Drought-Prone Zone
13	Brick Aggregate	Traditional baseline; used in all zones for comparison	Control section material; standard LGED practice	Brick production affects fertile topsoil; to be phased out	No innovation impact; widely accepted	Can be used in all zones as base layer



Chapter 4

Area specific considerations

4 Area specific considerations

This chapter addresses the specific considerations for Green Roads for Water in each of the five geographical zones. For each of the regions, annexes (Annex 3.1 to 3.5) provide more notes and photos from the field visits. In each area, several districts and types of roads have been visited, as shown in the table below and the map on the right.

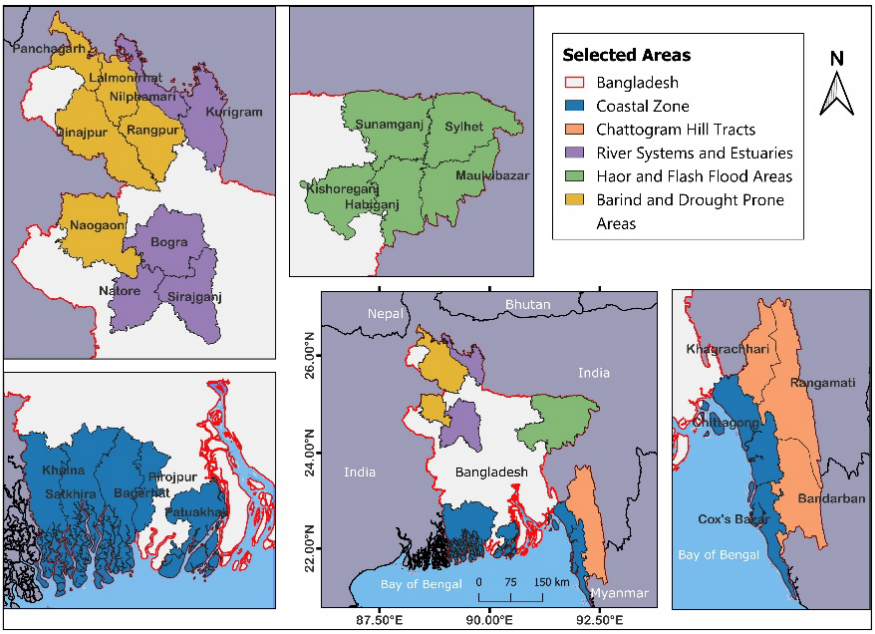


Figure 19 Overview of visited districts and the zones the areas they are part of according to the Bangladesh Delta Plan

Table 9 Overview of visited districts and the zones the areas they are part of according to the Bangladesh Delta Plan

Areas	*Districts*
Coastal Zone	Bagerhat
	Chittagong
	Cox's Bazar
	Khulna
	Patuakhali
	Pirojpur
	Satkhira
Barind and Drought Prone Areas	Panchagarh
	Dinajpur
	Naogoan
	Nilphamari
	Rangpur
Haor and Flash Flood Areas	Sylhet
	Habiganj
	Kishoregonj
	Moulvibazar
	Sunamgonj
Chattogram Hill Tracts	Bandarban
	Khagrachari
	Rangamati
River Systems and Estuaries	Natore
	Bogura
	Kurigram
	Lalmonirhat
	Sirajganj

4.1 Coastal zone

In the coastal zone, within the polders, roads, bridges, culverts, and gates strongly influence the flow of water, its distribution, and the water levels. Water logging and the lack of drainage, amongst others due to silted canals at multiple scales and reduced capacity of sluices and regulators, are among the core challenges of the dynamic coastal zone, which is illustrated by the frequently heard phrase that agricultural yields in the coastal zone can double if water management issues are resolved[16]. This notion aligns with what programs like Blue Gold have shown in practice.

The natural hydrology of the coastal polders has been heavily influenced by the development of polders and their embankments, making it impossible for water to enter the inland areas, resulting, amongst others, in the speedy siltation of the water system, and in unfavourable height differences between the river and the polders. Within the polders, water shortages occur due to inadequate and non-functional sluices/regulators. The central region of the polders often faces acute water scarcity, affecting agriculture, fisheries, and livestock production. An integrated approach encompassing water management, agriculture, and infrastructure is needed.

The network of internal roads, including small village roads and pathways, divides the polders – which a large part of the coastal zone consists of - into compartments, separating relatively higher and lower lands. Polder road infrastructure may impede drainage and create water logging, affecting land use and the capacity of the soil to absorb rain during high rainfall events. Cross drainage structures (bridges, (gated) culverts and pipes) are often not enough and too narrow, obstructing water flows. Likewise, bridge sills may be too high and impede drainage causing water logging.

At the same time, though they are now not constructed on these principles, roads can be powerful instruments to better regulate water levels in the fields and hence contribute to improved agricultural production. If properly fine-tuned, roads inside the polders are the main infrastructure to create areas with relatively low and high water levels and hence allow a more varied, multiple cropping land use patterns. At present, road alignment is often not designed in accordance with catchment hydrology. As mentioned, water-crossing structures may have inadequate dimensions, be wrongly located or be plainly absent. Neither are they systematically provided with gates, which would provide a huge opportunity to actively manage water levels and store and/or release (flood) water between different sections of the polders. At the same time, new roads designed without paying attention to drainage required are quickly damaged by erosion and subsidence. Thus, in summary, the benefits of combining road development with water management in the coastal zone are be multiple: less water logging, less road damage, improved agriculture production and improved overall livelihoods of rural communities.

Characteristic of the coastal zone are the ghers, which erode the side slopes of the rural roads due to wave action and due to being constructed too close to the road. Specific types of roadside vegetation that can handle the saline and harsh environment of the coastal zone can be helpful in reducing the impact. Salinity is also to be considered beyond vegetation; it can have a detrimental effect on infrastructure and can significantly reduce its lifetime if not carefully considered. Increasingly, rising sea levels are also to be considered for maintaining already present roads and developing new roads. Lastly, what furthermore characterises the coastal zone are the tidal flows that are to be considered in developing any infrastructure in the coastal zone. If not carefully considered, the impact of tidal flows can be devastating.

[16] https://www.cgiar.org/news-events/news/institutional-change-in-polder-water-management-governance-brings-revolutionary-potential-in-bangladesh/

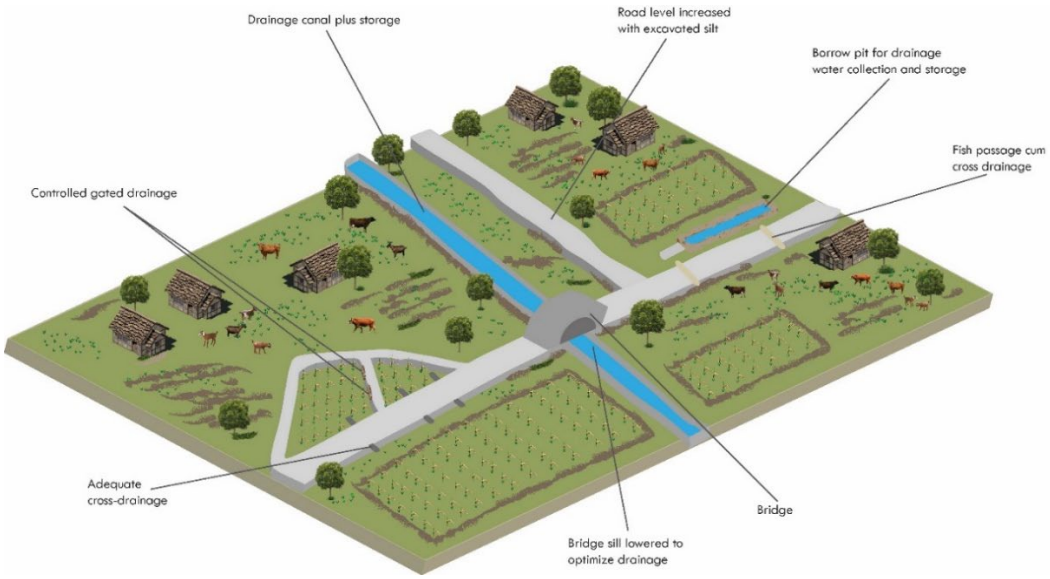
Roads combined with flood embankments

There is a strong link between roads and flood embankments. Many of these embankments are also used as roads – the top of the embankment serves as a subgrade for the road pavement. In addition, there are also several examples of roads functioning as embankments of rivers, channels, and canals. There are, at times, mismatches between these transport and flood protection functions. This happens when a paved road is developed on an embankment, which has not yet reached its safe and climate-proof level but, because of the road pavement, cannot easily be increased. There are instances where the height of the embankment is reduced to create a wider road and improve transport functions. In addition, when a road is developed, it tends to compact the body of the embankment: this makes it stronger but also may cause subsidence of the embankment body of up to 30 cm. This threatens the essential flood protection functions of an embankment. The current issues can be turned around by dovetailing road and embankment development – which would make both stronger, and designing embankments following criteria to accommodate a future road. It should, however, also be noted that that it has been frequently observed that a paved road on the top of an embankment, that is well operated and maintained, possibly thanks to having a road on top, can improve the flood protection function of the embankment. This should be seen in the context of many embankments, for which BWDB is responsible, lack regular routine maintenance.

Roads more systematically serving as temporary flood shelters and evacuation routes

Another important nexus between roads or embankment roads and flood resilience is that roads act as shelters and as safe havens during times of inundation but also, after the floods recede, as places where affected people and livestock can temporarily settle and rehabilitate. There is a need to systematically develop these linkages – with roads in areas with high risk of inundation providing evacuation routes and safe places for people and cattle. In general, unlike in the Flash Flood Areas and parts of the "River Systems and Estuaries" zone, the tidal and flood water in the coastal zone recedes relatively quickly from the affected areas, unless waterlogging, caused by local compartmentalization processes due to unplanned rural road embankments, is present. Refuge sections of roads in the coastal zone have, therefore, different characteristics than those in the other zones mentioned.

In general, as the coastal embankments act as the first defence walls against tidal surges, those polder embankments need to be upgraded to highly resilient standards so that water does not overtop the embankments. Hence, priority should be given to the upgrading of polder embankments rather than upgrading of internal roads within polders for shelters.



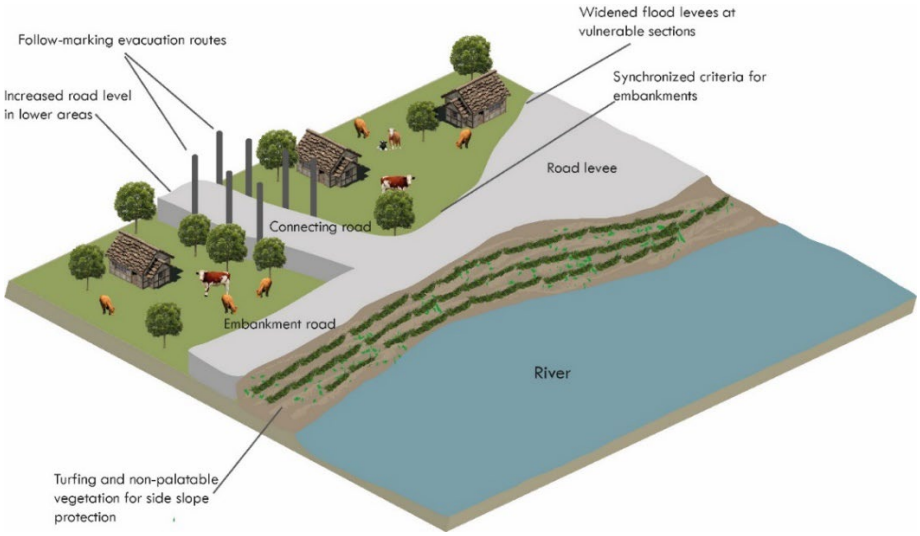


Figure 20 Visualization of some of the suggested good practices for coastal polders

Road protection and nature-based solutions to stabilize the river

Protective measures such as stone pitching, grassing, an soil-cement layer can protect embankments against splash erosion, water flow, waves, storm surges, and other natural calamities. For instance, soil bags are used as a sustainable and cost-effective solution for protecting the steep slopes of the embankments (Kalam and Matsushima 2016). The embankment slope facing the river or sea can be covered using flexible protection: dumped graded rock, hand-placed graded rock, rock mattresses, flexible mats, flexible pump-up revetment mattresses and vegetative cover. Rigid protection can be applied, but it is more expensive: grouted rocks, rigid pump-up revetment mattresses and concrete slabs (Smith 2006).

Vegetation is the cheapest way to protect steep slopes of earth embankments. It is practical and easy to use local plants. Vetiver grass (*Chrysopogon zizanioides)* grows naturally across many of the humid parts of lowland southeast, Asia and it survives to deep inundation up to 6m (Howell 2008). Vetiver grass is being used as an efficient bio-technology for slope protection in many countries, especially for its attributes: longer life, strong and long finely structured root system and high tolerance to extreme climatic conditions.

Recently, road projects have used seeding/mulching or turfing techniques for grassing road embankments (Howell 2008). Other methods can be used combined with vegetation: bamboo, cut branches, banana leaves and other brush mats can be applied as a cover on the slope of road embankments (Howell 2008). Moreover, wattle fences or brushwood can be placed on the side slope of the embankment with stone protection of the toe; barriers made with bundles using brushwork, fascines or wattling, stones mixed with strong timber sections; timber crib wall; reed planting among stone pitching, rip rap and reed rolls, of wire netting filled with stone, gravel and clumps of (Schiechtl and Stern 1997); and root wads. In the forthcoming guidelines, these nature-based solutions will be described with visuals.

Figure 21 Impression from possible nature-based solutions: From left to right: brushwood mattresses with toe protection, root wads, fascine bundles. More illustrations, pictures, and notes on their applicability for different zones of Bangladesh will be provided in the forthcoming guidance note.

Gated culverts

Gated culverts are exceptional and very uncommon for minor water control by farmers, while they are very promising instruments for water level control throughout Bangladesh. They are useful in the coastal polders, but also to manage water levels in e.g. drought prone areas. Gated water crossing structures – particularly box culverts and pipes - will help control water levels with the road infrastructure. Note that using gated culverts is not recommended for roads that serve as flood embankments. Water levels in a large area can be controlled with these relatively simple devices. They also make it possible to manage the water level in the upstream area for high-yielding (Aman) rice cultivation, in particular by opening or closing the gate. The gates also make it possible to release water upstream and drain the area, for instance, when fertilizer is applied.

In this way, properly controlled cross-drainage from roads goes hand in hand with the cultivation of high-yielding rice varieties. The gates on the cross-drainage structures can also be used to manage water storage upstream of the roads – for instance, for dry season cultivation or for aquaculture. In this case it may be useful to provide some additional protection to the roadside to prevent that they are eroded by the water pressure (caused by water velocity and quantity).

Figure 22 Left: Box culvert with slot for gate, Right: Gated culvert

Roads as sediment traps and raising land

In low-lying areas, roads can be used to capture sediments, increasing the land level on one side to deal with river level water rise gradually. This practice now occurs by chance, but if it were better managed, maybe the impact would be noticeable. In Polder 2 (Satkhira), the ground level has increased by 150cm upstream since the road was made 20 years ago. The higher ground is less prone to flooding and/or waterlogging; thus, farmers can

Figure 23 Impact of road on ground level; using roads as a sediment trap

grow a wider variety of dry-season crops. Selecting low-lying polders to use roads to trap sediments should be done as part of the polder level road planning, informed by hydrological mapping.

Bridges: Avoid sedimentation and silted bridges

Cross drainage structures, including bridges, are often not enough and too narrow, obstructing water flows. If water is not controlled and has to move freely at all times for larger crossings, a bridge is preferred; also, a bridge is considerably lower cost than a culvert of the same size. Furthermore, bridge sills are often too high and impede drainage, causing water logging. It is also important to recognize that water flow within polders is already regulated by existing sluices and regulators along the embankments. Therefore, the design of bridges and culverts within polders must take these control structures into account to ensure proper drainage and hydrological performance.

4.2 Barind and Drought Prone Areas

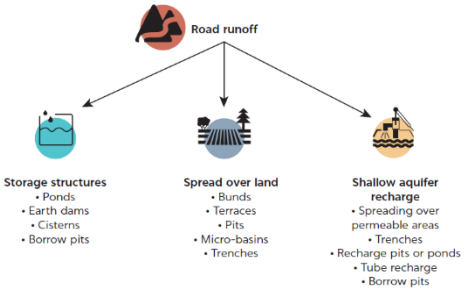


Figure 24 Water runoff and ways it can be stored

In drought-prone areas, roads can be pivotal instruments in ensuring water storage and making the most use of the limited available water. Drainage and culverts can be designed in such a way that they make water flow to roadside storage – which can also include borrow pits - ponds, or groundwater recharge areas. Especially in the monsoon, it is important to store as much water as possible, to have a buffer for the dry spells following, and to reduce the damage that comes with flash floods. Turning this problem around and ensuring that the flash floods, not present in the Barind area but disturbing in other drought-prone areas, are used productively is a promising approach in this area.

The Barind region, located in the northern part of Bangladesh is characterized by its vast stretches of barren lands, frequent droughts, and limited availability of water resources. With limited rainfall and inadequate water resources, farmers struggle to grow crops and maintain livestock. Embracing the Green Roads for Water concept, one would advocate for using roads for water storage. Currently, most of the rainwater is lost as runoff into nearby canals (*Khari*), rivers, and not stored in the groundwater, of which the levels are dropping due to overexploitation. Rainwater harvesting and managed aquifer recharge have, therefore, in the past decades, been promoted and researched in this area (Jahan et al., 2021).

Using road drainage and culverts for storage

The challenge is thus not only to capture the rainfall runoff but also to store it for later use. Runoff in the landscape that is guided by road infrastructure can be stored in three different ways (Figure 24):

- In surface storage structures such as ponds and converted borrow pits.
- Spread over land areas and used to replenish soil moisture, for example, as rain-fed cultivation or rangeland improvement, or retained by bunds, terraces, or micro-basins.
- Routed to recharge areas where it will replenish shallow aquifers; water can be pumped up from shallow aquifers for later use.

It should be noted that the storage capacity of surface reservoirs such as ponds and borrow pits is limited to the size of the basin, but the water is readily available at the surface. Surface storage systems also suffer losses from evaporation. In contrast, much greater quantities of water can be stored in the soil, in shallow aquifers, or both provided that the geology of the area is suitable. Also, shallow aquifer water is available for a long time (whereas surface storage systems are depleted over time because of evaporation) and can be accessed on demand, making it suitable for precision uses. The disadvantage

of shallow aquifer storage is that the water must be pumped up, but there are many low-cost solutions to this challenge. Very shallow groundwater is, therefore, among the optimal storage options; low-cost centrifugal pumps or solar pumps have the suction required to lift water up to 10 meters, making smallholder irrigation possible as a route from poverty to prosperity.

Percolation ponds and recharge areas

Runoff can be guided to recharge wells or percolation ponds, which collect the water for recharge into shallow aquifers. In some cases, these bodies may be abandoned dug wells or out-of-use borrow pits. It is important that these recharge structures penetrate a water-bearing layer with good transmissivity (ability to convey water) and spare storage capacity (not saturated).

If excavated treatments are needed for conveying or storing water, they should be located well away from the carriageway (usually more than 20 meters or more if possible, depending on the travel speeds on the road) and if not, road users should be protected by appropriate safety barriers.

Borrow pits

Borrow pits can be systematically used as recharge, storage, or seepage ponds. These pits are excavations of source materials—sand, gravel, soil—for road construction and are usually located very near the road itself. Rather than backfilling the pits or leaving them unattended, the borrow pits may be systematically converted into storage structures to serve as sources of irrigation or livestock water. In areas where there is no alternative, borrow pits may even become sources of domestic water.

Borrow pits may be used for water supply in three ways:

1. Water retention. The borrow pit is used for direct storage of runoff water. In such cases, the pit should have a relatively impermeable bed to prevent stored water from leaking away.
2. Infiltration ponds. In this case, the water that is collected infiltrates and feeds the shallow groundwater. Such borrow pits should have relatively permeable beds to facilitate groundwater recharging. They may even be supplied by excess water from nearby streams diverted or pumped into the converted borrow pit.
3. Seepage ponds. Borrow pits can serve as seepage ponds in areas with high groundwater levels, such as the floodplains of major rivers. In this case, the pits will fill constantly with groundwater seeping from adjacent areas and provide an almost permanent water source.

Water harvesting structures along the road

Runoff is preferably intensively managed throughout the entire water catchment. A large proportion of the runoff in a catchment can be retained by implementing several water conservation techniques – such as retention ponds, soak pits, infiltration galleries, terraces, and eyebrows—throughout the watershed and along the road.

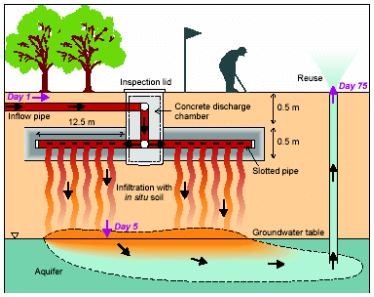


Figure 26 Infiltration galleries (Leviston et al., 2006)

Figure 25 Eyebrow terraces (van Steenbergen et al. 2021)

Another principle for water harvesting is to slow down runoff by guiding water to level land and spreading it. Water runoff loses its erosive nature at slower speeds, and sediments can settle. Reducing the speed of runoff also enables water infiltration to increase. Installing check dams, guiding water from steep slopes, building terraces, and other techniques can be used to slow water runoff speeds.

What is furthermore important to consider is the sustainability of road-water harvesting structures. Some earthwork structures will need regular repair. Water users will need to establish routines for inspecting the water management systems periodically (after each rainy season) and modify or improve the systems as required to address impacts such as erosion or overflowing and remediate any health, safety, and environmental concerns.

Table 10 Water-harvesting techniques from roads and applicable storage

Harvesting technique	Surface storage	Soil moisture storage	Shallow groundwater recharge
Floodwater spreaders along road surfaces		✓	
Flood diversion from culverts and road drainage		✓	✓
Infiltration structures fed from road drainage			✓
Cascading irrigation from road drainage			
Surface storage fed from road drainage (borrow pits, ponds, and cisterns)	✓		✓
Road bodies used as dams for water storage	✓		
Raised road embankments with raised culverts	✓	✓	✓
Road crossings used as sand dams or as water-spreading structures		✓	✓

Non-vented drifts

Figure 27 Road drift on a small river in Kenya

Road drifts can be used to build up water storage in sandy dry riverbeds, which will help build up moisture in the sand deposited upstream of the drift in a manner like sand dams. The road drifts should not include a culvert, making them non-vented drifts. Furthermore, the centre of the drift should be lowered, and there should be adequate spillover capacity. Non-vented road drifts can create water storage in semiarid areas and prevent rivers from braiding. The non-vented drifts are especially worth consideration in areas close to hilly areas, and can therefore alsoe be applicable to the Chattogram Hill Tracts. Working with non-vented drifts requires a different mindset and way of working with land and water. For the implementation of this measure, we, therefore, stress the importance of conducting a feasibility study on the acceptability and perceived disadvantages and advantages of the measure, at the local level.

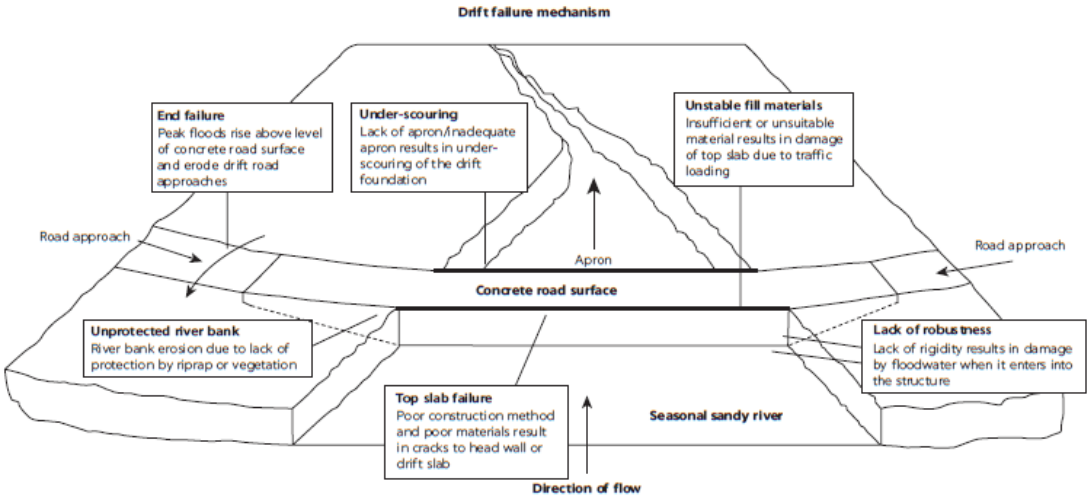


Figure 28 Overview of non-vented drift with preventable failure features

Roadside tree planting

Planting trees, shrubs, and grasses along the road can create a productive asset and can alleviate the negative effects of roads on the local environment (see also Chapter 3.3). Roadside trees can help mitigate negative effects such as erosion, loss of fertile soils, gully formation that undermines road foundations, heavy dust, wind-related desiccation, and more. Dust lifted by vehicles, especially along unpaved roads, has a direct effect on the health of people and livestock living near the roads and on crop production.

In the Barind and drought-prone areas, roadside tree planting ideally takes place with tree species that can absorb a lot of water in the rainy season to avoid settling roads in the wet season. Furthermore, roadside tree planting can be combined with other slope protection measures.

Careful assessment of road safety risks is essential before designing roadside tree-planting programs. Trees can pose a significant risk of death and severe injury to occupants of vehicles that run off the carriageway unintentionally and strike trees at travel speeds as slow as 30 kilometres per hour. Also, care should be taken to prevent negative consequences in terms of shade, as also illustrated in the preliminary overview table in Chapter 3.3.

4.3 Haor and Flash Flood Areas

Roads have a major impact on haor and flash flood areas hydrology: they often divide the floodplain into a wetter section and a drier section. Bridges may constrict the floodplain, and bridge sills may raise water and silt levels. Road building in a floodplain requires special attention to keep floodplain conditions alive and to prevent uncontrolled breaking of the road embankment. Amongst the pivotal considerations are adequate drainage with fish passages (French mattresses and culverts will preserve floodplain conditions), low-embankment roads with floodways (to facilitate controlled flooding into wetland areas and recharge zones) and using submersible roads in floodplains that are inundated for part of the year. A common phenomon in the Haors are earthen submergible flood embankments, which are every year reconstructed – as a form of fundamental routine maintenance - to protect crops from flash floods.

Retaining moisture

In the haor and flash flood areas, retaining moisture from retreating flood water is a promising implementation of the Green Roads for Water principles. To do so, one needs to consider roads, and their (gated) cross-drainage structures, as instruments for agricultural water management. This requires a shift in thinking and doing. Even in the backdrop of persistent flooding of the floodplains in the Haors for eight months per year, gated culverts allow for optimizing water management. They can provide promising avenues for creating more desired circumstances, especially in the four remaining months.

Orientation of roads

While important throughout Bangladesh, the orientation of roads is especially important in the Haor areas. Ideally, roads should be constructed or developed as much as perpendicular to the direction of flash flood to reduce potential damages, optimize rehabilitation, and reduce maintenance costs. The cause way (drifted rigid pavement) needs to be constructed alongside the bridges/culverts to allow passages of huge floodwater. This is in line with some of the sections below (on overflow sections and bridges), advocating for designing sufficient space for the water.

Submersible roads

While all-weather roads have first been welcomed as a solution, they are – in the haor and flash flood areas – increasingly seen as a problem. Locals say that all-weather roads disrupt the free flow of water in the haor, causing untimely floods which damage crops. Some even go further and say that there should not be any road in the haor, and that the authorities should develop a modern water transportation system here, to prevent flooding problems and the loss of biodiversity[17]. Currently, in the monsoon season, boats are the main means of transportation in the haor area.

Figure 29 Submersible roads in Singra Municipality, Bangladesh (https://singramunicipality.gov.bd/wp-content/uploads/2023/06/Submersible-road.pdf)

[17] https://www.tbsnews.net/bangladesh/all-weather-road-kishoreganj-was-solution-now-its-problem-439910

Submersible roads are inundated during the flooding season but facili-tate transport during the dry period when they reemerge. They can be reused, usually after some small repairs. These submersible roads do not interfere nega-tively or positively with the flood regime in the floodplain. However, drainage is still a key consideration, even in submersible roads. The road corridor should be low enough to release the drainage water. Frequently, the submersible roads are still made too high and, thereby, are still problematic. One issue with submersible roads is the sediments that settle on them after a flood. It has been reported that a settlement of 10-15 inches of clay is common. The construction of all-weather elevated roads, while often found fruitful for connectivity, can thus come with significant negative consequences, if hydrological features are not properly taken into account.

Overflow sections

Roads in flood-prone areas may be built with lower embankments and equipped with controlled overflow “floodway” structures instead of high embankments. This reduces costs enormously because the expenditure on the embankments is considerably less, and roads do not wash out in unpredictable locations.

Overflow embankment sections, or floodways, prevent overtopping of the embankment in an uncontrolled manner by allowing high water to pass over part of the embankment in a controlled manner when necessary. Low-embankment roads will conserve floodplain functions and prevent uncontrolled overtopping, but they will suffer predictable flood damage when overtopped.

One disadvantage of floodways is that overtopping renders a section of the road unusable during flood events. This lack of access causes inconvenience, and can be harmful to the welfare of adjacent communities, and is a possible hazard to road users. Careful consideration and calculation are required to determine the direction of inundation to floodways and the implications of the resulting traffic dis-ruption. Installation of poles with height markings along floodways can help road users estimate water depth and determine when crossing an inundated floodway would be unsafe and may also reduce the disruption associated with inundation.

Bridges

Bridge sills can be used for controlled drainage in the haor and flash flood areas, as they will effectively determine the water level in the upstream section of the road. However, too often, Cross-drainage structures (bridges, culverts or gated culverts, and pipes) are often insufficient or too narrow, and obstruct water flows. Likewise, bridge sills are often too high, impede drainage, and cause waterlogging.

Roadside vegetation

There is scope for more tree planting along higher sections. Trees and shrubs are important, as grasses are often not enough to keep roads intact. In haors, there is a need for swamp trees, which very well keep the soil together but are limited available, such as (local language) hijol and karo. Planting aquatic plants alongside the raised lands to reduce the energy of waves and thereby protect the land from erosion is a promising and proven nature-based solution in this regard.

4.4 Chattogram Hill Tracts

The Chattogram Hill Tracts, located in the southeastern part of Bangladesh, are distinctly different from the rest of Bangladesh, as it is the only extensively hilly area of Bangladesh. Rugged hills, dense forests, and numerous water bodies characterise the area. The area has to deal with severe erosion and landslides induced by rainfall variability and flash floods. Deforestation and land degradation furthermore increase erosion and put livelihoods under pressure. While rural road infrastructure development has aggravated the pressing situation in the past, it is aimed to reduce the negative impacts by embracing the Green Roads for Water concept and instead using rural road infrastructure for better water management.

Bioengineering

Bioengineering, the use of plants for slope stabilization and runoff control, encompasses a range of vegetative measures to stabilize slopes along mountain roads. It involves using plant parts such as roots, cuttings, and stems as a cost-effective and locally adaptable means of erosion control. Bioengineering ranges from planting deep-rooted species to a combination of vegetation and civil engineering structures. Examples of bioengineering include planting grass lines along contours vertically or diagonally, turfing, jute netting together with seedlings, brush layering, fascines, palisades, wattling, live check dams, bamboo fencing, and vegetated stone pitching (Devkota et al. 2014).

For the Chattogram Hill Tracts, bioengineering, including structural and vegetative measures, is considered very effective in avoiding landslides. Vetiver is commonly used for this purpose. Because of its deep, strong roots and high survival rate, vetiver rows have – globally - been applied widely on steep, erosion-prone slopes. Native plants that are known to adapt well to harsh settings and that have the positive mechanical and hydrological characteristics to strengthen the critical slope segments are preferred. Plant shoots are preferably planted when the live cuttings are without leaves. Vegetative measures are often combined with a gabion stone toe; the gabion stabilizes the slope while plants are placed on the upper sections. Additional measures are often used to further protect and reinforce slopes, such as brushwood mattresses, fascine bundles, timber crib walls, or riprap in selected sections.

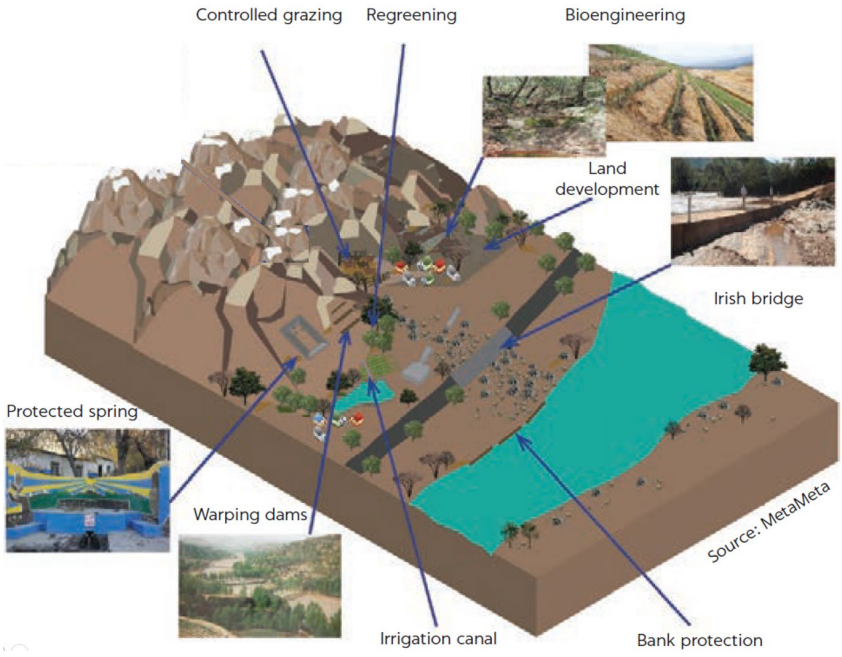


Figure 30 Integrated road-landscape management practices to be considered in mountainous areas

Vetiver grows in practically any soil and therefore also performs well in soils, such as fresh cut and fill areas, that are devoid of nutrients (Greenfield 2008). Its deep roots make vetiver able to withstand high runoff speeds and volumes. Vetiver is also a very resilient plant that can grow under a wide range of climate conditions, including air temperatures ranging from −15 °C to more than 55 °C and rainfall varying from less than 300 millimetres to more than 5,000 millimetres per year. Given this versatility, vetiver has a range of uses, including slope stabilization, vegetation rehabilitation, and as a source of fodder and thatch (Pinners, n.d.). Planting parallel hedges of vetiver on steep slopes can control runoff erosion related to road construction or drainage. Although common in some countries, several proven uses of vetiver have not been introduced in many other countries where they could make a significant contribution. The same applies to bioengineering.

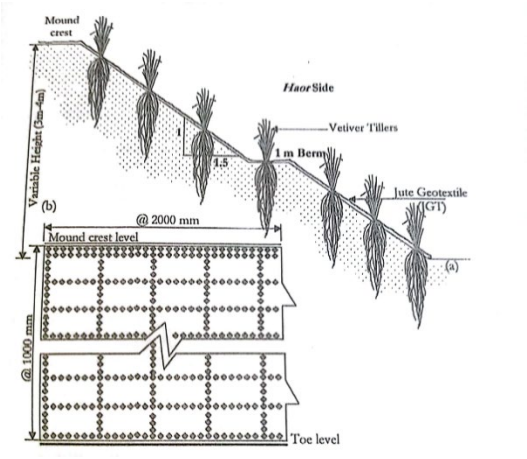


Figure 31 Normal lay-out design of vetiver grass (source: bioengineering training jointly arranged by LGED & ADB)

Table 11 Bioengineering functions, Adapted from J. Howell. 1999. Roadside Bio-engineering: Site Handbook. Government of Nepal, Department of Roads: Kathmandu.

Engineering functions	Requirements of plants
Catch eroding material down a slope, as a result of gravity alone or with the aid of water. The stems of the vegetation perform this function.	• Strong, numerous, and flexible sterms • Ability to recover from damage
Armor slopes against surface erosion from both runoff and rain splash This requires a continuous cover of low vegetation; plants with canopies alone do not armor the slope.	• Dense vegetation covers • Low canopy • Small leaves
Reinforce the soil by providing a network of roots that increases the soil's resistance to shear. Reinforcement depends on the form of the roots and the nature of the soil.	• Plants with extensive roots with many bifurcations • Many strong, fibrous roots
Anchor surface material by extending roots through potential failure planes into firmer strata below. If the potential failure is deeper than 0.5-meter, anchoring can be achieved by large woody plants with big vertical tap roots.	• Plants with deep roots • Strong, long, vertically oriented roots
Support the soil mass by buttressing and arching. Large, heavy vegetation, such as trees, at the base of a slope can provide support in the form of buttresses; or on a micro scale, clumps of grass can buttress small amounts of soil above them. Across the slope, a lateral effect is created in the form of arching: this is where the soil buttresses is supported from the sides by compression.	• Extensive, deep, and wide-spreading root systems • Many strong, fibrous roots
Reduce the velocity of water or wind movement across the surface of the soil. This is done by the sterms of vegetation offering resistance that retards the flow of water or air.	• Strong, numerous, and flexible sterms • Many strong, fibrous roots
Drain excess water from slopes. The planting configuration of vegetation can enhance drainage by channelling runoff down a slope, along erosion-protected lines, thereby avoiding saturation and slumping. Vegetation can also reduce pore-water pressure on the slope by extracting water via the roots and transpiring it out through the leaves.	• Plants small enough to be planted in closely packed lines • Ability to resist scour • Large leaf area to maximise transpiration

Bioengineering techniques are suitable and recommended throughout Bangladesh, especially in the shoulders and embankments of the roads. However, in the hill tracts, the measures are beyond that also more applicable in the landscapes surrounding the roads (see table 11).. Suitable bio-engineering measures in Southeast Asia include vertiver planting, grass planting, direct seeding, brush layers and fascines, truncheon cuttings, live check dams, tree planting, large bamboo planting, vegetated stone

pitching, geotextile coverings, wattle fences, and hydro-seeding (ADB, 2020). The potential for bioengineering is currently largely unemployed in Bangladesh; the Climate Resilient Rural Road Manual (LGED, 2019) does not fully incorporate bio-engineering methods for slope protection and jute geotextile applications. In this regard, it is promising that bioengineering is gaining more momentum with the LGED bio-engineering guideline developed with assistance of BUET, which will be further reflected upon in the forthcoming guidance note.

Weep holes in retaining walls

Weep holes are small openings or drains designed to allow the drainage of water from behind retaining walls. They play a crucial role in maintaining the stability and effectiveness of retaining walls. They prevent the build-up of water in the soil retained by the wall, which would otherwise cause increased lateral pressure and could even lead to the structure failing.

Figure 32 Weepholes provided at the bottom of a retaining wall (https://civildigital.com/weep-holes-civil-engineering-structures-retaining-walls/weepholes/)

Storing drainage water

As also in other areas of Bangladesh, it is very promising to better store the drainage water, to on the one hand, reduce damage to the roads and, on the other hand, have water resources available. For mountainous areas, the Green Roads for Water guidelines for Nepal recommend free-draining, downward-sloping road crowns that gently spread the runoff that gathers on the road. Good water exits at hairpin bends are required so that water does not remain on the road surface in these sections and careen downstream where it will accumulate and cause damage. An adequate number of causeways (or drifts) at stream intersections and other measures to control for stream crossing and spring management will be part of good road alignment and design. Note that this design requires the protection of the downside of the embankment to ensure that water running over it does not erode the embankment. Additionally, an ongoing water flow across the road can lead to the embankments becoming soaked, causing subsequent loss of strength, and carrying capacity.

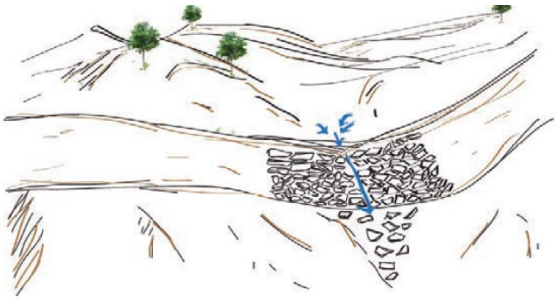


Figure 34 Tilted causeway (van Steenbergen et al., 2021)

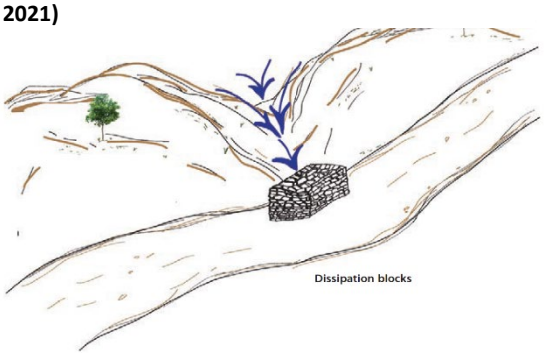


Figure 33 Use of dissipation blocks is recommended where a minor stream descends onto the road (van Steenbergen et al., 2021)

Road drifts as sand dams

Roads are often traversed by several mountain streams. At these places, causeways should be made of flat stones. Like the entire road, causeways are tilted at a slight angle toward the downhill side to facilitate drainage of the water from the stream. This is a good practice because it ensures the use of local material and provides structures that are easy to maintain. A depression can be made in the middle of the causeway to improve and guide the removal of water.

Beautification

The concept of beautification can also work out positively for the Chittagong Hill Tracts. Roadside tree planting, as a way of beautification, can further boost tourism in the region, as also Jhum cultivation. It is a traditional agricultural technique that involves clearing land of trees and other vegetation, burning it, and then cultivating it for a set number of years. However, Jhum cultivation, currently with too short fallow periods, accelerates erosion, land degradation, deforestation, and impoverishment of the tribal people in the Hill Tracts. The total land available does not match the current demands for Jhum cultivation, making the situation unsustainable. Roadside tree plantations can be a promising avenue for livelihood diversification.

Selecting road alignment

An important factor in selecting road alignment is to keep a safe elevation and distance from existing streams and rivers. A safe distance could prevent the road from becoming inundated or damaged by floods in such rivers and streams and reduce road runoff discharge into these watercourses. The road layout should be aligned with the current and predicted hydrological situation. An analysis of current hydrological data and future scenarios can inform this decision and contribute to further climate resilience. An elevated road could, if properly designed and maintained, also function as a sediment-catching structure, further stabilizing the landscape.

Spring protection

In mountain areas, the development of roads—either through the removal of unconsolidated material or the cutting of rock formations—will affect the occurrence of seeps and springs. Seeps are different from springs; a seep does not have a clear orifice, and water exits over the entire water-bearing strata. The management of such springs and seeps is important: in many mountain regions, they are the main source of domestic water supply and small-scale irrigation.

Once the road is developed, the presence of springs and seeps will be evident, and whether the spring or seep will be used must be determined. In areas with low population densities, springs may not be used, but they should still be managed to prevent discharge from damaging the road body. Table 12 suggests methods for managing different types of springs in different circumstances.

Table 12 Methods for managing different types of springs in different circumstances

Spring type	**Description of use**	**Spring management**
Spring with concentrated discharge	Not used	Retaining wall with weep holes or with longitudinal drain to collect excess water and traverse drains (French mattresses) underneath the road
	Used for agriculture	Retaining wall with longitudinal drain to collect excess water and traverse drains (French mattresses) underneath the road
	Used for domestic water supply	Spring box (capture) and conveyance to benefit community, or tap fitted onto protected spring
	Used for domestic water supply and storage	Spring box (capture) and conveyance to benefit community; include possibility of spring closure (tap) to store water inside the mountain aquifer (especially in karst areas)
Spring or seep with diffuse discharge	Not used	Develop road drainage in up-road section to collect seepage and convey to safe place
	Used for agriculture	Use gravel section in road to convey water to agricultural land

4.5 River Systems and Estuaries

Submersible road

As also in haor areas, submersible roads emerge as a, already widely in place, promising approach to address the challenges posed by the dynamic nature of Bangladesh's river systems and estuaries. It should be noted that this does not apply to the full river systems and estuaries zone, but to parts of it, as outlined in the area specific assessment (Annex 3.5). Submersible roads, designed to withstand varying water levels, can provide a resilient solution. Submersible roads can be a sustainable solution to combine the needs for transport and connectivity, without negatively affecting biodiversity and flood risks. Often, the roads become waterways once submerged and are thereby still vital means of rural transportation.

Water logging

Waterlogging is one of the key challenges in Bangladesh's agricultural sector. Fields that are flooded for too long periods negatively affect agricultural productivity and yield, and thereby, rural livelihoods. Roads can be used as instruments to control waterlogging and water levels and contribute to agricultural productivity. Especially in the riverine area, roads can be used as instruments to prevent waterlogging and as tools to guide the water – both when flooding and retreating.

Gated cross-drainage

Gated water crossing structures – in particular, box culverts and pipes - will help to control water levels with the road infrastructure. Note that using gated culverts is not recommended for roads that serve as flood embankments, as the culverts may then be the weakest link in the chain of water safety. With these relatively simple devices, water levels in a large area can be controlled for the benefit of agriculture and other livelihoods. They also make it possible to manage the water level in the upstream area for high-yielding (Aman) rice cultivation, in particular by opening or closing the gate. The gates also make it possible to release water upstream and drain the area, for instance, when fertilizer is applied. In this way, properly controlled cross-drainage from roads goes hand in hand with the cultivation of high-yielding rice varieties. The gates on the cross-drainage structures can also be used to manage water storage upstream of the roads – for instance, for dry season cultivation or for aquaculture. In this case, it may be useful to provide some additional protection to the roadside to prevent them from being eroded by the water pressure (caused by water velocity and quantity). Gated culverts must be designed to cope with/have limited siltation problematic, and be managed by regular desiltation and by ensuring flows when gates are open are vigorous enough to prevent sediment build-up.

Road side vegetation and slope protection with local varieties

Roadside vegetation is quite common in this area, though it can be improved and more mainstreamed. In general, plants selected for roadsides must be able to resist harsh conditions because the land adjacent to the road is often degraded. Native species are preferred because they are adapted to local conditions. The choice of species is based on the objectives of the planting (economic or environmental) and the space available. Multipurpose trees (fruit, fodder, timber, fuelwood species) can be incorporated to provide economic benefits. If the prime purpose of the planting is to block dust (such as along unpaved roads), generally speaking, species with pointed leaves, such as conifer needles or rough, hairy, and sticky leaves, are recommended. In the forthcoming guidelines, this topic will be discussed in depth, focusing on Bangladesh and its species.

Some of the main criteria for selecting species – not necessarily for the river systems and estuaries zones, but everywhere – to be reviewed and possibly adapted - are as follows:

- Tree species should be evergreen or remain green for most of the year.
- Species should be fast-growing.
- Tree species should not be broad-rooted because tree roots may penetrate the road surface.
- Tree species should have a crown architecture with a more horizontal than vertical extension.
- Tree and grass species should be tolerant of seasonal drought and insects and pests.
- Tree species should be deep-rooted to resist wind and drought stresses; deep-rooted trees are also strongly preferred because they are less likely to damage the road.
- Thorny plants are to be avoided because they may cause tire punctures.
- Tree and grass species should never be invasive.
- Tree species should have one or more aspects of social and economic value, such as medicinal, food, fuelwood, feed, or shade.
- If tree species are edible by livestock, fencing is needed in the growing stages to protect the tree and enable it to mature.
- Tall-growing trees should not be selected for planting beneath power lines.
- Trees that do not grow large-diameter trunks can be given preference because they pose less risk to errant vehicles.

For slope protection, it is also highly recommended to work with local varieties to stabilise soil and reduce erosion. In the forthcoming guidance note, we will further address this theme and the specific potentials of different varieties. The use of eucalyptus for this purpose is strongly discouraged, in line with the Government of Bangladesh's May 2025 announcement, which classifies eucalyptus as an invasive species and prohibits its inclusion in any tree plantation programs.

It should be noted that there are some chars under the “River System and Estuaries” zone, which are distinct in nature from plain land of the same category. Sustainable road development and maintenance in those areas are extremely challenging. The application of the Green Roads for Water concept in those areas shall be discussed in the forthcoming guidance note, where also recommendations will be made.

Chapter 5

Next steps

5. Next steps

The present report is an elaboration of the earlier prepared and reviewed assessment report, based on deskwork, field trips, consultations, and local workshops, and further improved and revised with new and specific findings. It explores the opportunities with LGED to systematically make roads instruments of water management and climate resilience in the different parts of the country whilst at the same time preserving and even improving the transport functions of roads. The assessment report serves as a key input and building block for the forthcoming country-specific Guidance Note on Green Roads for Water. It is understood that the Guidance Note will inform the formulation of new road investment programs.

The next step will be the validation of the findings and the suggestions for improved processes (chapter 2) and practices (chapter 3 and 4) in field visits to the five geographical zones of Bangladesh. A draft guideline presentation with main points will be prepared for this purpose. This will allow the finalization of the Guidance Note for discussion and approval by LGED. For the latter a workshop is planned in June 2025. The content for the Guidance Note is given below:

Proposed Content of Guidance Note

1. Introduction
   - 1.1 Road program of LGED
   - 1.2 Benefits and principles of Green Roads for Water
   - 1.3 Opportunities and challenges for different geographies in Bangladesh
   - 1.4 Harmonizing planning, development and after care processes

2. General principles and work process
   - 2.1 Assessment checklist
   - 2.2 Localization
   - 2.3 Local engagement

3. Design and modification of road network for GR4W
   - 3.1 Reference to existing practices and guidelines
   - 3.2 Proposed recommendations

4. Design and modification of road cross sections and embankments
   - 4.1 Reference to existing practices and guidelines
   - 4.2 Proposed recommendations

5. Establishing and maintaining roadside vegetation
   - 5.1 Reference to existing practices and guidelines
   - 5.2 Proposed recommendations

6. Design and modification of road drainage
   - 6.1 Reference to existing practices and guidelines
   - 6.2 Proposed recommendations

7. Design and modification of bridges
   - 7.1 Reference to existing practices and guidelines
   - 7.2 Proposed recommendations

8. Conclusion

Note: A chapter on pavement and constructions materials will be added into this outline of the guidelines.

In the annexes to this report, some of the elements of the Guidance Note are already included for early review, in particular the generic road cross sections (annex 6) and matrix for selection of species in roadside forestry (annex 7).

Following the Guidance Note, a very concise training outline will be developed with a number of key presentations. Examples of such presentations are included in annex 8 for feedback.

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Annexes

Annex 1 Meetings, consultations and workshops for the assessment

On 15 April 2025, a kick-off meeting/workshop took place with LGED, World Bank, and MetaMeta. In this meeting, MetaMeta and ADSL presented their approach, methods, and timeline, which were subsequently discussed with LGED. Agreements were reached on the next steps and follow-up engagements.

This meeting followed earlier engagements with LGED in 2023 and 2024, including the workshop that took place on 23 October 2023 with several engineers from a variety of departments of LGED and CReLIC, and workshops/meetings that took place in the field visits. This workshop was meant to inform all attendees of the then ongoing work as well as to present the initial findings, and to discuss those. By clicking on the slide below, the slide deck can be seen and downloaded. Such a meeting is foreseen to also be organised in the course of the next weeks/months, but then with a central role for the draft guidelines and for the capacity strengthening components of the project.

Figure 35 Slides from the workshop on 23 October 2023. By clicking on the picture, the slide deck (35 slides) can be seen and downloaded.

Notes from the attendees of the workshop include the following.

- Nurul Huda (additional chief engineer of LGED) suggested not say Green Roads for Water – but Green Roads to Water as that would better capture our assignment.
- Mr. Faruk Biswas of CReLIC mentioned that some points should be included: issues regarding climate resilience, climate data, climate mitigation and adaptation issues in relation to Green Roads activities. He also pointed out that CReLIC has documents that would be helpful for this assignment.
- Mr. Engr. Anwar Hussain (superintending engineer maintenance of LGED) pointed out that the existing available information should be collected and further development should be incorporated.
- Mr. Shomasi (project director of LGED) pointed out that LGED has lots of information on road construction and maintenance that we should address / build our work upon.
- Mr. Joasim (superintending engineer planning of LGED HQ) stresses that Green Road for Water concept, after talks with WB, tried to initiate some new idea through MetaMeta. He stressed the importance of asset management. The roads should be sustainably managed as assets.
- Measures can also be taken further away from the road. Not only on the road, shoulders etc. This area is often not owned by LGED, so it requires involvement of other stakeholders. It is important to also involve those in the field trips. Can also think of increasing ownership of beneficial measures by having them at least partly paid by local stakeholders, and not just by e.g. WB / GoB.

Outcomes from other consultations with LGED engineers and other stakeholders are woven through the report. Key outcomes from the consultations with LGED engineers include the following:

- With an increasing frequency of erratic rains, it becomes increasingly important to consider how roads and their shoulders can handle this. This needs to be considered for a variety of soil types, especially also for sand which is easily erodible.
- Promising ways to protect shoulders include the use of deep-rooted vegetation and well selected trees, and the use of well compacted/compressed soil.
- To tackle all challenges, one needs interdisciplinarity and a wide range of solutions, including modern technologies, vegetation, water harvesting techniques, and considerations for bridges and culverts.
- In the haors, roads are submerged frequently. There, the current vegetation does often not successfully keep the roads and shoulders intact. There is a need for suitable tree species, such as Hijol and Karoj, which are recommended to plant on the slopes of submersible roads in haor areas, though not in saline areas.
- One engineer notes that the benefits of community involvement in infrastructure projects and maintenance are currently for the greater good, and that it is important to think also about individual benefits.
- Important considerations brought up for green roads include:
    - The importance of side extension of roads every now and then (e.g. 250 to 500 m) – to let traffic pass and to function as a shelter for floods.
    - The importance of considering 4 to 5 days of extreme rainfall in designing roads, and the importance of designing sufficient cross drainage.
    - The importance of considering wave action on both sides of the roads if the road passes through any marshy land / beel / potentially water logged area.
    - The importance of slope stabilization and protection by, amongst others, nature-based solutions (NBS).
    - The importance of natural surface drainage along longitudinal and cross-sectional dimensions.
    - The importance of participatory methods of construction and maintenance.
    - The importance of routine water removal by communities – to ensure that there is no water staying on roads.
    - The importance of LCS, which are only there for some roads at the moment. LCS are mentioned to be satisfied in general and to have individual accounts to get payments directly and in a transparent way.
    - The importance of considering salinity, which can hugely affect construction and materials; lots of rotting due to salinity. There are mixtures that resist salinity – but those are expensive.
    - The importance of considering the local geography and circumstances.

Annex 2 Deep Dive Guide for Field Assessments

This guide has been used as a guide in conducting the deep dive field visits in 2023, including surveying the roads and soliciting opinions and views. It starts with some background information on the concept, then lists the suggested road survey activities. It also includes a suggested data collection sheet (Annex 4.1), and lastly a list of questions / topics for the meetings and interviews (Annex 4.2).

The concept of Green Roads for Water (GR4W) aims to transform the way roads are built and maintained all over the world by incorporating water management and climate resilience in the design and construction of roads. The overall aim is to turn around the currently negative impact of roads on landscape and livelihoods to a positive one while at the same time protecting the road infrastructure and ensuring transport.

Based on work in 10+ Asian and African countries, we found that the GR4W approach is a low-cost approach (5% of total cost of road construction) that can bring substantial benefits in many aspects. The main benefit streams are summarized below:

- To reduce water-related damage to road infrastructure and ensure access to markets and important facilities.
- To reduce damage to the surrounding areas (flooding, drainage congestion, erosion, sedimentation) triggered by roads.
- To create useful assets in terms of harvested water and increased flood protection using the roads as instruments for these.
- To improve the livelihoods of roadside communities by providing skill development and employment opportunities.

Opportunities are wide ranging, and concern amongst others roadside tree planting, converted borrow pits, storage ponds, and structures for water diversion, water harvesting for roadside agricultural fields and ghers, roadside businesses and facilities, and livelihoods derived from activities near roads. More information on the different GR4W strategies and measures can be found on the Green Roads for Water: Guidelines for Road Infrastructure in Support of Water Management and Climate Resilience which was published by the World Bank in 2021.

The objective of the road survey is to assess the issues and opportunities for Green Roads for Water. In the current assignment, road surveys will be undertaken in five representative regions, in particular the coastal/delta region, the flood plains, the haors regions, the hill tracts and the dry North West. In each region, at least one district will be visited to make an inventory of the current challenges regarding roads and water, the existing practices used to deal with them as well as the experiences, needs and priorities of local stakeholders and communities along the roads.

Local stakeholders, especially LGED and CReLIC, will be consulted for identifying suitable road stretches for the road surveys in each region (Figure 36). Road stretches are to be identified per region where the road survey will take place. All categories of rural roads will be considered.

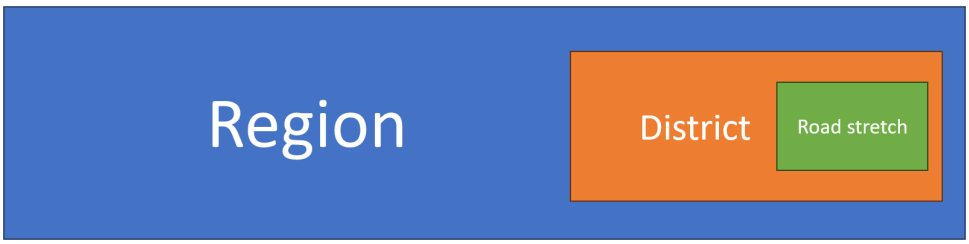


Figure 36 Selection of road stretch per district per region

Road survey activities are described below, and are to be executed in an adaptive manner during the field visits.

- Road transect drive: 50-100 kilometre transect road survey along different types of rural roads, recording main water-road, roadside interactions, road side tree planting/ grass planting practices – problems and good practices, on different kind of roadside uses and optimization, road drainage (see Annex 4.1). Also, factual cases and images will be collected that can be inputs for the guidance note and capacity strengthening material.
- Discussions with local stakeholders
    - Focus group discussions, including discussion of the activities of Labor Contracting Societies (see Annex 4.2)
    - Discussion with key persons on current stages road planning practice (with road drainage lagging behind road construction), road asset management and road-side management.
    - Discussion on implementation of measures in road-side tree planting and assess difference between successful and less successful examples; sampling of roadside tree plantation, understanding species and sourcing.

Annex 2.1 List of factors to consider in road survey

Exemplary types of issues regarding roads and water to consider:

- Faults, damages to the roads and bridges
- Effect of bridge sills on river hydrology (can increase river levels and impede drainage)
- Faults, damages on road hydraulic structures (such as culverts, ditches, mitre drains etc.)
- Road elevation – effect on landscape and flood protection
- Road slopes, current practice
- Road-induced erosion (such as gullies, landslides etc.)
- Road-induced/ influenced flooding
- Road-induced waterlogging (this in fact is often due to non-inclusion of bridges and roads in the first instance)
- Road-induced sedimentaton/ land rise (can see difference on either side of the road)
- Road damage due to heavy precipitation, especially the unpaved shoulders
- Road side vegetation – density from road, damage to road from vegetation or rather protection, dangerous traffic situation or improved traffic situation (less movement from animals/ people)

Exemplary road water management/Green Roads for Water experiences:

- Current use/ non-use of water
- Existng water harvestng, water recharge and retention practices along roads
- Water harvesting structures / mechanisms
- Water storage with roads, Borrow pits nearby road, status, and use – elongated borrow pits collecting excess water
- Road crossings (design and issues)
- Roadside trees and how they are managed, how much, density, species, renewal
- Use of bridges/culverts for water management (with gates)
- Use of roads during flood events
- Use of silt from canals for construction of roads
- Other interesting features

Annex 2.2 List of questions for discussion with LGED and other stakeholders from road, water, agriculture, disaster risk management and climate sectors

First, pitch the Green Roads for Water approach and explain them about our study. Then, to discuss the following:

Road development and maintenance

- How is the process of road development and maintenance in this area?
    - Selection
    - Planning
    - New roads / upgrading /right of way
    - Who owns the roadsides? Up to where? How is the right of way of the road-side enforced?
    - How is construction organized? (note it sometimes is done de facto in stages, first the road itself and later – as there is often not enough budget, so culverts and bridges are sometime left out)
    - How is maintenance organized?
    - What is the role of LCS? How are they organized? What goes good / what can go better?
- If the road has a dual purpose – see flood protection – how is then the cooperation with the BWDB, how is cooperation with others?
- What are the main features to consider in road development/design in this area? (Possibly includes geology, hydrology, climate, soil, land use, agriculture, socio-economy)
- How is road maintenance organized?

Roads and water

- Do you face issues between roads and water in their areas?
- … and what are the main issues (e.g. related to erosion, flooding, road damage, loss of agricultural production etc.)
- What do you think about the Green Roads for Water approach?
- Are you already practicing this or similar approaches? How is it organized? Who owns?
- What are the best/most promising measures for their areas?
- What are the main challenges in puttng them into practice and upscale them?
- Are the main challenges related to current regulations or implementation?
- How do you cooperate between different sectors towards this? How is this at different levels? Within district and outside district as watershed level?

Road side vegetation

- What do you think about planting of road side trees and grasses?
- Are you already practicing this or similar approaches? How is it organized? Who owns?
- What are the best/most promising measures for their areas?
- What are the main challenges in puttng them into practice and upscale them?
- Are the main challenges related to current regulations or implementation?
- How do you cooperate between different sectors towards this? How is this at different levels?

Annex 2.3 List of topics for discussion with roadside communities

FGD are meant to find out more about the roads and water, about the current practices, about the potential for NBS and GR4W, and about the current and possible role of the local communities. Part of those FGD can be any local community living close to roads constructed and maintained by LGED, and particularly also UP chairmen and members.

Introduction / warming-up

- What is the history of this area?
- Have there been many changes in this area?
- What are important challenges?

Drawing

- Making a drawing of what the current situation is with the road (in general)
- When was the road developed? Who were involved in it?
- To include/discuss how it developed over time?

<u>Zooming further in:</u>

Roads general:

- What are the good things and not-good things on the roads (possibly include safety, animal crossings, encroachment, use of roadside, accessibility over the year)
- What could be better?
- If time/energy is there; make a drawing of what could be better (or add that to the present drawing)

Roadside water management

- Effect of roads on water
- Effects of water on roads
- Positive and negative experiences
    - Possibly including: Gated culverts, Roadside water storages, Etc.
- Roads / bridges / culverts used to control water with gates
- Situation during drought
- Situation during floods/ typhoons
- Is water collected from roadside used – for what?

Roadside tree planting

- How is the appreciation of the roadside trees, which trees are best, why, what are the benefits (productive use, dust, safety, biodiversity, etc.)
- How is the appreciation of roadside grasses (type, use)
- What are the challenges?

Use of roadsides

- How are they used, for what?
- Is it controlled/regulated?
- What are the issues?

Effect of road on:

- Sedimentation
- Erosion / Scouring
- Other effects?

Road building material

- Where is it coming from?
- What happens to the material sources?

Role of communities in road construction and maintenance

- Role in construction
- Role in maintenance

- Role in vegetation planting

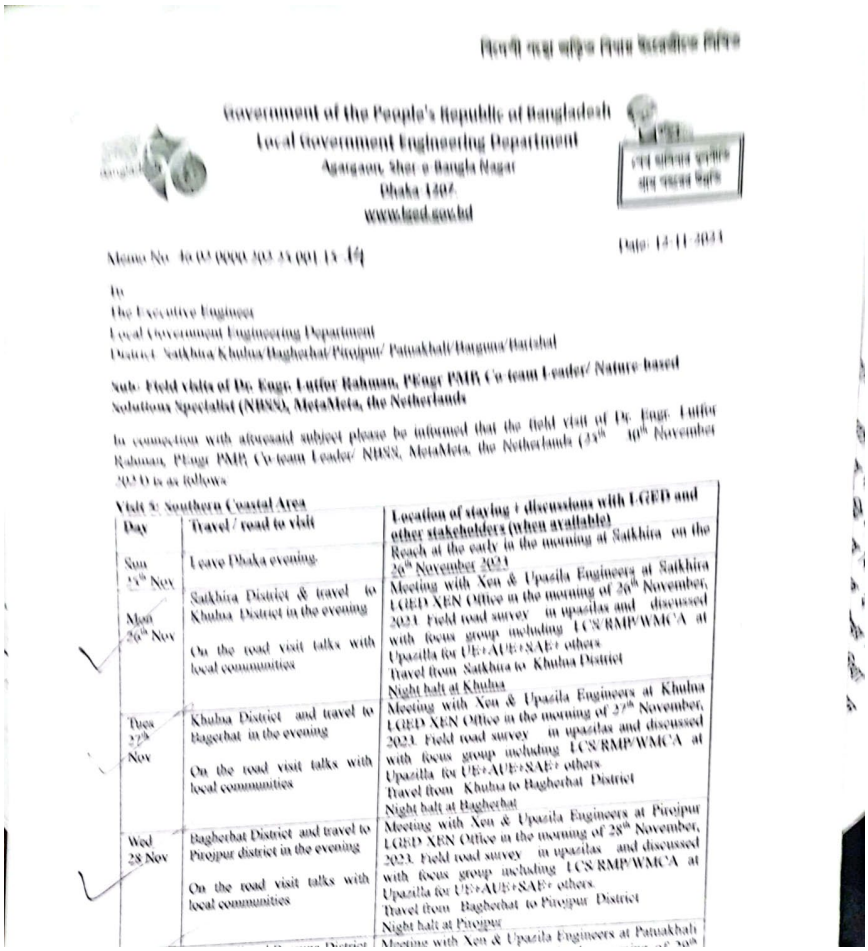
Topics to discuss with LCS

- How does maintenance by LCS work?
- For what organizations / institutes do the LCS work?
- What are procedures to get it started?
- What work is typically done by LCS?
- What goes good / what can go better?
- What is the experience from the LCS?
- The possible role of LCS in GR4W / NBS practices

Annex 3 Area specific assessments

This annex provides more details on each of the representative geographical zones studied and visited. It should be noted that under some of the field visits, visits from other adjacent zones have been visited. The overview of visited districts and the zones the areas they are part of, as presented in the beginning of Chapter 4, is correct.

Annex 3.1 Coastal Zone



Government of the People's Republic of Bangladesh
Local Government Engineering Department
Agargaon, Sher e Bangla Nagar
Dhaka 1207
www.lged.gov.bd

Memo No: 46.03.0000.303.33.001.13-44

Date: 13-11-2023

To
The Executive Engineer
Local Government Engineering Department
District: Satkhira Khulna Bagherhat Pirojpur/ Patuakhali Barguna Barishal

Sub: Field visits of Dr. Engr. Lutfor Rahman, PEngr PMP, Co-team Leader/ Nature based Solutions Specialist (NBSS), MetaMeta, the Netherlands

In connection with aforesaid subject please be informed that the field visit of Dr. Engr. Lutfor Rahman, PEngr PMP, Co-team Leader/ NBSS, MetaMeta, the Netherlands (25th - 30th November 2023) is as follows:

Visit 3: Southern Coastal Area

Day	Travel / road to visit	Location of staying + discussions with LGED and other stakeholders (when available)
Sun 25th Nov	Leave Dhaka evening.	Reach at the early in the morning at Satkhira on the 26th November 2023
Mon 26th Nov	Satkhira District & travel to Khulna District in the evening On the road visit talks with local communities	Meeting with Xen & Upazila Engineers at Satkhira LGED XEN Office in the morning of 26th November, 2023. Field road survey in upazilas and discussed with focus group including UCS/RMP/WMCA at Upazilla for UE+AUE+SAE+ others Travel from Satkhira to Khulna District Night halt at Khulna
Tues 27th Nov	Khulna District and travel to Bagerhat in the evening On the road visit talks with local communities	Meeting with Xen & Upazila Engineers at Khulna LGED XEN Office in the morning of 27th November, 2023. Field road survey in upazilas and discussed with focus group including UCS/RMP/WMCA at Upazilla for UE+AUE+SAE+ others Travel from Khulna to Bagherhat District Night halt at Bagherhat
Wed 28 Nov	Bagherhat District and travel to Pirojpur district in the evening On the road visit talks with local communities	Meeting with Xen & Upazila Engineers at Pirojpur LGED XEN Office in the morning of 28th November, 2023. Field road survey in upazilas and discussed with focus group including UCS/RMP/WMCA at Upazilla for UE+AUE+SAE+ others Travel from Bagherhat to Pirojpur District Night halt at Pirojpur
		Meeting with Xen & Upazila Engineers at Patuakhali

Figure 37 Field visit order and plan as established in consultation with and approved by LGED.

Notes from discussions, meetings, and interviews

Notes from discussions, meetings, and interviews have been grouped and summarized below.

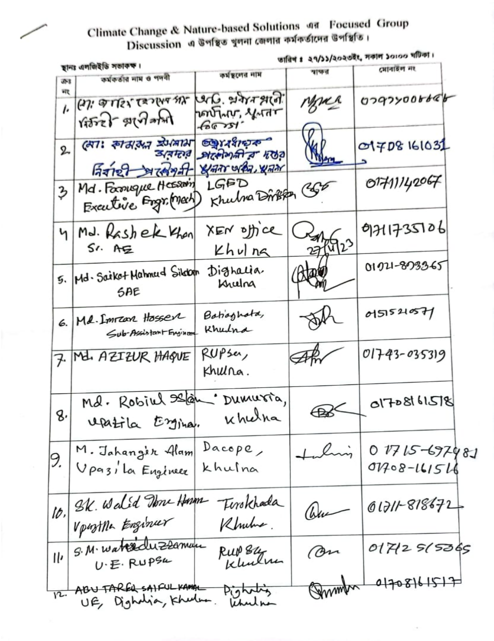
- **Land acquisition** is challenging. There is a need to ease this. Problems within land requisition are the removal of electric poles, plants in the existing road alignment.
- River & Khal near the road make the roads and water deal with each other intensively. This calls for good **side slope protection**. There is a need for rules for the preservation of shoulders besides ponds and khals. Also ghers put shoulders frequently at risk. With the large pressure on land, shrimp farmers cut road shoulders for fish farming.
- **Heavy rainfall** can erode roads and causes a rise in water next to road.
- **Political involvement**. Contractors are said to be mostly political persons and do not always have the public interest.

- The potential for **drainage** is too low with the current road system in the coastal zone. Also, drainage needs to be much more considered in any new road developments. More drainage (in the forms of culverts, bridges, drains, and openings) is needed to reduce water logging.
- There is a need to adjust the **rate schedule** with the increasing costs of materials.
- There are problems with **heavily loaded vehicles** damaging the roads. The roads are not designed for the heavily loaded vehicles used nowadays. Heavy vehicles also damage small culverts.
- There is **deforestation** besides the roads, but no to too little reforestation.
- Roads are generally **less wide in the bends**, increasing the risk for accidents.
- There is a need for **environmentally friendly construction materials**. Clay bricks should not be used; instead recycling stones/rock aggregated to be used. There is also a High potential for using geo-bags in the coastal zone give the soil textures.
- Sometimes, **rising the roads** can have many benefits – including being able to use it for a larger part of the year, but also using it for water management.
- **Ownership** issues of the right of way can cause problems in sustainably managing roads.
- **Labour:** uniblock construction is a hard job.
- **The increasing frequency of natural disasters** further increases the need for climate-resilient infrastructure. Also, this increases the need for flood shelter constructions. Cyclone storm surges in the coastal zones have deteriorated the side slopes, shoulders, and embankments of many roads.
- There is scope to employ more **LCS & RERMP** workers to maintain roads.
- **Salinity** should be considered in the construction and material selection phase.
- **Road user association** must be formed to build ownership.

Impression of field visit

Figure 38 Xen Bhola-Barishal Office Meeting

Figure 39 Presentation and subsequent focus group discussion at XEN Pirojpur Office

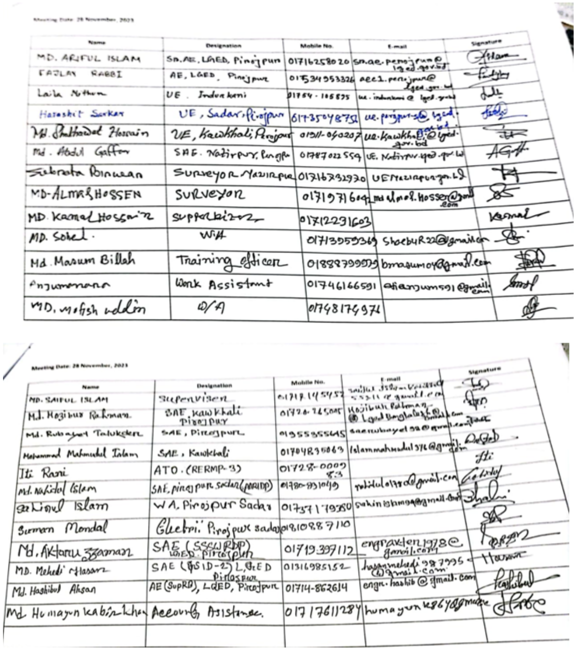


Climate Change & Nature-based Solutions এর Focused Group Discussion এ উপস্থিত খুলনা জেলার কর্মকর্তাদের উপস্থিতি।

তারিখ : ২৭/১১/২০২৩ইং, সকাল ১০:০০ ঘটিকা।

ক্রম নং	কর্মকর্তার নাম ও পদবী	কর্মস্থলের নাম	স্বাক্ষর	মোবাইল নং
1.	মো: কাবির হোসেন ... নির্বাহী প্রকৌশলী	এল.জি.ইডি ... খুলনা	[signature]	[illegible]
2.	মো: কামরুল ইসলাম ... নির্বাহী প্রকৌশলী	[illegible]	[signature]	01708161031
3.	Md. Farouque Hossain Executive Engr. (mech)	LGED Khulna Division	[signature]	01711142067
4.	Md. Rashek Khan Sr. AE	XEN office Khulna	[signature]	01711735106
5.	Md. Saiket Mahmud Sikder SAE	Dighalia, Khulna	[signature]	01921-873365
6.	Md. Imran Hossen Sub Assistant Engineer	Batiaghata, Khulna	[signature]	[illegible]
7.	Md. AZIZUR HAQUE	Rupsa, Khulna.	[signature]	01743-035319
8.	Md. Robiul Islam Upazila Engineer	Dumuria, Khulna	[signature]	01708161518
9.	M. Jahangir Alam Upazila Engineer	Dacope, Khulna	[signature]	01715-697481 01708-161516
10.	SK. Walid ... Upazila Engineer	Terokhada Khulna.	[signature]	01711-818672
11.	S.M. Wahiduzzaman U.E. Rupsa	Rupsa Khulna	[signature]	01712 515365
12.	ABU TAREQ SAIFUL KAMAL UE, Dighalia, Khulna.	Dighalia Khulna	[signature]	01708161517

Figure 41 Participation list 27 November 2023



Meeting Date: 28 November, 2023

Name	Designation	Mobile No.	E-mail	Signature
MD. ARIFUL ISLAM	Sn. AE, LGED, Pirojpur	01716258020	[illegible]	[signature]
FAZLAY RABBI	AE, LGED, Pirojpur	01534953326	[illegible]	[signature]
Laila ...	UE Indurkani	[illegible]	[illegible]	[signature]
Harashit Sarkar	UE, Sadar, Pirojpur	01735487??	[illegible]	[signature]
Md. Shahadat Hossain	UE, Kawkhali, Pirojpur	[illegible]	[illegible]	[signature]
Md. Abdul Gaffar	SAE, Nazirpur, Pirojpur	[illegible]	[illegible]	[signature]
Subrata Biswas	Surveyor, Nazirpur	[illegible]	[illegible]	[signature]
MD. ALMAS HOSSEN	Surveyor	[illegible]	[illegible]	[signature]
MD. Kamal Hossain	Supervisor	01712291603		[signature]
MD. Sohel	WA	[illegible]	[illegible]	[signature]
Md. Masum Billah	Training officer	[illegible]	[illegible]	[signature]
Anjumanara	Work Assistant	01746166591	[illegible]	[signature]
MD. Mofish uddin	Q/A	[illegible]		[signature]

Meeting Date: 28 November, 2023

Name	Designation	Mobile No.	E-mail	Signature
MD. SAIFUL ISLAM	Supervisor	[illegible]	[illegible]	[signature]
Md. Hasibur Rahman	SAE, Kawkhali Pirojpur	[illegible]	[illegible]	[signature]
Md. Rubayat Talukder	SAE, Pirojpur	[illegible]	[illegible]	[signature]
Mohammad Mahmudul Islam	SAE, Kawkhali	[illegible]	[illegible]	[signature]
Iti Rani	ATO (RERMP-3)	[illegible]		[signature]
Md. Nahidul Islam	SAE, Pirojpur Sadar	[illegible]	[illegible]	[signature]
Sahidul Islam	W.A. Pirojpur Sadar	[illegible]	[illegible]	[signature]
Suman Mondal	[illegible]	[illegible]		[signature]
Md. Aktaruzzaman	SAE (SSWRDP) LGED, Pirojpur	[illegible]	[illegible]	[signature]
MD. Mehedi Hasan	SAE (PSID-2) LGED Pirojpur	[illegible]	[illegible]	[signature]
Md. Hasibul Ahsan	AE (SupRD), LGED, Pirojpur	01714-862614	[illegible]	[signature]
Md. Humayun Kabir	Accounts Assistant	01717611287	[illegible]	[signature]

Figure 40 Participation list 28 November 203

Figure 42 Road in coastal zone with side slope protection but no to limited vegetation

Figure 43 Uni-block road without bituminous black top/ 2-20%

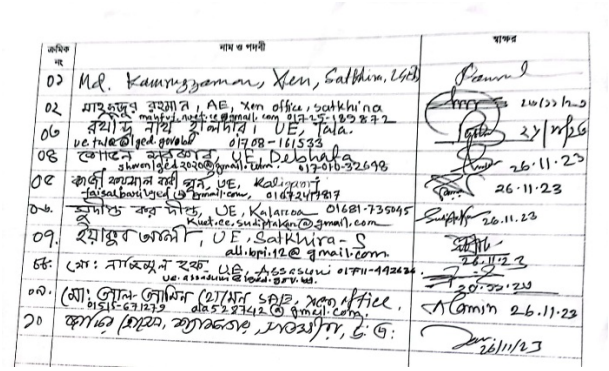
Figure 44 Narrow shoulder in bend

Figure 45 Bituminous carpeting road with tree plantation and geo-bag wave erosion protection

Sl. No.	Name & Designation	Mobile No & E-Mail No.	Work Place	Signature
1	2	3	4	5
1.	Md. Sharifuzzaman Executive Engineer	Mob: 01708-123181 e-mail: xen.bagerhat@lged.gov.bd	Executive Engineer Office LGED, Bagerhat.	
2.	Jyotirmay Mohanta Senior Assistant Engineer	Mob: 01708-161083 e-mail: sr.ae.bagerhat@lged.gov.bd	Executive Engineer Office LGED, Bagerhat.	
3.	Nitish Ranjan Gaine Assistant Engineer	Mob: 01708-161163 e-mail: aec.bagerhat@lged.gov.bd	Executive Engineer Office LGED, Bagerhat.	
4.	S.M. Hasan Ibna Mizan Upazila Engineer, Sadar	Mob: 01708 161 506 e-mail: ue.bag-3@ lged.gov	Upazila Engr.	
5.	Gulzer Hassan UE	ue.rampal.bag@	Rampal	Verified
6.	Saddam Hossain UE	ue. chitalmari	Chitalmari	"
7.	Ariful Islam UE	ue.morrelganj@ "	Morelganj	"
8.	Md. Anwar Hakim UE	ue. basar. kachua ae.lged.gov.bd.	Kachua	"
9.	~~Md.~~ Shoukat Hossain; UE	ue.mollahat@ "	Mollahat	—
10.	Ferdous Alam UE	ue.sharankhola@ "	Sharankhola	Verified
11.		ue. fakirhat @ "	Fakirhat	
12.		ue.mollahat@ "	mollahat	
12.		ue.mongla@ "	mongla	

Figure 46 Participants Bagerhat Focus Group Discussion

Figure 47 Impression rural road network around Bagerhat



ক্রমিক নং	নাম ও পদবী	স্বাক্ষর
01	Md. Kamruzzaman, Xen, Satkhira, LGED	
02	মাহফুজুর রহমান, AE, Xen office, Satkhira	26/11/23
06	[illegible]	26/11/23
08	[illegible]	26.11.23
04	[illegible]	26.11.23
05	[illegible]	26.11.23
09	[illegible]	26.11.23
08	[illegible]	26.11.23
07	[illegible]	26.11.23
10	[illegible]	26/11/23

Figure 48 Attendees Satkhira focus group discussion

Figure 50 Rural road moving through a shrimp gher area

Figure 49 LCS cleaning the road shoulder

Figure 51 Drainage channel besides the road

Figure 52 Road damage by tidal movements

Annex 3.2 Barind and Drought Prone Areas

বিদেশী সংস্থা জড়িত বিধায় ইংরেজীতে লিখিত

Government of the People's Republic of Bangladesh
Local Government Engineering Department
Agargaon, Sher-e-Bangla Nagar
Dhaka-1207.
www.lged.gov.bd

শেখ হাসিনার মূলনীতি
গ্রাম শহরের উন্নতি

Memo No:46.02.0000.202.25.001.15-11 Date:25-10-2023

To
The Executive Engineer
Local Government Engineering Department

District:Dinajpur/Panchaghar/Nilphamari/Lalmonirhat/Kurigram/Rangpur/Joypurhat/Chattogram/Rangamati/Bandarban/Khagrasari/CoxBazr/Sylehet/Shunamganj/Moulovibazr/Hobiganj.

Sub: Field visits of Dr. Engr. Lutfor Rahman, PEngr PMP, Co Team Lead and NBS Specialist, MetaMeta, the Netherlands.

In connection with aforesaid subject please be informed that the field visit iterinary of Dr. Engr. Lutfor Rahman, PEngr PMP, Co Team Lead and NBS Specialist, MetaMeta, the Netherlands (xx – xx October 2023) is as follows:

Visit Nr. 2 – Barind and Drought Prone Areas

Day	Travel / road to visit	Location of staying + discussions with LGED and other stakeholders (when available)
Thu 26 Oct	Leave Dhaka early. Panchagarh to Dinajpur District On the road visit talks with local communities	Visit LGED XEN Office of Panchagarh District Discussions meeting with focus group least one Upazilla for UE+AUE+SAE+ there. Visit LGED XEN Office of Dinajpur District Discussions meeting with focus group least one Upazilla for UE+AUE+SAE+ there. Night halt at Dinajpur
Fri 27 Oct	Dinajpur to Nilphamari to Lalmonir hat On the road visit talks with local communities	Visit LGED XEN Office of Nilphamari District Discussions meeting with focus group least one Upazilla for UE+AUE+SAE+ there. Visit LGED XEN Office of Lalmonir hat District Discussions meeting with focus group least one Upazilla for UE+AUE+SAE+ there. Night halt at Lalmonir hat
Sat 28 Oct	Lalmonir hat to Kurigram to Rangpur On the road visit talks with local communities	Visit LGED XEN Office of Kurigram District Discussions meeting with focus group least one Upazilla for UE+AUE+SAE+ there. Visit LGED XEN Office of Rangpur District Discussions meeting with focus group least one Upazilla for UE+AUE+SAE+ there. Night halt at Rangpur
Sun 29 Oct	Rangpur to Joypurhat On the road visit talks with local communities Travel to Dhaka	Visit LGED XEN Office of Joypurhat District Discussions meeting with focus group least one Upazilla for UE+AUE+SAE+ there.

Figure 53 Field visit order and plan as established in consultation with and approved by LGED.

Notes from discussions, meetings, and interviews

Notes from discussions, meetings, and interviews have been grouped and summarized below.

- **Ponds situated near the road** and insufficient water in the ponds, are part of the steep slopes related problems, including instability of the shoulders and thereby road.
- **Ownership of roadside land** is problematic: often, land is donated for road development by the roadside communities, but they still (want to) use the area the shoulders take for other purposes. There is, in general, a pressure on land. Also, markets/houses are often located very close to the road, or even on the (extended) shoulders.
- Need for more **awareness** at community level on the need for **O&M of roads**. Also, officials raise the importance of **gender considerations** for road maintenance.
- **Planned tree plantation** is needed on the side slopes of the road.
- In this region, **floods are due to precipitation only**. But sudden floods can still be damaging.

- **Insufficient drainage** due to lack of openings such as bridge culverts. Also, shifting river courses can make bridges and culverts outflanking. In line with the limited drainage/bridges, etc., boat movement is often obstructed due to insufficient navigation clearance. Insufficient drainage leads, even in this dry area, to water logging. The not equal road carpeting further drives drainage problems. Especially in places with limited drainage, **bank protection** is important.
- Need for increased **emergency funds**.
- **Vehicle loads** are too heavy for the current road designs. Also, larger (future) **traffic volumes** are to be considered – advocating for wider roads and sill coats.
- **Extreme weather events**, **field conditions**, and **changing climate** are to be considered in road design.
- BIWTA standard navigation clearance should be provided.
- **Material availability** is challenging, e.g. stones are often not available and there is a shortage of earth in the roads.

Impression of field visit

Figure 54 Presentation and focus group discussion with LGED engineers in Dinajpur District Office

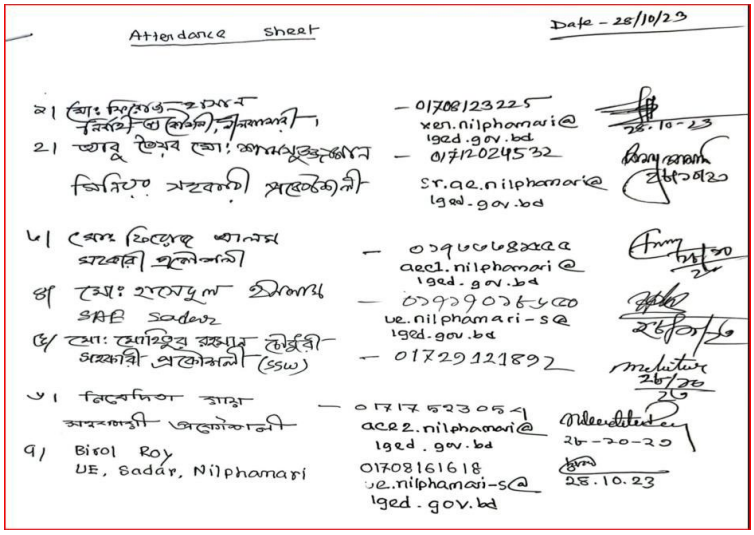
Figure 55 Field Photographs from Birampur Upazila , Dinajpur

Name	Designation	Mobile No.	E-mail
Md.Mahmud Jaman	Xen, Panchagarh	01712296141	Xen.panchagar@lged.gov.bd
Md. Abdul Motin	Sr.AE	01711-907700	-
Md. Siddiqur Rahman	UE, Tetulia	01717525462	Ue.tetulia @gov.bd
Md. Farhad Hossain Sourov	AE, Xen Office	01772711610	Sourovss14@gmail.com
Md.Joynal Abedin	Surveyor	01737845447	-
Md. Alamin	SAE	01717641964	Alaminfaruk.lged@gmail.com

Figure 56 Participants in the Panchagarh session

Figure 58 Officers providing input

Figure 57 Road damaged in the left & water mismanaged damaged roads



Attendance Sheet

Date - 28/10/23

2) [illegible] — 01708123225 — xen.nilphamari@lged.gov.bd — 28.10.23

2) [illegible] — 01712024532 — sr.ae.nilphamari@lged.gov.bd

4) [illegible] — aee1.nilphamari@lged.gov.bd

5) [illegible] — ue.nilphamari-s@lged.gov.bd

6) [illegible] — 01729121892

7) [illegible] — aee2.nilphamari@lged.gov.bd — 28-10-23

9) Biroj Roy, UE, Sadar, Nilphamari — 01708161618 — ue.nilphamari-s@lged.gov.bd — 28.10.23

Figure 59 Nilphamari participants

Figure 61 Officers providing input

Figure 60 Impression of road

Attendance Sheet for Participants

Subject : Discussion of Green Roads for Water :
Date : 28-10-2023
Venue : LGED Bhaban, Rangpur

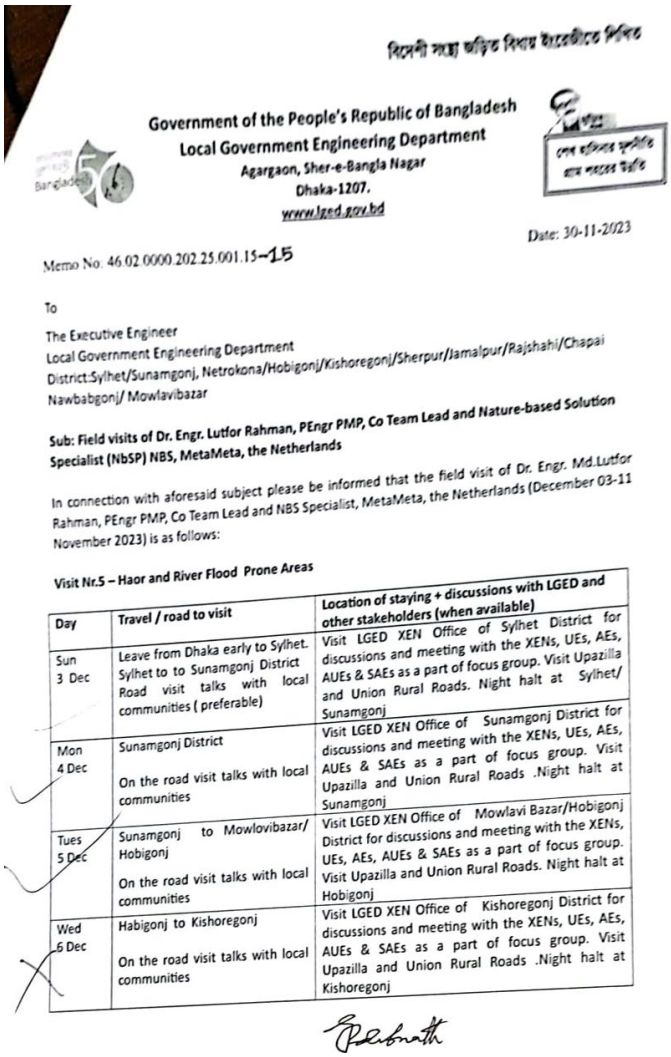
Sl No.	Name of Participants	Designation	Work Place, Address & Mobile Number	Signature
01	MOHAMMAD SHAHJA HAN ALI	XEN	01708123254	
02	Md. Badsha Alamgir	Sr. AE	Xen office, Rangpur 0172-572400	
03.	Md. Asaduzzaman Jemi	UE	Kaunia, Rangpur 01710-[illegible]	
04	Md. Mashiur Rahman	Upazila Engineer	Pirgonj, Rangpur 01708161656	
05	Md. Akhteruzzaman	Upazila Engineer	Mithapukur, Rangpur 01716115490	28-10-2023
06	Md. Alimuzzaman	SAE	Rangpur Sadar 01712-669497	
07	Md. Mamunur Rashid	SAE	XEN Office, Rangpur 01715181955	

Figure 63 Rangpur participants

Figure 62 Rangpur session

Figure 64 Further impressions

Annex 3.3 Haor and Flash Flood Areas



Government of the People's Republic of Bangladesh
Local Government Engineering Department
Agargaon, Sher-e-Bangla Nagar
Dhaka-1207.
www.lged.gov.bd

Memo No: 46.02.0000.202.25.001.15-15

Date: 30-11-2023

To

The Executive Engineer
Local Government Engineering Department
District:Sylhet/Sunamgonj, Netrokona/Hobigonj/Kishoregonj/Sherpur/Jamalpur/Rajshahi/Chapai Nawbabgonj/ Mowlavibazar

Sub: Field visits of Dr. Engr. Lutfor Rahman, PEngr PMP, Co Team Lead and Nature-based Solution Specialist (NbSP) NBS, MetaMeta, the Netherlands

In connection with aforesaid subject please be informed that the field visit of Dr. Engr. Md.Lutfor Rahman, PEngr PMP, Co Team Lead and NBS Specialist, MetaMeta, the Netherlands (December 03-11 November 2023) is as follows:

Visit Nr.5 – Haor and River Flood Prone Areas

Day	Travel / road to visit	Location of staying + discussions with LGED and other stakeholders (when available)
Sun 3 Dec	Leave from Dhaka early to Sylhet. Sylhet to to Sunamgonj District Road visit talks with local communities (preferable)	Visit LGED XEN Office of Sylhet District for discussions and meeting with the XENs, UEs, AEs, AUEs & SAEs as a part of focus group. Visit Upazilla and Union Rural Roads. Night halt at Sylhet/ Sunamgonj
Mon 4 Dec	Sunamgonj District On the road visit talks with local communities	Visit LGED XEN Office of Sunamgonj District for discussions and meeting with the XENs, UEs, AEs, AUEs & SAEs as a part of focus group. Visit Upazilla and Union Rural Roads .Night halt at Sunamgonj
Tues 5 Dec	Sunamgonj to Mowlovibazar/ Hobigonj On the road visit talks with local communities	Visit LGED XEN Office of Mowlavi Bazar/Hobigonj District for discussions and meeting with the XENs, UEs, AEs, AUEs & SAEs as a part of focus group. Visit Upazilla and Union Rural Roads. Night halt at Hobigonj
Wed 6 Dec	Habigonj to Kishoregonj On the road visit talks with local communities	Visit LGED XEN Office of Kishoregonj District for discussions and meeting with the XENs, UEs, AEs, AUEs & SAEs as a part of focus group. Visit Upazilla and Union Rural Roads .Night halt at Kishoregonj

Figure 65 Field visit order and plan as established in consultation with and approved by LGED.

Impression of field visit

Figure 67 Submerged during flood, planned elevated road

Figure 66 Rigid pavement, scope for plantation

Figure 71 WMCA office near the SSWDP

Figure 70 Roadside tree plantation

Figure 69 Block placing in the road slope to prevent erosion

Figure 68 Road side to be possibly used for water storage

Annex 3.4 Chattogram Hill Tracts

বিদেশী সংস্থা জড়িত বিধায় ইংরেজীতে লিখিত

Government of the People's Republic of Bangladesh
Local Government Engineering Department
Agargaon, Sher-e-Bangla Nagar
Dhaka-1207.
www.lged.gov.bd

শেখ হাসিনার মূলনীতি
গ্রাম শহরের উন্নতি

Memo No: 46.02.0000.202.25.001.15- 12 Date: 01-11-2023

To
The Executive Engineer
Local Government Engineering Department
District: Chattagram/Rangamati/Khagrachari/Cox's Bazar/
Sylhet/Sunamgonj/Mowlovibazar/Hobigonj

Sub: Field visits of Dr. Engr. Lutfor Rahman, PEngr PMP, Co Team Lead and Nature-based Solutions Specialist (NBSS), MetaMeta, the Netherlands.

Ref: Memo No: 46.02.0000.202.25.001.15- 11 Date: 25-10-2023

In connection with aforesaid subject please be informed that the field visit of Dr. Engr. Lutfor Rahman, PEngr PMP, Co Team Lead and NBS Specialist, MetaMeta, the Netherlands (5th – 11th November 2023) is as follows:

Visit 3: Chattogram & Chattogram Hill Tracts

Day	Travel / road to visit	Location of staying + discussions with LGED and other stakeholders (when available)
Sun 5th Nov	Leave Dhaka evening.	Reached at the early in the morning on the 6th November 2023
Mon 6th Nov	Chattogram District & travel to Khagrachari District in the evening On the road visit talks with local communities	Visit LGED XEN Office in the morning of 7th November Chattogram District and discussions meeting with focus group and at least one Upazilla for UE+AUE+SAE+ others. Travel from Chattagram to Khagrachari District Night halt at Khagrachari
Tues 7th Nov	Khagrachari District to Rangamati in the evening On the road visit talks with local communities	Visit LGED XEN Office in the morning of 8th November Khagrachari District Discussions meeting with focus group least one Upazilla for UE+AUE+SAE+ there. Night halt at Rangamati
Wed 8 Nov	Rangamati to Bandarban district in the evening On the road visit talks with local communities	Visit LGED XEN Officein the morning of 9th November Bandarban District Discussions meeting with focus group least one Upazilla for UE+AUE+SAE+ there. Night halt at Bandarban
Thurs 9 Nov	Bandarban to Cox's Bazar On the road visit talks with local communities	Visit LGED XEN Officein the morning of 10th November Cox's Bazar District Discussions meeting with focus group least one Upazilla for UE+AUE+SAE+ there. Returned to Dhaka

1 55 Page-2

Figure 72 Field visit order and plan as established in consultation with and approved by LGED.

Notes from discussions, meetings, and interviews

Notes from discussions, meetings, and interviews have been grouped and summarized below.

- Green Roads for Water concept is helpful for **addressing disasters**.
- Big scope for more **water storage** with measures, allowing for easy irrigation. Big potential for storage reservoir to use water in dry seasons. There is a need to better protect water sources and water storage. Under climate change, there is an increasing frequency of **non-seasonal precipitation and flows**, which can be addressed with directing water to storage facilities – reducing damage and creating beneficial use.
- **Land acquisition** is costly, there is often insufficient space for **shoulders**. Convincing local people to sell/lease land is challenging.
- **Deforestation** further drives erosion in the hill tracts, making roads flooded, especially during rains.
- **Road bends** are suboptimal, and often dangerous spots.
- The **brick fields** create problems.
- There is a scope for increasing **biodiversity** with overpasses and underpasses.
- There is scope for more roadside tree and grass **plantations**.
- There is a need for **retaining walls** to protect from landslides.
- Scope for making **environmentally-friendly roads.**
- Important to consider **drainage.**
- There is illegal tree and hill cutting going on, damaging the biodiversity of the area.
- There is a **mismatch in the construction / timing / approval** of roads on the one hand, and bridges/culverts on the other hand. **Bureaucracy** is mentioned to be problematic.
- **Earth work** needs to be properly done to reduce the number of accidents.
- There is **lack of in-depth studies** of bends and curves, of the positioning of structures, such as bridges, and culverts.
- There is a need to provide adequate **road signs**.
- Mentioned is a lack of **foreign training**.
- There is a lack of **sufficient materials**.
- There is a lack of **skilled manpower.**

Impression of field visit

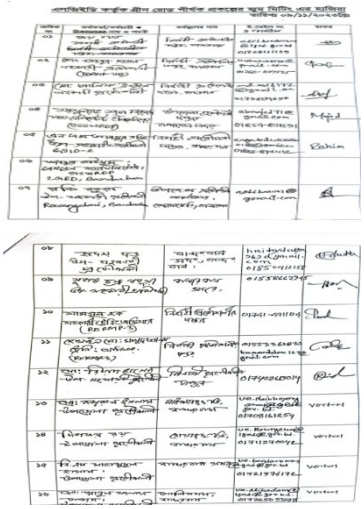


Figure 74 Participants of focus group discussion

Figure 73 Focus group discussion

Figure 76 Impression of road

Figure 75 Road erosion due to runoff water

Figure 78 Hill top road, potentially beautiful tourist spot

Figure 77 Drain (left side) with potential to be used for water storage

Figure 79 Impression of road

Figure 81 Severe erosion, dangerous situation

Figure 80 Discussion with LGED officers

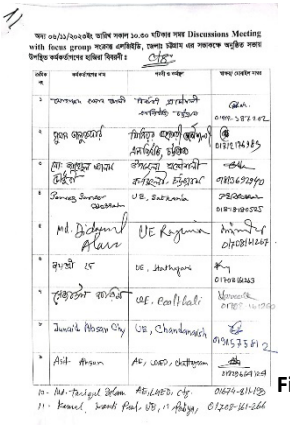


Figure 82 Participants of FGD Chittaggong

Figure 83 Impression of visit around Chittaggong area, with heavy erosion due to floods

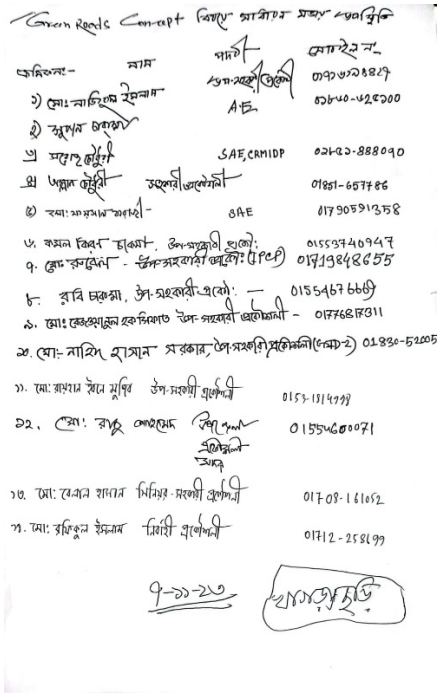


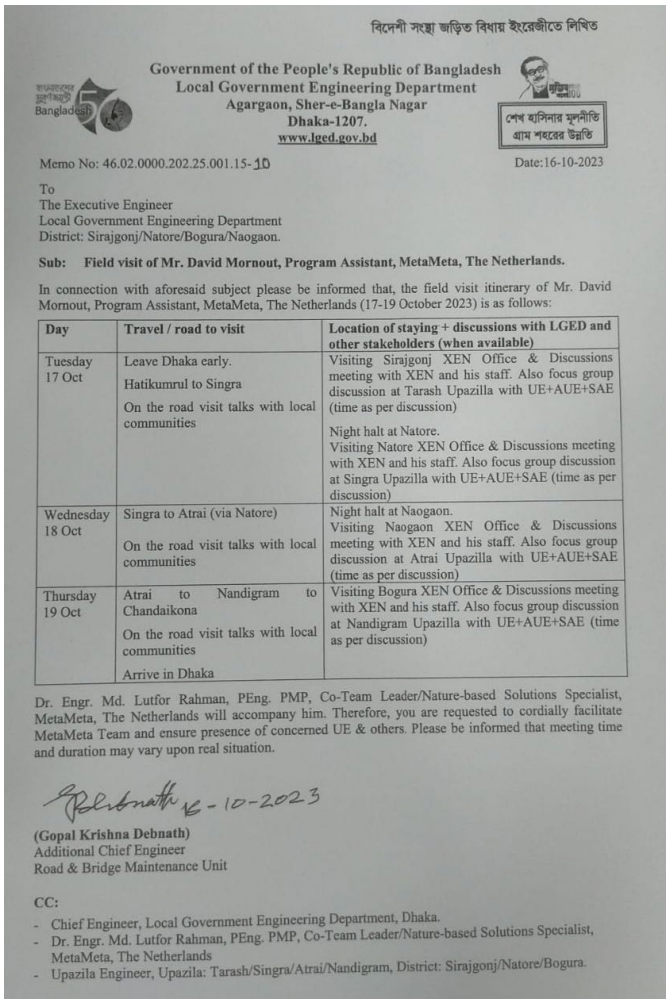
Figure 84 Participants of FGD Khagrachari

Figure 85 Scope of bio-engineering in Sadar Upazila Bandarban District

Figure 86 A site of the hilly Bandarban District in Sadar Upazila. On the right side of the road, there is ballah piliting for slope protection. On the left side of the road, there is a slope from which water flows down during monsoon season. Bioengineering is a promising approach on this site.

Figure 87 Roadside protection wall with hollow blocks, with geo-bags placed under the blocks.

Annex 3.5 River Systems and Estuaries



বিদেশী সংস্থা জড়িত বিধায় ইংরেজীতে লিখিত

Government of the People's Republic of Bangladesh
Local Government Engineering Department
Agargaon, Sher-e-Bangla Nagar
Dhaka-1207.
www.lged.gov.bd

শেখ হাসিনার মূলনীতি
গ্রাম শহরের উন্নতি

Memo No: 46.02.0000.202.25.001.15-10 Date:16-10-2023

To
The Executive Engineer
Local Government Engineering Department
District: Sirajgonj/Natore/Bogura/Naogaon.

Sub: Field visit of Mr. David Mornout, Program Assistant, MetaMeta, The Netherlands.

In connection with aforesaid subject please be informed that, the field visit itinerary of Mr. David Mornout, Program Assistant, MetaMeta, The Netherlands (17-19 October 2023) is as follows:

Day	Travel / road to visit	Location of staying + discussions with LGED and other stakeholders (when available)
Tuesday 17 Oct	Leave Dhaka early. Hatikumrul to Singra On the road visit talks with local communities	Visiting Sirajgonj XEN Office & Discussions meeting with XEN and his staff. Also focus group discussion at Tarash Upazilla with UE+AUE+SAE (time as per discussion) Night halt at Natore. Visiting Natore XEN Office & Discussions meeting with XEN and his staff. Also focus group discussion at Singra Upazilla with UE+AUE+SAE (time as per discussion)
Wednesday 18 Oct	Singra to Atrai (via Natore) On the road visit talks with local communities	Night halt at Naogaon. Visiting Naogaon XEN Office & Discussions meeting with XEN and his staff. Also focus group discussion at Atrai Upazilla with UE+AUE+SAE (time as per discussion)
Thursday 19 Oct	Atrai to Nandigram to Chandaikona On the road visit talks with local communities Arrive in Dhaka	Visiting Bogura XEN Office & Discussions meeting with XEN and his staff. Also focus group discussion at Nandigram Upazilla with UE+AUE+SAE (time as per discussion)

Dr. Engr. Md. Lutfor Rahman, PEng. PMP, Co-Team Leader/Nature-based Solutions Specialist, MetaMeta, The Netherlands will accompany him. Therefore, you are requested to cordially facilitate MetaMeta Team and ensure presence of concerned UE & others. Please be informed that meeting time and duration may vary upon real situation.

16-10-2023

(Gopal Krishna Debnath)
Additional Chief Engineer
Road & Bridge Maintenance Unit

CC:
- Chief Engineer, Local Government Engineering Department, Dhaka.
- Dr. Engr. Md. Lutfor Rahman, PEng. PMP, Co-Team Leader/Nature-based Solutions Specialist, MetaMeta, The Netherlands
- Upazila Engineer, Upazila: Tarash/Singra/Atrai/Nandigram, District: Sirajgonj/Natore/Bogura.

Figure 88 Field visit order and plan as established in consultation with and approved by LGED.

Notes from discussions, meetings, and interviews

Notes from discussions, meetings, and interviews have been grouped and summarized below.

- The area is very sensitive for waterlogging and has a limited drainage potential.
- Frequently, **steep shoulders/slopes** are observed, which are not always vegetated. **Shoulders** are too often damaged, amongst others by **rain cuts**. The steep slopes put road stability further under pressure and are also dangerous. Erosion on shoulders is amongst others due to roadside communities making ponds too big and too close to road
- **Erosion** due to water flowing over the road is problematic. In the monsoon season, there is a lot of damage to the shoulders via floods and wave action. Walls, vegetated shoulders, and more bridges/culverts could reduce this issue.
- Water stays on the surface of the road (**water logging** on the road), due to a **lack of drainage**. This can damage the road. Drainage is also problematic within the road system at a larger scale. There is a need for more and larger culverts/bridges to allow for less damage and improved water management. That will also be very beneficial for **fisheries, ecology, and biodiversity.**
- When road passes more populated areas, such villages, markets, bazars, there is almost no drainage on the road – as there is very **high land demand** there.
- Some see **cattle** staying on the road as problematic.

- There is too little space for the curvatures of the road; there is limited site clearance so that the safety is hampered. Land acquisition is challenging.
- Flood water and wave action from floods damage shoulders and roads, and so does the water from ponds and ghers when those are located close to the shoulder of a road. Ponds/ghers should be at a required distance from the road to prevent damage and leave room for shoulders. Having waterbodies located to close to the road, is also furthermore dangerous.
    - Large scope for more **roadside tree plantations** for climate change adaptation and mitigation. Roadside tree liske Palm, Akasia, Mehgoni, Ecliptus and Vetiver are said to be good species to be planted. Not all roadside landowners agree with roadside tree plantation; trees would give too much shadow or would not be good for their adjacent crops/ponds. Recently, LGED has been experimenting with **vetiver** on shoulders / slopes – which can very well deal with the water/erosion – this has been observed in the field visits. Vetiver is said to be increasingly available in Bangladesh.
- Some roads in rural areas are under LGED, others are under RHD. Even though often they share the same characteristics, their design standards are different. This makes LGED roads more vulnerable to the increased heavy traffic load than the RHD roads. Also, LGED roads are not as width, which is perceived problematic.
- A large proportion of the roads is **submersible**, which does not meet the demand for all-weather roads, but which is affordable and practical for the LGED. There are also roads that flood that are not submersible by design.
- **Fish passage** in area is hindered by road construction (it reduces **hydrological connectivity** too much) – this also hampers natural fishing. This is not problematic for the artificial fisheries. This problem is linked to the **lack of funding for cross-drainage** when constructing or designing a new road.
    - LGED wants more **RCC** (Reinforced Cement Concrete) roads.
    - At the moment, there is according to the LGED, **no need for new roads** – just a need for improving the already present. However, some local people mention a need for new roads to allow for easy transport of agricultural produce.
    - LGED has not so much **"power" in the shoulders**; landowners donated land and still feel they can do what they want. The main challenge in road development is land acquisition, because 1) people don't want to donate their land and 2) this is a very bureaucratic process, and thereby takes a lot of time, money, and effort. In general, according to LGED, once the road is there, people don't see the value of the shoulders anymore. **Maintaining the right of way** is challenging, as people take pieces from shoulders for their own benefits.
    - Too much **bending and curves in road** are also observed as problematic by LGED. It makes road difficult to manage, more dangerous, and creates more problematic spots.
    - **Roadside brick fields** are mentioned to damage the roads.
    - **Unplanned bridge/culvert construction** is mentioned to damage the roads.
    - **Settlements besides the roads** damage roads by reducing drainage potential of road.
    - For **roadside slope and shoulder protection**, several LGED staff members advocated for guide walls, toe walls, CC blocks, proper earth works – next to road side tree plantations.
    - **LGED collaborates with others, e.g., RHD, BWDB and forest department** – especially when there are funded projects for which they then have different tasks. For maintenance, collaboration is more difficult, as less money is available there.
    - There is a **big contrast between LGED and RHD**, according to LGED staffs. RHD has the ability and money to buy land for shoulders and the widening of roads. But, RHD has much less km of total roads than LGED.
    - The guidelines for shoulders and right of ways are not always properly followed due to on the ground realities / land pressure / the "donation situation".
    - In Singra, a road was heavily damaged, but this road could not be maintained/repaired as that can only happen once every 4 years, and it was already done a few years ago.

- At some places, there is potential for **better using the borrow pits** – at other places the borrow pits have already turnt into ponds.
- There is a **mismatch in demand, funding, and biophysical characteristics** of the area. Many of the local people advocated for strong all-weather elevated roads, which in the current setting do not seem to be feasible everywhere. Also, local people tend to take away shoulders for private benefits, putting the sustainability of rural road infrastructure under pressure.

Notes from interactions with LCS

Notes from interactions with LCS are summarized below

- The LCS work daily, are appointed for initially one to two years, and are proposed by the local governments. The LCS always consists out of poor women.
- The women mention to also run households and work in agriculture next to their LCS work. The LCS work takes place from 8 AM to 2 PM approximately.
- The LCS take vegetation from the road to prevent water logging on the road, put soils in rain cuts and repair them, and make small drains where and when needed. They also take away excess vegetation from the shoulders to prevent dangerous situations, and to prevent too much shadow on fields/roads. Also, the LCS make sure that road lines and signage remain visible by removing excess vegetation and soil.
- The LCS members get paid partly directly, and partly to a savings account. All payments are transferred to accounts from the LCS members.
- A major challenge in executing the LCS work is getting soil for filling up the rain cuts, which cannot just be taken from roadside landowners.
- LCS are said to be important for maintenance but not for permanent solutions.
- LCS also take care of plants when doing afforestation. The trees present in Singra included mango, dates, acacia, and litchi. There are different arrangements possible on this matter.
- LCS/LGED say that the LCS work is popular. They indicate there is more demand than availability of LCS positions.
- LGED, by hiring experts, also trains LCS on other topics.

Impression of field visit

Sl. No.	Name	Designation	Mobile No.
1	Engr. Md. Shafiqul Islam	Executive Engineer	01711949438
2	Engr. Md. Harun-Or-Rashid	Sr. Assistant Engineer	01708-161090
3	Sourov Kumar Saha	Assistant Engineer	01710-359012
4	Md. Hafizur Rahman	Assistant Engineer (SSWRDP)	01731-061582
5	Mr. Shuvo Basak	Assistant Engineer (Sup RB)	01743-712601
6	Md. Abul Kalam Azad	Sub-Assistant Engineer	01712-665446
5	Md. Badarruddin	Sub-Assistant Engineer	01748-608490
6	Md. Amirul Islam	Sub-Assistant Engineer (GSID-2)	01745-535042
7	Md. Ruhul Amin	Sub-Assistant Engineer (CRMIDP)	01719-039727
8	Md. Rasadhul	ATO	01718- 181166
9	Shamim Ara	JSE	01719-811907
10	Md. Golam Mostafa	FRE	01745-728823

Figure 90 Participants of discussion meeting at Sirajgonj XEN office

Figure 89 Discussion meeting at Sirajgonj XEN office

Figure 93 Start of LGED road, linking to RHD road. Photo taken on road assessment from Tarash to Singra.

Figure 91 No drainage facilitaties. Photo taken on road assessment from Tarash to Singra.

Figure 92 Photo taken on road assessment from Tarash to Singra.

1	Md Fazlul Haque		01935335978
2	Md Babul Akter	Sub assistant engineer	01712221990
3	Sulov Kirmoor Gehosh		
4	Md. Akbor Ali	Sub assistant engineer	01764959959

Figure 94 Participants of discussion meeting at Taraj Upazila XEN office

Figure 97 Meeting at Tarash Upazila

Figure 96 Eroded shoulder with pond very close to road. Photo taken on road assessment from Tarash to Singra

Figure 95 Eroded shoulder. Photo taken on road assessment from Tarash to Singra.

Figure 100 Scour / erosion / bridge. Photo taken on road assessment from Tarash to Singra.

Figure 99 Partly under water road. Photo taken on road assessment from Tarash to Singra.

Figure 98 Partly under water road. Photo taken on road assessment from Tarash to Singra.

1	Md. Ahmed Rafique	01718489822
2	Ajharul Islam	01754735753
3	Sontohs Kumandev	01716104151

Figure 101 Participants of discussion meeting at Singra Upazila

1	Md. Shahidul Islam	XEN	01708123222
2	Md. Shalinu.. Rtutman	SAE	01716152883
3	Md. Shanenaz	AE	01718674300
4	Md. Shahidul Islam Dewan	AE	0172292203
5	Abu Saleh Md. Nasim	AE	01766326310

Figure 102 Participants Natore XEN office

Figure 103 Interactions at Natore XEN office

Figure 104 Road widening on going on at RHD road. Photo taken at road assessment from Singra towards Atrai / Naogoan.

Figure 105 Left: Pond close to road / erosion, Right: Protection wall that needs maitenance. Photo taken at road assessment from Singra towards Atrai / Naogoan

Figure 107 Bridge currently being upgraded with more consideration for cross-drainage

Figure 106 New village road constructed close to bridge. Photo taken at road assessment from Singra towards Atrai / Naogoan.

Figure 108 Two types of village roads. Right only for walking, left also for vans (currently being improved). Photo taken at road assessment from Singra towards Atrai / Naogoan.

Figure 110 Left in frame: poor construction and damaged, right in frame: good construction and no damage. Photo taken at road assessment from Singra towards Atrai / Naogoan.

Figure 109 Singra LCS Group

Figure 111 Eucalyptus tree survives in water in Singra

Figure 112 ***Water quickly flowing over road, eroding road and shoulders***

Figure 114 Bridge allowing for cross drainage. Photos taken in Singra.

Figure 113 Vetiver in road shoulder close to Singra

Figure 115 Impression of LCS close to Singra, with at the right a small drain.

1	Md Imran Khan	UE Atria	01717412377	imrankbuet@gmail.com
2	Md Shasoon Islam	AE Noagoan	01756688007	Sislam688@gmail.com
3	Md Shahariar	AE Noagoan	01760995939	Shahariar.13.25@gmail.com

Figure 116 Meeting at Atrai Upazila with amongst others representatives Naogoan XEN office.

Figure 117 Road assessment near Atrai Upazila, where too small sluicegates cause road to overflow and damage roads. On this roads, interestingly, now a lot of young trees seem to have been planted.

Figure 118 ***Rubber structure in place in between the settle blocks. This balloon type of dam is used to keep water in the area in dry season. It was mentioned that BWDB appreciates this dam. The balloon is pumped empty to prevent being obstacle for water once there is much water in the wet seasons. Photo taken during road assessment near Atrai Upazila.***

1	Md Younus Hossain Biswas	XEN LGED Bogura	01712-115737 , xen.bo01719799372gura@lged.gov.bd
2	Md. Thuhidul Islam	Assistant Engineer	01719799372
3	Md. Ali Hossain	Senior Assistant Engineer	01712631126
4	Safina Mustary Shams	Assistant Engineer	017489677898
5	A.K.M. Shariful Alem	Sub Assistant Engineer	01751514210

Figure 119 Participants of discussion meeting at Bogura XEN office

Figure 120 Group photo at Bogura XEN office.

Sharid Shahneqaz	01718-936552
Md. Shahidul Alam	01711-441016
Md. Zahidul Islam	01784-087094

Figure121 Participants of discussion meeting at Nandigram Upazila

Figure 122 Road damage due to heavy vehicles. Photo taken at road assessment around Nandigram.

Figure 123 Example of good shoulder with trees and grasses (left), and one with only trees (right). Photo taken at road assessment around Nandigram.

Annex 4 Policy and document review

This Annex concerns the policy and document review. For some themes, including road energy consumption and emissions (6.1), air pollution and health (6.2) and road sector policies (6.3) special reviews took place to inform the forthcoming Guidance Note. Annex 6.4 is an overview of the document data base developed as part of this assignment.

Annex 4.1 Road energy consumption and emissions

Roads play a crucial role in the development and connectivity of nations, but their construction and usage also have significant environmental implications. According to ATO, about 8126,08 thousand tonnes of CO2 was emitted from road transport in Bangladesh in 2020 (10); this is due to the increasing number of vehicles on the road, coupled with inadequate emission control measures from the transportation sector (Yaacob et al, 2020). These factors have contributed to a decline in the country's climate index ranking with an index 23,7 in 2019 (10), highlighting the negative impact of road development on Bangladesh's vulnerability to climate change. As Road construction and maintenance require significant amounts of energy, the energy consumption associated with road infrastructure development indirectly contributes to climate change (Gambatese and Rajendran, 2005). In 2020, the total road energy consumption in Bangladesh contributed about 115176TJ to greenhouse gas emission; which is associated with the extraction and processing of raw materials, such as concrete and asphalt, as well as the operation of construction machinery (Sreedhar et al, 2016). In 2020, diesel roads, which are frequently used in heavy-duty vehicles such as trucks and buses, significantly contributed 1232,7 thousand tonnes of CO2 emissions. Gasoline roads, on the other hand, emitted lower levels of CO2 (579,5 thousand tonnes) due to the use of lighter vehicles such as cars and motorcycles (10).

Table 13: Bangladesh Climate Change Status from the ATO Database

Bangladesh (BGD) Climate Change					
Indicator Name	**Indicator Code**	**Indicator Sources**	**Value/Years**		
			2018	**2019**	**2020**
Gasoline Road	CLC-VRE-005	UN Energy Statistics Database	509,90 thousand tonnes	579,83 thousand tonnes	579,52 thousand tonnes
Diesel Road	CLC-VRE-006		1481,50 thousand tonnes	1407,31 thousand tonnes	1232,66 thousand tonnes
Total Road Energy Consumption	CLC-VRE-081		N/A	129211 TJ	115176 TJ
Natural Gas Road	CLC-VRE-010		51045,48 TJ	48638,83 TJ	40554,61 TJ
Road in Transport CO2 Emissions	CLC-VRE-054	Emissions Database for Global Atmospheric Research (EDGAR)	8914,38 thousand tonnes	8728,43 thousand tonnes	8126,08 thousand tonnes
Global Climate Risk Index	CLC-VRE-004	GermanWatch	N/A	23,70	N/A
Transport CO2 Emissions/Capita	CLC-VRE-049	Climate Analysis Indicators Tool (CAIT)	0,08	0,07	N/A

			Million Tonnes	Million Tonnes	

Annex 4.2 Air Pollution and Health

Road transport is a major source of Particulate matter (PM), Nitrogen oxides (NOX), Black Carbon (BC), and Sulfur oxides (SOX) emissions in Bangladesh. The combustion of fossil fuels in vehicles releases fine particles and toxic compounds into the air. Older vehicles, especially those with outdated emission control systems, contribute significantly to these emissions (ADB, 2009). In 2018, PM 10 accounted for about 1,1170 Thousand tonnes whereas PM 2.5 was about 1,1169 thousand tonnes respectively. NOX on the other hand is most emitted toxic compound, accounted for 66,3611 thousand tonnes, BC accounted for 0,5998 thousand tonnes, whereas SOX accounted for 0,0566 thousand tonnes of emissions (Table 14). Exposure to high levels of PM, NOX, BC and SOX emissions can lead to increased respiratory problems, such as asthma, bronchitis; These emissions are also link to lung cancer cardiovascular diseases including heart attacks and strokes (WHO, 2016). The vulnerable population, such as children, older people, and those with pre-existing health concerns, is more likely to suffer negative health impacts (Lindsay et, 2022). In 2018, there were around 5230,4 deaths per 100,000 population as a result of the health impact of road transportation; also in 2019, there was an average deaths of about 159,34 due to occupational exposure to diesel engine exhaust (Table 14).

Table 14: Bangladesh Air Pollution & Health Status from the ATO Database

Bangladesh (BGD) Air Pollution & Health					
Indicator Name	**Indicator Code**	**Indicator Sources**	**Value/Years**		
			2017	**2018**	**2019**
Deaths due to Occupational exposure to diesel engine exhaust	APH-AAP-001	Global Burden of Disease (GBD)	142,46 Average Deaths	151,06 Average Deaths	159,34 Average Deaths
Road Transport air pollution health impact	APH-AAP-002(1)	McDuffie et al.	4587,7 Deaths	5230,4 Deaths	N/A
PM 10 Emissions from Road Transport	APH-VPA-001	Emissions Database for Global Atmospheric Research (EDGAR)	1,0418 Thousand tonnes	1,1170 Thousand tonnes	N/A
PM 2.5 Emissions from Road Transport	APH-VPA-031	Emissions Database for Global Atmospheric Research (EDGAR)	1, 0418 Thousand tonnes	1,1169 Thousand tonnes	N/A
NOX Emissions from Road Transport	APH-VPA-006	Emissions Database for Global Atmospheric Research (EDGAR)	60,6863 Thousand tonnes	66,3611 Thousand tonnes	N/A
BC Emissions from Road Transport	APH-VPA-011	Emissions Database for Global Atmospheric Research (EDGAR)	0,5588 Thousand tonnes	0,5998 Thousand tonnes	N/A

SOX Emissions from Road Transport	APH-VPA-016	Emissions Database for Global Atmospheric Research (EDGAR)	0,0502 Thousand tonnes	0,0566 Thousand tonnes	N/A

Annex 4.3 Road Sector Policies

Recognizing the importance of a functioning transportation industry, the Bangladeshi government has instituted many road regulations aimed at expanding road connectivity, maintenance, safety to foster economic growth, and improve the general standard of living of its population (Table 15).

Table 15: Bangladesh Road Sector Policies and Targets as Available in ATO

Bangladesh (BGD) Road Sector Policies and Targets		
Policy	**Targets**	**year**
Road Expansion Plan (Bangladesh Eighth FYP p.398).	• Construction of 4/6/8 lane roads = 550 km • Construction of new roads lane = 150 km • Construction of bridges/culverts = 37,500m • Construction of Rigid Pavement = 375 km	2025
Road Maintenance Plan (Bangladesh Eighth FYP p.398 & Road Master Plan 2009)	• Improvement/ Rehabilitation of National Highways = 1800 km • Improvement/ Rehabilitation of Regional & Zila Highways = 12,700 km	2025
	• Recovery program for 6,865 km of Zila Roads	N/A
Road Safety Plan (`Bangladesh Eighth Five Year Plan - June 2025 p.400)	• Road safety accident death rate by country (WHO 2018) (per 100,000 people) = 13.0 number of fatalities due to road traffic accidents on national highways will be reduced by 25%	2025

Other Bangladesh's policies in climate, economic growth, NDCs (and NAPs) are summarized in Table 16.

Table 16: Other Bangladesh Relevant Policies and Targets as Available in ATO

Other Relevant Bangladesh (BGD) Policies and Targets			
Policy	**Targets**	**Year**	**Green Road (GR) Theme**
Emission Level (Bangladesh Eighth FYP p.398).	• Mean urban air pollution of particulate matter 1. PM10 in µg/m3 = 120 2. PM2.5 in µg/m3 = 73	2025	1,2.3,4
Vehicle emission standards	• Bangladesh announced plans to introduce Euro 6 emission standards	2025	1,2.4

Climate change Plan (Bangladesh NDC, Updated)	• Reduce GHG emissions from BAU 2012 (Economy- wide) levels 1. unconditional - 27.56 Mt CO2e (6.73%) 2. conditional - 61.9 Mt CO2e (15.12%) 3. combined - 89.47 Mt CO2e (21.85%)	N/A	1,2,4
	• Reduce GHG emissions from BAU 2012 (Transport GHG) levels 1. unconditional - 3.39 Mt CO2e (12.3%) 2. conditional - 6.33 Mt CO2e (10.23%) 3. combined - 9.72 Mt CO2e (10.86%)	N/A	1,2,4
Climate Change (Mujib Climate Prosperity Plan)	• Shift at least 30% of the transportation fleet to electric by 2030	2030	1,2
	• 30% renewable energy by 2030 and at least 40% by 2041	2030/ 2041	1,2
E-mobility Policy	• 10,000 hybrid and electric vehicles • Shift at least 30% of the transportation fleet to electric	2030	1,2
	• The import duty rate for importing Soler & electric car into Bangladesh is 25% , the import VAT is 15%, when classified under Cars & Motorcycles • Regular fuel cars below 1500cc will be subjected to 45 percent supplementary duty, whereas for hybrid cars it will be only 30 percent. The duty on regular fuel cars between 1501cc and 2,000cc is 100 percent, for hybrid cars with similar engine capacity it is 60 percent. For 2001 to 2700cc cars, the duty is 200 percent, while their hybrid counterparts will enjoy 150 percent supplementary duty.	N/A	1,2

Annex 4.4 Reference material

Below is an overview of the reference material collected and reviewed for the assessment. These concern mainly public documents that were in many cases difficult to retrieve. It is proposed to place this material on a dedicated section in www.roadsforwater.org, so as to be available for reference.

Table 17 Documents

LGED Key Documents					
#	Name	Year	Hard copy	Soft copy	
1	Asset Management Policy	2019			
2	Climate resilient rural road manual	2019			
3	Climate Resilient Slope Protection of Embankments	2018			
4	Grass Plantation Guideline	2018	*To be obtained, not availanle in LGED*		
5	Guideline for bridge design	2018			
6	Guideline for implementation of rural roads and culverts maintenance program , Rural Infrastructure Maintenance Guidelines	2010			

7	Guideline for implementation of rural roads and culverts maintenance program , Rural Infrastructure Maintenance Guidelines	2010			
8	Gezette				
9	Guidelines for operation and maintenance	2018			
10	Plantation Guideline	2004			
11	Road design standard	2021			
12	Sample of project documents, such as BOQs	*Requested, not yet received*			
13	Strategic Asset Management Plan	2019			
14	The instructions / guidelines on road cross drainage	*Requested, not yet received*			
15	Training manual on Road Maintenance Management	2010			
16	Water Resources Infrastructure Guideline	2022			
Other LGED Reports that are possibly of interest					
1	BUET Report "Consultancy Services for Assessment of Road Design and Pavement Standards of LGED"	2018			
2	BUET Report Appendix A - Road Carriageway Width With Shoulder	2018			
3	Rural Road and Bridge Maintenance Policy	2013			
CReLIC Reports that are possibly of interest					
1	Draft Recommendations and Adjustments of Standard Designs (Rural Road and Drain)	2023			
2	Identification of Standard Criteria for Conducting Gap Analysis of Selected Guidelines, Standards and Procedures	Oct. 2023			
3	Recommendations and Adjustments of Standard Designs (Cyclone Shelter/Building, Bridge and Culvert)	Oct. 2023			
4	Revised Design and Cost Estimate for Climate Resilient Urban and Rural Upazila and Union Road (Type 5 and Type 8)	Jun. 2023			
Forestry Department					
1	National Forest Policy	2016			
National policies and plans					

1	National Adaptation Plan of Bangladesh (2023-2050)	2022			
2	Bangladesh Delta Plan 2100 (BDP 2100)	2018			
Other					
1	Several outputs from TA on Promoting and Investing in Natural Capital in Asia and the Pacifics by ADB	2022			
2	Training Report: Developing Bio-engineering Capacity for the Local Government Engineering Department Operations in the Chattogram Hill Tracts, Bangladesh	2022			
World Bank					
1	RTIP-2/SuPRB				

Annex 5 Case studies/ blogs

Annex 5.1 Choking bridges: the death of tidal rivers (link to TheWaterChannel)

Md. Saif Uddin, Lutfor Rahman and Frank van Steenbergen

It is a river but without water. Instead of water, there is silt, silt from bank to bank. The Sholmari River is one of the many tidal rivers in the Bangladesh South West coastal belt. In all these rivers, there is a very fine balance between water coming in with the tides from the sea with sediments, and the sediments are pushed downwards with the upstream flow, which has been reduced ever since India diverted more water upstream with the construction of Farakka Barrage in 1975.

The Sholmari River is now dead; besides less upstream flow, the other culprit is the Batiaghata bridge that restricted and choked the river. To save on costs, the bridge was made narrower than the river width and the bridge span length was kept small, which increased the number of piers. A large number of piers in the river changes the river's hydro-morphodynamic condition, which increases the sedimentation in the river. In other words, the construction of the bridge set in motion a chain reaction that totally destroyed the river. With the changing morphology, the inland reach of the tides also affected, further disturbing the river.

The end result is a dead river full of sediment – blocking the removal of water from the adjacent land, where cultivation becomes impossible and habitation difficult. This is a high tragedy. As the land cannot drain into the blocked river, water logging becomes widespread, and farming systems and residential areas are destroyed, including Beel Dakatia. The area of the 23 small and major beels that are affected, was approximately 1,500 hectares. An estimated 2,500,000 crores worth of agricultural and fishery products are produced annually in the aforementioned region. These areas are at risk of experiencing significant inundation due to the siltation in the Sholmari River. Several thousand already poor people may have to pick up their belongings and go nowhere.

The Sholmari River is not the only river killed by bridges; there are more examples in almost all rivers in the Southwest Region. Over the last 40 to 50 years, infilled channels have added around 90 km2 of new land, or about 2 km2 every year. The loss of tidal waterways accounts for a 60% reduction in total channel length over the region's 3000 km2 of poldered terrain, or roughly two-thirds of the region's navigable waterways over the last 40 years. It all speaks for making a strong connection between building roads and bridges, managing water and silt, and, where possible, going for mutually beneficial effects. It speaks for counting in local hydrology whilst developing infrastructure. It speaks for not working in isolation but in combining forces between road and water agencies.

Annex 5.2 Roadside social forestry: managing roadside commons (link to TheWaterChannel)

Kiran Sankar Sarker and Dr. Frank van Steenbergen

All over the world there are millions of kilometres of roadsides. They are important commons but as commons go, they are often unmanaged. Not so in Noakhali Division in coastal Bangladesh. Much of the land in this area is hard fought over – conquered from *char* mudflats in the mighty Meghna Delta, by first planting mangroves on the emerging shifting land and then placing embankments with drainage control structures around them. With the pioneer population – who often had lost land to the moving river elsewhere – the area was wrestled from local land grabbers and developed over the years. Rural roads are an important part of it.

To make use of the road embankments and protect the roads from encroachment, social forestry groups are given the custody of designated sections of the road embankments. The Forestry Department with these SFGs clear the road embankments and plant a mixture of trees. The SFGs take care of the road sections under a tripartite agreement they sign with the Forest Department, the LGED that owns the road side land and the local government, the so-called Union Parishad. Under this agreement the SFGs have the usufruct of the roadside forestry i.e., the tree twigs and branches, obtained from pruning, thinning, and other maintenance of the plantations. Besides the SFGs are allowed some cropping of for instance papaya, ladyfingers or pigeon peas. At the harvest – typically after 15-20 years – the trees are cut and the proceeding are divided. Here is the formula:

- Forest Department 10%
- LGED 20%
- Social Forestry Group 55%
- Union Parishad 5%
- Tree Farming Fund 10% (for new planting).

After the trees are harvested at the instigation of the Forest Department, a new cycle starts. In the meantime. the Social Forestry Groups protect the roadsides against encroachment by shops and houses, as common on most other roads. As a result, the concerned road is tranquil, almost serene.

Annex 6 Generic cross-sections

The generic cross-sections presented below—for roads in plain areas, hilly terrain, and adjacent to water bodies—serve as the foundation for the conceptual cross-section designs to be included in the forthcoming guidance note. These cross-sections have been developed by the MetaMeta-ADSL team.

The thickness of pavement layers and side slopes depends on factors such as intended road use, soil type, and other key design considerations. Proper pavement design is essential to extend the road's lifespan, reduce maintenance frequency, protect the subgrade from moisture and weather-related damage, maintain structural integrity under varying climatic conditions, and safely distribute vehicular loads. It also helps prevent deformation or failure of the underlying soil, ensuring long-term durability.

In hilly areas, road gradient—defined as the rise or fall in elevation over a horizontal distance and typically expressed as a percentage or ratio—is a critical design element. These roads are inherently more hazardous due to their slopes and reduced sight distance. Because hilly terrain presents variable topography, gradient requirements may differ across sections. Designers must work within a maximum allowable gradient for safety and structural performance, while also incorporating a minimum gradient to ensure effective surface drainage.

The upcoming guidance note will further elaborate on various road cross-sectional templates that support adequate cross slopes and drainage measures, as illustrated in Figure 124.

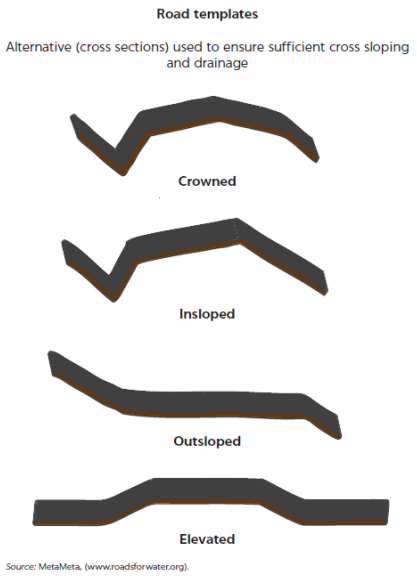
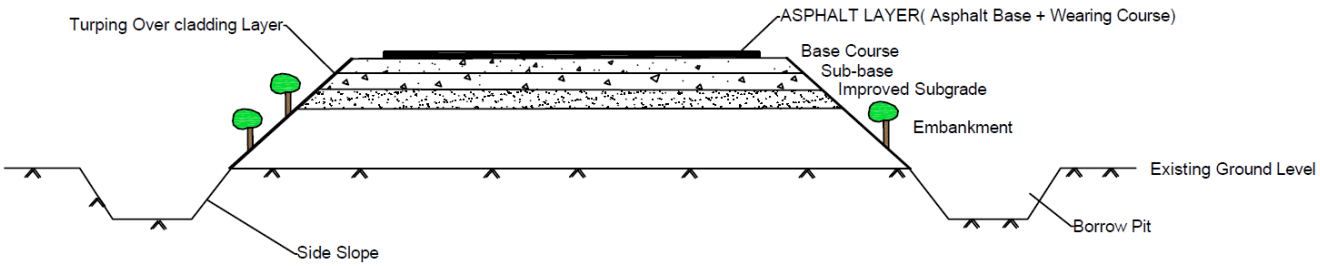
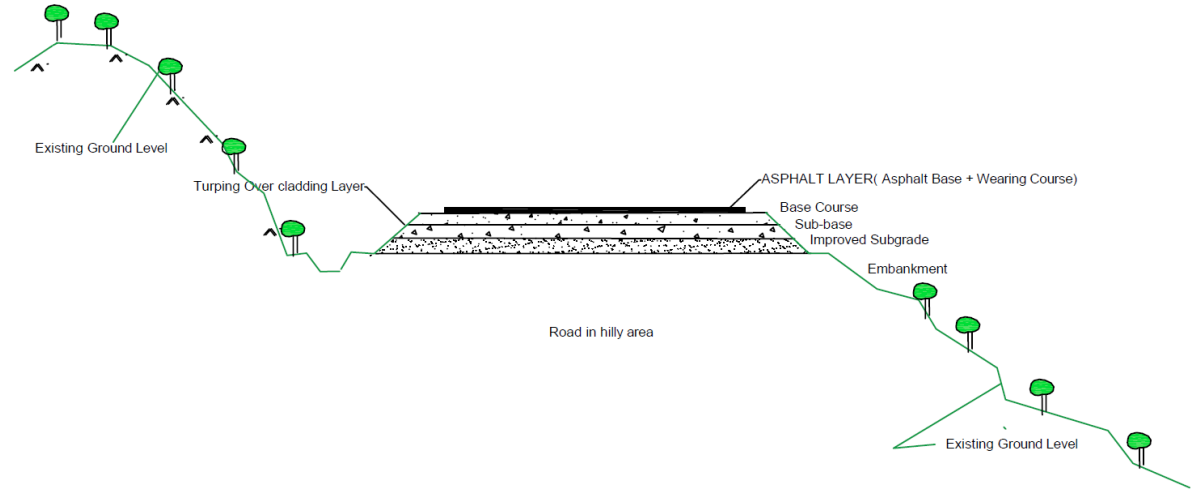


Figure 124 Alternative (cross sections) used to ensure sufficient cross sloping and drainage (van Steenbergen et al., 2021)

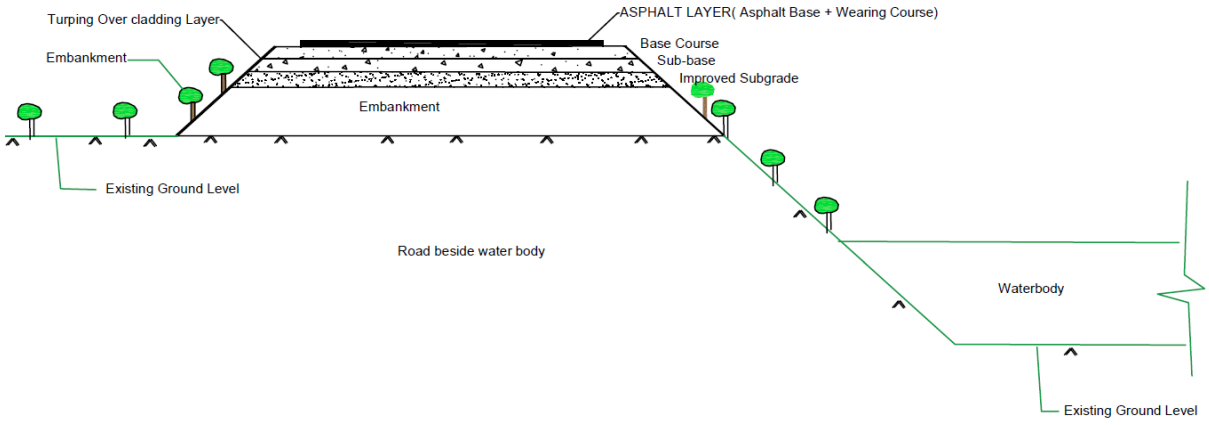
Road in plain land



Road in hilly area



Road besides water body



Annex 7 Template for roadside forestry

The table below presents a draft layout for a forthcoming section of the guidance note on forestry. It will be completed in due course. For each species, the table will outline the associated benefits and costs across various impact areas, as well as indicate its geographical applicability. A preliminary list of potentially suitable species has been compiled by the MetaMeta-ADSL team. This list will be reviewed and validated in close collaboration with regional stakeholders and, in coordination with LGED, with input from the Forest Department and forestry experts.

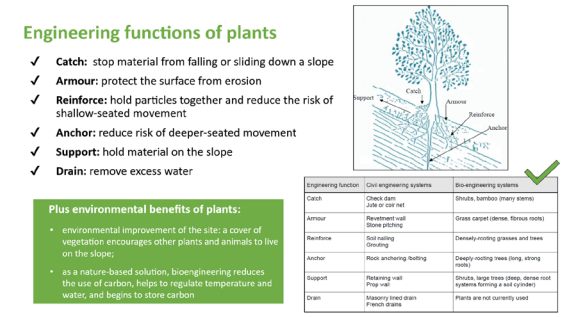
Table 18 Draft layout for a forthcoming section of the guidance note, for the section on roadside forestry

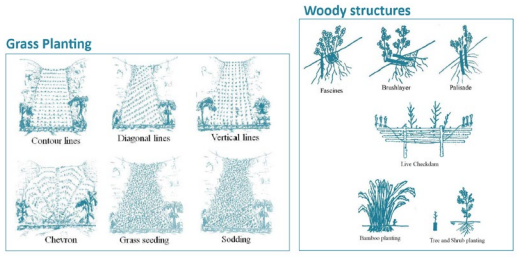
Suitable area					Tree species	Stable root system	Time to maturity and end of life	Height at maturity	Main-tenance	Carbon seque-stration	Economic value - timber	Economic value non-timber	Climate value windbreak	Climate value shading	Biodiversity harbour	Pollution absorption - bioaccumul ation	Dust trapping	Sound proofing	Esthetic value	Other benefits
Coastal zone	Barind and Drought Prone Areas	Haor and Flash Flood Areas	Chattogram Hill Tracts	River Systems and Estuaries		Deep tap root not interfering with pavement	Year till maturity and end of life		Removal of litter, need for pruning	Time to maturity, biomass	Timber, fuel wood value over the years	Leaves, fruits, other economic values	Effect on windspeed and windforce	Effect on cooling and aerial extent	Shelther and speciall biotope	Ability to absorb heavy metals and other pollutants	Ability to intercept dust	Ability to reduce noise	Contri-bution to scenic effect and special effects (blossom)	For instance nitrogen fixation
					1	…														
					2															
					3															
					4															
					Etc.															

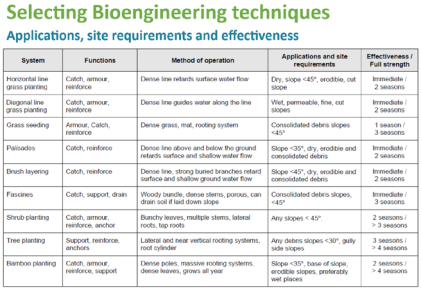
Annex 8 Development of training materials

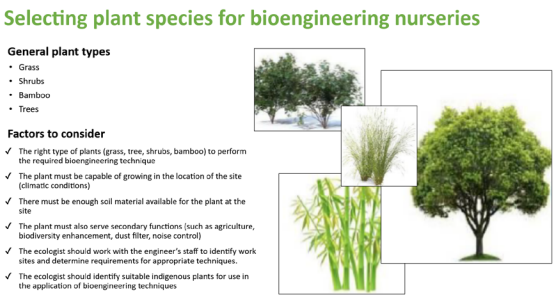
As an integral part of this assignment, training of trainers (TOT) materials will be developed. The two slide decks provided below, give an impression of what the training material will look like, and are included for review.

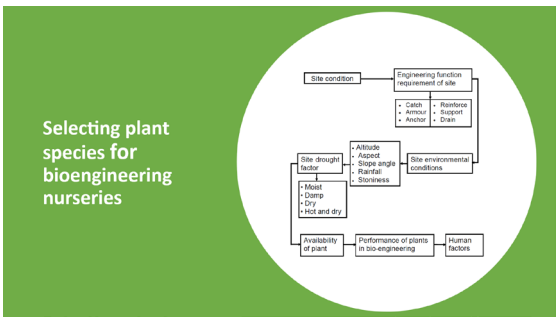
Annex 8.1 Bioengineering experience in Bangladesh











Selecting nursery sites

The selection of a suitable nursery site is the most crucial decision affecting the efficient production of good quality plants for bioengineering.

Recommendation for selecting a nursery site

- You must choose the site at least six months before the first seed is to be sown
- Nurseries need to be as close as possible to the sites they will serve but also the location must be technically suitable.
- You will rarely be able to get everything just right, so the final selection should be based on evaluating the relative advantages and disadvantages of three or more possible sites after thoroughly inspecting the area.

Aspects to consider

- Water supply
- Location and its physical features
- Availability of materials and labour
- Land ownership

Bioengineering Maintenance tasks

1. **Protection works:** protection of plants and planting sites from grazing, theft of firewood and timber, and fire protection works;
2. **Plant treatment:** weeding, mulching, trimming, pruning, grass cutting and thinning of plants;
3. **Repair to vegetation structures:** repairs to palisades, fascines and brush layering, and turfing and vegetation enrichment;
4. **Repairs to inert structures:** repairs to revetment and prop walls, gabion walls, bolsters, jute netting and wire netting, and sealing cracks;
5. **Geophysics:** small slope trimming, small slip clearance, cleaning subsoil drain outlets.

Planning, Design, Implementation of Procedural Steps for Bioengineering

PHASE	STEP	ACTION TO BE TAKEN	RESULT/OUTPUT EXPECTED	LOCATION
Planning	1	Make an initial plan of the year's works	List of sites requiring treatment	Office
	2	Prioritize the work	List of sites in priority order	Roadline
	3	Initial site appraisal	Divide the sites into segments for assessment	Sites
	4	Assess the site	Detailed plan of site with problems identified	Sites
	5	Determine combination of works required	Initial plan of civil and bioengineering techniques	Sites
	6	Choose the optimal techniques for the site	List of techniques to be designed in detail, with measurements	Sites

Source: Bioengineering for Green Infrastructure

Planning, Design, Implementation of Procedural Steps for Bioengineering

PHASE	STEP	ACTION TO BE TAKEN	RESULT/OUTPUT EXPECTED	LOCATION
Design	7	Design the civil and bioengineering works	Detailed designs for all required works	Office
	8	Select the species to use	List of actual species of plants to be used	Office
	9	Calculate the required quantities and rates	Table of quantities, rates, and costs for all required works	Office
	10	Finalize priority against available budget	Finalization of site works to be completed within available budget	Office
	11	Plan plant needs	Determination of the actual sources of bioengineering plants	Office
	12	Prepare documents and arrange implementation	Draft contract documents and arrange procurement	Office

Source: Bioengineering for Green Infrastructure

Planning, Design, Implementation of Procedural Steps for Bioengineering

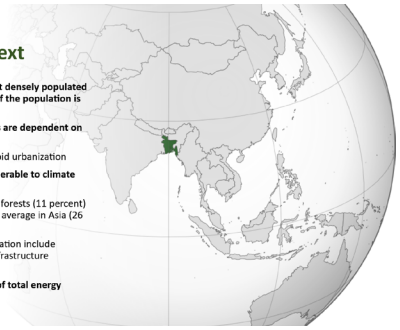
PHASE	STEP	ACTION TO BE TAKEN	RESULT/OUTPUT EXPECTED	LOCATION
Implementation	13	Prepare for plant propagation or procurement	Arrangements made for provision of all required plants	Nursery/Source
	14	Make the necessary site arrangements	Contracts and other procurement and logistical arrangements	Office/Sites
	15	Prepare the site for work	Site access and safety provisions completed	Sites
	16	Implement the civil engineering works	All earthworks and hard engineering completed	Sites
	17	Implement the bioengineering works	All bioengineering works completed	Sites
	18	Monitor the works	Regular inspections undertaken to ensure works are functioning	Sites
Maintenance	19	Maintain the works	Repairs, cleaning, and refinement undertaken, as necessary	Roadline/Sites

Source: Bioengineering for Green Infrastructure

Examples of bioengineering

Annex 8.2 Roadside Tree Planting Experience in Bangladesh

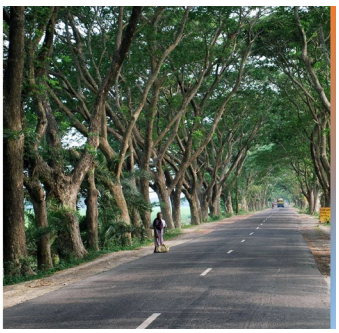
Bangladesh Context



- Bangladesh is among the **most densely populated** countries in the world - **70% of the population is still rural**
- Some **19 million Bangladeshis are dependent on forests** for their livelihoods
- The country is undergoing rapid urbanization
- The country is extremely **vulnerable to climate change and natural disasters**
- The proportion of land under forests (11 percent) is substantially lower than the average in Asia (26 percent)
- Direct drivers of forest degradation include clearing for agriculture and infrastructure development
- **Fuelwood accounts for 60 % of total energy consumption**

Social Forestry Program

- **Social forestry was initiated by the Bangladesh Forest Department (BFD) in the early 1960s** through the forest extension programmes for socio-economic development and poverty alleviation of rural communities
- **Social Forestry Rules were approved in 2004** to give a legal basis for benefit sharing among the government and local people (participants), with further amendments in 2011
- **Roadside tree planting and Trees outside Forest (ToF) are the two major components of the Social Forestry Program**

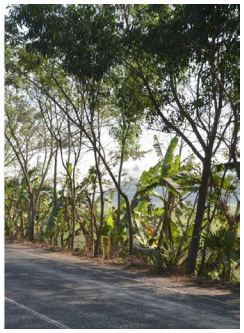


Implementation Arrangements

- **BFD has signed MoUs with Roads and Highways Department;**
- **Land along local roads (right of way) remains in the custody of Roads and Highways Department, but the trees are planted and managed by the** communities;
- **BFD invests in a 1st rotation of plantations** and provides technical expertise, engages and organizes local communities for roadside tree planting;
- **Each community participant (family) is entering into a 10-year MoU with the BFD**, which specifies the credentials, particular strip of right of way, tree species for planting, management plan, and conditions for harvesting and benefits sharing;
- **BFD harvests the trees (usually after a 10-year rotation period), sells on auctions, and shares sell proceeds** according to the Social Forestry Rule 2004 with the community participants and land-owning agency;
- **On average, a participant can receive between $3.5 thousand to $17.7 thousand over a 10-year period** rotation of strip plantation (3 lac to 15 lac Taka);
- **Tree Farming Fund is established (10% of sell proceeds) for replanting after the 1st rotation of strip plantations**

Implementation Status

- **Strip plantations (roadside trees) were established on about 73,223 km since the program was established.**
- **About 2,664 km of strip plantations were established under the Government's Climate Change Trust Fund.**
- **More than 700,000 beneficiaries/participants** have been involved in the Social Forestry Program, of which **134.5 thousand participants are women**
- **About 104 m saplings were sold to the participants** at a minimum price from forest nurseries or distributed between 2009 and 2020 to increase the country's tree cover
- **Country's timber growing stock is 384 m cub m and 66 percent of it is accounted from trees outside forest**
- **About another 15 thousand km of strip plantations will be raised during the 8th Five-Year Plan period (2020-2025).**



Revenues

- **Roadside trees were felled from 18,362 kilometers and from 43,943 hectares of plantations** till 2018-19 under the Social Forestry Program in Bangladesh.
- **About $145m was earned by selling wood, fuel wood and poles** (1227 crore 82 lakhs 18 thousand 9 hundred 10 taka).
- **About $45m or 31% was distributed among 191 thousand beneficiaries/participants** (383 crore 23 lakh 5 thousand 45 taka).
- **About $13m has been deposited as Tree Farming Fund (TFF)** to plant trees in the felled areas (110 crore 20 lakhs 17 thousand 3 hundred 85 taka).
- **So far, the BFD deposited $51.2m as revenue** (433 crore 58 lakhs 45 thousand 2 hundred 32 taka); in addition, $25.7m was distributed to the landowners, the Union Councils, and among others (218 crore 49 lakh 73 thousand 214 taka).

Sustainable Forests & Livelihoods Project (SUFAL, P161996)

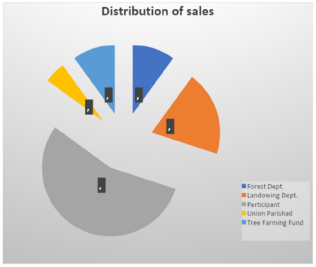
Implemented by the World Bank in collaboration with the Bangladesh Forest Department

- ✓ **Development Objective:** to improve collaborative forest management and increase benefits for forest-dependent communities in targeted sites.
- ✓ **Implementation period**: 2019-2023, US$175.0m IDA credit with GoB financing of US$ 3.9m
- ✓ **3,665 km of strip plantations established** (by March 2021)

Project Component Name	Component Cost (USD millions)
Strengthening Institutions, Information Systems and Training	16.24
Strengthening Collaborative Forest and Protected Areas Management	96.45
Increasing Access to Alternative Income Generating Activities (AIGAs), Forest Extension Services & Trees outside Forests (TOF)	54.14
Project Management, Monitoring and Reporting	12.07

Benefits & Lessons

- **Significant income-sharing opportunities**
- **Captures carbon** and provides **embankment stabilization**
- **Provides critical raw material for local SMEs** and green value chains
- **Substitutes for fossil fuel, heavy materials**, such as concrete, steel, plastic, etc., lock in carbon
- **Trees need management/maintenance** (windblow can damage roads)
- **Over emphasis on fast-growing species for quick returns**, less on native trees and creating habitats
- **Lack of land means strips are too narrow**



Communities Engagement

Participants are selected within one km² distance of the plantation based on the following **criteria**, as given under Social Forestry Rule 2004:

- **Landless**
- **Distressed women**
- **Backward community group**
- **Forest villager**
- **Poor people**
- **Poor freedom fighter**

Management of strip plantations
Forest Department identifies roads and invests in establishing strip plantation
Planting is by 1-year old seedlings at 2m x 2m spacing, with tending operations for next two years
A watcher is engaged immediately after planting for two years to protect young trees
Participants are selected and agreements signed for 10 years, 5 participants per kilometre
A Forest Management Committee is formed to take care of the plantation, with regular meetings at least once in three months
Participants take the all harvested thinning material at the age of 7 years
Forest Department harvest the trees and sells through an organized auction
Distribute sell proceed according to Social Forestry Rule 2004
Participants are allowed up to three rotations for social forestry practices



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