Recommended Good Practices

Road Development to Support Water Management and Flood Resilience

Summary

This document with Recommended Good Practices intends to facilitate the systematic integration of road development with internal polder water management and improved flood resilience in the coastal areas of Bangladesh. The document is the consensus result of the Steering Expert Committee.

When roads are used as instruments for polder water management, three main opportunities arise: (1) roads can improve water management inside the polders controlling water levels between different section of the polders and helping to create storage; (2) roads and embankments act as flood defence; (3) and roads can be used as evacuation routes and temporary flood shelters - In order to accomplish these opportunities a better institution arrangement among roads and water authorities is needed. The implementation of such good practices will result in enhanced climate resilience, reduction of flood risks, increased agricultural production and more durable and reliable road infrastructure.

We recommend there for the following four musts:

- Improve internal polder water management through basic initial hydrological assessment for any rural road, embankment road and water drainage structure designs, planning and improvements; follow always standard design templets for roads, embankments and drainage structures; integrate borrow pits and gates for drainage control in the planning; and re-use of excavated silts.
- Enhance the flood defence function of embankment roads by strengthening collaboration between BWDB and LGED for synchronized design criteria (height, width, side slope), carpeting and use of affordable and simple bioengineering techniques.
- Use roads as temporary flood shelters and evacuation routes by increasing heights of roads leading to cyclone shelters, heightened roads in low lying areas, created levees provide a clear evacuation route signs along roads.
- Strengthen governance and coordination among road (LGED, LGIs, PIO) and water agencies (BWDB, WARPO, WMGs) for fund disbursement, carpeting of roads, routine maintenance, information sharing, land use planning, and engaging local communities for decision making.

A follow up of this document is a sample Polder Road Development Plan is prepared for one polder, looking at road infrastructure, water management and storage, flood disaster management measures and supporting measures. The future road development (both alignment and design) would be done by considering hydrology, land use and socio-economic issues and with inputs of different local stakeholders (WMG, WMCAs). As the road development decision is carried out by the local Upazila administration, they would follow the polder plan.

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Acronyms

BARD: Bangladesh Academy For Rural Development

BG: Blue Gold

BUET: Bangladesh University of Engineering and Technology

BWDB: Bangladesh Water Development Board

CEIP: Coastal Embankment Improvement Project

DDM: Department of Disaster Management

DEM: Digital Elevation Model

GRP: Global Resilience Partnership

LGED: Local Government Engineering Department

LGIs: Local Government Institutions

MoU: Memorandum of Understanding

MM: MetaMeta

NOC: No Objection Certificate

O&M: Operation and Maintenance

PIO: Project Implementation Office

SSWRDSP: Small Scale Water Resources Development Sector Project

UP: Union or Upazila Parishad

WARPO: Water Resources Planning Organization

WB: World Bank

WMA: Water Management Associations

WMCA: Water Management Cooperative Association

WMG: Water Management Groups

WRS: Water Retention Structure

Preface

This report is the outcome of consultative expert discussion [1] with the aim to make a stronger connection between roads, water management and climate resilience. Roads have a huge impact on surface and subsurface hydrology and as such are a main though often forgotten factor in water management in Bangladesh. The relation between roads and water management now is often not positive (roads causing water logging and drainage congestion). However, this can be turned around with roads becoming instruments for water management and climate resilience and higher productivity. This will help also the transition of Bangladesh to middle-income status by having more reliable roads, higher water productivity by facilitating multiple cropping and better flood resilience and more reliable evacuation routes from roads.

We hence are happy to present this Recommended Good Practices document, the outcome of collaborative discussion between four main organizations working on roads, water management and flood resilience in rural Bangladesh. We sincerely hope that the good practices will be followed in earnest – as they will protect vital road infrastructure, aid the better water productivity and food security in agricultural areas and stream line flood resilience practices along roads.

The Consultative Group and Support Team [2]

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1. Objective

There are in Bangladesh few interventions that have such an impact on water management as the construction of roads and footpaths. At present roads construction often undermines local water management: they cause water logging and uncontrolled flooding in polders. When flood embankment also serves as roads the flood protection function is sometimes jeopardized. However, this need not be, and roads can be transformed into instruments for polder water management and for flood resilience. This document is addressed to an audience of water managers, road engineers, agriculturalists and local government – all having an interest to optimize the use of roads for better water management and flood resilience whilst at the same time ensuring the integrity of the road assets.

The objective of this document is to facilitate the systematic integration of road development with internal polder water management and improved flood resilience in the coastal areas of Bangladesh. The combined planning and management of roads, cross drainage structures and flood embankments by the respective authorities is a powerful strategy to enhance climate resilience, to improve flood disaster risk reduction, to increase agricultural production and to ensure durability and reliability of road infrastructure in the coastal areas. Many of these recommended practices may be relevant outside the coastal areas.

This document describes several recommended good practices, both at technical and governance level. It is the result of a comprehensive field assessment of road-water interaction in four sample polders and detailed discussion with local communities as well as with experts working on road planning and design as well as water management and flood protection.

The report is prepared by the Consultative Group that convened on invitation of BUET and MetaMeta. The Consultative Group consists of high level experts of the different concerned organizations working on rural roads: Bangladesh Water Development Board, Local Government Engineering Department, WARPO and the Department of Disaster Management (DDM)

2. Opportunities

There is a strong connection between roads and water management and flood protection inside and outside the polders of coastal Bangladesh. This connection is as yet not systematically operationalized. This presents both a huge opportunity missed, and, in several cases, a substantial problem created.

There is much scope for an integrated approach whereby roads can become instruments for water management and flood resilience. There are three main opportunities: (1) Roads contributing to improved water management within the polders (2) Roads functioning as flood embankments (3) Roads more systematically serving as flood shelters. This is discussed in Section 3. Addressing these important opportunities is helped by coordination and collaboration among institutions responsible for water and road management (Section 4).

Roads for improved water management inside the polders

Within the polders, roads, bridges, culverts and gates strongly influence the flow of water, its distribution, and the water levels. The network of internal roads, including small village roads and pathways, divides the polder 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 to the catchment hydrology. As mentioned, water crossing structures may have inadequate dimensions, wrongly located or plainly absent. Neither are they systematically provided with gates which would provide a huge opportunity to actively manage water levels, 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, to summarize by combining road development with water management, benefits would be multiple: less water logging, less road damage, improved agriculture production and improved overall livelihoods of rural communities.

Roads combined with flood embankments

Secondly, there is also a strong link between roads and flood embankments. Many of these embankments are also used as roads – the top of the embankment serves as subgrade for the pavement of the road. 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 it 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 the 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. Another issue is the construction of bridges in the flood embankment that may either weaken or strengthen the flood protection function. 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.

Roads more systematically serving as temporary flood shelters and evacuation routes

The third important nexus between roads or embankment roads and flood resilience is that roads act as shelters and as safe heavens 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.

There is a need to improve institutional collaboration. The polders were constructed for flood protection and agriculture production. Road development was done independently but with the large impact of roads on water management and drainage there is a need to optimize road and water management functions. This is an opportunity for responsible organizations (LGED, BWDB, WARPO and the concerned LGIs) to work together on issues related to water management infrastructure and hydrological considerations to provide flood resilience, agriculture production inside the polders.

3. Recommended Good Practices and Important Considerations

The interaction between roads and water management was systematically explored in four polders in Bangladesh (Polders 26, 32, 432F and LGED Subproject in Khajuria) and an inventory of common issues (flood protection, water logging, water scarcity, affected roads quality, reduced agriculture production, siltation) have been identified, validated, and ranked with main actors (BWDB, BGP, LGED, UP, WMGs, WMAs).

These issues can be turn into improvement opportunities for effective water management, which will benefit the vulnerable people inside the polders. The inventory was used as a starting point to create this document of Recommended Good Practices including important considerations for improved water management and flood resilience through roads development within polder areas. Figure 1 below gives an overview of the recommended practices and important considerations on the three categories of opportunities listed with bullet points:

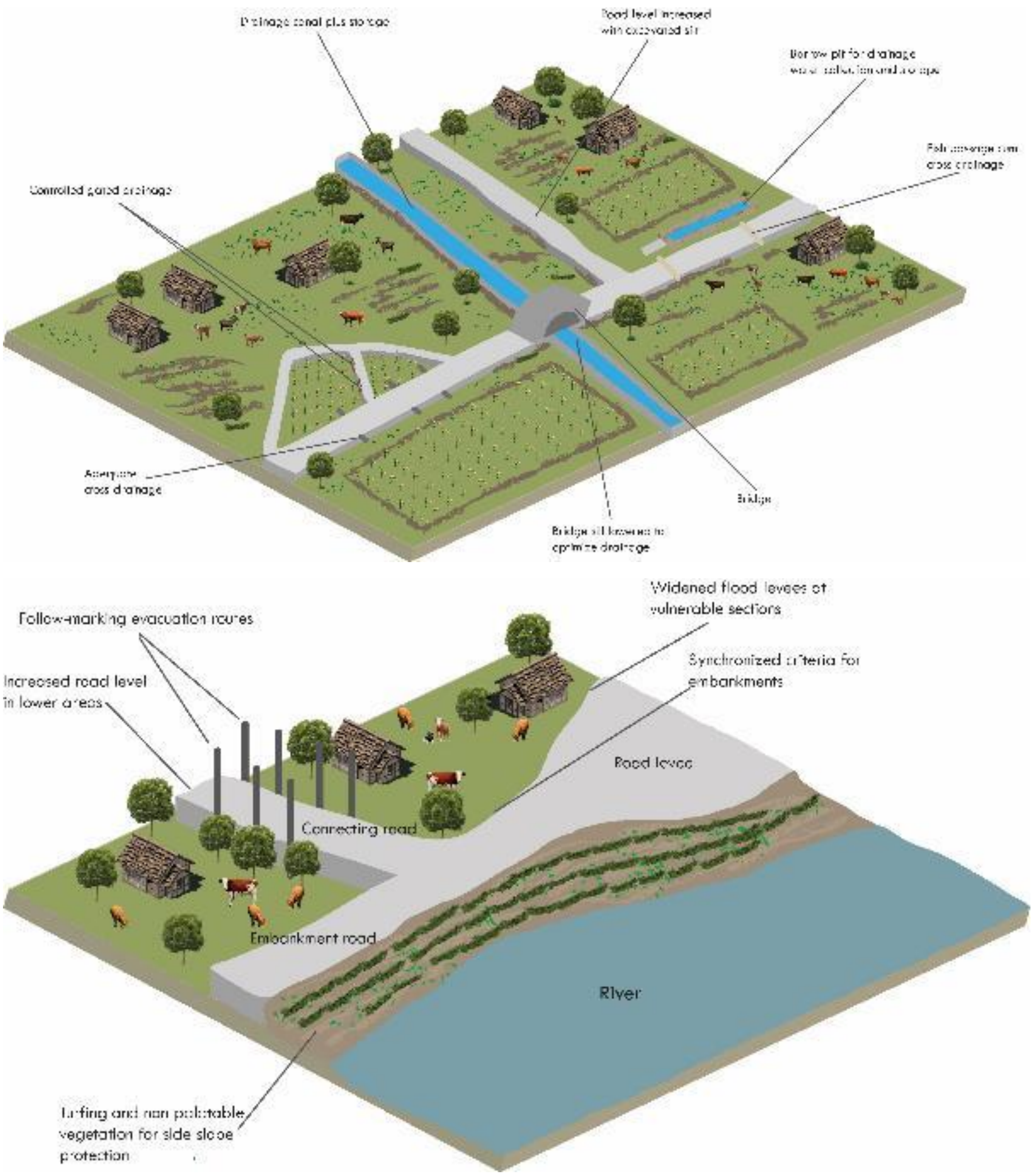

Figure 1. Overview of recommended good practices for coastal polders

1. Roads for water management inside the polders (see section 3.1)

- Conduct a basic hydrological assessment for internal rural roads
- Planning the boundaries of roads and paths as divisions between high, middle and low lands in the polders
- Integrate drainage structures in the initial road design
- Use gated crossings (culverts, pipes) to retain and control water

- Consider extending culverts and pipe inlets and outlets to allow future widening of road embankments
- Multiple functions of borrow pits
- Use roads to raise lands
- Avoid damage to road surface by using proper water draining road templates
- Re-use the excavation material from khals to increase the level of roads

2. Roads and embankments as flood defense (see section 3.2)

- Synchronized planning of design criteria for road embankment
- Coordinate development/improvement and implementation phase of road/embankment
- Use cheap bio-engineering techniques turfing or vegetation for side slope protection

3. Roads as temporary flood shelter and evacuation routes (see section 3.3)

- Prioritize the development of roads that connect to cyclone shelters
- Prioritize the development of roads in the lowest areas
- Consider levees alongside roads and embankments to temporarily accommodate flood affected persons
- Plan and mark evacuation routes

In the next section the Recommended Good Practices are discussed against these three categories of opportunities to create more climate resilience, higher agricultural and aquaculture production and to better preserve the road bodies. This should ideally take place in an overall framework of adequate drainage in the polders with functioning sluices and enough storage in the khals and canals. The functioning of this water related infrastructure would make a major contribution to agricultural performance and sustainability of all infrastructures inside the coastal polders, including roads.

3.1. Roads for improved water management inside the polders

The following practices are recommended in Table 1 as improvements over the current section:

Table 1. Recommended practices of roads for water management inside the polders

	Current practice	Improved practice
Improving roads for better water management inside the polders	No hydrological assessment in planning of smaller roads	Basic hydrological considerations should be taken care of for internal polder roads (mainly village roads)
	Roads planned based usually on land availability, no concerns for benefits of hydrological compartmentalization	Roads can also serve as boundaries that separate high, middle and low lands in the polders to store water for irrigation and facilitate the timely and controlled drying of land

	At present gradual approach is followed: no consideration of catchment and impact on water logging at planning stage	Integrate cross drainage from beginning in road development and dimensioning and placing culvert and pipes in accordance to hydrological catchments in the polder
	Gated culverts are exceptional/very uncommon for minor water control by farmers	Using gated culverts and pipes so as to make these road structures instruments for control of water level
	Not always happening leading to road damage when roads are widened	Consider extending culverts and pipe inlets and outlets to allow future widening of road embankments – although this may also be done once the road is widened
	No collective and integrated planning on planning of borrow ditches and pits	Have road side borrow pits (in country side) to serve as drainage ditches and provide critical dry peak/ dry season irrigation or use for aquaculture
	For Village Class B roads and roads and paths made by community initiative no prescribed template	Avoid damage to road surface by using proper road design templates
	No systematic planning of water storage vis-a-vis water demand or systematic reuse of excavated material	Re-excavating khals to create adequate storage for the dry season and to reuse the spoil for constructing roads, embankments or flood levees

3.1.1 Conduct a basic hydrological assessment for internal rural roads

There are three types of rural roads: type 1 roads that connect growth centers with farms; type 2 roads that connect union headquarters and local markets with villages and farms; and type 3 roads that include roads within the village. Roads and Highways Department (RHD), the central agency of the Government, is responsible for construction, improvement and maintenance of the national, regional and type A feeder roads. Type B feeder roads and rural roads (except municipal roads) are built and maintained by the Local Government Engineering Department (LGED) in collaboration with local government bodies such as district council, Upazila Parishad and Union Parishad.

Figure 1. Seepage on rural road

Figure 2. Water seepage cause road collapse

The conditions of internal rural roads are often not good. Internal rural roads have: many holes, uneven surface, cracks, no pavement, no drains, no passengers path. At present the effect of roads on surface hydrology is generally not taken into account during the road development, in particular for the internal rural roads and footpaths. This results in road damage due to seepage (Figure 1 and 2) and waterlogging around roads, whereas opportunities for improved productive water management are missed. There is a recent agreement between BWDB and LGED (MoU, January 2018) to coordinate the development of roads, particular where they have a flood protection function. The scope of the MoU is to manage national water resources in an integrated manner and to ensure the implementation of national water management plans and policies. This is a huge step forward, but in practice Local Governmental Engineering Department (LGED) does not conduct hydrological surveys for the development of new rural roads. The criteria in the design of village roads (Type A and B) are mainly based on traffic, public demand, land availability and socio-economic connectivity (access to market and surrounding villages).

Hydrological conditions must be considered as top most priority in planning and designing a future road network. The Bangladesh Water Act emphasizes that in planning a road network, waterways have to be ensured. In order to do so, model output (if available) and local experience should be synchronized. It is essential to consider basic hydrological aspects when developing roads inside polder area such as: flood drainage, stream channels and topography, afflux, debris properties, scour risk, road alignment, soil conditions, and fish movement (Queensland 2015). A full survey as is done with highways by the Roads and Highways Department is not possible, but it is proposed that at least a community mapping is undertaken under guidance of the local LGED office and that local stakeholders are consulted, preferably through Water Management Organizations where they exist. The engagement of WMGs in water resources projects is enabled by the Bangladesh Participatory Water Management Rules under BWDB, as well as the Water Management Cooperative Societies under LGED. The existence of these local organizations makes it possible to systematically engage local water users in the development of road-water infrastructure. This maybe helped by local mapping.

The proposed mapping should discuss:

- Location of road – does it follow boundary between high and low land
- Current land use on either side
- Discuss micro relief in the area and make drawing giving boundaries for each sub-areas own outlet
- Command areas created by road alignment
- Map current drainage patterns along the roads, consider openings if roads crosses river/canal
- What are the drainage requirements during monsoon (water to be removed within)
- What are the disposal facilities (relates to khals and sluices)
- What are the drainage requirements under normal circumstances
- What are the water storage requirements
- Calculate the total dimension of the passage + rainfall/highest water level – to be removed days is – inundation
- Modify location of roads in accordance to the land acquisition problem.
- Identify locations of pipes, u-drains, culverts and bridges
- Identify needs for gates on the cross-drainage structures

A crucial element is the location of culverts and U-drains. If the discharge can be estimated, then the culvert and pipe size can also be estimated using charts and nomographs. UP/PIO should follow the instructions of LGED and training of UP/PIO staff may be arranged for awareness on drainage and culvert design (dimensions only).

3.1.2 Planning the boundaries of roads and paths as divisions between high, middle and low lands in the polders

Roads redefine the surface hydrology of the coastal polders according to the topography of the territory dividing it in high, middle and low lands. Although land acquisition is a problem in Bangladesh, LGED should align roads as much as possible following contour lines and compartmentalizing farmland in high, middle and lowland. This allows the optimal productive use of different levels of land. Roads can in fact even modify the contour lines – as level differences are usually less than one meter and road bodies are the 1/20-year flood level plus 30 cm free board.

If detailed Digital Elevation Model (DEM) or flood free zoning are available can be used combined with land use zoning. If not, then the planning of roads as **divisions** between high, middle and low lands in the polders (as well as the location of cross drainage structures) can be done on the basis of systematic discussion with Water Management Organizations and Local Government.

The compartmentalization of land of different levels can also be used to slowdown monsoon run-off of floods storing it behind the polder road embankment before overflowing into the next stretch of land. This slows down the velocity of water, reduces erosion and siltation leading to more groundwater recharge. Local people can retain water using gates at higher areas and serve as storage for lower areas or used for irrigation during the dry season.

3.1.3 Integrate drainage structures in the initial road design

Figure 3. Waterlogging

At the moment LGED does not always systematically integrate the drainage structures (culverts and pipes) into the initial road design. In several instances - the location of culverts or pipes is decided later on when road damage happens due to seepage (Figure 1 and 2) or when water logging (Figure 3) occurs. This is called the gradual approach. Thus, rural roads have insufficient or inadequate drainage gaps to overcome the excess of water flow during the monsoons.

It may be a better practice to decide on the drainage requirements when the road or pathway is first constructed. The Bangladesh Water Act states that normal flow should be ensured in planning the road network. Therefore, based on the land zoning (previous described) future road network has to be planned/designed with enough and adequate drainage structures where necessary. However, some of the roads may need to be redesigned with appropriate openings where necessary since they were not included in the initial planning. In other cases, these openings may need to be moved or relocated due to their inappropriate location.

The ‘gap rule’ (LGED 2005)_describes the recommended length (in meters) of drainage openings (bridges, culvers and pipes) per 100 meter of roads (Table 2). It is based on the type of road and the geographical location.

Table 2. Gap requirements by type of road, m/km

Road class	**Road design type**	**Geographical location**			
		Swampy	Hilly	Hoar	Plain
Upazilla and Union	Type 6, 5, 4 Type 8, 7	10-15	7-15	10-15	6-10

At present BWDB is discussing that achieving climate resilience may require additional drainage capacity. During design of drainage structures, an addition 15% (total 115%) rainfall should be considered for climate change. It is recommended to also increase the recommended gap criteria.

In deciding the location and type of cross-drainage structures the following practice is recommended:

- Observe the natural drainage patterns and place the cross-drainage structures along natural drainage paths
- Discuss the need for drainage of the higher command areas and the opportunities to discharge it – and consider the controlled cross drainage structures (see next) in those locations
- Consider pipes or culverts (with gates) if there is a need now or in the future to constrict the flow (back up of water upstream) and control the water. 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.

3.1.4 Use gated crossings (culverts, pipes) to retain and control water

Gated water crossing structures (Figure 4 and 5) – in particular box culverts and pipes - will help to control water levels with the road infrastructure, in particular with the roads inside the polder[3]. With these relatively simple devices water levels in a large area can be controlled. 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.

Figure 4. Box culvert with slot for gate

Figure 5. Gated culvert

[3] This practice is not recommended for roads that serve as flood embankment (see 3.2)

In this way proper 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)

Gates should be provided at specific locations based on the local discussion and agreement to control drainage, to manage water levels of fields, khals, and ponds and increase availability of water for different purposes (irrigation, aquaculture, households). The size of the culverts/pipes will be based the canal cross section and the highest water level. The gates may be made of wood or iron, but an important consideration is that they should be theft and tamper proof. The local discussion – undertaken preferably through Water Management Organizations – should also create clarity on the rules and responsibilities for operating the gates.

To make gates on cross drainage structures the following is proposed:

- For box culverts provided internal slot or external railing for stop logs or gates
- For pipe culverts that have a superstructure provide a hook or railing to attach the gate

Especially where there is more than 0.50-meter difference between upstream and downstream, land scour protection may be provided. The protection could be combined with vegetation or small stone pitching both on the upstream section and the downstream flow path. This will prevent damage from the water gushing through, once upstream water is released.

3.1.5 Consider extending culverts and pipe inlets and outlets to allow future widening of road embankments

Gated pipes and culverts provided in road bodies should be the same length as the width of the road. A current problem is the wrong dimensions of the culverts/pipes in comparison to the dimensions of the road or embankment width.

If the length of inlet/outlet is smaller than the width of the embankment (Figure 7) it undermines the durability of embankment roads and their flood protection function. Water passing through the culvert or pipes will erode the sides of the embankment (Figure 8). When culverts/pipes are designed it is recommended to keep a length of at least 0.5 meter longer than the width of the road on the outlet side to place the gates if needed and have the road body around it protected by riprap or vetiver vegetation. On the inlet side care should be taken that there is adequate storage for the drainage water to pass through the cross-drainage structure and that the area around the culvert or gate is protected with rip rap or hardy grasses such as

Figure 7. Inadequate pipe length

Figure 8. Eroded side road

vetiver. At the inlet preferably, the culvert or pipe should be at least 30 centimetres wider than the road body.

3.1.6 Multiple functions of borrow pits

Figure 9. Borrow pits along the road

Borrow pits (Figure 9) are excavations done to collect materials – sand, gravel, soil – for road construction and maintenance. They are typically located parallel to the road. The Guidelines (2004) of SSWRDSP of LGED establish criteria for borrow pits: the depth should not exceed 1.5 m, and the width of the embankment side berm and the edge of borrow pit should be from 3m to 10 m. During monsoon season borrow pits will fill with water. They serve several useful functions:

- They act as a drainage reservoir taking excess water from the adjacent (paddy) fields
- They serve as water storages and can increase the ground water table
- They can be used for important functions such as aquaculture, harvesting aquatic plants and jute retting

It is useful if in most instances not to backfill the raad side borrow pits but to discuss their location and dimensions with the users and owners of the land where they are located, preferably under the guidance of the local Water Management Organizations. The location of the borrow pits should be following number of considerations:

- Clear ownership of land and future borrow pit
- Future function defined
- Ability to landscape the borrow pit and make it safe from danger

3.1.7 Use roads to raise lands

In low-lying areas roads can be used to capture sediments increasing the land level on one side to gradually deal with river level water rise (Figure 10). This practice now occurs by chance but if it would be better managed maybe the impact can be noticeable. In Polder 2 (Satkhira) ground level increased 150cm on the upstream since the road was made 20 years ago. The higher ground is less prone to flooding and/or water logging; thus farmers can 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. The following would be required:

Figure 10. Use roads to capture sediments

- The intake points into the polder are mapped and an assessment is made on their silt levels

- This is mapped in line with the internal drainage pattern in the polder and the high, medium and low-lying areas
- The opportunities for (new or existing) road infrastructure to guide relatively silt-laden water to low lying areas and depressions by diverting part of the surface flow should be mapped.

3.1.8 Avoid damage to road surface by using proper water draining road templates

It is important that no water accumulates on road bodies. This will damage the road surface first and subsequently it may affect the subgrade as well. It can jeopardize the water management function of the roads. In low gradient areas such as the coastal polders drainage from the road surface can be achieved by using and maintaining so-called crowned road templates that drain water away from the road surface during heavy rainfall.

The Standard Design Road Manual (LGED 2005) includes design templates (crest width, slope, pavement, subgrades) for the main rural roads: Upazila Roads (template type 4, 5, and 6), Union Roads (template type 7 and 8), Village Roads A (template type 8).

For Village Road B however there is no template available. Village roads B and earthen roads constructed under 'Food for Works' project are often not planned and designed following any guideline. The same is true for footpaths and minor roads made by community initiative. Field survey revealed that such roads often become inaccessible (Figure 11) because they are muddy, have broken bricks, and sloped that are eroded (Figure 12). This can be avoided if all rural roads, including unpaved village roads and footpaths are constructed with a road template – to ensure water drains to the side of the roads.

Figure 11. Too narrow road. Inaccessible

Figure 12. Muddy earthen road

3.1.9 Re-use the excavation material from khals to increase the level of roads

The internal drainage inside the polder areas consists of a network of canals – also called khals. These khals are multifunctional: they remove excess water when required but also they serve as water storage or are used for aquaculture.

Figure 13. Siltation of khals

Siltation of khals is a constant challenge: it will increase the water levels in these drainage canals causing drainage congestion and water logging (Figure 13). Regular cleaning and re-excavation of khals is needed to ensure khal system connectivity, continuous water drainage and more water retention inside the polder. The excavated silt can be re-used systematically: to create land for agriculture, to increase the level of cultivated areas, to increase the level of settlements, but also to make roads and/or embankments roads and flood levees. This is also discussed in the next section

3.2. Roads and embankments as flood defence

Most flood embankments are used for transportation next to their role in flood protection. In addition, there are also new roads developed in coastal areas, which include a new embankment that is used – that include the embankment of the roads (Figure 14). As different organizations are involved, in particular BWDB and LGED, it is important that the criteria for roads and embankments are synchronized – with regards width, side slope and height. Similarly, the planning of the development of roads and embankments should be coordinated. Traffic functions and flood safety should be combined and not compromised either way. Table 3 is an overview of recommended improved practices in this field:

Figure 14. Embankment road

Table 3. Recommended practices for roads as flood embankments

	Current practice	Recommended practice
Roads and embankment as flood defense	Insufficient synchronization between LGED and BWDB. Recent MoU (January 2018) is calling for this but now needs to be operationalized	Synchronize criteria for flood embankment heights, width and slopes
	Insufficient coordination for the development/improvement and implementation phase of road/embankment. – often roads prematurely paved – making it politically difficult to raise embankments to desired level	Ensure proper coordination between embankment raising, road development (carpeting) through polder level planning
	Not standard the use affordable bio-engineering techniques on all the embankment slope protection	Use cheap bio-engineering techniques such as indigenous vegetation for side slope protection and decrease erosion

3.2.1 Synchronized planning of design criteria for road embankment

BWDB and LGED should work together and establish common standard criteria for road embankment design. Road embankments should be designed and constructed with sufficient width and height to ensure protection from floods – to preserve the land, people and roads and to be functional for transport. The standard design of Village Roads of SSWRDSP, LGED (2004) provides for a minimum crest width between 2.5 and 4.9m for road embankment (Table 4) and the standard Manual for road design of LGED (2005) establishes a crest width for village roads of 5.5m. Moreover, the current crest width used by BWDB for embankments is 4.3m. It is proposed to use at the minimum the largest crest width, i.e. 5.5m for road embankments. This creates also extra space for human and livestock shelters during flood events.

Table 4. Standard width for embankment road, SSWRDSP, LGED 2004

Standard Crest Width of Road Embankment	
Road Grade	**Required crest width (m)**
Rural Road (R3)	2.50
Rural Road (R2)	3.70
Rural Road (R1)	4.90
Feeder Road	7.30

Moreover, BWDB has developed a new design criterion for embankments based on climate scenarios: with 6m crest, width, and the height based on return flood period of 1:100 (or 1:200 for large rivers), adequate side slope protection, size and number of drainage structures based on climate change. At the moment BWDB is applying them only in polders under the CEIP project. Once these are tested/applied it would be good to dovetail these with the practice of LGED on embankment road planning/development criteria. Afterwards, BWDB and LGED should follow the new design criteria for future new road embankment design and/or improvement works.

Synchronization between the concerned water and road authorities should also be done for the height of the embankment. At present the criteria for BWDB and LGED for the height of the road embankment coincides: both use 20 years flood levels plus 0.9 m free board. Criteria for internal roads are only in use by LGED: 20 years flood levels plus 0.3m free board. It is recommended that data on flood levels be shared. BWDB is also reconsidering its criteria for embankments so as to provide better flood defenses (see above). It is recommended that the new criteria – accommodating also the different return floods (1:100)- to be shared and discussed with others water agencies.

It is also recommended that for an embankment used as road, the slope criteria of BWDB should be followed. This is in line with the Memorandum of Understanding of 2 January 2018. Whereas the slopes for roads are steeper (1:1.5 to 1:3), BWDB uses the following criteria:
- Side slope of 1:7 on seaside and 1:3 on countryside are prescribed, where the embankment has no protective works.
- For protected embankments, side slope of 1:5 on sea side and 1:3 on the country side are recommended
-For interior embankments with that are less exposed to surge and wave action, side slopes of 1:3 on both sides are generally prescribed.

The BWDB[4] has developed stricter guidelines that may be adopted in due course.

4
The proposed new criteria are:

- Big rivers: 1:3 in both sides
- Small rivers: 1:7 (river side) 1:3 (country side)
- Block protected: 1:5 (river side) 1:3 (country side)

3.2.2 Coordinate development/improvement and implementation phase of roads/embankments

The development of roads and embankment in practice is not always coordinated among the road and water agencies. This is manifest in roads being carpeted on embankments, before these have reached their safe flood levels. There are also instances where even the top part of the embankment was lowered to accommodate for the width required for the road. There are agreements between LGED and BWDB on this – including the recent agreement of 2 January 2018 that need to be followed. The crest width and the side slope prescribed by BWDB is binding, the budget for road development may also include provision for raising the road embankments to these safe levels in addition to the funding for road pavement and subgrades. When developing a road on an existing embankment the effect of compaction of the existing embankment should be accommodated as well. If a road is constructed on an embankment that is not yet at prescribed levels, the pavement is considered temporarily and may be demolished to be rebuilt after the embankment is raised.

3.2.3 Use low cost bio-engineering techniques for side slope protection

Low cost bio-engineering measures to protect side slope should be incorporated into the initial design of roads or embankment roads) and the berms of the embankments (Islam 2000). Local vegetation (grass and shrubs, but no trees) should be used to protect the side slope of roads, in particular the embankment roads. Suitable grass species such as Vetiver at 0.3 m x 0.3 m spacing, mixed with *Ipomoea*, *Nypa*, *Typha*, *Pandanus recommended by* Islam (2000) for embankment erosion control in Bangladesh. Studies show that vetiver application is about 8 times cheaper than the masonry wall protection and about 5 times cheaper than the revetment stone slope protection system. Thus vetiver grass plantation for slope protection could be a sustainable, green and cheaper bio-engineering solution (Shariful Islam 2013). Vegetation on the berm slopes is a barrier against runoff and erosion. Slope protection with grass increase the stability of the slope decreasing road erosion leading to road stability and flood resistance. Furthermore, turfing is a must for side slope if the road is parallel to a canal/river. Turfing can be combined with the use of jute or coir netting to prevent soil erosion (figure 15).

Figure 15 Use of turfing combined with jute netting

The selection of the indigenous plant species should be done in consultation with the local community. Often in coastal areas all land is at a premium and is heavily contested. The use of side slopes and the protection of the newly planted vegetation should be discussed with the local government as well, deciding in particular who is allowed the use of the side embankment and who is responsible for guarding the side slope as well how this is supervised and enforced. In addition, what should be done is that the grass vegetation is evenly spread and well maintained and that no animal paths with associated gullies develop, that can undermine the embankment. On the other hand, if the vegetation is evenly spread the hoof action of animals may compact and strengthen the embankment.

Figure 16. Mangroves in Bangladesh

Coastal area embankment roads may be also protected by a 50-200 m wide belt of mangrove (Figure 4.5) in the tropical regions or non-mangrove plantation following the staggering method. This practice may protect embankments from erosion caused by tide effect but not from the impacts of storm surges (Islam 2000). Mangrove retain nutrients in their roots increasing soil stability and keeping up with sea-level rise (Alongi 2008). Moreover, mangrove act as a buffer towards strong winds and cyclone tidal effect.

It is recommended to integrate the use of roadside low-cost bioengineering techniques into road planning or development plans/programs, in particular for unpaved roads. Detailed planning for roadside vegetation combined with other measures should be developed, as part of road development programs, – showing the main objective of the roadside vegetation (dust control, beautification, improved visibility, erosion control, etc.) and the preferred planting for the different roadside stretches. In spite of the considerable benefits it brings, roadside vegetation is still exceptional. India is a main exception, as it launched Green Highways Policy in 2015. This includes the provision to set aside 1% of all road investments into a roadside tree development fund. Different type of vegetation species and other inexpensive bio-engineering techniques are explained in Annex 4.

Box 4.1 Repairing embankments by using Green Soil Bags.

A special newly developed method to prepare or repair embankment is the Green Soil Bag. The Green Soil Bag is a unique measure developed to block water like a traditional hessian sack. The big advantage compared with the traditional sand bag is that the Green Soil Bag is fully bio-degradable and filled with mix of grass seeds and rich ground. The seeds will germinate depending on the temperature and grow outwards through the jute. The first 1.5 years, the bag itself will ensure stability in the dike / embankment. Later the bag will be digested, and the grass net will take over the function by blocking erosion with rooting of the subsoil. Dutch water boards use this smart and simple invention to strength their levees and harvest the grass. It was designed for repairing dikes and flood defenses as well as increasing their height. The Green Oil Bag was also introduced under a pilot project in Gondamari, Bangladesh where local communities are very enthusiastic with the first evidence with good first responses. A first impression is that these bags are effective to prevent minor erosion impact, but not to protect against major tidal waves and strong river erosion.

Green Soil Bags used to build levees in Kalapara

3.3. Roads as temporary flood shelter and evacuation routes

Roads are important part in flood disaster response. Because of their higher location, they serve as emergency flood shelters and provide evacuation roads. In the past years many cyclone shelters have been constructed. The cyclone shelters however are not in all areas able to accommodate the entire population in an effected area; hence roads complement cyclone shelters and other flood response measures.

The following good practices are recommended in Table 5:

Table 5. Recommended practices for roads as flood shelter and evacuation routes

	Current practice	Recommended practice
Roads serving as temporary flood shelters and evacuation routes	This practice is recommended but not always practiced	Prioritize the development and heightening of roads leading to designated cyclone shelters and killas
	No planning of such higher road bodies – leaving people in lower parts of the coastal polders and outside the coastal polder very much exposed	Create heightened road bodies in low lying areas of the polder to create safe routes to the temporary cyclone shelters during flood events and refuge areas in the post flood scenario
	Currently, local communities settle illegally on embankments and roadsides.	Create levees along internal roads and specific embankments sections to temporary (15-30days) shelter people and livestock with the usage regulated by local government
	No planning of evacuation routes	Plan evacuation routes using road infrastructure, making it higher where possible

3.3.1 Prioritize the development of roads that connect to cyclone shelters

Figure 16. Cyclone shelter

During repair/development works LGED/PIO/UP should give priority to the roads that connect cyclone shelters. (Figure 16). In making a road development plan for a coastal polder the road network should be designed in such a way that it is possible for humans (women, children and disabled) and livestock to use as an evacuation route and reach the cyclone shelter shortly. Road development should be part of Disaster Risk Reduction Plans including standard guidelines for routine maintenance.

3.3.2 Prioritize the development of roads in the lowest areas

The roads in low-lying areas are the most affected by water logging, road breaching and muddy conditions. The essence of rural road development in low lying areas should be accessibility to shelters in case of emergency such as cyclone shelters, community centres, schools and health clinics.

Roads also provide important functions during floods themselves– as safe shelter during and immediately after floods. These functions should be systematically strengthened. In designing new roads priority may be given to the road sections in the lowest part of a polder and to raise them to at least the design specifications (1/20 years flood levels plus 0.3meter additional free board). Where possible excavation material from local khals may be used. It is recommended that Local Government offices (LGED, UP) should consider this practice into the development and maintenance plans/programs of rural roads to ensure accessibility and mobility of people for emergency during cyclones. Priority should be given to include local people and NGOs into the development of rural roads in low lying areas.

3.3.3 Consider levees alongside roads and embankments to temporarily accommodate flood affected persons

The construction of flood and post flood shelters may harm the sustainability of the embankments. Bangladesh Water Act discourages the construction of any house, establishment or other structure on flood control embankment. As per Article 21 of the Water Act, *to ensure the sustainability of the flood control embankment, no person shall, without the permission of the appropriate authority, be allowed to construct any house, establishment or any other structure on, or on the slope of such embankment. The EC may issue a removal order or impose any restriction by issuing a protection order*.

During the cyclone people must take shelter in the cyclone shelter because it is not safe to use roads/embankments as shelter during the cyclone. People can use roads/embankments as shelter after the cyclone for a period of 15-30 days when their houses are damaged or under water. Thus, in addition to raising the roads in the lowest sections of the polders, levees may be created along internal roads and along specific embankment sections to shelter people and livestock after flood/cyclone. These higher sections should be created especially in flood prone areas, outside flood free zone, using the remaining silt from the excavation of khals, ponds or

Figure 17. Cattle shelter

Figure 18. Temporary shelters (house, garden)

rivers. Such sections along the roads could provide the opportunity to accommodate temporary (period of 15-30 days) flood victims (people, cattle and goods) until they have rehabilitated their houses (Figure 17 and 18). The UP/WMA should have written authority to remove people from these levees after that certain period (15-30 days). Moreover, the construction and use of these levees should be regulated by the local governments, to avoid the permanent occupation of the flood shelters. The spacing of the levees should be done strategically – placing them at distances so that they are accessible throughout the flood prone areas, and placing them along more exposed section of flood embankments, so they serve as an additional reinforcement. The same may also be done for the area outside the embankments.

As a rule of the thumb, the minimum space needed for a person to take shelter lying down is 1.5m^2 or 3.5m^2 for a sphere standards space (Cross Red 2013). An average a household in Bangladesh has 4.6 members (Begum 2004). A family needs approximately a shelter area of 15-16m^2. For livestock between 2 to 4 meters space would per head would suffice. Therefore, on a longitudinal section of 100m of embankment with a width of 3m (10 ft.) 85 people can take shelter (without livestock). If there are multiple areas of 300m^2 in specific locations along an embankment, the number of people that would benefit of temporary shelter would be much proportionally larger.

It is also important to protect such levees by stabilizing them embankments by planting hedges, vetiver and other grasses on their slopes and toes to protect them from erosion (Islam 2000).

3.3.4 Plan and mark evacuation routes

People in Bangladesh are well aware about the location of the nearest shelter and the evacuation routes. However, during emergency some prefer to stay at home to protect their properties. Despite the Cyclone Preparedness Programs and early warning system, pre-cyclone evacuation remains a challenge in Bangladesh. In the rural areas there is still lack of awareness, illiteracy and communication which unable people to understand the warnings and evacuate. Moreover, dissemination of warning messages is not efficient because most residents in coastal areas don't have radio or television, so they prefer to rely on natural warning signs (Haque et al. 2012). During floods and cyclones roads are an important part of the evacuation of people and livestock. LGED is developing a Guidelines for Rural Roads development applying GIS for investment prioritization. This will provide a disaster damage database of rural roads at Upazila level: flood affected road segment information, road embankment damaged information and structure damaged information, update of river data, and update on settlement data (LGED 2010). The Disaster Risk Reduction Teams could use this database to plan the evacuation routes at Union level. This is can be done by:

- Mapping population centers
- Mapping road network look in particular at the level above ground
- Mapping for flood, inundation risk and escape route (Figure 19) (WMO & GWP 2011)
- Create flood signs as part of the evacuation route planning (Figure 20) (WMO & GWP 2011)
- Analyze main gaps and deficiencies and identify vulnerable areas
- Identify locations that are easily inundated and consider placing poles or other markers in such areas to mark the road bodies
- Provide awareness so that a large number of persons are aware of the evacuation routes.

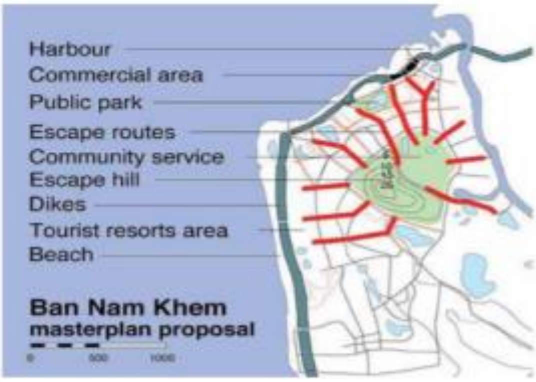

Figure 19. Map of escape route in Thailand

Figure 20. Flood sign in Kasiru Village, Kenya

4. Recommended Improvements in Governance and Coordination

Previous recommended practices can become useful and effective if there is a good cooperation and collaboration among road and water organizations to avoid overlapping, ensure transparency and more efficient results in roads development and water management inside the polders. Table 6 lists recommended practices in terms of governance:

Table 6. Recommended practices in governance and collaboration

	Current practice	Recommended practice
To improve governance and coordination among road and water agencies	Limited synchronization, that may cause delays in the implementation works	Synchronize fund disbursement with road development/improvement period
	Only limited coordination between relevant organizations for road development	Improve cooperation between road and water management agencies for embankment/road carpeting
	Challenges in routine maintenance of roads, embankments and water drainage structures	Ensure routine maintenance of infrastructure (roads, embankments and water drainage)
	Limited information sharing	Share information
	Water Management Organizations exist in many places, but they are as yet not always active in polder water management or flood resilience	Engage Water Management Organizations in polder water management, in flood resilience and in sediment management by making it part of their annual plans
	Constraints in the field staff from LGED and BWDB	Increase field staff from LGED and BWDB for field work.
	At best limited coordination with NGOs working on roads	Mandatory coordination – preferably linked to polder plans
	Community engagement is haphazard, not systematic	Systematically engage local communities in road and water management planning – preferably through UPs and WMOs in polder planning
	No vision on road development or water management within the polders	Undertake polder planning
	No land use planning	Undertake land use zoning in support of polder planning

4.1. Synchronize the fund disbursement with the timing of road development/improvement activities

Insufficient roads quality (Figure 21 and 22) is often due to the development or improvement of roads during rainy season or beginning of rainy season. Construction is at times delayed in the rainy season, which hampers the construction process. In such cases compaction of the road becomes a challenge as the soil is saturated with water reducing the stability and sustainability of the structure. The late execution of the works is due to the late disbursement of funds in July (financial year is July-June), which is also beginning of the monsoon season (June to October). By that time plans are approved, field surveys done, and works are ready to be started, it is already the inception of the rainy season. Likewise, khal excavation is not possible because of the same reason.

Figure 21. Damage to road

Figure 22. Inadequate construction material

4.2. Improve cooperation in embankment road paving

There is inadequate coordination and cooperation among water authorities (BWDB, WARPO) and roads authorities (Roads and Highways Department, and LGED and PIO) both vertically and horizontally. Regarding feeder roads and rural roads, in particular collaboration between LGED/UP and BWDB could become stronger. Moreover, local people who are the road users are as yet not involved in the construction and maintenance of roads, but this through WMCAs and WMGs could improve.

Figure 23. Poor road carpeting

For instance, the lack of communication between BWDB and LGED, results in extended time needed by BWDB to approve LGED's plans for developing an embankment road. When LGED paves an embankment, height and width are not always according to the standard road design criteria. Thus, this leads 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 for reasons similar to those already mentioned for internal roads (Figure 23). This results in rapid degradation of the road, and later on also leads the deterioration of the embankment.

However, this can be changed. The process to approve embankment carpeting plans shall be streamlined, design heights for embankments and embankment roads adopted by LGED and BWDB should be harmonised, following the BWDB guidelines. The road templates and construction materials used for carpeting should also comply the LGED guidelines. Before starting the implementation, LGED should wait until BWDB reshapes the embankment in accordance to the Guidelines specifications. Afterwards BWDB can give clearance (No objection certificate-NOC) to LGED for carpeting the embankment. A better monitoring by BWDB is needed of embankment roads implemented by LGED.

4.3. Ensure routine maintenance of infrastructure

Roads, embankment roads and water drainage structures need very regular maintenance to ensure continuous water flow within the polder. Currently, many pipes, culverts and sluices openings are silted damaged or blocked (Figure 24). Structures are blocked by high amount of sediments deposited through runoff, 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 khals capacity to store water decreases due to siltation leading to drainage congestion. However, the 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.

Figure 24. Silted sluice and bridge

Moreover, roads and embankment roads need also regular maintenance. Earthen roads become extremely muddy, slippery, unstable side slopes, and uneven under the pressure exercised by the wheels of motorized vehicles. Road bricks are frequently damaged or displaced leaving behind large potholes (Figure 25), ruts, and portions of muddy soil, inaccessible due to road collapse or degraded state of carpeting (Figure 26).

Figure 25. Pothole on road

Figure 26. Damage to road carpeting

Road maintenance is done by LGED or local government, local representatives of MP and UP. Currently, demand of maintenance works is very high and most priority is given to high volume asphalt roads. LGED does not repair newly developed roads for the first four years. In theory, every month, the sub assistant engineer (Upazila level) surveys the road conditions (mainly Asphalt road). The information is sent to the District and then Regional level for approval. Routine maintenance is done regularly by the LCS group (poor women) but only on Upazila roads. Funds may be available, but the bottom up process takes very long: as a result, funds do not become available when it is needed to keep up with the routine maintenance.

Routine maintenance at earthen rural roads is limited due to lack of funds and men power. Currently, earthen roads are mainly construct/maintain by the PIO (project implementation office). Surveys are carried out to identify the roads problems which are repaired based on the available funds. However, more funds are needed at local level for roads and water structures routine maintenance. A similar women or youth group can be created to take care of routine maintenance at local level. Routine maintenance should include the same tasks at the LCS group:

- Ensure 5% side slope
- Repair holes
- They must drain water puddles
- Filling ratholes, rain cut, ditches
- Remove bushes and plants
- Remove vegetation that block the culverts or pipes
- Clean debris of outlet/inlet
- Remove trees
- Turfing on the side slope
- Stockpile dry land on the side of the road for the monsoon

Furthermore, this group responsible for the maintenance works should be managed and monitored by the PIO. A local committee could be in charge to collect additional funds to cover these routine maintenance works. Some suggestions for funds collections are:

- Users of the water drainage infrastructure for agriculture or domestic purpose could pay an annual fee.
- Users should pay a symbolic road tax for the use of the village roads

Road maintenance costs have a tendency to increase. Therefore, substantial savings can be made on maintenance costs if routine maintenance of water infrastructure and roads/embankment roads will be improved in the polders. Moreover, these actual expenditures are typically 30-40% below actual need.

4.4. Share information

Each authority should make sure that the website is up to date with standard design manuals, reports of recent projects, regulations. Access to information could minimizes administration time and avoids request always permission within a hierarchical system. Moreover, LGED and BWBD should invite each other for workshops and seminars to share knowledge to enhance cooperation.

4.5. Engage Water Management Organizations

Under various programs Water Management Organizations have come into existence in the water systems in Bangladesh. Many of these are registered either under the Participatory Water Management Rules of 2014 or under the Co-operative Society Act. These WMOs have a large role to play in improved water management and improved 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 provider are 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 (fill potholes, rat holes, side slope protection, cleaning openings of garbage). WMG/WMCA should register monitor and document all the activities they do and the related costs and report back to the local executive engineer or local government. Training and coaching should be provided to the WMOs members to fulfil such tasks. Moreover, according to for instance the LGED guidelines, as people are getting benefit from improved water management, they must systematically set aside funds for the O&M costs.

This is a way of involving local people, who are users of the infrastructure, in the process of roads/embankment roads and water infrastructure in order to ensure better water and rural governance.

4.6. Increase men power for field work from LGED and BWDB

It was found out that LGED and BWDB lack of field staff to do field surveys and to support WMOs in their tasks. There is an urgent need to rebalance the staff requirements and field staff available and to equip field staff with logistics and technical means.

Training programmes are needed to increase the capacity of the manpower of the local government organizations working in the areas of road construction/improvement and maintenance.

4.7. Cooperation among Government offices and NGOs

Many of the rural roads and water infrastructure are constructed by local NGOs such as Care, or Islamic Relief. It is recommended to ensure an effective cooperation among government offices (LGED, UP) and NGOs working on rural road and water construction/improvement and maintenance, as well as cross drainage structures.

4.8. Involve local communities in polder development plans/projects

LGED and BWDB should involve local UP/WMO/WMGs in the whole process (survey and implementation) of any planning/improvement of roads/embankment roads and water drainage structures. Local people are the users of the infrastructures and their participation within 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 ameliorate/ mitigate any land acquisition problems.

It is recommended to consider their opinion/perception and engage them actively in working together with UP and governmental departments through:

- Interviews
- Focus group discussion with the different stakeholders' groups (farmers, fishermen, business people, freelancers, teachers, among others)
- Local workshops
- Jointly design roads and water management infrastructure.

4.9 Start process of polder planning

At present there is no systematic forward planning on how roads are developed in a polder area or where the bottlenecks are and what should be remedied on a priority basis. The same is true for water management at polder level. There are arrangements with respect to the operation of sluices but there is no overall plan on how to optimize water management within the polder, though this is highly relevant with the transition to multiple cropping. Neither is there a vision on how to make road and water development within the polder areas reinforce one another and what priorities are required for road planning or the development of cross drainage.

The Consultative Group that developed these Recommended Good Practices strongly recommends the development of medium term Polder Development Plans looking at:

- Road infrastructure
- Water management and storage
- Flood disaster management measures
- Supporting measures.

Such plans should be owned by the LG bodies in the polder and subscribed by the main organizations working in the polder on these topics – but as the case may require. The Polder Plans should be based on the preferences and ideas of the WMOs within the Polder where they exist or other local representative organizations where there are no WMO so far.

All water related infrastructural development works (roads, bridges, culverts, embankments, canals etc.) within the polder is to be covered in the Polder Development Plan. Moreover, the future road development (both alignment and design) would be done by considering hydrology, land use and socio-economic issues and vetted by the local stakeholders (WMG, UP, livelihood groups etc.). Additionally, the design criteria of roads that do not fall under any of the LGED category would be provided in the plan.

Such plan can be developed by on a trial basis for Polder 26 and handed for replication in phases.

4.10 Develop land zoning in the polder area

In the long run the Polder Development Plans should be followed by land use zoning in the polder areas. Zoning means to classify land and waterbodies for specific uses and to develop regulated land use maps. Zoning is important to facilitate planning and to ensure maximum utilization of land).

The mapping of the demarcated zones should be undertaken by the Local Government authority with the support of the Deputy Commissioner. NGOs should be involved in the preparation of the zoning maps and Union Parishads should be the land use policy unit. NGOs and civil society representatives should be included into the land management committee, Upazila Committee for Lease Settlement and Waterbodies Management Committees (Barkat et al. 2007). Rural land in Bangladesh has mainly two types of uses: 25% of settlements and the rest 75% is agriculture and forest land. Land use changes between 2010 and 2030 show that cultivated land declines and build-up areas increase. Thus, a systematic land use zoning can support decision-making of planners to conserve/exploit land resources in a more sustainable manner. Moreover, this should result in less social conflicts related to land acquisition and it will improve the overall livelihood in rural areas (Hasan et al. 2017).

Complementary to the hydrological survey/study a flood control zone shall be specified by referring to the boundaries of the mouza (village) map. Delineation of flood free zone is utmost important in planning the road network. According to the article 25 of the Bangladesh Water Act, the EC may declare *any wetland as flood control zone to ensure easy passage of the flow of flood water. For protection of flood control zones, the Executive Committee may impose prohibition or condition on any activity that obstructs or diverts the water flow through such zones.* This flood free zone should be delineated by the BWDB and should be easily available for the road agency in planning/development of road networks.

Current practice is that land grabbing and encroachment are a constant threat in Bangladesh and land zoning may be 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.

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Annex 1. Bio-engineering measures for side slope protection of roads and embankments – background note

Protective measures such as stone pitching, grassing, 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 slab (Smith 2006).

In Cambodia, Vietnam and India the following methods are used to control erosion on road embankments:

Side slope protection with vegetation

Vegetation is the cheapest way to protect steep slopes of earth embankments. It is practical and easy to use local plants such as the one mentioned in Table 8.

Figure 28. Vetiver grass on road embankment slopes

Vetiver grass (*Chrysopogon zizanioides)* (Figure 28) grows naturally across many of the humid parts of lowland south-east 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 of extreme climatic condition. This technique has recently been employed successfully in certain areas of side slope protection against rain-cut and wind-induced erosion (Shariful Islam 2013). Vetiver shows successful erosion control in fresh water, brackish water rivers and canals. Moreover, farmers can use it as an animal feed supplement, or to tie up rice seedlings and rice straw (Dung et al. n.d.). Studies state that vetiver application is about 8 times cheaper than the masonry wall protection and about 5 times cheaper than the revetment stone slope protection system. Thus vetiver grass plantation for slope protection could be a sustainable, green and cheaper bio-engineering solution (Shariful Islam 2013).

Table 7. Common plants colonising roadsides. Source (Howell 2008)

	Botanical name	**Comments**
Grasses		
	Phragmites vallatoria	Large-leaved tall grass found very commonly on river edges
	Cynodon dactylon	Small, creeping sward grass, very common on grazed land; withstandsheavy grazing and long inundation, but rooting is shallow.
Shrubs and small trees		

	Pithecellobium dulce	Small tree, 6 to 10 m tall, small leaves and thorny branches, common on embankments; edible fruit.
	Eucalyptus sp.	Two main species are most common: *E. tereticornis* and *E.* *camaldulensis*. Spindly tree with white bark, up to 15 metres tall.
	Jatropha curcas	Shrub 2 to 5 metres high; grows easily from cuttings; widely used for hedging; shallow-rooted but easy to propagate.
	Mimosa pigra	Thin, thorny shrub that grows widely on the edges of wet areas and the lower edges of embankments; not liked by farmers, who say that it damages young fish during floods and causes infections.
	Calotropis gigantea	Bushy shrub, large pale green leaves and milky sap, that colonises embankments; deep tap roots; difficult to germinate from seeds in nurseries.
	Barringtonia asiatica	Tree that colonises embankments; very common.
	Pandanus humilis	Shrub with long thorny, fleshy leaves, 2 to 3 metres high, producing many suckers; grows on river banks, used for hedges.
	Combretun quadrangulare	Small tree common on embankments.
	Acacia auriculiformis	Fast-growing Australian tree often planted along roadsides.
Non-grass herbs and other small plants		
	Cassia tora	Annual leguminous herb or sub-shrub with purple flowers and small seed pods
	Eichhornia crassipes	Water hyacinth, an aggressive, invasive weed in slow-moving waterways.

	Eupatorium adenophorum	Weedy annual herb with weak, shallow roots.
	Mimosa pudica	Creeping herb with sensitive leaves; colonises many bare areas.

Figure 29. Turfing

Recently, road projects have used seeding/mulching or turfing (Figure 29) techniques for grassing road embankments (Howell 2008). Vegetative turfing can be covered by biodegradable geotextiles or geosynthetic nettings. A mixture of straw/wood shaving and cow dung can be used as mulch and applied as a 2.5 cm layer. This is very helpful for embankments less than 3m high. They should be fixed in place with bamboos to avoid to be washed away(CSIR-CRRI 2013).

Under the Coastal Embankment Rehabilitation Project (CERP) several biological means have been used for protection against embankment erosion. Several grass species have been used for erosion but also as fodder: including vetiver (*Vetiveria zizanioides*), Napier grass (*Pennisetum purpureum*), Para grass (*Brachiaria mutica*), German grass (*Echinoclora grousgali*), in addition to other suitable plants like Ipil-Ipil *(Leucaena leucocephala*), Jhau (*Casuarina equisetifolia*), and Akashmoni (*Acacia auriculiformis*) (Islam 2000).

Planting shrubs, thorny bushes along the bank channels provide good protection on the slopes of the embankments (CSIR-CRRI 2013). It is not recommended to plant trees along the side slope because the roots of the trees can cause breaching of embankment. Tree planting on embankments was not accepted by BWDB for 30 years. However, the integration of timber trees, fruit trees, grasses, shrubs, other agricultural elements, and animal husbandry has not been tested systematically in the field on sea-facing embankments (Islam 2000).

Vegetative debris combined with inert techniques

Other methods can be use combined with vegetation: bamboo, cut branches, banana leaves and other brush mats can be applied as a cover on the slope 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 (Figure 30); barriers made with bundles using brush work, fascines or wattling (Figure 31), stones mixed with strong timber sections (Figure 32); timber crib wall (Figure 33); reed planting among stone pitching (Figure 34), rip rap (Figure 35) and reed rolls, of wire netting filled with stone, gravel and clumps of reeds (Figure 36) (Schiechtl and Stern 1997); and root wads (Figure 37) (SEPA, 2005).

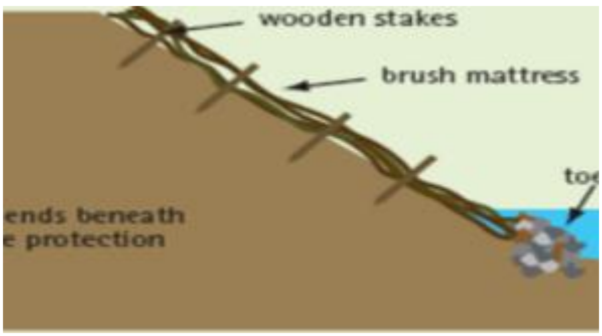

Figure 30. Brushwood mattresses with toe protection

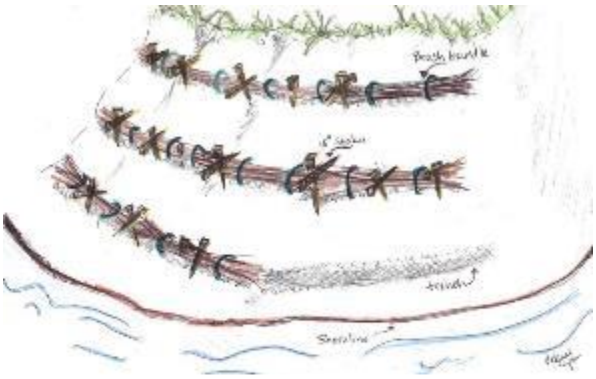

Figure 31. Fascine bundles

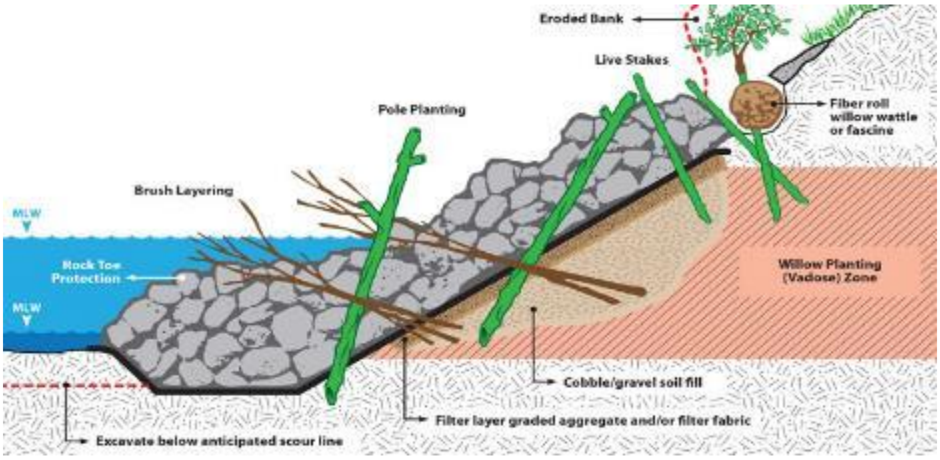

Figure 32. Stones with live cutting

Figure 33. Timber crib walls

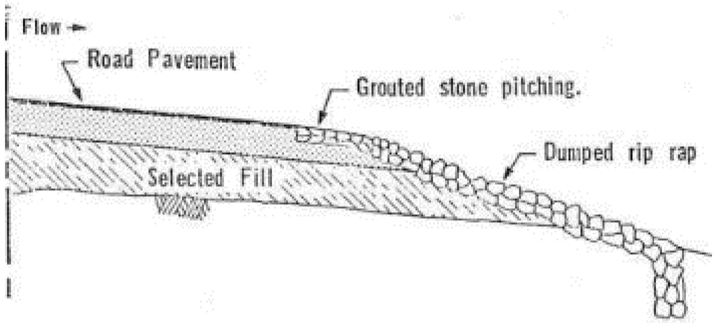

Figure 34. Stone pitching

Figure 35. Rip rap

Figure 36. Rock rolls

Figure 37. Root wads