Environmental Impact Assessment

Roads to the Rescue

Contents

1. Introduction

The Project "Roads to the Rescue" emphasizes the potential role of roads for water management, drainage, and flood resilience in Coastal Bangladesh. There is a strong connection between roads, water management, and flood protection in polders of Coastal Bangladesh. Yet, the role of roads for flood resilience and polder water management has not been sufficiently systematised in the planning and management of roads and water infrastructures, which creates a huge opportunity to explore.

Based on comprehensive assessments of road-water interactions and issues in Polder 26, Polder 32 (Dacope Upazila), Khajuriya subproject (Mehendiganj Upazila), Polder 43 2F the project highlights ways to improve these issues making roads instruments for water management and flood resilience. It also analyses the potential environmental and socio-economic impacts (both positive and negative) of the proposed interventions.

Validation workshops were organised with local representatives of BWDB, LGED, UP, WMG/WMCA and local farmers. The main findings of the field assessments were presented and discussed with the participants to look for solutions based on relevance of the issues and economic feasibility of solutions. This report focuses on the environmental and socio-economic impact of the solutions identified.

2. Description of the Polders

Polder 26

The temperature in Polder 26 is between 19 and 29°C, maximum rainfall is 343mm in July and the lowest is 7mm in December. Relative humidity in Khulna is 73 to 88%. Wind speed is around 160kph in April and 40kph in November. The elevation of 48% of the polder is between 1.26 and 1.73m. Water levels during high tide ranges from 1.7 to 2.3 m +PWD, during the low tide water levels range from 0.7 to 1.2 m below the MSL.

The polder is surrounded by a tidal river, Mora Bhadra River in the north and east and the Teliganga River in the east. Mora Bhadra River has completely been silted up and converted into an agricultural field while the Telikhali River is the properly functioning as a peripheral river. The total population of Polder 26 is of 15,175 inhabitants. The gross area of the polder is about 2,664 ha of which Net Cultivable Area (NCA) is about 1,993 ha.

The Polder is surrounded by an embankment with a length of 20 km which provides protection against tidal and storm surges and salinity intrusion. There are three drainage sluices and a small number of drainage khals. Only 5% of the peripheral embankment is paved, which allows vehicles to move during the dry season. The overall condition of the internal drainage channels of polder 26 is pretty good except some siltation problems of the khals namely.

The main crops are "Fallow –HYV T Aman – Boro" in 40% of the NCA (net cultivable area) with an intensity of 143%. Annual total crop production stands at about 9,637 tons of which 8,552 tons are rice and 1,085 tons are non-rice. Fish is cultivated in the polder in an area of 245 ha.

Polder 43 2F

The climate is tropical with a maximum temperature between 29°C and 36°C and a minimum temperature of 10.3°C to 24°C. The maximum rainfall is 590 mm in July and the lowest is 7 mm in December. The monthly average relative humidity in Patuakhali varies from 74 to 90%. 81% of land in the area has elevation between 1.4 and 1.61 m.

Polder 43/2F is located in Gulishakhali union of Amtali upazila, Barguna district. The polder is surrounded by Gulishakhali and Payra rivers in the west and the Kukua River (in the east). The polder covers an area of 4,130 ha, with a Net Cultivable Area (NCA) of 2,590 ha (63%). The total population of Polder 43/2F is more than 28,000 consisting of 6,400 households. The density of population is about 563 people/km^2. Thus, the average household size is 4.39.

The polder area is bounded by a 33 km embankment that protects the area against tidal and storm surges as well as salinity intrusion. Besides, there are 16 drainage sluices, 4 drainage outlets and a number of flushing inlets within the area. The embankment is vulnerable to erosion when floods occur.

Total cropped area is about 2,590 ha of which rice cultivation is 63 with a cropping intensity of 166%. The annual total crop production is around 10,212 tons (1.162 tons of rice and 4,050 tons non-rice). The main crop is Fallow-Lt Aman- Fallow, which is 34% of the NCA and Fallow – Lt Aman – Sesame which is about 25% of the NCA. Moreover, the estimated fish habitat area is 309 ha.

Polder 32

Polder 32 is located in the southwest region of Bangladesh near Sundarban Mangrove Forest. The polder covers Kamarkhula and Sutarkhali Unions, part of Dacope upazila of Khulna District. It is surrounded by Sibsha and Dhaki Rivers to the west and north, Chunkuri, Bhadra and Sutarkhali Rivers to the east and south. The soil texture is mainly clayey and loamy, with acidic top soils in the dry season. The climate is tropical with monthly mean maximum temperature between 19.3°C and 30.4°C and mean monthly rainfall of 7 to 400mm (World Bank 2013).

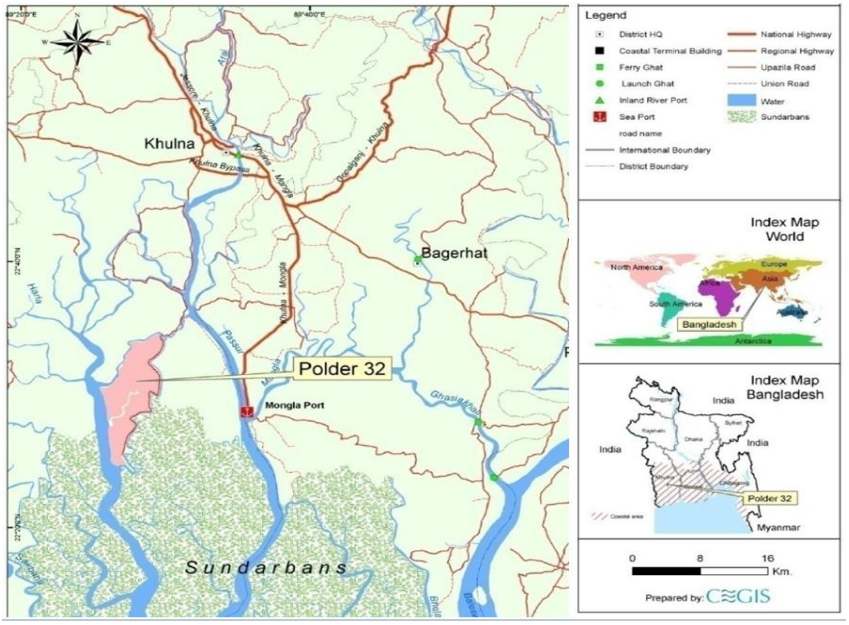

Figure 1. Location of Polder 32

The total area of the polder is 8097 ha of which 6.500 ha are cultivable (80%), followed by human settlements (7.6%) and water bodies (2.4%). The total population is 33.456 (16.985 men and 16.471 women) living in 8.399 households with an average size of 3.98 people per household. Therefore, the

population density is 980 people per km^2. The main occupation of local communities is agriculture production, and a minority get their income from industry and service (World Bank 2013)

LGED Khajuria Sub-Project

The Khajuria subproject area is located at Biddanandapur Union of Mehendiganj Upazila under Barisal district. The subproject is part of 400 subprojects of the ADB funded LGED Small-Scale Water Resources Development Sector Project (area < 1000ha). It has a gross benefited area of 719 ha with a net benefited area of 650 ha (SSWRDSP 1998). The total population of the area is 12.000.

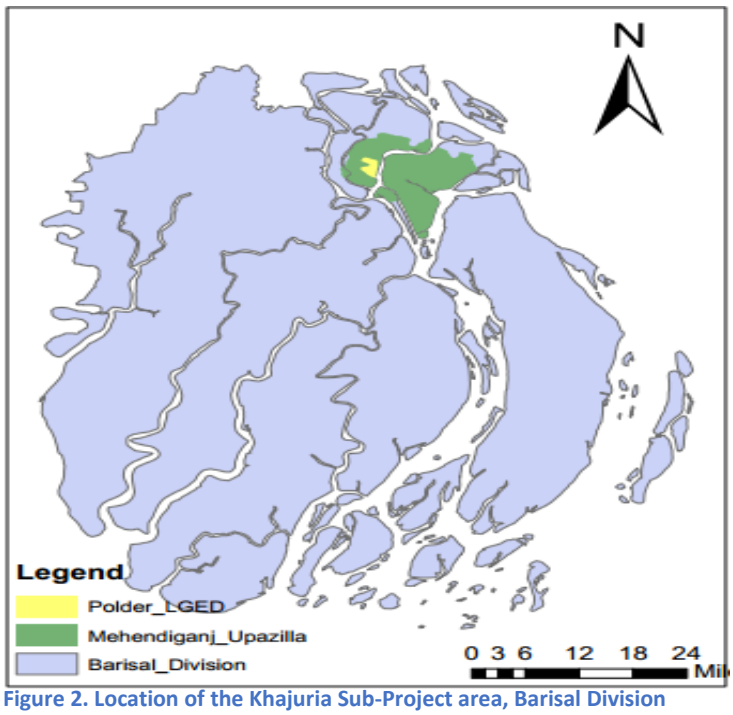

Figure 2. Location of the Khajuria Sub-Project area, Barisal Division

The subproject is surrounded by Naya Bhangani River in the north, Lata River in the east and Chilmari River in the west and south west. Therefore, this area is exposed to tidal inundation during monsoon season. A Union Road divides the Sub-Project area is two, East and West side. This road is the most used and most important road since it connects the project area with District Head Quarters (SSWRDSP 1998).

The Sub-Project has 5 large khals flowing from the East to the West of the Project area. The pucca Union Road crosses all these large khals and two other small khals which are provided with adequate water crossing structures. There are 10 large openings in the project area. However, only three of them located in the north are provided with single vent sluices. Therefore, water enters from the rivers accumulating in the low-lying areas causing drainage congestion which leads to road damage and agriculture loss. Drainage congestion due to insufficient water structures to control water levels within the polder is the main concern of this sub-project area.

3. Problems and Issues in the Polders

Polder 26

Polder 26 is divided in an East Part and a West Part by a pucca (asphalt concrete) Union Road aligned along the North - South axis and crossing several large khals flowing from the East to the West of the polder. Most of the functioning sluices are located on the West Part of the polder. Since connectivity between khals on the East of the polder and those on the West is partly interrupted by the Union Road, a lot of water accumulates on the East side of the polder. As a result of few functioning sluice gates, siltation of khals, and insufficient water crossings along roads, waterlogging is widespread: it constitutes a major problem in Polder 26 (Figure 3). Another challenge in the polder is the poor quality of internal roads,

particularly earthen village roads, which deteriorate rapidly and become inaccessible during the rainy season, which is partly due to inadequate road drainage.

Fieldwork highlighted that there are insufficient water crossings (culverts and bridges) along internal roads to ensure the connectivity of both the khal system and communication ways for people living in the polder. Waterlogging impacts severely on farming, reducing its potential, and on other productive activities such as aquaculture. Household surveys reported direct crop damages and delayed farming activities leading to reduced yields and harvest losses. Crops are particularly vulnerable at the flowering stage, approaching maturity, and at the seed and seedling stages because water would wash the seeds away. Waterlogging also limits crop choices to few crops which tolerate better waterlogged conditions, and restricts vegetable farming.

Figure 3 . Waterlogged areas on the East of the main Union Road. These photos were taken in March 2017, during the dry season.

The majority of respondents to household surveys reported to face recurrent crop failures (almost every year) and to have abandoned some portions of their cultivable land, in some cases up to 70 percent, because of flooding. In areas that are irrigated with khal or river water, which was reported to be somewhat saline especially during the dry season when flows are smaller, a secondary effect of waterlogging is salinization of soil. For a number of farmers this is a major cause of loss of land productivity. Aquaculture activities are also affected as fish is flooded away out of ponds during high water.

Several families reported extremely intense rains that would cause water entering into their homes and other public buildings such as schools. Besides, water tends to flow toward and concentrate in lowlands, causing drainage congestion and waterlogging here. In high lands, pump lifting.

The majority of the polder population is affected to some extent by poor road conditions, particularly during the rainy season. Many village roads are earthen or paved with bricks. During the rains, earthen roads become extremely muddy, slippery, and uneven under the pressure exercised by the wheels of motorized vehicles. Brick roads are frequently damaged with bricks being displaced and leaving behind large potholes, ruts, and portions of muddy soil. Current road conditions affect people's lives and livelihoods in a number of ways: the use of motorized vehicles is limited during the rainy season, riding bicycles causes waist pain because of the ruts and potholes, transport of goods, products, and household supplies to and from the market is hampered, general communication and mobility is reduced and time-

consuming, school attendance is a challenge, and so is the transport of sick people to the hospital, the risk of accidents is also reported to be higher.

Moreover, premature erosion of embankment roads and internal roads occurs often in correspondence of pipe culverts and pipe inlets/outlets. Two are the reasons: i) the length of pipe inlets/outlets is smaller than the width of (embankment) roads so that water scours the shoulders of roads and road embankments, ii) Collar joints are not fixed adequately when laying down pipe culverts so that water leaks out of the joint and erodes the road above.

Polder 43 2F

Polder 43 2F is surrounded by rivers, one being a large river (Payra River), and it is crossed by many khals, several of them as wide as rivers. Compared to Polder 26, waterlogging is much less severe because drainage and water infrastructures are more extensive and functional. There are 19 sluice gates and 36 inlets/outlets along the embankment and a high number of internal water-crossings. Moreover, the system of khals is better interconnected than in Polder 26. Overall sluices and outlets are functioning well and even during monsoon, water can be drained off the polder during low tide. Waterlogging occurs mostly around settlements and in low lands.

Whereas in Polder 26 drainage and waterlogging were the main constraints, in Polder 43 2F water control for irrigation emerged as a pressing issue. Bad quality and conditions of roads features as a main problem in this polder. Moreover, there is a prevalent safe drinking water scarcity because there are no sufficient boreholes. Drinking water availability was highlighted as the main water-related problem in the polder.

Defective structures (Figure 4 and 5) (sluice gates, inlets and outlets) that do not close hermetically lead to water losses out of the system or entering of unwanted river water creating flooding risks. Moreover, many khals have silted up in the years after the development of the polder. Siltation has occurred partly as a natural process because the bottom of sluice gates has been positioned higher than the bottom of khals, partly as because of human encroachment.

Figure 4. Defective sluice gate: this gate can neither retain water when it is needed (water losses) nor block water from entering when it is not needed (flooding). Figure 5. Drainage congestion around a house. This photo was taken in March 2017 during the dry season, 2-3 days after a rain event

It has been observed that in several cases, the length of the inlet or outlet is smaller than the width of the embankment as often, the design length is not chosen in view of future widening of the embankment that accompanies the carpeting of an embankment road. Water entering or leaving the polder through the pipe gets in contact with the sides of the embankment and erodes them. This reduces the stability and height of the embankment and reduces flood protection

The risk of river flooding is higher in Polder 43 2F than in Polder 26 because the polder is surrounded by rivers, one being a very large one and very close to its embankment. The perception among the majority of household respondents, is that the embankments do not protect them sufficiently from river surges. It was observed in several cases that the carpeting of an embankment affects the height of the embankment and reduces thus flood protection.

Polder 32

According to the field survey, the major problems in Polder 32 are: water logging during heavy rainfalls, water scarcity during the dry season and salinity intrusion. However, the field assessment revealed that water logging is less problematic than water scarcity during the dry season. Drainage congestion lead to muddy roads, breaching of embankments and roads. Additional related issues: bad quality of drinking water and poor hygienic sanitation facilities.

Internal roads change the natural water flow inside the polder causing water drainage congestion which leads to water logging. Siltation of internal khals reduces the conveyance capacity of the khals to carry out water raising water levels inside the polder causing water logging in certain areas and water scarcity in others. As a consequence of heavy rainfalls 30-40% of the lower-lying areas get inundated in Polder 32.

Based on the field survey, agriculture is affected by water logging 2-3 times per year because seeds are washed away. Respondents answered that the main challenges of water logging are insufficient water crossing structures (under construction or under-dimensioned structures to drain out the excess of water. During the validation workshop (November 2017) local farmers confirmed that 40% of the cultivated area is affected by floods.

Another cause of drainage congestion is due to the blockage of culverts openings for fish cultivation which impede continuous water flow and increasing canal siltation. Silted canals are not deep enough to collect the rainfall water, so the drainage system gets obstructed. Waterlogging leads to delays in crop production and marketing of products. The risk of waterlogging could be intensified by its proximity to the sea and the intensity and frequency of storm surges due to climate change.Besides, people's livelihood is dramatically affected by water logging when large cyclones happen such as Sidr (2007) and Ayla (2009).

Figure 6. Waterlogging conditions, Ward 1, Sutarkhali

Figure 7. Silted khal, Ward 3, Sutarkhali

The field survey revealed that farmers are significantly affected by water scarcity during the dry season and they cannot cultivate any crops. During the dry season farmers also face salinity problems between December and May due to both sea and river water intrusion. Farmers don't have any source of water for irrigation, not even a canal because water is affected by salinity intrusion or it's too far away. Moreover, during the dry season there is no water in the canal. Farmers estimate a yield loss of 35.000BDT (74% of the crop income) due to lack of water or a proper irrigation system during the dry period.

Water regulators such as sluices are constructed and maintained by BWDB. They are box sluices of 1 or 2 vents with an outfall function. Many of them are damaged or they are not functioning properly because the gates are silted, or their dimension is not adequate to the local hydrological conditions.

The main issues related to roads are: brick collapse, unstable side slopes, muddy and slippery earth sections. Embankments are damaged because of water logging, siltation, excessive river flow and high tide erosion, increase in the frequency and intensity of heavy rainfalls.

Most roads are mainly made of earth, semi-pucca (bricks) or both, earth and semi-pucca. Based on household survey, roads are not in good conditions because they are too narrow and low to protect people and crops from flooding. Earthen roads get muddy and slippery during the rainy season which makes villages inaccessible. The semi-pucca roads are in good conditions but in certain section bricks are starting to collapse. And the mix roads are in good conditions except the sections without bricks which cause problems in the rainy season. During the monsoon season most of the roads are overtopped with water such as in 1988, 2007 and 2009. Based on field survey although current state of the embankments is good some embankments are breaching due to of heavy rainfall, lack of maintenance, and deforestation.

The main problems people are facing due to the bad road conditions are the following: delays to school delays, difficulties to reach hospital, UP, cyclone centre and other important place in time. These bad conditions affect much more vulnerable people, such as farmers and over-aged people.

The main causes of these problems are:

- Heavy rainfalls and the lack of cross drainage structures to drain the excess of water.
- Lack of routine maintenance.
- Poor quality of construction materials for carpeting
- Lack of transparency of political economy. Related to implementation of physical works at LGLs have more decision influence local LGED engineers.
- Delays of road development works due to the funding disbursement in July which is the monsoon season.

All respondents said that embankments are not adequate for flood protection because their width and height are too low to protect people and agriculture fields from flooding. Moreover, embankment roads also have a flood protection function since they give access to cyclone shelters, people use them as temporary flood shelter where they build their houses, shops and cultivate on the side of the slopes

LGED Khajuria Sub-Project

All the internal roads except the Union Road have been developed parallel to the khals without water control structures. Therefore, water flows freely through the khal system and in rainy season after a heavy rain, water flows out with high velocity during low tide damaging the roads very badly. These roads get eroded due to the high-water current as well as poor road design. However, roads are not overtopped during the rainy season. The quality of both internal and embankment roads is the biggest challenge in Khajuria Sub-Project.

The bad roads quality is mainly a consequence of insufficient cross drainage structures. During construction or improvement of roads, it is very important to provide sufficient water crossing structures (culverts and bridges) to avoid drainage congestion especially during rainy season. Based on the field survey, only two working culverts were found in the project area. This leads to road damage such as potholes or road collapse which are very common problems in the project area as it was explained before.

Additionally, during the heavy rainfall, the strong water current flushes away everything that is on the way: houses, goods, shoes, crops, trees, fish plantation. The frequency of the heavy rainfalls is once in 10 years putting people's lives in danger or making them lose all their goods properties. Bridges seem to be in good conditions, only 2 out 9 need to be repaired or replaced because they are too old.

At the moment, water accumulates in the low-lying areas causing multiple damages, but especially to Aman and Boro rice. According to household survey, 75% of the farmers are facing water scarcity during dry season because they don't have water for irrigation. Half of the interviewees pump groundwater as water in the khals is limited. Some farmers take water directly from a close swamp, pond or canal. There is a pond inside the project with water available but it's not accessible for everyone. This water is used for drinking, household and cultivation purposes. In this subproject area, farmers don't face salinity problems in the dry season.

Figure 8. Silted khal and eroded side slope

Most of the village roads are parallel to the large khals and get eroded in the rainy season due to the high current of khal water. During high tide and monsoon water enters the polder added to the rainfall stored within the polder. During low tide all this water rapidly flushes out eroding and breaching roads, internal structures, and embankments. In this project area khal siltation is aggravated because sluices sills are positioned higher than the bottom of khals. As a result, water availability in the canal is limited during the dry season.

4. Proposed interventions

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. Addressing these important opportunities is helped by coordination and collaboration among institutions responsible for water and road management.

4.1 Roads for improved water management within 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 areas into compartments, separating relatively higher and lower lands. 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.

Figure 9. Box culvert with slot for gate

Figure 10. Gated culvert

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 low-lying coastal areas are the main infrastructure to create areas with relatively low and highwater levels and hence allow a more varied, multiple cropping land use patterns by for instance using gated culverts (Figure 9 and 10). 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 low-lying coastal areas. At the same time, new roads designed without paying attention to drainage required are quickly damaged by erosion and subsidence. Thus, 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.

Table 1. Recommended practices to improve water management inside the polders

	Current practice	Recommended 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
	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

4.2 Roads combined with flood embankments

In coastal areas flood embankments next to their role in flood protection are used for transportation. In addition, some newly developed roads in coastal areas double up as flood embankments. As different organizations may be involved (road departments, disaster risk reduction department or water departments) 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 2 gives an overview of recommended improved practices in this field:

Table 2. Recommended practices to use roads and embankment as flood defense

	Current practice	Recommended practice
Roads and embankment as flood defense	No synchronization between recent MoU is calling for this	Synchronize criteria for flood embankment heights, width and slopes
	No such consideration – 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 of vegetation on all the embankment slope protection	Use vegetation for side slope protection such as vetiver

Figure 11. Embankment used as road

Figure 12. Too narrow and low embankment. High erosion and breaching. Ward 3, Kamarkhola.

4.3 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 several areas emergency shelters have been constructed. The emergency shelters however are not in all areas able to accommodate the entire population in an effected area; hence roads complement typhoon shelters and other flood response measures. There are several good practices to better connect road development and emergency responses in coastal areas:

Table 3. Recommended practices for using roads as temporary 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 higher road bodies – leaving people in lower parts of	Create heightened road bodies in low lying areas of the polder to create safe routes to the

	the coastal polders and outside the coastal polder very much exposed	temporary cyclone shelters during flood events and refuge areas in the post flood scenario
	Use of roads as flood shelter. No such practice	Create berms along internal roads and along specific embankments sections to temporary (15-30days) shelter people and livestock
	No planning of evacuation routes	Plan evacuation routes using road infrastructure, making it higher where possible

Figure 13. Access to cyclone. Ward 7, Sutarkhali

Figure 14. Temporary shelter. Ward 1, Sutarkhali.

5. Prediction and Evaluation of Potential Impacts

The proposed interventions will affect a number of environmental and social components either positively or negatively. The improvements mentioned below will have multiple positive impacts related to internal polder water management and flood resilience: improved water drainage and reduced water logging inside the polders, reduced damage to roads and properties, better transport conditions, provide temporary flood shelter, increase agriculture productivity (multi-cropping, flexibility in farming activities), reduced maintenance costs, household income increase, and overall better livelihood conditions.

It is estimated that the improvements proposed would yield the following benefits:

- Reduced waterlogging in 60% of the area (around 1200 ha) in Polder 26 – freeing land for a double crop, which equals to an added benefit of 103.2 million BDT (approx. 1.16 million EUR) considering a mixed cropping system of irrigated Boro rice, pulses (lentil, mung bean) and oilseeds (sesame, linseed). The surfaces considered for the different crops are 50% for Boro rice, 25% pulses, and 25% oilseeds.
- Improved water retention in higher elevated lands of Polder 43 2F in 20% of the area (approx. 200 ha) – allowing cultivation in the rabi season, leading to an added benefit of 17.2 million BDT (approx. 194.000 EUR) in case of mixed cropping of irrigated Boro rice, pulses, and oilseeds.

- In Polder 32, if water could be stored highland within a 20% area of the polder (approx. 1300ha in Sutarkhali Union) during dry season, the yield would be 5.5 t/ha with a net benefit of 185 Mill BDT (2.2 mill $). Currently, for the same area farmers are getting a paddy yield of 2.2 t/ha leading to a net benefit of 73.8 mill BDT (888.755 $). Therefore, gated culverts would help farmers to retain water for irrigation with a yield increase and benefit of 247%.
- In LGED sub-project if water could be stored upland where farmers could irrigate a 20% cultivated area (130ha) during dry season the net benefit would be 3.8 Mill Taka (49.682 $). If there is enough water they can also grow pulses, chili, potatoes.
- The construction of new embankments for the unprotected section in Khajuria will allow local community to grow more rice in an area of 120ha, getting a yield of 7.4 t/ha and a net benefit of 3.8 Mill BDT (45.855 $). Moreover, if new embankments are designed as roads, access to rural settlements will be more reliable adding value to the isolated farms.
- More reliable access to small rural settlements ensuring higher added value of farm produce.
- By improving carpeting of embankment roads, design of pipe inlets and outlets, and by creating berms at specific locations for flood shelter along embankments, the multiple functions of embankment roads are altogether optimised: flood protection through structure integrity and reduced damage of embankments and side slopes, additional low-cost flood shelters, and transport/mobility.
- Culture fish productivity will also be increased due to reduction of flood risk for re-sectioning of the embankment.

Table 4. Summary of proposed interventions and positive impact

Proposed intervention	Benefit
Gated water crossings to retain and control water	Retain water in high lands and control water levels in different compartments of the polder Reduce drainage congestion in low lands Increase fresh water storage for multiple purposes Diversify crop production and increase number of crops per year Obtain higher yields
Excavating pond, canals and khals	Create adequate water storage for the dry season Better irrigation during dry and pre-monsoon seasons Better drainage, thus reducing waterlogging Improved fish movement and migration
Increase number and size of water crossings	Reduce waterlogging Increase yields, agricultural productivity and overall socio-economic development
Use borrow pits for multiple 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 fishery, harvesting aquatic plants and jute retting
Re-use the excavation material from canals to increase the level of roads	Ensuring system connectivity, continuous water drainage and more water retention inside the polder

	The excavated silt can be re-used 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
Improve the carpeting of embankment roads for flood protection	Durable embankment roads and stable, flood-proof embankments
Use turfing or vegetation for side slope protection	Slope protection with grass increase the stability of the slope decreasing road erosion leading to road stability and flood resistance.
Additional culverts	Reduced waterlogging Increased yields Reduced water-borne diseases
Use roads to raise lands	Ground level increased on the upstream. The higher ground is less prone to flooding and/or water logging – and farmers can grow wider variety of dry season crops
Consider levees alongside roads to temporarily accommodate flood affected persons	shelter people and livestock during flood (risk) and high water

5.1 Negative effects

Even though no significant negative or irreversible impacts are expected to occur after implementing the proposed measures, Table 5 summarized some potential negative effects of the interventions.

Table 5. Summary of proposed interventions and negative impact

Measure	Potential negative effect	Good practice
Gated water crossings to retain and control water	Gates not properly operated, leading to waterlogging	Appoint a body responsible for their operation and maintenance
	Increase in use of pesticides and fertilizers leading to pollution of water resources and affecting local fauna	Integrated Crop Management (ICM)
Use turfing or vegetation for side slope protection	Introduction of invasive species	Local vegetation (grass and shrubs, but no trees) should be used to protect the side slope of roads, in particular the embankment roads The selection of the species should be done in consultation with the local community.
Levees alongside roads to temporarily accommodate flood affected persons	Undesired permanent occupation of the flood shelters	The use of these levees should be regulated by the local governments

5.2 Situation with and without project intervention

The situation regarding the main environmental problems in the polders is expected to improve when the proposed interventions are implemented. The table below summarizes the situation with and without the proposed improvements.

Table 6. Environmental problems with and without the implementation of the proposed intervention

Issue	Without proposed interventions	With proposed interventions
Waterlogging	Crop damages and delayed farming activities leading to reduced yields and harvest losses Limits crop choices to few crops which tolerate better waterlogged conditions, and restricts vegetable farming Communities affected by water-borne diseases Aquaculture activities affected as fish is flooded away out of ponds during high water.	Increase yields Improved socio-economic development Improved transport connectivity Reduced damage to property and goods
Erosion	Erosion of embankment roads and internal roads High run-off	More groundwater recharge More stable roads and embankment roads Better flood resistance of embankments
Salinity	Loss of land productivity Salinity affects shrimp productivity	Improved land productivity
Fish movement	Fish movement hampered from river to khal vice-versa due to khal siltation	Internal fish migration facilitated significantly after re-excavation of khals
Fisheries productivity	Reduced due to khal siltation	Increase water availability and water quality will increase fisheries' productivity

6. Conclusion

Based on the assessment and classification of road - water issues in Polder 26 and 43 2F, Polder 32 and LGED Khajuria Sub-project, this report outlines several options and opportunities to improve these issues. Overall, the implementation of the proposed measures will lead to environmental benefits in the polder areas by reducing waterlogging, erosion and salinity. At the same time, agriculture productivity will increase and the overall socio-economic situation in the polders with improve.

Main improvement options are:

(a) Improve the number and size of water crossings - adding and enlarging a number of water culverts in the two polders will already contribute to reduce the waterlogging problem. The number and size of culverts should be based on the appreciation of the khal density and on an analysis of mean water levels and flows generated in the khals during monsoon. This will increase yields, agricultural productivity and overall socio-economic development.

(b) Use (more) gated crossings to retain and control water (in high areas) – providing gates at specific water crossings based on DEM analysis and field surveys will improve polder water control, retention and availability of freshwater in highland while reducing drainage congestion and waterlogging in lowlands. The benefits include increased yields, more crops per year, increased farmer flexibility to choose among a wider range of crops and plan better the farming activities.

(c) Re-excavate khals to reconnect drainage ways and retain more water – this improvement goes hand in hand with providing additional and gated culverts. This will improve connectivity of drainage system and at the same time increase in-canal storage capacity of water for multiple purposes

(d) Improve the quality of (embankment) roads – improve the road construction process and the choice of materials used for construction, especially for subgrade, to both ensure stability of the road and adequate drainage. The impacts are large: the life of the roads is increased , maintenance and repairing costs are reduces, and first of all, mobility and transport and overall livelihoods of polder inhabitants are improved. Moreover, carpeting of embankment roads has to improve by streamlining approval procedures and harmonising design heights adopted by different implementing organisations. Quality carpeting has huge impacts on the robustness of embankments and flood-safe crest height. Altogether this influences flood protection and resilience of polder communities.

(e) Improve design of pipe inlets and outlets – to improve the durability of embankment roads and their flood protection function. The length of pipe inlets and outlets along the embankment should be chosen in view of future widening of the embankment so as to avoid erosion of the embankment.

(f) Improve shelter function of (embankment) roads by creating levees along internal roads and berms along specific embankment sections to shelter people and livestock during flood (risk) and high water.