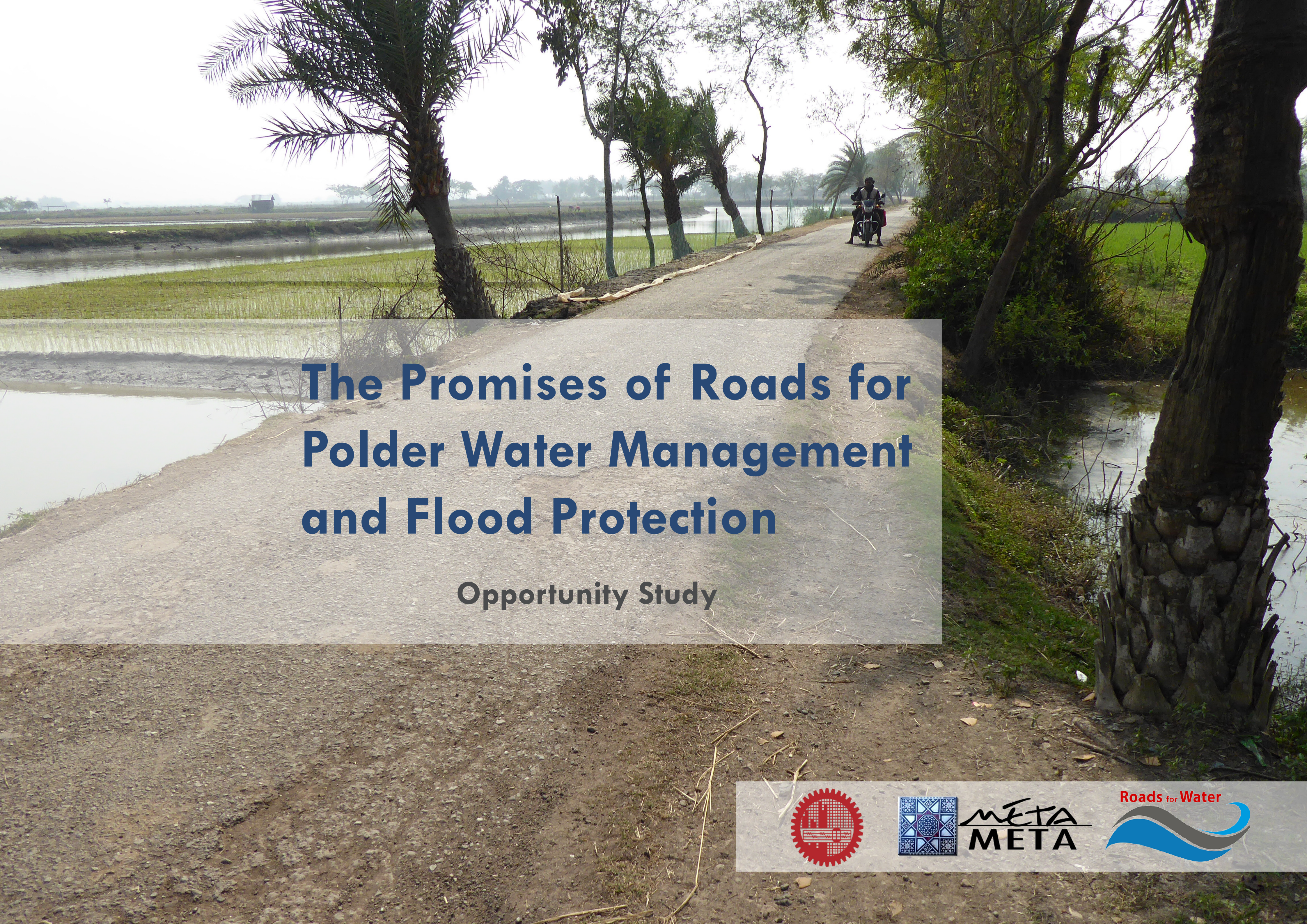


The Promises of Roads for Polder Water Management and Flood Protection

Opportunity Study

META META
Roads for Water

1. Executive Summary

Funded under the Blue Gold Innovation Fund and supported by Blue Gold, EKN, the Global Resilience Partnership/Z Zurich Foundation, this opportunity study explored the scope of and ways to integrate (embankment) road development and polder water management and flood protection. There are many connections between roads and water/flood management: i) roads change and disrupt natural drainage flows and khal connectivity, accentuating waterlogging in polders ii) many embankments double up as roads and flood shelters and iii) road-water crossings, if provided with gates, being potential sites for water control and distribution. Despite these many connections, roads in many occasions sit at odds with water management. Yet this challenge can be turned into an opportunity. With an estimated 30000 kilometre of internal polder roads and 3500 kilometre of embankments that double up as roads, the potential contribution of roads to water management and flood protection in Coastal Bangladesh and the scope for upscaling is enormous.

During a period of 6 months (December 2016-May 2017), a comprehensive assessment of road-water issues and impacts has been carried out by MetaMeta and BUET in Polder 26 and 43 2F; practical solutions have been identified, validated, and ranked with main actors (BWDB, BG, LGED, UP, WMGs, WMAs). Following priority issues and lines of improvement at the road-water interface have been identified:

(a) **Improve the siting and size of water crossings** based on hydrological analysis, in order to reduce waterlogging and increase yields, agricultural productivity and overall socio-economic development.

(b) **Use (more) gated crossings to retain and control water** (in high areas) while reducing drainage congestion and waterlogging in lowlands.

(c) **Re-excavate khals to reconnect drainage ways** and retain more water for multiple purposes.

(d) **Improve the quality of (embankment) roads and carpeting** to ensure stability and durability of the road and of the embankment.

(e) **Improve design of pipe inlets and outlets** to improve the durability of embankment roads and their flood protection function.

(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.

It is estimated that these improvements 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 of irrigated Boro rice, pulses (lentil, mung bean) and oilseeds (sesame, linseed).

- 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.

- 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.

Main outcomes of the opportunity study are:

- An overview of possible physical works for immediate implementation (Annex I)

- A proposal to systematise the integration of road for polder water management and flood protection in in all polders of Coastal Bangladesh and beyond

- Growing interest and potential uptake by governmental agencies and donors (for instance in the preparation of the CEIP – Phase 2)

- A step has been made to prompt cooperation between concerned players involved in road and embankment development, and water and flood management

To take these outcomes to the next level and systematise the integration of roads and polder water management and flood protection, two main steps have to follow:

(1) Quick implementation of some of the improvements mentioned above (and shortlisted in Annex I) to keep the momentum going and continue learning and adapting the concept.

(2) Rolling out roads for polder water management and flood protection through the development of Guidelines for Roads for Polder Water Management and Flood Protection comprising of a standard assessment procedure of main issues and solutions, examples of designs, a protocol to monitor the process and impacts of (1), and supporting training activities.

2. Introduction

The overall objective of this opportunity study supported by Blue Gold, EKN, the Global Resilience Partnership/Z Zurich Foundation was to explore the scope for optimising the role of roads, both internal and embankment roads, for polder water management and flood protection in Coastal Bangladesh. At the moment roads in many occasions sit at odds with water management, but precisely because of the close connection, we think the current problems can be turned into an asset. Because there are an estimated 30000 kilometre of internal polder roads and 3500 kilometre of embankments that double up as roads, the potential contribution of roads to water management and flood protection is enormous in Coastal Bangladesh.

In the polder areas, especially inland polders, intensive rainfall, and not river surges, is the major cause of flooding. This is aggravated by infrastructures and settlements that create obstacles to the natural drainage in the polders. Internal roads, bridges, and culverts within the polders influence the water flow, the water distribution, and the water levels both in waterways (khals), around settlements, and on farmland. The network of different types of internal roads, including village feeder roads and pathways, interrupts the connectivity of the natural drainage system consisting of khals, and divides the polder into disconnected compartments. Roads (both internal and embankment roads) have a great role to play in contributing to effective water management and reducing waterlogging.

Despite this, road design and water and flood management are still largely disconnected. This is a missed opportunity. If well designed and implemented, and provided with adequate cross-drainage structures, roads can make a huge difference in avoiding drainage congestion and making for effective polder embankments. Moreover, if road-water intersections are provided with water control structures, roads can be turned into instruments for regulating water distribution and water levels in different compartments of the polder. On the other side, if roads and road crossings are well designed and constructed in a way to facilitate drainage and flood management, road damages and maintenance/repair costs are significantly reduced.

This opportunity study discusses the role of embankment roads and in-polder roads for flood protection, drainage, and polder water management. Based on the assessment and classification of road-water issues in Polder 26 and 43 2F, this feasibility outlines several options and opportunities to improve these issues. Moreover, it proposes a way forward to systematise the integration of roads for polder water management in in all polders of Coastal Bangladesh.

It is estimated that these improvements 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.

- 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.

In undertaking the activities for this opportunity study a start has been made in prompting cooperation between concerned players resulting in an agreement on the potential and ways to optimise road infrastructure development for flood protection and in-polder water management.

3. Methodology

The opportunity study was carried out by MetaMeta and BUET during a period of 6 months from December 2016 to May 2017. Kick-off workshops were conducted in Khulna on December 12, 2016 and Patuakhali on December 14, 2016, with key stakeholders of, respectively, Polder 26 and Polder 43 2F. In both workshops attendance and engagement was very encouraging with representatives of Blue Gold (BG), the Bangladesh Water Development Board (BWDB), the Local Government Engineering Department (LGED), Union Parishad (UP), Water Management Association (WMA) and Groups (WMGs).

The objective of the inception workshops was both to raise awareness among concerned actors of the many existing connections between roads, water management, and flood protection, and to do a screening of main road – water issues and possible improvements. The outcomes of the workshops helped delineating and focusing the fieldwork.

From January to March, 2017, a team of 8 students from BUET and Dhaka University conducted the fieldwork supervised by Prof. Rowshan Mamtaz (CERM-BUET) and coordinated by Dr. Cecilia Borgia (MetaMeta). The fieldwork comprised of a physical survey of the state of road-water infrastructures (internal roads, embankment sections, culverts, bridges, sluice gates, inlets and outlets), focus group discussions with UP and WMG members, as well as KII with local staff of BWDB, LGED, and BG.

The aim was to develop a catalogue of road-water issues, understand the nature and magnitude of these issues, but also to jointly identify possible improvements to polder infrastructures and solutions to these issues. Moreover, household surveys were conducted with 52 households in Polder 26 and 59 in Polder 43 2F to understand how challenges created at the road-water interface (e.g. waterlogging, flooding, bad quality of roads, defective and damaged road-water crossings etc.) affect people's livelihoods, productive activities, and socio-economic development. Through this combination of methodological tools, it was possible to cover the majority of polder area and almost all physical structures (i.e. sluice gates, inlets and outlets, bridges and culverts).

In April, validation workshops were organised in the two polders with representatives of BWDB, LGED, UP, WMA and WMGs. Key findings were validated and integrated, the technical, organisational and social feasibility of different solutions was discussed and solutions were ranked based on their relevance, feasibility, and economic viability.

This report discusses the role of (embankment) roads for flood protection, drainage, and polder water management, and suggests concrete steps for action and improvement.

Chapter 4 presents what based on the assessment and raking of road – water interactions in Polder 26 emerged to be the main issues but also starting points for improvement. Along with describing the nature and impact of the issues, the report also outlines concrete ways to improve those issues. Chapter 5 presents main road-water issues and solutions in Polder 43 2F.

Finally, Chapter 6 summarises main road-water issues in the two polders. Most importantly, it proposes a two-tiered plan to move forward: i) rapid implementation of a series of physical works as quick-win improvements paralleled by ii) a methodology and guideline to systematise the integration of roads for polder water management in all polders of Coastal Bangladesh.

4. Polder 26

4.1 Main features

Polder 26 is divided in an East Part and a West Part by an 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 (Figure 1). 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. On the West side there are 3 working sluices. Sluices on the North-East of the polder have fallen into disrepair and are no longer used because the peripheral river flanking the polder on the East side has completely silted up. The only functioning sluice gate for the East side is Kadamtola Private Outlet. 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. BG is currently constructing 3 additional outlets to help improve drainage in the polder. 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.

4.2 Road – water management issues and solutions

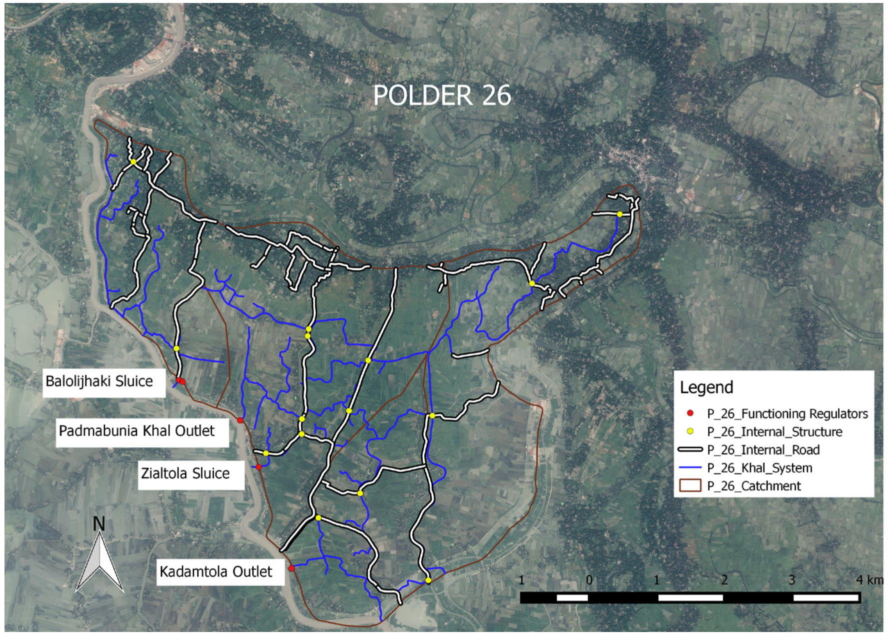


Figure 1: Polder 26: Physical infrastructures.

A catalogue of issues and solutions was developed based on the assessment of road - water interactions and the feasibility and opportunities of different solutions is also discussed. Issues and solutions are presented in an order that reflects local priorities emerging during focus groups and the final validation workshop.

(a) Rethink number and capacity of water crossings

Internal roads change natural drainage patterns and direction of water and waterways. Roads thus shape how water is distributed and lead to differentiated water availability and waterlogging conditions within the polder. 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. Figure 1 shows the scant distribution of internal structures at the intersection between roads and canals.

As mentioned above, the main Union Road crosses two large khal system flowing from East to West. Along this road there are two culverts allowing the water to flow from East to West, but these structures are insufficient to convey the large flows of water generated during monsoon.

One is located at the intersection between Shaka Bai khal and the Union Road, the second is situated where the road intersects Kata khal (Figure 2). As a consequence of few water crossings, large areas of farmland on the East side of the main road are waterlogged (Figure 3).

Figure 2: Culvert on Shaka Bai khal measuring 15 x 12 SF (left) and culvert on Kata khal measuring 7 x 15 SF (right).

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.

Coping strategies adopted by farmers include delaying cropping or replanting in case the seeds or seedlings have been washed away. Other respondents try to compensate losses through other sources of income and/or other crops. Some would address their concerns and request before the UP chairperson to dig additional khals to improve the drainage.

Roads are not only developed by LGED and UP. Earthen pathways are also constructed by people to restore communication across khals, often to be able to transport agricultural products from their fields to the nearest road (Figure 4). This unplanned construction of roads, however, encroaches on the connectivity of the khal system and creates additional barriers to drainage flows.

Figure 4: Earthen road constructed by local people across Ziler khal for communication for around 45 families. A culvert is needed to maintain the connectivity of this khal.

Besides insufficient numbers of water crossings, the capacity of several existing ones is not enough to convey the large flows of water generated within the polder catchment during the rainy season. This is an even more important aspect in view of BG/BWDB plan to re-excavate several khals in the polder.

Figure 5: The box culvert upon Dangar Khal is very narrow (right). Culvert on Boyersing khal connects two khals. If Boyersing khal will be re-excavated as by plans, then the capacity of the existing culvert too low to convey the water. in March 2017, during the dry season.

During the physical survey, 10 of 15 internal structures(i.e. culverts and bridges) were assessed. Of these 10 structures, 5 were found to be functional, 2 not functional, and 3 had low capacity according to local respondents (Figure 5). The map below (Figure 6) locates functional and non-functional culverts and bridges, and low capacity culverts. The two non-functional internal structures comprised one culvert constructed along a village road but which was not connected to any khal or drainage ditch. Probably the course of the original khal had shifted and is now following another path. The second non-functional drainage structure is a bridge which was found to be completely blocked by a net pata (a large fishing net) so that water is not flowing beneath it.

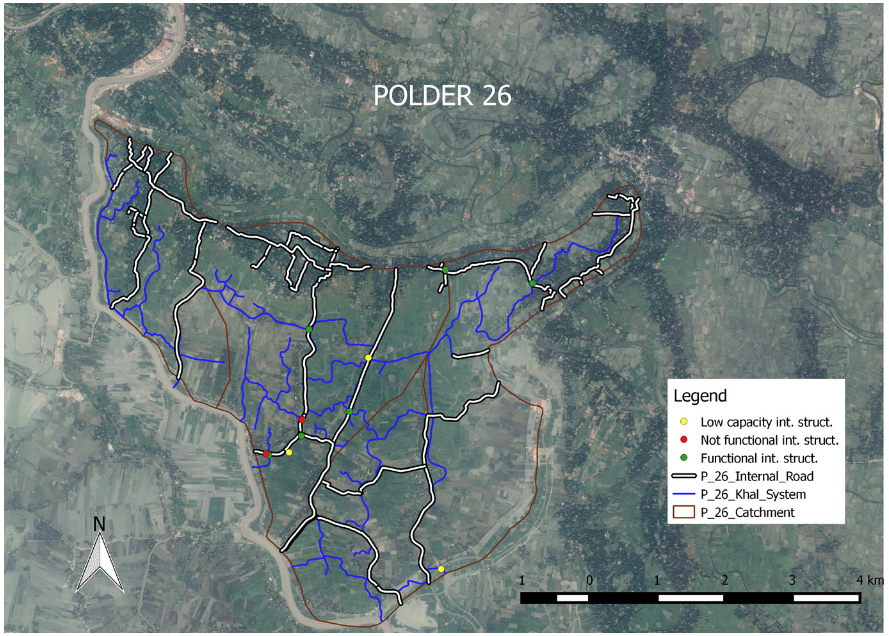


Figure 6 Polder 26: State of internal structures

In the North of the polder, where settlements are concentrated and density of khals is lower, drainage is poor both along roads and around homesteads and waterlogging is a problem.

According to respondents, in certain areas water would stay for 2-3 months. Several families reported extremely intense rains that would cause water entering into their homes and other public buildings such as schools. Some families cope with this situation by laying down pipes and excavate ditches around their homes to help direct the excess water towards safer areas such as farm fields. BG has a provision for around 200 small pipes to improve drainage in settlements.

Waterlogging affects several areas in the polder. Thus, adding a certain number of water crossings is seen as a top priority by the local community as it will have large impacts in terms of reducing waterlogging, increasing agricultural productivity, creating opportunities to diversify crops, improving communication and local livelihoods, improving overall socio-economic development. During the validation workshop, there was unanimous support of the idea by participants representing the various key organisations, including LGED, the main responsible authority for implementing internal structures. Moreover, current design specifications for roads adopted by LGED foresee one culvert every 500 m, irrespective of the density of canals. Modifications to this design should be considered to assure adequate cross-drainage. For instance, 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. In turn, improved drainage will increase the durability of roads and related structures and reduce maintenance and repair costs significantly.

Overall, at least 17 additional culverts and 1 bridge are needed and the size of 4 other culverts needs to be increased. Problematic locations where additional culverts or bridges are needed have been identified through physical survey and focus group discussions with UP and WMG members. Two examples are shown in Figure 7. This list has been confirmed and integrated during the validation workshop in Khulna on April 10, 2017 (see Annex I Overview of possible interventions).

Figure 7: Main pucca Union Road cuts the Shaka Bai khal. Connectivity shall be restored by providing a large culvert on this road (left). A bridge is needed near Baloijakhi Sluice. People use a bamboo bridge to transport goods (right).

b) Re-excavate and reconnect khals

The re-excavation of khals to increase both drainage and storage capacity of fresh water for multiple purposes is seen as very important by the local community and should go hand in hand with the provision of adequate (water crossings. A number of khals have lost their original carrying capacity due to siltation and the overall connectivity of the khal system has decreased because of land reclamation to create space for settlements, farming, fishing, and road construction (often unplanned) without providing enough cross drainage.

Implementing organisations (i.e. BWDB and BG) indicated that re-excavating khals is a challenge as several khals have been leased out by the government to landless, and others have been encroached by powerful individuals, fishing (Figure 8) and settlements.

Because of the complex socio-political nature of the issue, it was suggested during the validation workshop that the re-excavation of khals should be a joint effort of governmental agencies, UP, WMGs, and BWDB. UP members can play major role in creating awareness about the benefits that reconnecting the khal system would yield for the whole community. WMG members expressed their interest in being involved in khal maintenance by mobilising the local community to carry out excavation and maintenance works. There was also the suggestion to extend participation in WMG committees to UP members to improve and accelerate the implementation of water management related activities.

Figure 8: A fishing net in front of the opening of a culvert is encroaching on the khal system creating obstacles to the natural flowing of water and disrupting drainage connectivity.

This intervention is in line with BG plans to re-excavate a number of khals in Polder 26 (Figure 9) and in general with BWDG/government plans targeting khals in other polders of Coastal Bangladesh.

In addition to khals included in BG plans, participants in FGDs and validation workshop added a list of khals that need re-excavation. These khals are:

- Kaliduhar khal
- Bujtola khal
- Ziler khal
- Kurir beeler khal
- Hoglabunia khal from Molmolia to Chingra Kodalkata khal

(c) Gated water crossings to retain and control water

The When they were first developed in the 1960s, polders were designed with the main objective to protect lands from flooding and with a focus on drainage of flood and runoff water, allowing the safe settlement of people and their socio-economic development. Water control for farming and other productive uses was not integrated in the original design. Today, the need to improve water control and water distribution within the polder becomes increasingly manifest. Higher elevated lands are difficult to irrigate because there are no water regulators built into the khal system to retain water in specific areas of the polder at needed times. Water tends to flow toward and concentrate in lowlands, causing drainage congestion and waterlogging here. In high lands, pump lifting of water from the khals to the field is needed in several cases.

Roads represent an opportunity and should be turned into instruments of polder water management by providing regulation structures at water crossings. The gains are multiple:

(a) Retain water in high lands and control water levels in different compartments of the polder

(b) Reduce drainage congestion in low lands

(c) Increase fresh water storage for multiple purposes

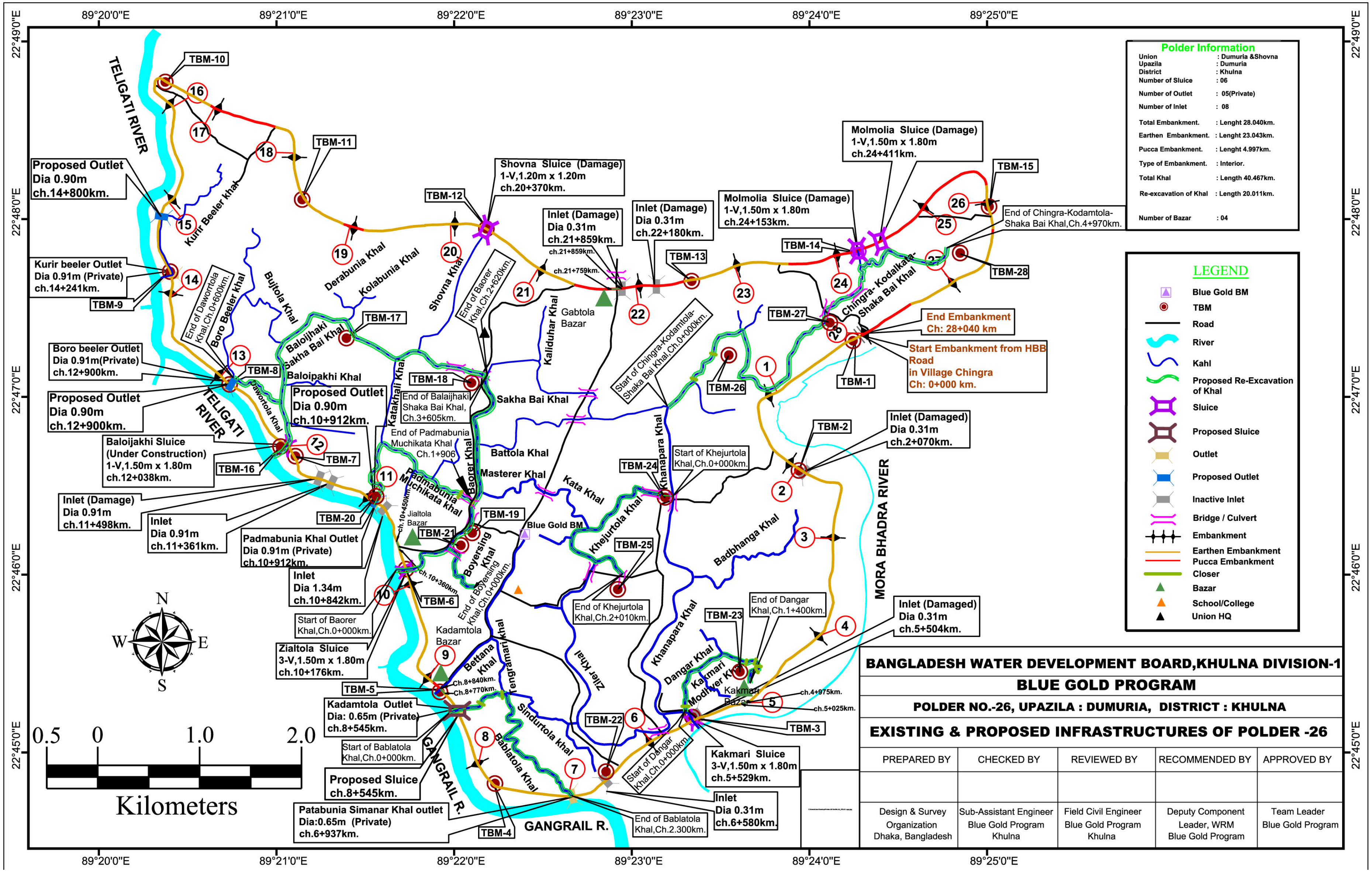


Figure 9: Map of existing and proposed infrastructures of Polder 26.

(d) Diversify crop production

(e) Increase number of crops per year

(f) Obtain higher yields

(g) Grant more flexibility to farmers to plan their cropping patterns and farming activities

Once gated water crossings are implemented, there should be a body responsible for their operation and maintenance. WMGs expressed their willingness in being involved in internal polder water management. LGED's Participatory Small Scale Water Resources Sector Project (PSSWRSP) has already proven successful in engaging the community in polder water management through water management cooperative associations responsible for O&M.

Fieldwork and validation workshop have indicated potential locations for gated water crossings which are presented in Annex I.

(d) Improve quality of (embankment) roads

The quality of both internal and embankment roads is a challenge in Polder 26 and household surveys highlighted that 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 (Figure 10). Tarmac roads also deteriorate due to the corrosive effect of water. Portions of the tarmac carpet detach from the subgrade leaving large holes and unpaved portions.

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

Figure 10: Earth and brick roads deteriorate rapidly and create many challenges to communication and transport

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. Several poor quality road sections have been recorded during the physical survey and their location is presented in the map below (Figure 11).

The list of problematic roads has been integrated during the validation workshop.

The main causes of poor quality roads are:

- Poor quality of soil used as subgrade. Sourcing of good soil is challenging in some locations and it cannot be found within cost-effective transportation distance

- Construction is often delayed in the rainy season, which hampers the whole construction process. Compaction of the road becomes a challenge as the soil is imbued with water. This reduces the stability and sustainability of the structure. A contributing cause to the late execution of works is the disbursement of funds to LGED in July (financial year is July-June) so that by the time plans are approved, field surveys done, and works are ready to be started, it is already the inception of the rainy season.

- Quality checks on contractors is challenging

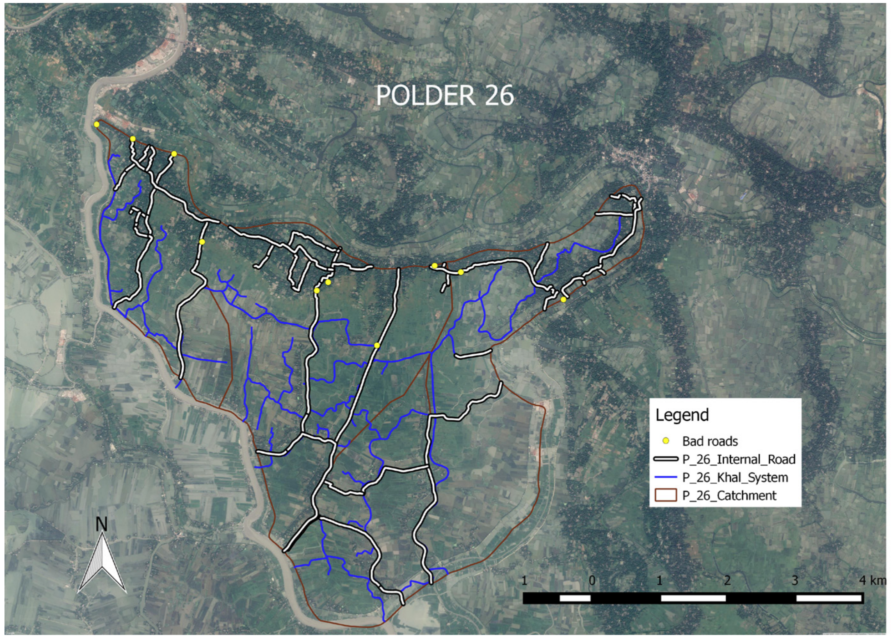


Figure 11: Location of problematic road sections.

- Roads are not provided with adequate drainage facilities and water erodes and damages carpeting and road sides
- No regular maintenance is done, only periodic interventions to fix major damages or for carpeting and widening of roads

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.

The quality and sustainability of roads can be improved by addressing the issues highlighted above. For instance, during validation it was proposed to form community-based committees responsible to check the quality of road construction works and when needed demand relevant authority to deliver higher quality work.

Moreover, design modifications to pipe culverts and pipe inlets and outlets shall be done and appropriate length should be chosen to match future widening and carpeting of (embankment) roads.

5. Polder 43 2F

5.1 Main features

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 (Figure 12). 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. Overall water supply for irrigation through the khal system is sufficient to achieve two harvests per year: one paddy crop during the rainy season and a system of mixed dry crops during the dry season (e.g., potato, chili, nuts, sunflower, beans). However, due to the irregular topography and the presence of scattered pockets of higher elevated lands, it is difficult to control and retain water when and where it is most needed.

Similarly to Polder 26, bad quality and conditions of roads features as a main problem in Polder 43 2F. Moreover, there is a prevalent safe drinking water scarcity in this polder because there are no sufficient boreholes. Drinking water availability was highlighted as the main water-related problem in the polder.

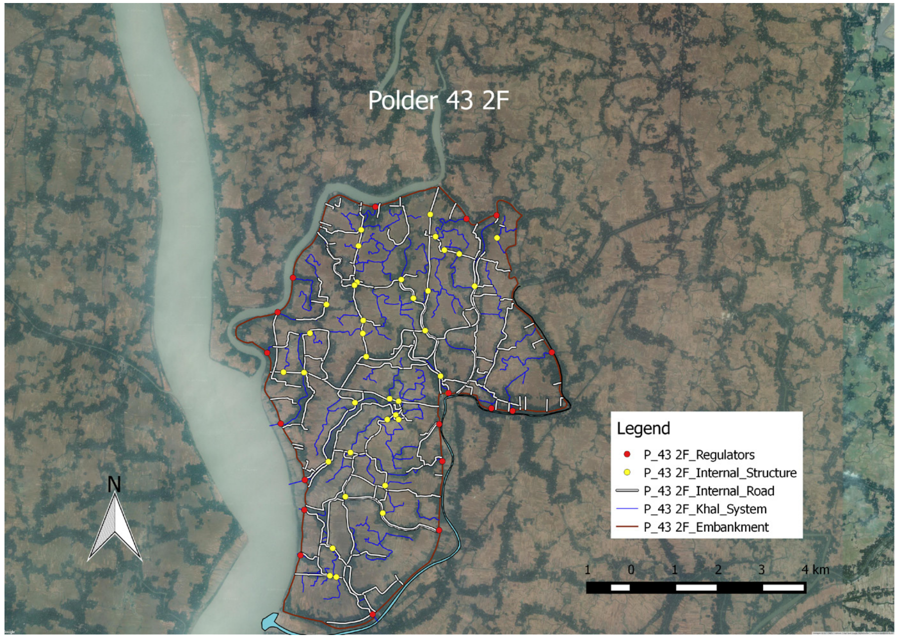


Figure 12 Polder 43 2F: Physical infrastructures.

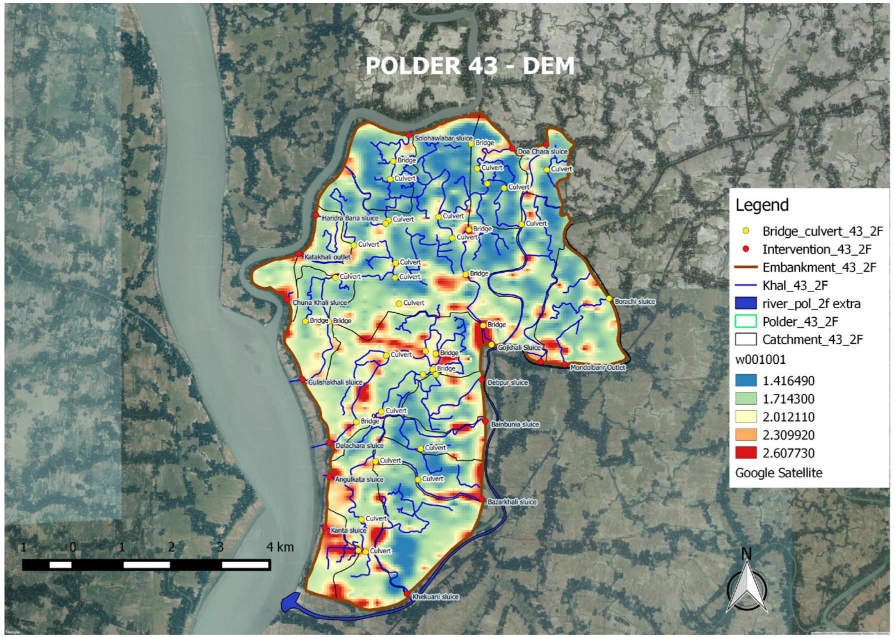


Figure 13: DEM of Polder 43 2F showing high (red) and low (blue) lands.

5.2 Catalogue of road-water management issues and solutions

(a) Gated water crossings and regulator structures to retain and control water

Due to the irregular relief and the absence of water control structures on the khals, farmers face challenges to access canal water to irrigate higher elevated fields, particularly during the dry season. Figure 13 shows the DEM of the polder. This problem occurs especially in the middle of the polder in Dalachhara Cat. Here, farmers have to pump water from the khals to their Boro paddy fields. Retaining water on highlands and controlling water levels in canals would enable farmers to grow a second paddy rice crop in the year and in general increases their farming flexibility and crop options. In Polder 26 farmers have access to groundwater and can thus attain two paddy harvests per year.

To improve the distribution and management of water in the khal system, there is a need to segregate different parts of the polder and to control the water flow and water levels in the khals.

There are many internal structures, culverts (box and pipes) and bridges. These could be used as regulator structures to distribute and retain water where and when most needed. Road crossings can be turned into instruments for improved water management. There is only one gated culvert (Figure 14). Many more of these should be implemented to achieve a win-win situation of decreased drainage congestion and waterlogging in lowlands while improving water retention in highlands. Box sluices (i.e. box culverts provided with gates) should be provided at specific locations at transition points between high and low lands. Annex I presents a potential list of locations where gates could be provided at existing culverts. Further analysis is currently being done by BUET to match this preliminary list with a DEM analysis to see whether based on the relief, these are appropriate sites for water control.

Figure 14: Gated culvert to control water flow and water levels at water crossings.

Moreover, to improve overall polder water management, embankment regulators (sluice gates, inlets, and outlets) should be repaired and regularly maintained to improve water control and water retention in the polder. Defective structures (Figure 15) that do not close hermetically lead to water losses out of the system or entering of unwanted river water creating flooding risks. Of the 19 surveyed sluice gates, 10 had some defects and do not allow for full water control.

Moreover, inlets and outlets should be provided with gates and maintenance should be done routinely. In 2016, BG repaired 38 inlets and 3 outlets,

Figure 15: 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).

yet the provision of gates is responsibility of the Mechanical Engineering Department of BWDB. BG has plans to construct 4 new outlets in 2018. Out of 34 surveyed gated inlets/outlets along the embankments, 20 were found to be lacking the gate. Of the total 36 surveyed inlets and outlets, 23 were silted up or blocked by farmers with earth or bricks to control the water flow because still devoid of metal gates (Figure 16). Inlets and outlets are designed to pass water in one direction only, yet farmers usually use inlets also to drain out water, which damages the structure.

Figure 16: Inlet blocked by mud and devoid of vertical metal gate.

(b) Re-excavate khals and increase water storage

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. Thus, a re-excavation of khals is needed and has emerged as a major improvement to increase the drainage and water retention capacity of the khal system. This would reduce waterlogging and increase water availability for different uses. According to farmers, increasing the capacity of khals to store freshwater would enable them to grow a rabi paddy crop during the dry season. This intervention goes hand in hand with the previous solution, the provision of regulation gates to water – crossings. The order of intervention should be the re-excavation of khals first and the intervention on the water -crossing after that.

BG is planning to re-excavate 10 khals in Polder 43 2F. WMA and WMGs are involved in the selection of khals needing re-shaping (Figure 17). The idea is that after khals are being rehabilitated, regular maintenance will be taken over by the local community.

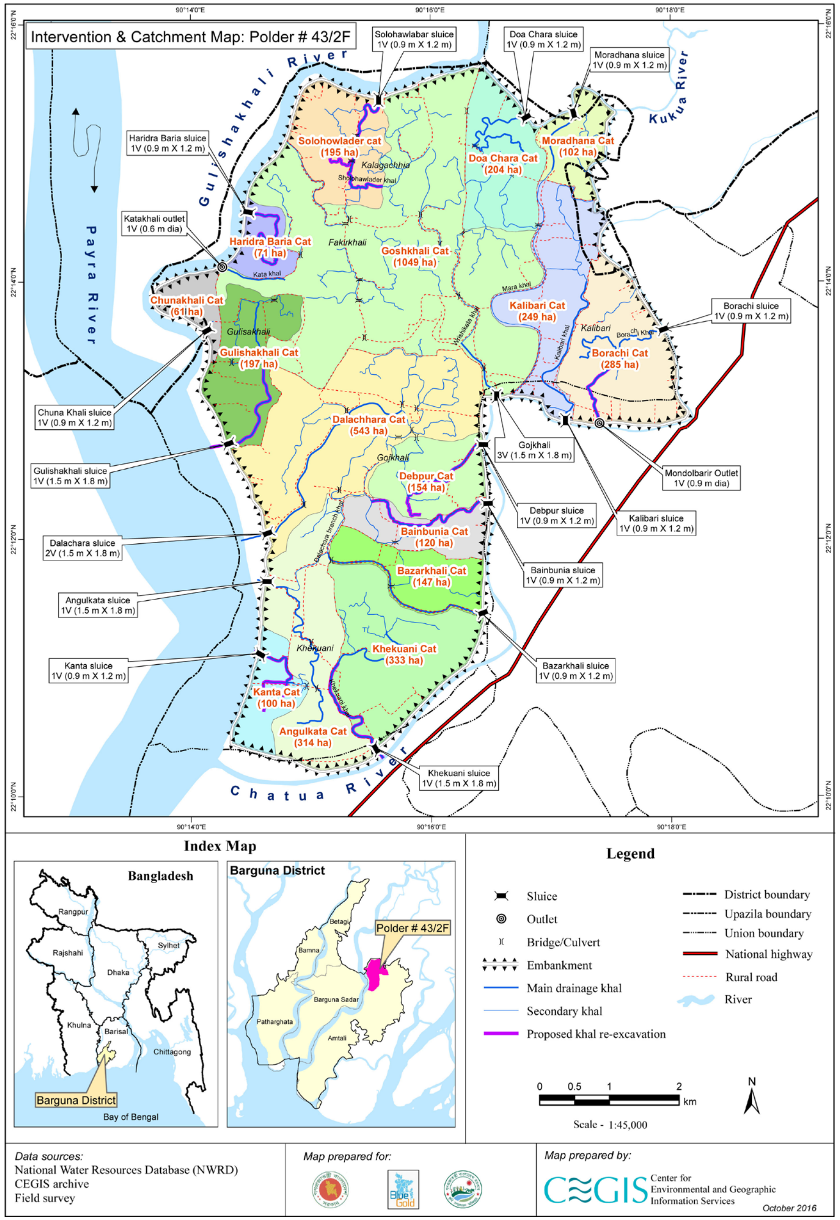


Figure 17: Intervention map for polder 43 2F.

In addition to those already planned by BG, a list of khals that need to be re-excavated has been suggested in FGDs and the validation workshop:

1. Zintola khal
2. Angarpora khal
3. Rishikata khal
4. Madartola (South) khal
5. North Gojhkhali (North) khal
6. Bahannow kura khal
7. Gunachonda khal
8. Dalachara khal
9. Chandra khal
10. Patabuniya khal
11. Shoilabunia khal
12. Dhupaihuta khal

However, there is a limit to reshaping and increasing the capacity of khals which is the capacity of sluice gates and internal structures. BG is planning to construct a new sluice gate in 2018 and to replace the Khekuani sluice gate by a new one. BG has already repaired 15 sluices in 2016, yet the gates remain still to be replaced by the ME of BWDB in 2018. The reparation of the gates is fundamental in order to maximise water control and flood protection.

Another challenge is connected to the financing. Just as it happens for roads, the budget for the re-excavation of khals is disbursed in the rainy season, making the dredging and re-shaping very hard and unsustainable and affecting the overall quality of works. This type of works should be done during the dry season (October- December).

As mentioned previously, land acquisition for the re-excavation of khals is also a challenge. During the validation workshop it was suggested to leave out from re-excavation those khals which have been allocated by the government to landless people, to consider their needs and priorities. The feasibility of re-shaping khals should thus be discussed closely with the local community. Members of both UP and WMGs are willing to support in this process and WMGs showed interest in being more actively involved in the execution of excavation and maintenance works, if given the authority to do so by BWDB. Again, many lessons can be drawn from LGED's PSSWRS project.

(c) Improve the design of inlets and outlets

The length of the pipe barrel of inlets and outlets along the embankment is a design characteristic that has a huge impact on the durability and stability of the portion of embankment or embankment roads above the structure. 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 (Figures 18 and 19).

This relatively easy to fix design detail has so much impact on the sustainability and flood protection function of embankments and on the sustainability of embankment roads. Thus, design of inlets and outlets should consider future widening of embankments in view of a potential development of an embankment road.

Figure 18: Two examples of erosion and degradation of embankment roads in correspondence of inlets.

Figure 19: Erosion of an embankment section in correspondence of a pipe inlet.

(d) Improve shelter function of (embankment) roads

Embankments, embankment roads and also higher elevated internal roads are used as shelters during floods and high water. 19 of 59 HH survey respondents seek shelter on high sections of internal roads and on embankments when river flooding occurs (or there is risk thereof) and when intense rains and insufficient drainage cause internal flooding in the polder. The majority (8 respondents) said to seek shelter on roads once every 10-15 years, 5 other every 5-10 years, 5 every 1-2 years, one respondent uses roads as flood shelter every year. The shelter function of internal roads and embankment roads has to be enhanced, not neglected, as it is an important safety haven for polder inhabitants for durations that can go from 3 days up to 20 days according to HH survey respondents in Polder 43 2F. An option would be to make levees along targeted roads where people (and livestock) could find shelter.

As for embankments, current design manuals for the construction of embankments by both LGED and BWDB prohibit the use of embankments for afforestation and for flood shelters (from stability considerations). However, special additions could be made to existing design to allow the provision of berms at specific embankment sections to shelter people and livestock during flood (risk) and high water.

(e) Improve the carpeting of embankment roads for 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. In 4 of the 5 carpeted embankment sections surveyed, the height of the embankment was found to be lower than the other embankment sections (Figure 20).

In many cases, a lack of coordination and cooperation between BWDB and LGED and long time needed by BWDB to approve LGED's plans for developing an embankment road lead to premature carpeting of an embankment, before it is raised up to safe standard levels. Moreover, the quality of carpeting of embankment roads is not good enough for reasons similar to those already mentioned for internal roads. This results in rapid degradation of the road (Figure 21), which, in turns, also leads to the deterioration of the embankment.

This needs to change. 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 and better monitoring is needed by BWDB of embankment roads implemented by LGED. Quality carpeting respects safety height standards for embankments and implies. Moreover, it implies the use of good materials and a close monitoring of the construction process, which altogether lead to durable embankment roads and stable, flood-proof embankments.

Figure 20: Low embankment section where carpeting has already started.

Figure 21: Poor quality embankment road.

(f) Additional culverts to improve waterlogging

Despite the large number of water-crossing structures, sluice gates, and the extensive khal system, a large number of respondents are affected by waterlogging. Waterlogging occurs in patchwork manner in low lying lands and around homesteads (Figure 22). A large number of respondents reported to have abandoned some land because of waterlogging.

Figure 22: Drainage congestion around a house. This photo was taken in March 2017 during the dry season, 2-3 days after a rain event.

A vast majority of respondents reported regular damages to crops and crop failures because of waterlogging. Excess water washes seeds and seedlings away, is cause of rot, delays farming activities and marketing of crops. Altogether this reduces yields, crop quality, and the price farmers can get from their products.

Flooding and waterlogging on farmland can be largely reduces by re-excavating and re-shaping khals to increase their water storage and drainage capacity, and by repairing sluice gates and providing outlets and inlets with gates. Waterlogging around homesteads and settlements can be improved by simply adding some additional culverts and pipes to safely divert excess water to ditches and khals or beels. In addition to damaging property and goods (e.g. furniture, food storage, livestock and small animals), hampering communication and mobility, waterlogging around homes is also source of water- borne diseases.

People would dig drainage ditches around their homestead and lay down rudimental pipes to drain water from around their house to safer areas such as farm fields.

A number of additional culverts and pipe drains should be implemented at different locations, particularly in and around villages, to drain water toward drainage khals and beels.

6. The way ahead

Based on the assessment and classification of road - water issues in Polder 26 and 43 2F, this report outlines several options and opportunities to improve these issues. Moreover, it proposes a way forward to systematise the integration of roads for polder water management in all polders of Coastal Bangladesh.

Main improvement options are:

(g) 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.

(h) 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.

(i) 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

(j) 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.

(k) 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.

(l) 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.

It is estimated that these improvements 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.

- 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.

To systematically integrate (embankment) road design into polder water management and flood protection, two lines of action – to be implemented in parallel - are suggested:

(3) Quick implementation of some of the improvements mentioned above (and shortlisted in Annex I) in Polders 26 and 43 2F before the rainy season 2017. This is important to keep the momentum going. Polders 26 and 43 2F should act as learning polders whose results will feed into the development of a strategy to upscale and systematise roads for polder water management in other polders of Coastal Bangladesh.

(4) Rolling out roads for polder water management and flood protection - as addition to the work done on polder water management under BG - in all 22 BG polders as well as in LGED irrigation schemes and other polders such as those under the CEIP-2. This can take the form of Guidelines for Roads for Polder Water Management and Flood Protection comprising of a standard assessment procedure of main issues and solutions, examples of designs, a protocol to monitor the process and impacts of (1), and supporting training activities. The guidelines should also align with the work done by LGED under the Participatory Small Scale Water Resources Sector Project.

The guidelines should act as a working document, which goes hand in hand with the implementation of physical interventions under (1) and should actually develop and be refined based on lessons learnt during implementation. The idea is to spread good practice on roads for polder water management and flood protection in in all polders of Coastal Bangladesh and LGED areas.

The guidelines should provide indications on a number of aspects related to both polder water management and flood protection:

<u>Roads for polder water management</u>

- location and number of culverts
- use of different culvert in different part of polder (gated culvert, box culvert, pipe culvert)
- control of private roads/unplanned earth roads and drainage obstruction

<u>Embankment roads for flood protection</u>

- synchronized standard height and width
- quality of carpeting
- use of reinforced levees in roads as (post) flood shelters
- width of pipe regulators (taking into account future embankment road development)
- regulated multifunctional use of embankments

Finally, it is worth highlighting that many opportunities emerged during the opportunity study in terms of support from different key actors involved in roads and embankment development, and water and flood management.

For instance, LGED demonstrated clear interest in being involved in polder water management as they could contribute much with learning from and collaboration with the PSSWRSP. WMGS and WMAs also showed interest in being actively involved in polder water management, khals re-shaping and maintenance, and operation and maintenance of gated water crossings.

The integration of road development and water management /flood protection has significant upscaling potential as interest and endorsement is building up from different donor and governmental agencies. For instance, there is the scope to integrate the roads for water theme in the preparation of the Coastal Embankment Improvement Project – Phase 2.

Annex 1 Overview of possible physical works in Polder 26 and 43 2F

Polder	Type of culvert	Current status	Location and Photo	Coordinates	Design/action	Impact/comments	Cost
Polder 26							
	Drainage culvert	Missing	On Kakmaripurbopara road (Photos 174, 176)	Photo 174 lat 22.7625111111 lng 89.3870694444	Add box culvert at least 10 ft wide	A culvert (at least 10 feet wide) is needed to connect two important khals. This would solve the water logging problem in a large area	
		Missing	To connect Ziler khal and Sindurtola khal (Photos 180-183)	180 lat 22.7523666667 lng 89.3773555556 182 lat 22.752325 lng 89.3771277778 183 lat 22.7523666667 lng 89.3773527778	Add box culvert at least 10 ft wide	A culvert (at least 10 feet wide) needed to connect Ziler khal and Sindurtola khal	
		Missing	On the earthen path across Ziler khal (Photos 178,179)	178 lat 22.750975 lng 89.3820194444 179 lat 22.7508305556 lng 89.3819583333	Add Pipe/box culvert?	People built an earthen path across Ziler khal to improve communication for around 40-50 households. A culvert on this path will restore the connectivity of Ziler khal. Need to check whether pipe culvert can do or box culvert needed.	

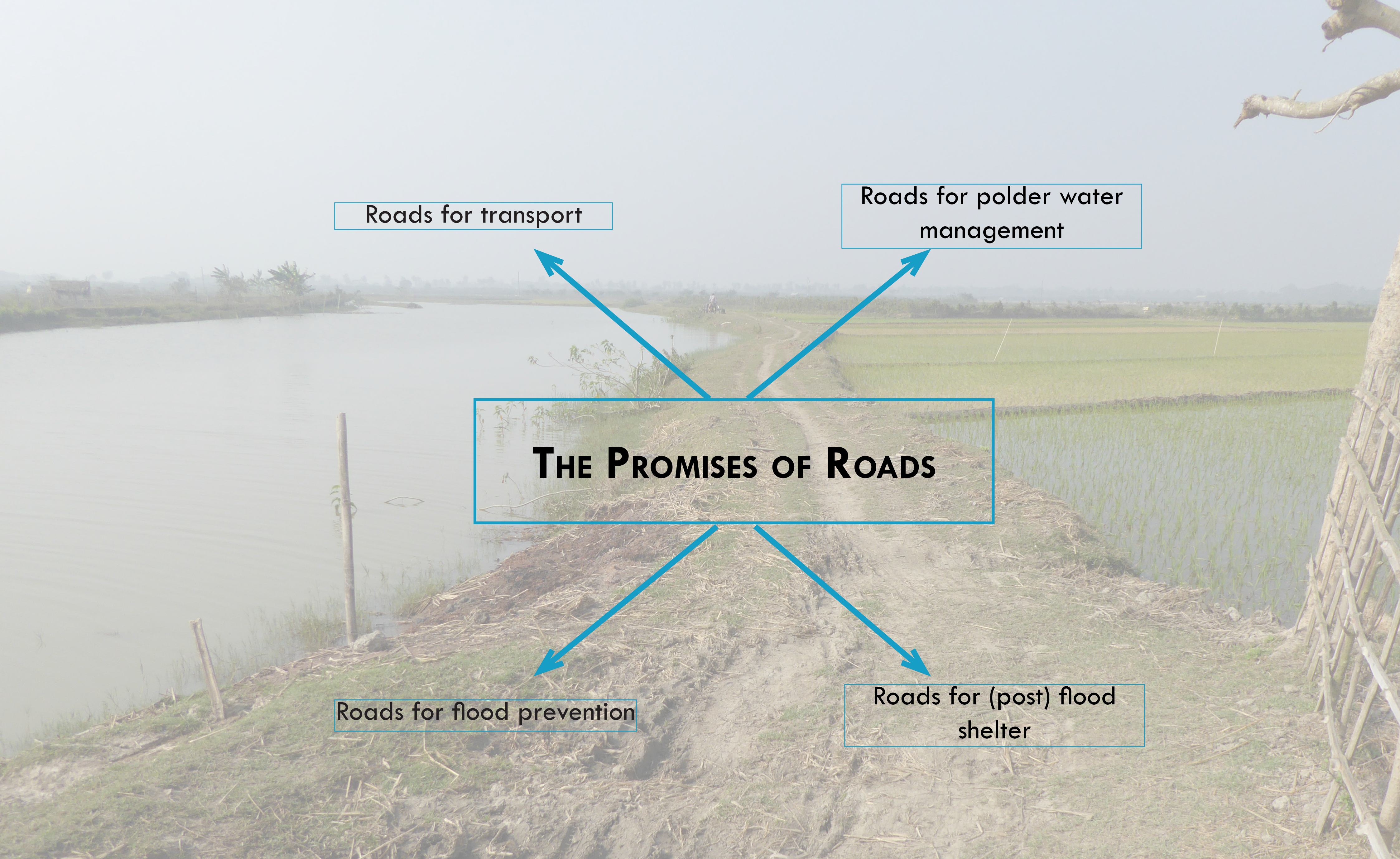
		Missing	Photos 122, 123	122 lat 22.7916833333 lng 89.371125 123 lat 22.7916638889 lng 89.3710916667	Add box culvert	A culvert is needed to improve cross-drainage and reduce waterlogging	
		Missing	Photos 129, 130	129 lat 22.7921333333 lng 89.3708694444 130 lat 22.7905944444 lng 89.3695333333	Add box culvert	Lack of cross drainage along this road creates waterloggingA culvert is needed would improve drainage.	
		Missing	Photo 159	lat 22.7930166667 lng 89.3902083333	Add box culvert	Waterlogging occurs due to lack of cross drainage on this road. Culvert would improve drainage.	
		Missing	Photo 210	lat 22.7938833333 lng 89.3998722222	Add box culvert	Waterlogging occurs due to lack of cross drainage on this road. Culvert would improve drainage.	

		Missing	Photos 214, 215, 216, 217	214 lat 22.800275 lng 89.3521388889 215 lat 22.80435 lng 89.3463861111 216 lat 22.8087055556 lng 89.3431888889 217 lat 22.8087638889 lng 89.3432888889	Add small pipes	Lack of cross drainage can be solved by small pipes	
		Low capacity: culvert (4 x 10 SF)	Culvert on Boyersing khal (Photos 223,224)	223 lat 22.7691166667 lng 89.3658333333 224 lat 22.7691166667 lng 89.3658333333	Culvert has to be made wider	This culvert connects two khals. BG has a plan to dredge Boyersingkhal and if they do so then the existing culvert will fail to pass water. This culvert needs to be enlarged to solve water logging problem in around 600 acres land.	
		Low capacity (2 x 15 SF)	Culvert on Dangar khal is very narrow (Photo 173)	lat 22.753625 lng 89.3877416667	Box culvert has to be made wider than 15 ft	A wide culvert is needed near Kakmari sluice. This box culvert connects two very important khals (Khanapara khal and Dangar khal)	

		Culvert (15 x 12 SF) low capacity	Culvert on Shaka Bai khal (Photo 97)	lat 22.7816694444 lng 89.3772527778	Larger culvert/ bridge needed	This culvert is crucial in assuring connectivity of the large Shaka Bai khal and would reduce waterlogging significantly	
	Water control (Retention) culvert	Missing	Gated culvert (or bridge) on Shakhabai khal (Photos 197-199)	197 lat 22.7833277778 lng 89.3780694444 198 lat 22.7833111111 lng 89.3781333333 199 lat 22.7833111111 lng 89.3781333333	Larger gated culvert/bridge wider than 15 ft	A gated culvert or bridge is needed to maintain the river connectivity and to control water levels for irrigation on the east side of the polder	
		Missing	Photo 162	lat 22.7849833333 lng 89.3883277778	Gated culvert needed	The North East part of the polder is high. So it's very difficult to store water for irrigation in high lands. For this reason WMGs suggest a gated culvert near Modhu's House (in the middle of a beel)	
Polder 43/ 2F							
	Drainage culvert	Pipe culvert (1 ft diameter) low capacity	467	lat 22.1979333333 lng 90.2663638889	Replace pipe with box culvert		
		Pipe culvert (1 ft diameter) low capacity	468	lat 22.1958277778 lng 90.2662361111	Replace pipe with box culvert		

	Water control (Retention) culvert	Box culvert 3 x 25 SF	313	Lat 22.181325 lng 90.2481444444	Add gate	Is this location appropriate in terms of water control for irrigation? Further analysis (DEM) needed	
		Box culvert 5 x 15 SF	317, 318	317 Lat 22.1820277778 lng 90.2435861111 318 lat 22.1818416667 lng 90.2436916667	Add gate	Is this location appropriate in terms of water control for irrigation? Further analysis (DEM) needed	
		Box culvert 3 x 25 SF	319	Lat 22.1819833333 lng 90.2404611111	Add gate	Is this location appropriate in terms of water control for irrigation? Further analysis (DEM) needed	
		Box culvert 3 x 20 SF	400	Lat 22.2346416667 lng 90.2799527778	Add gate	Is this location appropriate in terms of water control for irrigation? Further analysis (DEM) needed	
		Box culvert 2 x 20 SF	403	Lat 22.2333305556 lng 90.2793444444	Add gate	Is this location appropriate in terms of water control for irrigation? Further analysis (DEM) needed	
		Box culvert 2 x 30	405	Lat 22.2313694444 lng 90.2724194444	Add gate	Is this location appropriate in terms of water control for irrigation? Further analysis (DEM) needed	

		Box culvert 2 x 15 SF	472	Lat 22.2013138889 lng 90.2505472222	Add gate	Is this location appropriate in terms of water control for irrigation? Further analysis (DEM) needed	
		Box culvert 2 x 15 SF	511, 512	511 lat 22.2460361111 lng 90.2519333333 512 lat 22.2459888889 lng 90.2520611111	Add gate	Is this location appropriate in terms of water control for irrigation? Further analysis (DEM) needed	
		Box culvert 4 x 15 SF	547	Lat 22.2329916667 lng 90.2336083333	Add gate	Is this location appropriate in terms of water control for irrigation? Further analysis (DEM) needed	
		Box culvert 3 x 20 SF	555	Lat 22.2323666667 lng 90.239875	Add gate	Is this location appropriate in terms of water control for irrigation? Further analysis (DEM) needed	
		Box culvert 3 x 20 SF	556	Lat 22.22875 lng 90.2409472222	Add gate	Is this location appropriate in terms of water control for irrigation? Further analysis (DEM) needed	



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