Traditional Ecological Knowledge on Flow and Erosion processes in the Braided Jamuna river in Bangladesh: Part-II

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The Jamuna is a large scale sand bed braided river. It always changes its courses within its braid belt. Erosion is a major problem along the Jamuna river. More than thirty bank protection structures have been constructed along both banks of this river to protect bank from erosion. The response of these structures to the river is different. The people neighborhood of these structures has already gained experience-based traditional ecological knowledge. The main objectives of the present study are to investigate experience-based Traditional Ecological Knowledge (TEK) on flow and erosion around different bank protection works. Participatory Rural Appraisal (PRA) method was used to investigate the (TEK) around different bank protection works. Different tools of PRA such as: Focus Group Discussion (FGD), Key Informant Interview (KII) and Informal Group Discussion have been used around some selected bank protection works along the braided Jamuna river. Finally, comparisons are made among the experienced-based TEK, field engineer’s knowledge, field measure result and result obtained from laboratory experiment. It has been found that there are similarities among the experienced-based traditional knowledge, field engineer’s knowledge, field measure result and result obtained from laboratory experiment. The following Traditional Ecological Knowledge (TEK) have been investigated from the present study such as: (i) the TEK on flow and erosion processes around Sirajganj hardpoint, Betil and Enayetpur spurs, Shuvogacha spurs and around bandal structures, (ii) the experienced-based TEK on flow and erosion processes are very similar to scientific analysis from the field measured data, (iii) the causes of failure of the Sirajganj hardpoint, Betil and Enayetpur spurs and Shuvogacha, (iv) the indication of failure of bank protection works. It is clear that the local peoples experienced-based TEK can play a vital role in the management activity during emergency situation.

Keywords: Traditional knowledge, Flow and erosion, Bank protection works, Braided Jamuna river

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It is a companion paper on Traditional Ecological Knowledge (TEK) on flow and erosion processes in the braided Jamuna river: Part-I. The definition of Traditional Ecological knowledge (TEK) given by Huntington (1998) is the system of experiential knowledge gained by continual observation and transmitted among members of a community. It is set in a framework that encompasses both ecology and the interactions of humans and their environment on physical and spiritual planes. The term technical or scientific knowledge is attributed to some facts and principles that are acquired through the long process of inquiry and investigation. The investigation takes long time because it goes through various aspects to come to a conclusion and the aspects include all the laws theories, concepts and models.

It has already been discussed in Part-I that the people of Bangladesh use much TEK in their daily life. The TK has enormous role in different sectors. So, Bangladesh Resource Centre for Indigenous Knowledge (BARCIK) has taken scheme in preservation, documentation, and dissemination of TEK in a variety of development related fields including agriculture, health care and environmental conservation. A number of papers have already been published by BARCIK on traditional knowledge for sustainable biodiversity conservation, health development, wise use of water and watershed resources, sustainable agriculture, and everyday survival.

It has been discussed in Part-I that the Bangladesh is a disaster prone country. The people of this country always combat with different types of disaster such as: cyclones, tornadoes, tidal bores, floods, river erosion, droughts, and earthquakes. The people inhabiting a disaster-prone country in particular have their localized knowledge and practices, developed through cumulative experience, that constitute a survival strategy in the face of natural disasters.
The erosion and morphological change or river shifting of the Jamuna river is the recurrent phenomenon. A lot of people are living on the sand bar of the Jamuna river and along the bank line of the Jamuna river. They cope with the changing phenomenon of this river. Some TK of the riparian people of the Jamuna river on response strategies from riverbank erosion, to cope with the Jamuna and morphological change of the river are summarized here. The inhabitants of flood plain are more dependent on traditional strategies to cope with river bank erosion. They made their house using thatch, bamboo, wood and corrugated iron sheet instead of brick iron and steel. They use these materials, they can be dismantled, transported and rebuild within a short time in an emergency situation. The char people usually live in a clustered form. The clustered settlement strategy helps the char people to reduce economic losses and moral and emotional recovery from the hazard effect. They use country boats (local name dingis or noukas) to transport bulky material including housing material in an emergency situation. Sometimes they build protective bamboo crates and fences (locally called chegar) and place them on the water front. The border of the field is usually become non-recognizable due to sedimentation. So, the farmers plant the creeper kumli or the reed of shon to identify a field border. The char land people plant catkin reed to protect from erosion and promote the established new land. The charland people explained how the Jamuna river become shallower than deeper one? The river transported more fertile sediment, silt (doash) and fertile silt (pulla-mati) before 1960. But present time the river carries most of sand. The river loses its corridor to carry the discharge due to sand deposition. According to the local people, there are three methods of development of knowledge about the Jamuna river as: the observation of river phenomenon, experience through boat trip and measuring. A number of studies have been made on above different aspects. But attention is made on the experienced based TEK of the bank protection works. These structures are constructed late nineteen nineties. The main objectives of the present paper are: to explore the experienced-based traditional knowledge on flow and erosion processes around bank protection works.

The following Traditional Ecological Knowledge (TEK) are investigated through the present study such as: (i) the TEK on flow and erosion processes around Sirajganj hardpoint, Betil and Enayetpur spurs, Shuvogacha spurs and around bandal structures, (ii) the experienced-based TEK on flow and erosion processes would be compared to the scientific knowledge, (iii) the causes of failure of the Sirajganj hardpoint, Betil and Enayetpur spurs and Shuvogacha, (iv) the indication of failure of bank protection works.

**Research methodology**

**Study area**

The study areas are under Sirajganj district of Bangladesh. The area of Sirajganj district is about 2498 km². The main rivers are Jamuna, Baral, Ichamati, Karatoya and Phuljuri. The annual average temperature reaches a maximum of 34.6 °C, and a minimum of 11.9 °C. The annual rainfall is 1610 mm (63.4 in). The population has been measured at 3,215,873, made up of 92% Muslim, 6.5% Hindu and 1.5% other. Males make up 51.14% of the population and females 48.86%. The population density is about 1290 inh/km² and growth rate is 1.39%/year. Literacy rate of Sirajganj district is 27%. Nine administrative units called Upazila have under this upazila. Four of the nine upazilas are adjacent to the dynamic Jamuna river. These upazilas are erosion prone area.

**Bank protection works**

About thirty numbers of bank protection structures have been constructed along the both banks of the Jamuna river. These are hardpoint (revetment), RCC (Reinforced Cement Concrete) spurs with earthen shank, spurs, guide banks, bandal structures, etc. Among the thirty structures only four structural sides have been selected for the present study. The selection criteria are as follows: (1) the hardpoint is aligned along the bankline, (2) the RCC spurs are aligned normal to the bankline, (3) the bandal structures are made of bamboo extended towards the channel at an angle with the bank, and (4) the RCC spurs is not functioning due to damage. The hardpoint is located adjacent to the Sirajganj town. The RCC spurs are nearby of the Betil and Enayetpur under Chowhali and Belkuchi Upazila, respectively. The bandals (recurrent bank protection structures) is at Randhumibari bazar under Belkuchi Upazila. The damage RCC spurs is located at Shuvogacha under Kazipur Upazila.
Design parameters of different bank protection works

Some design parameter of hard point and spurs are shown in Table 1. Design high flood level Sirajganj hardpoint, Betil and Enayetpur spurs and Shuvogacha spurs are +15.75 mPWD, (+) 14 mPWD and (+)15.75 mPWD, respectively. The crest level of Sirajganj hardpoint, Betil and Enayetpur spurs and Shuvogacha spurs are (+)16.75 mPWD, (+) 15.5 mPWD and (+)16.75 mPWD, respectively. The maximum scour depth of Sirajganj hardpoint, Betil and Enayetpur spurs and Shuvogacha spurs are 33 m, 18 m and 17 m, respectively. The thickness of lunching apron of Sirajganj hardpoint, Betil and Enayetpur spurs and Shuvogacha spurs are 2 m, 1 -3 m and 1 m, respectively. Different sizes block sizes are used depending on flow velocity.

Bandal structure

The length of the bandal-like structures was about 10 m (extended towards the river from bankline) and makes an angle 50-60° to the bank line. The spacing of the vertical bamboo piles was about 46 cm center to center along longitudinal direction. The total length of the vertical bamboo piles were about 9 m. Half of the total length of the vertical bamboo piles was driven into river bed (but not less than 1.8 m) and half of the total length was remain above river bed. The inclined bamboo piles were also driven to prevent the horizontal thrust on the bandal structures. The inclined bamboo piles make an angle 45° with vertical bamboo piles. Spacing of the inclined bamboo piles was similar to vertical bamboo piles. Spacing between two bandal structures was about 32 m. To increase the stability of the bandal structures cross bamboo was connected with the vertical bamboo piles at the rate of 75 cm center to center. The upper portion of the bandal was closed by bamboo thatched (local name chatai) and the lower portion of bandal was opened. Water flow beneath bamboo thatched. The ranges of diameter of the bamboes used for bandal structures were 6 - 9 cm.

Participatory Rural Appraisal (PRA)

Participatory Rural Appraisal (PRA) method has been followed in the present study to investigate TEK or indigenous technical knowledge (ITK) or experienced-based technical knowledge on flow and erosion processes, bank protection measures, failure mechanism of protection works, social acceptance of bank protection works and socio-economic development around bank protection works.

The following tools have been used during PRA: Focus Group Discussion (FGD), and Informal Group Discussion and Key Informant Interview (KII) is adopted to find out the reason of changing flow process, flow process around bank protection works, actual reason of failure of bank protection works, bend development and crosscheck of information obtained from FGD and Informal Group Discussion.

Focus Group Discussion (FGD)

A series of FGDs were conducted with different groups such as mainland and charland people, erosion affected people (farmers, fishermen, loom workers, day laborers, rickshaw and van pullers, boat owners and boatmen etc.) and non-affected people (rich people, middle class farmer, poor farmer, day laborers, loom owners, loom workers, etc.). Using FGD TEK has been investigated on flow and erosion processes, erosion protection measures, failure mechanism of protection works. At the same time the social acceptance of bank protection works and socio-economic development around bank protection works have also been investigated. The PRA tools and group formation strategies are shown in Table 2.

Table 1—Design parameters of different bank protection structures

<table>
<thead>
<tr>
<th>Design parameter</th>
<th>Sirajganj hardpoint</th>
<th>Betil and Enayetpur spurs</th>
<th>Shuvogacha spur</th>
</tr>
</thead>
<tbody>
<tr>
<td>High Flood Level (HFL)</td>
<td>(+)15.75 mPWD</td>
<td>(+) 14 mPWD</td>
<td>(+)15.75 mPWD</td>
</tr>
<tr>
<td>Crest level</td>
<td>(+)16.75 mPWD</td>
<td>(+) 15.5 mPWD</td>
<td>(+)16.75 mPWD</td>
</tr>
<tr>
<td>Top of the lunching apron</td>
<td>(-)4.20 mPWD</td>
<td>(-) 9.5 mPWD</td>
<td>-</td>
</tr>
<tr>
<td>Maximum scour depth</td>
<td>33 m</td>
<td>18 m</td>
<td>17 m</td>
</tr>
<tr>
<td>Thickness of lunching apron</td>
<td>2 m</td>
<td>1-3 m</td>
<td>1 m</td>
</tr>
<tr>
<td>Size of the CC block</td>
<td>55 cm³ (upper slope)</td>
<td>40cmx40cmx20cm</td>
<td>40cmx40cmx20cm</td>
</tr>
<tr>
<td></td>
<td>85 cm³ (lower slope)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Side slope</td>
<td>1V:3.5H</td>
<td>1V:2H (upstream side)</td>
<td>1 V:1.5 H</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1V:3H (downstream side)</td>
<td></td>
</tr>
<tr>
<td>Flow velocity</td>
<td>3.7m/s</td>
<td>3m/s</td>
<td>3m/s</td>
</tr>
</tbody>
</table>
During FGDs groups were formed including 6 - 12 people. But sometimes the numbers of persons fall below the required limit due to the limited number of special groups of people available near the study area. The age of the participants was from 25 - 75 yrs. The elder participants were well known about the morphological change of the Jamuna river. They had clear knowledge how the Jamuna become shallower from the deep channel. For FGD an appropriate check list was prepared to collect required information. A team was formed for FGD including 2 - 3 persons. Among them one was facilitator, one was recorder and the other was organizer. The functions of the facilitator were as follows: to introduce the session, encourage discussion, encourage involvement, avoid being placed in the role of an expert, control the rhythm of the meeting but in an unobtrusive way, take time at the end of the meeting to summarize, check for agreement and thank the participants and listen for additional comments and spontaneous discussions which occur after the meeting has been closed.

The recorder kept the following items: date, time, place, names and characteristics of participants, general description of the group dynamics (level of participation, presence of a dominant participant, level of interest), opinions of participants, recorded as much as possible in their own words (especially for key statements), emotional aspects (e.g., reluctance, strong feelings attached to certain opinions), spontaneous relevant discussions during breaks or after the meeting has been closed, missed comments from participants and missed topics (the recorder should have a copy of the discussion guide during the FGD).

The PRA tools and information generated using different tools are shown in Table 3. The following informations have been collected through PRA:

(i) The flow and erosion processes around Sirajganj hardpoint have been investigated through FGD. During FGD several sketches on flow and erosion processes have been prepared as per opinions of fishermen, boatmen and boat owners and erosion affected people.

(ii) The actual causes of failure of the Sirajganj hardpoint have been found out through scientific investigation. At the same time what are the causes of failure of the hard-point as per local people opinions. Finally the both views have been clarified.

(iii) “How can they guess before the failure of the hardpoint”. This issue is clarified through FGD and scientific explanation.

(iv) What are the reasons of bustling out of air bubble and flowing of turbid water near the bank protection works? Regarding this issue several Key Informant Interview (KII) have been conducted with Sub-divisional Engineer (SDE), Section Officers (SO) of BWDB, and Work Assistance of BWDB.

Table 2—PRA tools and information generated

<table>
<thead>
<tr>
<th>PRA tools</th>
<th>Procedure</th>
<th>Information generated</th>
</tr>
</thead>
<tbody>
<tr>
<td>Focus group discussion (FGD)</td>
<td>Verbal conversation, Timeline, Figure</td>
<td>Morphological change of river, reason of bank erosion, preparation of erosion hazard map, rate of erosion, change of flow process, structural failure of bank protection works</td>
</tr>
<tr>
<td>Informal Group Discussion</td>
<td>Verbal conversation, Figure preparation of flow process</td>
<td>Reason of changing flow process, flow process around bank protection works, actual reason of failure of bank protection works, bend development</td>
</tr>
<tr>
<td>Key Informant Interview (KII)</td>
<td>Verbal conversation, crosscheck of information obtained from FGD and Informal Group Discussion, Figure preparation of flow process and structural failure</td>
<td>Reason of changing flow process, flow process around bank protection works, actual reason of failure of bank protection works, bend development</td>
</tr>
</tbody>
</table>

Table 3—PRA tools and group formation

<table>
<thead>
<tr>
<th>Group</th>
<th>Non-erosion affected people</th>
<th>Erosion affected people</th>
</tr>
</thead>
<tbody>
<tr>
<td>FGD Main land people</td>
<td>rich people</td>
<td>farmers</td>
</tr>
<tr>
<td></td>
<td>middle class farmer</td>
<td>fishermen</td>
</tr>
<tr>
<td></td>
<td>poor farmer</td>
<td>loom workers</td>
</tr>
<tr>
<td></td>
<td>day laborers</td>
<td>day laborers</td>
</tr>
<tr>
<td></td>
<td>loom owners</td>
<td>rickshaw and van pullers</td>
</tr>
<tr>
<td></td>
<td>loom workers, etc.</td>
<td>boat owners and boatmen, etc.</td>
</tr>
<tr>
<td>FGD Charland people</td>
<td></td>
<td>farmers</td>
</tr>
<tr>
<td></td>
<td></td>
<td>fishermen</td>
</tr>
<tr>
<td></td>
<td></td>
<td>loom workers</td>
</tr>
<tr>
<td></td>
<td></td>
<td>day laborers</td>
</tr>
<tr>
<td></td>
<td></td>
<td>rickshaw and van pullers</td>
</tr>
<tr>
<td></td>
<td></td>
<td>boat owners and boatmen, etc.</td>
</tr>
</tbody>
</table>
(v) To investigate flow and erosion processes around Betil and Enayetpur spurs a series of FGDs were conducted with different groups of people.

**Key informant interview**

KII’s were conducted with the local officers of BWDB, LGED, Ward Commissioners of Sirajganj Town, UP Chairmen, UP Members, village leaders, religious leaders and other people who are well aware of the relevant issues for major information and group formation for FGD. The KII was conducted with the BWDB officials, UP chairman and UP member during office time. The KII was conducted with the village leader, religious leader and Key Informant at their convenient time. The categories of key informant are shown in Table 4.

**Collection of secondary data**

Some scientific primary data have been collected by the authors using ADCP (Acoustic Doppler Current Profiler). The 3-D velocity data together with bed level have been measured using the Acoustic Doppler Current Profiler (ADCP: 1200 kHz: WH-ADCP Rio Grande by RD Instruments) to analyze the flow pattern. The ADCP uses the Doppler effect (the change in observed sound pitch that results from relative motion) to measure velocity by transmitting sound at a fixed frequency and listening to the echoes returning from the sound scatters, such as suspended sediment in the water. Global Positioning System (GPS) has been used to locate the measuring point.

The ADCP was connected with a specially designed plastic boat mounting downward. The plastic boat with ADCP was fixed by a rope with the country boat. Finally the entire system was connected to a laptop to collect the data. The 3-D velocity component could be measured by this instrument at a desired interval along the depth of flow. At a particular point the lower velocity data is recorded by ADCP at a distance about 0.08h above the channel bed. The 3-D flow velocity data were collected from near the Sirajganj hardpoint, the entire Betil and Enayetpur spurs area and near the Randhunibari bandal structure area. The flow velocity and discharge usually vary with time. Especially during dry season (December to March) the channel has no flow. The velocity data were measured from all transects in one day (i.e. July 16, 2008) during the active erosion period. The satellite images of different years have been collected from CEGIS (Center for Geographic Information Services).

**Traditional and Scientific knowledge**

To investigate flow and erosion processes around the Sirajganj hardpoint a series of FGD’s were conducted with different group of people such as: erosion affected people, fishermen, boatmen and boat owners, etc. A number of KII’s were also conducted with Sub-Divisional Engineers (SDE of BRE specialized Division, BWDB), Section Officers (SO) of BRE, Work Assistants (WA) of BWDB, Ward Commissioner of Sirajganj Pourashava, Chairman of Shuvogacha Union Parishad, Members of Shuvogacha Union Parishad, Member of the Saudia Chandpur Union of Chowhali Upazilla and other persons who were well known about the Jamuna River and the bank protection works. Several group discussions were also conducted with different classes of people. The information collected through FGD and KII on flow and erosion processes around different kinds of bank structures have been summarized in the following section.

**Results and discussion**

**Sirajgang hardpoint**

**Flow and erosion processes**

It has been found that they have clear idea on the flow processes around the hardpoint and surrounding area. A figure reproduced by hand sketching of respondents indicated that flow came towards the hard point from upstream (Fig. 1a). First of all the flow obliquely attacked the eastern side of the sandbar. As a result the eastern part of the sandbar was gradually eroded. After that the flow directly hit the upstream termination of the hard-point. A strong flow circulation along horizontal plain was formed in the western direction of upstream termination of the hard-point. The local people gave their opinion that the bed material was being washed away due to this type of

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**Table 4—Resource person selected for KII**

- Engineer and local officers of Bangladesh Water Development Board (BWDB)
- Engineer of Local Government Engineering Department (LGED)
- Ward Commissioners Sirajganj Pourashava
- Union Parishad (UP) Chairmen
- Member of UP
- Village leaders
- Religious leaders
- People enriched with Traditional Knowledge
- For formation of group for FGD
flow circulation. The upstream curved (bend) channel is usually dried up during the dry season. The flow starts through this channel when the water level rises in the main channel. During FGD it has been found that a strong return current (local term *ulta aoor*) existed adjacent to the eastern part of the upstream termination. The strong return current was also found in the field measured result Fig. 1c. The strength of the return current becomes stronger when high magnitude flow attacks to the hard point. The strength of the return current becomes weaker and the reattached length becomes shorter when flow magnitude is low. They provide information that the flow velocity changes with time. The flow passes in the downstream direction from the hard-point and again it attacks the upstream part of another sandbar. As a result, the upstream part of the sandbar is eroded. Then the flow is separated into two parts. First part of the flow goes towards the south-east direction (i.e. left bank of the Jamuna River) and second part flow goes towards the south-west direction. According to the local people the second part of the flow attacks the bankline downstream of the hardpoint resulting severe erosion is occurred. This issue has been confirmed through another field-based research performed by Rahman *et al.* (2011).

One question was asked to the respondents that ‘what is the reason of development deep scour hole’? They replied that the vortex flow (*local term vhorka*) is the main reason for the development of deep scour hole. They explained that the vortex flow (*vhorka*) is usually formed near the upstream termination. As a result the bed materials are washed away (*local term mati kete uthe jai*). Their observation is similar to the experimental investigation performed in the laboratory by Melville (1975) and Kandasamy (1989).

The flow and erosion processes around the Sirajganj hardpoint have also been sketched by the Sub-Divisional Engineer of BWDB (23.04.2010) as shown in Fig. 1b. The flow process upstream and downstream reach of the Sirajganj hardpoint are shown in Fig. 1a & b. But the flow process adjacent to the Sirajganj hardpoint are shown in Fig. 1(c). Hand sketching made by engineer was found to be moderately similar to hand sketching prepared by a fisherman during FGD. The fisherman has shown in Fig. 1a. It is found that the incoming flow directly attacks the upstream termination. Two flow circulation zones have been found in his sketching. The first one is just in the western direction of the upstream termination of the hardpoint. The second one is

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Fig. 1—Flow and erosion processes around the Sirajganj (Hardpoint) (a) Flow and erosion processes around the Sirajganj hardpoint (reproduced from hand sketching of the local people); (b) Flow and erosion processes around the Sirajganj hardpoint (reproduced from hand sketching of SDE of BRE specialized division); (c) Flow process on 19th August, 2009
adjacent to the eastern part of the upstream
termination of the hardpoint. The flow is diverted by
the upstream termination of the hardpoint as like flow
diversion structure. Later on, this flow obliquely
attacked the sandbar inside the river. As a result, the
western part of this sandbar has been washed away.
In his hand sketching he has also shown that the flow
again diverted by this sandbar. The flow diverted by
this sandbar is joined together with the direct flow
coming near the hardpoint. A flow circulation zone is
formed just in front of the damaged part of the
hardpoint. After that the joined flow goes in the
southern direction and again attacks another sandbar.
As a result, the northern side of another sandbar is
washed away.

From the above discussion, it has been clear
that the local people possess a good understanding
about the flow processes around a massive bank
protection works. They could give information about
the historical changes of the flow processes. One
important issue has been found from the present
study that the fishermen and boatmen could give
more accurate information about flow and erosion
processes than other groups of the riparian population.
They gave information that the thalweg (local term
katal) is shifted in the western direction at present
time (24.04.2010) from its eastern previous location.
The thalweg is usually shifted in an irregular and
sudden fashion during the rising and falling stages of
the river. It could be assumed that the boatmen
and fishermen are experts on river, flow and erosion
processes among the riparian population. Because
they always drive their boat into the river and they
observe the changing phenomenon of the river course.
Therefore, they can easily realize when, how and in
which direction the thalweg or deep channel is shifted.
So, without any hesitation we can give designation to
the boatmen and fishermen as traditional ecological
knowledge-based river experts.

Causes of structural failure of Sirajganj hardpoint

The causes of failure of the bank protection
structures along the right bank of the Jamuna river as
per BWDB officials are as follows: (i) one of the
main factors for the failure of the bank protection
structures is the shortage of funds (ii) timely, properly
and as per design implementation of bank protection
structures is not possible using insufficient fund;
(iii) starting of the construction work too late as a
result the construction work could not be completed
before the flood season; (iv) the original design is
followed but cut back; (v) inadequate design
assumptions for scour depth, resulting insufficient
falling apron; (vi) lack of fund for maintenance work;
(vii) irregular monitoring of the existing structures
especially during flood period, especially bathymetry
survey is required frequently for the prediction of
scoured depth for the protection work. About 70% of
BWDB officials have given the above stated reason.

The upstream termination of the hardpoint was
damaged in 2008. They local people explained that
the causes of failure of the hardpoint: “the approach
flow directly attacked the upstream termination”.
Their explanation is similar to the field measured
results as shown in Fig. 2a. The main hydraulic thrust
was on the upstream termination of the hardpoint.
Again they also explained that the causes of failure of
the hardpoint in 2009. A sandbar was formed adjacent
to the straight portion of the hardpoint in 2006 as
shown in Fig. 2b. Their information is verified by
satellite images collected from CEGIS (Fig. 3). A
sandbar is observed upstream of the upstream
termination of the Sirajganj hardpoint (Fig. 3b). The
local people’s information is exactly similar to the
satellite image. The sandbar adjacent to the hardpoint
was gradually washed away in 2008 flood season. A
channel was developed adjoining the hardpoint. The
channel development and washed away of sandbar
have been verified from the satellite images of 2006
and 2009 (Fig. 3). The thalweg (katal) was very close
to the upstream termination of the hardpoint in 2009
flood season. The straight portion of the hardpoint
was damaged at two locations on 10th and 17th July in
2009. The field measured results in March 2009 is
shown in Fig. 2(b). It is found in Fig. 2(b) that the
flow is guided towards eastern part of the hardpoint
by the sandbar. The explanations of the local people
concerning failure of the hardpoint in 2009 have been
summarized here: (i) washed away of the sandbar in
2008 flood season and, (ii) development of deep
channel very close to the eastern straight part of the.
They prepared a hand sketching showing reverse
flow. The reverse flow was observed in front of the
damaged part (Fig. 2c). A flow separation zone is
produced due to scour hole development. This is the
scientific explanation of the formation of reverse flow.

The CC blocks were dumped as lunching apron.
Bamboo grids were formed for properly placement of
the CC block during the construction of the hard-
point. Geo-textile was placed under the side slope
CC block. When the local people observed that air
bubbles were bustling out from the river bed, bamboo and geo-textile were coming out to the water surface, they assumed that something is going to be happened very soon. They conveyed this information to the BWDB personnel to take necessary steps. BWDB personnel immediately arrived at the site. They started to measure the depth of water at that location. The local people requested to the BWDB personnel for dumping CC block immediately to that place where an unusual situation is being observed. But the BWDB personnel delayed for taking decision for dumping CC blocks at desired location. Ultimately, the hardpoint was damaged on 10th July 2009. One question was asked to the local people that “What are the signs before of the failure of the hardpoint?” Their answers have been summarized here: (i) bustling out of bubbles (Fig. 4); (ii) vortex flow or reverse flow close to the damage part; (iii) floating out bamboo and geo-textile to water surface.; and (iv) flowing turbid water very close to the failure part.

The explanation of bustling out of air bubble from river bed and flowing of turbid water near the failure of the bank protection works have been given by Sub-Divisional Engineer, Section Officer and Work.
Assistance of BWDB. The three explanations have been given by them. These are as follows:

1. The collapse of the lower portion of the bank protection works is shown in Fig. 4a. After failure of the lower portion of the bank protection works the unsaturated materials are pile up on the river bed. Subsequently the unsaturated materials remove by flowing water very quickly. The air entrapped into the unsaturated materials is released as bubble form when the unsaturated materials are washed away. This phenomenon is shown in Fig. 4b. Finally the air bubble is bustling out to water surface.

2. The cement concrete (CC) blocks are usually placed on the sloping side of the bank protection works. The CC blocks or other materials from the sloping side of the revetment are collapsed over the river bed. Gas is usually produced through decomposing of the organic matter and it entrapped into the bed materials. The gas is released as bubble form the river bed when the CC blocks and other materials are dumped over the river bed.

3. The bed material is mainly consisted of mica. It looks is as like as ash. This mica content bed material is very quickly washed away with flowing water. The flowing water becomes turbid when the mica is mixed with water.

The local people only can give visual observational sign of failure of the bank protection works. The field engineer can give scientific explanation of the symptom of failure of a bank protection works. But there are strong similarities between the experience-based TK and knowledge of the field engineers. The TK could play an important role in the management activity during the emergency situation. Therefore, we should evaluate the TK for the emergency management activity. So, the management program should be formulated including the local people. The local people would provide information on the basis of experience-based TK as quickly as possible accordingly the management activity could be started.

Betil and Enayetpur spurs

Flow and erosion processes

The local people always observe the flow processes around Betil and Enayetpur spurs. So, they have clear understanding on the flow and erosion processes around both spurs. They sketched the flow processes around the Betil and Enayetpur spurs. The upstream morphology of both spurs is quite similar. The confluence of the approach channels is just upstream of the spurs. They explained that the flow obliquely attacked to the earthen shank of the both spurs as shown in Fig. 5(a-b). The local people’s hand sketching has been reproduced in Fig. 5(a-b). The earthen shank of both spurs fails due to this type of flow phenomenon. Minor erosion is occurred in between Betil and Enayetpur spurs. Though the rate of erosion is negligible but the valuable hand loom industry is affected by the erosion. So, the local people are well aware about the flow and erosion processes around the Betil and Enayetpur spurs.

A hand sketching prepared by Sub-Divisional Engineer (SDE) of BWDB (22.04.2010) on the flow processes around Betil and Enayetpur spurs is shown in Fig. 5(c). Local people and technical personnel both groups explained that the oblique flow is very dangerous for the Betil and Enayetpur spurs. From the field measured result it is confirmed that the flow obliquely attacked the earthen shank as shown in Fig. 5(d). The earthen shank or belmouth is damaged almost every year due to oblique flow. It is evident from the above discussion that the local people have clear perception on flow and erosion processes as like BWDB personnel and filed measured result. The reason of frequent failure of the belmouth of the Betil spur has been explained by SDE responsible for Betil spur. The reason is that after the rehabilitation work of the Betil spur a depositional zone is developed covering most of the length of the earthen shank this spur. So, a relatively shorter length of the Betil spur is exposed to the flow. The flow obliquely attacks at exposed part of the Betil spur (i.e. at the belmouth). As a result, the belmouth of the RCC spur is damaged.

Causes of failure of spurs

The flow of both approach channels jointly attacks at the earthen shank as reported by respondents of this study. The attacking of combined flow on the spur is responsible for the structural failure. There are also some hidden causes which have been explained by Sub-Divisional Engineer (SDE) as shown in Fig. 6(a). It is true that the oblique flow attacks to the earthen shank. At the same time, flow circulation is occurred and the bed materials are removed below from the launching apron. Consequently, the launching apron is displaced and slip circle failure is occurred. The flow phenomenon along the vertical plane sketched by SDE of BWDB has been further clarified through
the field measured results. The flow circulation normal to the earthen shank of the Enayetpur is shown in Fig. 6(b). The flow circulation normal to the belmouth of the Enayetpur is shown in Fig. 6(c). The bed materials are clean out by the circulating flow. A deep channel is developed close to the earthen shank of the spur. For this reason the slip circle failure is occurred.

**Shuvogacha spur**

*Flow and erosion processes*

The rate of erosion has been increased after the failure of the RCC spurs located at Shuvogacha as perceived by respondents of this study. The main causes of the failure of the RCC spurs were the alignment of the RCC spurs. Before construction of the RCC spur, local people gave their opinion to BWDB personnel about the alignment of spurs. Their opinion was that the spur should be constructed pointing downstream direction so that the flow could pass smoothly in the downstream direction. Their proposed alignment is shown in Fig. 7. But the BWDB personnel strongly refused the local people’s proposed orientation of the RCC spurs. The spurs were constructed pointing upstream direction as per BWDB personnel decision. As a result, the flow is
strongly obstructed by the spurs. The floating debris such as banana trees, grasses, etc. were accumulated upstream of the spurs. The vortex or reverse flow was formed near the earthen shank of the spur as shown in Fig. 8. The local people showed through hand sketching that the flow passing the spur again attacked the bank line after some distance downstream of the Shuvogacha spur. Severe erosion was occurred at that location. The erosion process was continued upstream and downstream sides of the earthen shank.

The flow phenomenon is sketched by the local people after 10 years of the failure of the RCC spurs (Fig. 8). The flow phenomena also sketched by the BWDB personnel during the failure of the RCC spur (Fig. 9). A similar type flow phenomenon is found from the hand sketching of local people and BWDB personnel. The BWDB personnel showed that a reverse flow was developed adjacent to the earthen shank. A strong return current was also generated downstream side of the spur. Interesting information found from the flow processes sketched by local people (Fig. 8) is that the flow processes around a spur is quite similar to that usually found in the laboratory investigation (Fig. 10). We can confidently state that local people’s experienced-based traditional knowledge on flow and erosion processes are not less than that of the technical persons working in the field and knowledge acquired through the laboratory investigation.

**Causes of failure of Shuvogacha spur**

The local people could give clear explanations about the causes of failure of the Shuvogacha spurs.

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Fig. 6—Flow circulation normal to the earthen shank (a) Flow circulation (Reproduced from hand sketching of SDE; (b) Flow circulation normal to the earthen shank of the Enayetpur spur; (c) Flow circulation near belmouth of the Enayetpur spur

Fig. 7—Alignment of RCC spur proposed by the local people pointing downstream direction (Reproduced from hand sketching of the local people)

Fig. 8—Reverse flow formed near the earthen shank of the Shuvogacha spur (observed the by local people) (Reproduced from hand sketching of the local people)
They explained that the erosion was accelerated along the bank line just upstream of the earthen shank due to reverse flow (local term ulta aoor or vhorka). The scour hole was developed adjoining the earthen shank and bank line due to this reverse flow. Finally, the earthen shank of the spur was collapsed. Water started to flow through space in between the RCC part of the spur and the bankline. It was found from a sketch prepared by the local people (Fig. 11) that a deep scour hole is near the edge of the RCC part. They believe that after failure of the Shuvogacha spur the rate of erosion has been increased towards the mainland and a bend channel is developed.

**Bandal structures**

*Flow and erosion processes*

The sketched of the flow processes around Randhunibari bandal site as prepared by local people is shown in Fig. 12. They explained that the flow entered into the Randhunibari channel from the main channel of the Jamuna river. The flow obliquely attacks the Randhunibari market place. Then the flow changes its direction towards the south-east direction. After that the flow attacks the Char Konabari. Again, water flows towards the Mukimpur groin. It is also clarified from the filed measured result (Fig. 13) that the flow entered into the Randhunibari channel from the main channel of the Jamuna River. The flow obliquely attacks at Randhunibari market place. Then the flow changes its direction towards the Char Konabari. It is clear that the local people’s perception is exactly similar to the filed measured result.

*Fig. 9—Actual flow phenomena observed during the failure of the Shuvogacha RCC spur (Reproduced from hand sketching of the BWDB personnel)*

*Fig. 10—Typical flow phenomena usually observed in the laboratory study*

*Fig. 11—Erosion processes after failure of the earthen shank of the Shuvogacha spur (Reproduced from hand sketching of the local people)*
Conclusions and policy implication

From foregoing study it could be learned that there are similarities among traditional ecological knowledge, field engineer’s knowledge, field measured result and laboratory based technical or scientific knowledge. There are close relationships of knowledge on flow and erosion processes around different types of bank protection works. First of all, they gather acquired through visual observation. Later on they could explain their experienced-based knowledge. The local people minutely observe the flow and failure mechanism of the bank protection structures. One important issue has been investigated from the present study that the local people can guess before failure of the bank protection work observing some indications. The indications are bustling out of air bubble, floating bamboo and geo-textile and turbid water. The field engineers are agreed with the above indications. The field engineers also explained the reasons of such indications in the technical viewpoint. If the field engineers, who are involved in the management activity of the bank protection works, take help from the local people’s experienced-based TEK regarding the failure event. Accordingly, taking management program the failure event may be avoided or the degree of damage may be reduced. There is scope of integration of TEK on failure event with technical knowledge regarding management activity.

It is evident that among different groups of the riparian population, the fishermen and boatmen are well aware of the changes of the river morphology and flow processes. We can get latest information without any technical measurement on flow and erosion processes at a particular region where they always move. Although they can give gross idea but we can guess actual field situation on the basis of their given information.

The following policy should be taken:

1. The TK knowledge on related to the orientation and location of the bank protection works could be used from beginning of project in conservation of natural resources nearby river.
2. The major bottleneck of the BWDB personnel and policy makers is they avoid the opinion of the local people.
3. The local people always observe the flow process around a bank protection works or along the bank line. They can gauge the real situation regarding failure of the bank protection works and bank failure. So, the community people should include into the management body in participatory manner to evaluate the constructions and monitoring of progress or sustainability issues around the flooded/river area.
4. Community participation should be made mandatory for the line departments to make sure that TK of local community are at least consulted and taken into confidence before constructing dam/construction.
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