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The floods of Bangladesh can be divided into three categories: (i) monsoon flood - seasonal, increases slowly and decreases slowly, inundate vast areas and causes huge loss to the life and property; (ii) flash flood-from sudden torrential flows, following a brief intense rainstorm or the bursting of a natural or man made dam or levee; and (iii) tidal flood - short duration, height is generally 3-6m, prevents inland flood drainage[1]. Tidal floods are similar in effect to tidal or storm surges, and usually occur with the "movement of a tide or tidal current toward the shore or up a tidal river estuary[2]". The distinction between a flood tide and a tidal bore is nuanced; according to the Proudman Oceanic Laboratory:

> In most tidal rivers the change from ebb to flood is a gradual process. The ebb current downstream slows, there is a period of slack water and then very slowly the flood tide starts flowing upstream. In a few rivers however, the behavior is remarkably different. The onset of the flood tide is marked by a distinct and sometimes very vigorous wave - a bore[3].

The storm surges that accompany the cyclones of the Bay of Bengal cause more destruction in the coastal areas and offshore islands of Bangladesh than the very strong winds that are associated with the cyclones. These storm surges are also called Tidal Bores. Such destruction includes the widespread demolition of houses, uprooting of trees, damage of crops, roads, buildings and structures, and death to human and loss of livestock. According to MSNBC, in New Orleans, the "... Ninth Ward was hit by a tidal surge that brought 12-foot floodwaters into many of the homes[4]."

Tidal bore (or just bore, or eagre) is a tidal phenomenon in which the leading edge of the incoming tide forms a wave (or waves) of water that travel up a river or narrow bay against the direction of the current[5]. Tidal bore is also known as 'ban' in Bangla, the native language. The

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[1] AM Chowdhury, BBS 1998 Statistical Yearbook of Bangladesh (19th edition), and K Nizamuddin quoted in banglapedia.search.com, copyright Asiatic Society of Bangladesh.
[2] The war fighter's Encyclopedia, "Useful Terms"
[3] Proudman Oceanic Laboratory "Dee and Mersey river bores"
[4] MSNBC, "Fats Domino Returns home to New Orleans"
[5] Wikipedia contributors, "Tidal bore," *Wikipedia, The Free Encyclopedia.*

precondition for the creation of a tidal bore is the existence of an outflow current speed from the mouth of a river that exceeds the incoming speed of waves from the ocean associated with the incoming tide. The wavelength of tidal waves is longer than the depth of the shallow water near the shore, so they move shoreward with a velocity that depends upon the water depth[6]. The most famous of the tidal bores is that in the Tsientang Kiang estuary in China. Tidal bores are more prevalent under the conditions of spring tides when the gravitational pulls of the Sun and Moon are in phase. Tidal bores occur in the Amazon River, the Severn River in England, the Petitcodiac River at the head of the Bay of Fundy, and the Seine, Orne and Gironde Rivers of France[7]. Tidal bores are very like tidal surges, except that both natural phenomena vary in intensity based on prevailing natural conditions.

For instance, the Thames River in London, U.K; according to the Environment Agency, the main causes for the flood surges are rising tide levels, due to a combination of factors including higher mean sea levels, greater storminess, increasing tide amplitude, the tilting of the British Isles (with the south eastern corner tipping downwards) and the settlement of London on its bed of clay[8]. According to the same agency, London and the Thames have a history of flooding:

> The last time that central London flooded was in 1928 when 14 people drowned. In 1953 there was disastrous flooding on the East Coast and the Thames Estuary with a toll of over 300 lives. If this flood had reached central London's highly populated low lying areas the result could have been horrifying beyond measure[9].

For the Thames, however, the notion of a movable barrier has been implemented, which is "a series of ten separate movable gates positioned end-to-end across the river. Each gate is pivoted and supported between concrete piers that house the operating equipment. Closing the barrier seals off part of the upper Thames from the sea. When not in use the six rising gates rest out of sight in curved recessed concrete cills in the riverbed, allowing free passage of river traffic though the openings between the piers. If a dangerously high tidal surge threatens, the rising sector gates are moved up though about 90° from their riverbed position and the four radial gates are bought down into the closed defense position. The gates thus form a continuous steel wall

[6] Hyperphysics "Tidal Bores", Georgia State University.
[7] Hyperphysics, "Tidal Bores", GSU.
[8] Environmental Agency, "Thames Barrier"
[9] EA, "Thames Barrier"

facing down river ready to stem the tide. Further rotation of the gates to the horizontal maintenance position renders them accessible for routine maintenance. [10]."

In other parts of the world, tidal bores have been known to occur, wherever estuaries or rivers come into contact with an ocean. One such place is Petitcodiac River in the Bay of Fundy, in New Brunswick in Canada, where the surge used to be the highest in North America, reaching up to 7.5 meters (25 feet) high. In 1968, a causeway was constructed which deleted the negative effects of this surge[11]. At present, this causeway has come under attack for causing grave ecological danger to the bio-diversity of that region; however, this is due to its poor design, which includes only a narrow sluice gate, which makes no room for the migration of aquatic organisms[12].

In Bangladesh, tidal bores are observed in the Meghna estuary and other southern coastal areas in the months of April-May and also between September-December. According to HS Mozaddad Faruque, the director general of Water Resources Planning Organization (WARPO), tidal bores are "much more devastating in Chittagong, Cox's Bazar, Barisal, Noakhali, Patuakhali, Barguna and Khulna. In the Meghna estuary, the 1970 Cyclone (Nov 12-13) with cyclonic surge of 3.05m to 10.6m high with wind speed of 222 km/h occurred during high tide causing most appalling natural disaster claiming 0.3 million human lives. On the 29 April 1991 a devastating cyclone hit Chittagong, Cox's Bazar, Barisal, Noakhali, Patuakhali, Barguna and Khulna along with tidal bore of 5-8m high with wind speed of 240 km/h which killed 150,000 human beings, 70,000 cattle head, and the total loss was about Tk 60 billion[13]".

It would seem there is much to learn from the Thames experiment in movable gates, at least as a solution to tidal floods that can be used in conjunction with other flood control measures. Causeways also merit serious attention. According to the Wikipedia, "a causeway is a road elevated by a bank, usually across a broad body of water or wetland. A roadway that is carried instead, on a series of arches, perhaps approaching a bridge, is a viaduct. In the U.S. a brief stretch of viaduct is called an overpass. The distinction between the terms *causeway* and *viaduct*

[10] EA, "How the Thames Barrier works"
[11] Wikipedia, "Tidal Bore".
[12] Wikipedia contributors, "Petitcodiac River," *Wikipedia, The Free Encyclopedia.*
[13] HS Mozaddad Faruque, "storm surge and tidal bore", banglapedia.net

becomes blurred when flood-relief culverts are incorporated[14]."

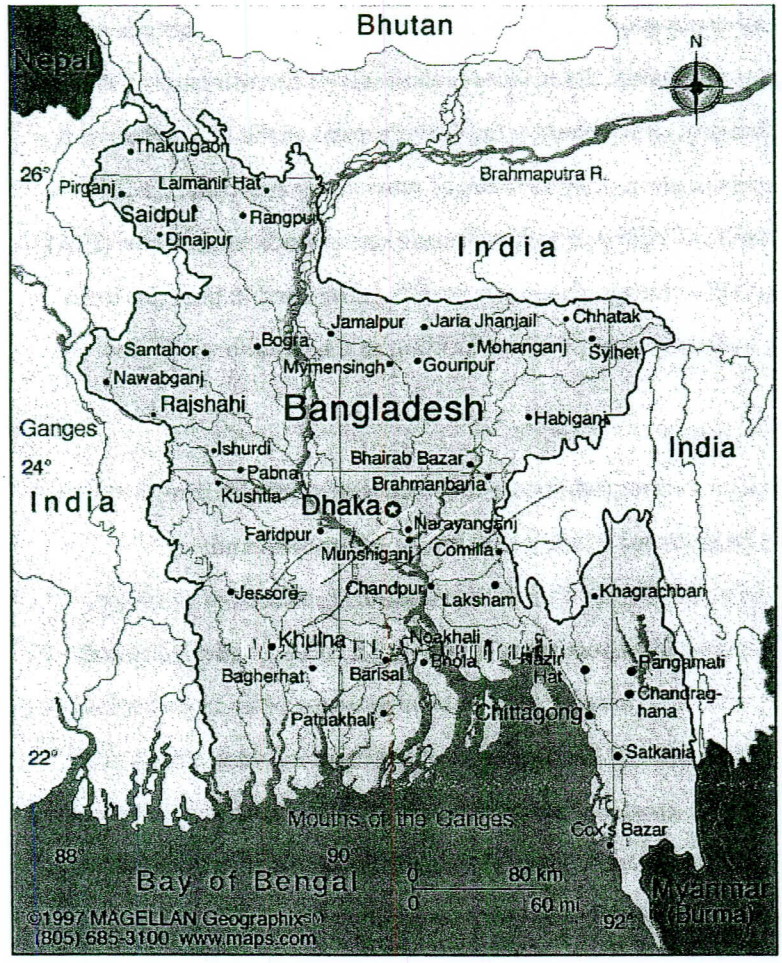
The Center for Environmental and Geographic Information Services (CEGIS) is an organization for integrated environmental analysis using geographic information systems and remote sensing, as well as information technology and databases. Set up under the aegis of the Ministry of Water Resources, Government of Bangladesh and supported by the Government of the Netherlands, it became an independent registered organization after 10 years of working as a project. CEGIS came into full operation from July 2002[15]. CEGIS did an Environmental Impact Assessment (EIA) in order to contrast the pros and cons of building causeways versus regulators, in order to form the basis for a proposal for building a causeway to prevent flooding due to tidal bores in the affected regions[16].

Many of the affected non-coastal regions in Bangladesh are so affected due to their direct connection with haors. According to M Shamsul Alam, professor of geography and environmental Studies at Rajshahi University, and Md Sazzad Hossain, Professor of Geology, Dhaka University, a Haor is a bowl-shaped large tectonic depression. It receives surface runoff water from rivers, and consequently, a haor becomes a very extensive water body in the monsoon and dries up mostly in the post-monsoon period. During monsoon a haor is a vast stretch of turbulent water, and high winds can cause great destruction to neighboring villages due to the waves created in these haors. However, Haors are also rich in alluvial soil, which is good for growing rice, as well as a premier location in Bangladesh for bio-diversity[17].

A study carried out by CEGIS found that there were negative experiences related to the functioning of sluices and regulators in different haors. Since there has never been a causeway built in Bangladesh before, the study was carried out in order to "identify the environmental impacts of the project components, specially the causeways and to develop an Environmental

[14] Wikipedia contributors, "Causeway," *Wikipedia, The Free Encyclopedia.*
[15] CEGIS, "about us", www.cegisbd.com.
[16] CEGIS, "EIA on replacing regulators with causeways in the Khaliajuri Flood Control and Drainage Improvement Project area", projects, www.cegisbd.com.
[17] Shamshul Alam & Sazzad Hossain, "Haor", banglapedia.net.

Management Plan (EMP), including mitigation measures for minimizing adverse impacts and an enhancement plan for increasing the positive impacts[18]."



This led stakeholders and field engineers of the Bangladesh Water Development Board (BWDB) to plan alternatives to sluices/regulators for preventing flash floods and facilitating drainage and navigation. Policy makers and political decision makers were also involved in the effort to plan such alternatives.

The impacts of the causeways were studied based on "different environmental parameters". It was found that poverty on an overall basis would be alleviated, and that constructing and maintaining such a causeway would aid in increasing fish migration and the size of the catch[19]. According to CEGIS, constructing causeways "... will provide more control against flash floods,

[18] CEGIS, "projects"
[19] Ibid.

and reduce drainage congestion and water logging. Agricultural production will be increased by 2,000 metric tons and damage will be reduced by 1,000 metric tons. The fish migration status will improve and fish disease will be eradicated. The terrestrial and aquatic land ratio will increase from 65:35 to 80:20, which will increase grazing land and improve wild life fish habitat. Moreover, the long demand of water transportation will be facilitated; the health and nutrition of the local people will be improved…[20]"

CEGIS also claimed that no one measure can be the be all and end all of flood control in the deltaic flood plains, and that processes like dredging should supplement the building of the causeway[21]. The organization emphasizes that care should be taken while designing and implementing the causeway: that it is important for the affected local population to be stakeholders in the project, that the causeway should not be built at all twenty-two locations i.e. where the haors exist, and that great care should be taken to ensure the ecological well-being of the area would not be affected by the causeway[22]. This seems a wise warning, especially since too often historically, as in the case of the Petitcodiac River, little care is taken in the building of causeways, and, in the Canadian case, not only did this cause serious ecological damage but it also directly benefited only a tiny minority of the population who lived near the Petitcodiac River[23]. However, with proper care and modern, environmentally conscious design, it should be possible to implement the causeway to the satisfaction and benefit of the majority of the affected population in Bangladesh.

CEGIS recommends that only one or two pilot spots should be chosen for the first causeways to be implemented, and they emphasize that in comparison to regulators, which are at present the most widely used method of flood control, causeways, "…are more environmentally friendly, socially acceptable, flexible … [this, in addition to being] the least costly …"[24]

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[21] CEGIS, "projects"
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[23] Wikipedia contributors, "Petitcodiac River".
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