Potential Application of Early Warning System for Urban Flooding: Case Study of Central Part of Dhaka City

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Abstract

Flooding in Dhaka City occurs for both excess rainfall and rise of river water level in monsoon. The central part of Dhaka city which is protected by embankment usually experiences flood due to excess rainfall or urban flooding. The unprotected area is affected by river flood as Dhaka is surrounded by rivers. In recent history, extreme rainfall events in 2004, 2007 and 2009[2] have caused major damage and suffering to the city dwellers. The major problem with central part is to deal with the excess overland flow due to heavy rainfall.

The city has four large lakes among which the Central part of Dhaka city drains to "Hatirjheel Lake". With the help of Early Warning of heavy rainfall, the retaining capacity of this lake can be utilized to the effect of the excess rainfall runoff.

The effect of the early warning system is analyzed using mathematical models and reduction of damage is calculated in Taka. It is observed that using this system can reduce the damage significantly.

1. Introduction

Dhaka is the hub of all economic and social activity of Bangladesh. As the economy of the country is growing, the city is growing with it and also the land use pattern is changing. New development such as high rise building, paved roads etc. are increasing the impervious areas of the city. Therefore the runoff due to rainfall is increasing. The unplanned manner of the growth of the city is not helping the cause. Furthermore the low lying areas, flood flow zones and lakes are being filled up by land grabbers.

The central part of Dhaka city is the heart of development and the drainage system of this part of the city drains to lake named "Hatirjheel". The lake is recently renovated and the retaining capacity of the lake has increased. Also a pumping station of 25 cumec is being constructed at the outfall of the lake[3] to pump out excess water.

With the help of early warning system the retention capacity of the lakes can be increased by pumping out the water and reducing water level at the lake. The sluice gates connecting the lake to canals will also be closed. The response of the drainage system was simulated using mathematical models and the economic analysis was done following the depth damage curve of "Strengthening the Resilience of the Water Sector in Khulna to Climate Change"[1]. These damage curves were produced for another megacity Khulna with the same characteristics. The objective of the study was to calculate the effect of early warning system.

2. Objective

The objectives of this study are the followings:

i. Generate flood maps using a 1d-2d coupling model for different scenarios.

ii. Analyze flood depth for different types of structures for different scenarios.

iii. Calculate damage due to flood for different scenarios using depth-damage curves.

iv. Reflect the effect of early warning system for the study area.

3. Methodology

This study has two components. One is to develop a mathematical model for the drainage system and generate flood maps and another one is to calculate the damage due to flood using depth-damage curves for different scenarios. The following scenarios are analyzed:

i. Water level of Hatirjheel Lake at 4m.
ii. Water level of Hatirjheel Lake at 6m.

4. Study area

The study area is located at the center part of Dhaka city. The boundary of the area is defined by the "Pragati Sharani" at east, "Mirpur Road" at the west, "New Airport Road" at the north, "New Elephant Road" at the south west and "Kakrail Road" at the south east. The total area is 26.5 km^2. The study area is shown in the **Figure 1**.

5. Drainage system

The drainage system of the study area is complex. It contains piped drainage as well as open channels. The drainage system has 5.4 km of box culvert of different size, 90.3 km of pipe network of different diameter and 4 sluice gates. The areas of “Gulshan” and “Banani” drains to adjacent lakes which drain to “Balu” river through “Hatirjheel” lake and “Begunbari Khal”. The only pump station is situated at “Rampura Bridge”, outfall of “Hatirjheel” lake. The capacity of the pump station is 25 cumec. The drainage system works by gravity in the dry season. But when the water level at Balu River is higher in monsoon the gates of the regulator at “Rampura Bridge” is kept close. In the event of rainfall of higher intensity and duration, the excess water from rainfall runoff is pumped out. The components of the drainage system along with the drainage catchment are shown in **Figure 1.**

6. Hatirjheel Lake

Hatirjheel Lake is situated at the central part of Dhaka city and it is an essential element of the drainage system of the city. The maximum surface area of the lake is 20 km^2. The lake is recently renovated. The bottom level of the lake is at -1.5 mPWD and the elevation of the roadway surrounding the lake is 7.5 mPWD[4]. The retention capacity of the lake is 1.5 million m^3 within 4m to 6m water level. The pumping hour required to reduce the lake water level from 6m to 4m is 14 hours considering efficiency of the pumps at 90 percent. The area elevation curve of the lake is shown in **Figure 2**.

7. Rainfall event

The average annual rainfall of Bangladesh is about 2000mm and 80% of that occurs in the monsoon. The intensity of the rainfall event has increased in the recent years. Three major event have occurred recently in 2004 (340 mm in 24 hours), 2007 (260 mm in 24 hours) and 2009 (333mm in 12 hours)[2]. The maximum daily rainfall is increasing as shown in **Figure 3**. All these events have caused huge economic damage and hazards to the city dwellers. For this study the real event of the 2004 is considered.

8. The mathematical model

A mathematical model is prepared to analyze the drainage system using Mike Urban. First the network was digitized and the properties of the network such as invert level, ground level, pipe diameter, slope, roughness, diameter of the manhole etc. were provided. The size and the operation criteria of the drainage structures and pumps were also incorporated. A 1D-2D couple model was prepared using this model and a 25mX25m DEM (Digital elevation model). The water level of Balu River was used as boundary condition at the outfall. Flood maps were generated for different water level at Hatirjheel from the simulated result of the 1d-2d couple model.

9. Land-use pattern

The land-use pattern is collected from DAP (Detail Area Plan) of RAJUK (Rajdhani Unnayan Kartripakkha). Percentage of the area of different land-use within the boundary of study area is provided in **Table 1.**

10. Results of the mathematical model

The result of the 1d-2d couple model is presented in the flood map shown in **Figure 4 and 5.** The number of effected structure for different flood depth is presented in **Table 2.**

11. Damage calculation

The damage calculation was done by using the depth-damage curves used in “Strengthening the Resilience of the Water Sector in Khulna to Climate Change”[1], a study conducted by IWM (institute of water modelling) for ADB (Asian development bank).

Survey was conducted to collect information about the damages incurred due to past events of similar natural disasters. Data from household survey provided information related to household losses due to these events in the past 10 years which could be traced in terms of loss of income/employment, losses in terms of sickness and sufferings from it, damages to assets and houses including trees. There were both tangible as well intangible damages and not all the damages were reported in monetary terms.

For estimation of the damage function beyond the level of water logging, a pseudo-damage function was used with some heuristic assumptions. This is because, the extent of future damage depends on the depth of water logging and also that the rate of change in the damage may not be the same. It was observed that duration of water logging do not significantly increase financial damages at the household. This is because households resort to some temporary mitigating activities (like relocation of families, shifting of valuable assets in safe area etc.) to avoid damages. Most of the damages occurred during the initial period of water logging. Based on this observation, FGD with

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 3 Issue 1, January - 2014

the households in the affected areas was conducted to estimate an extreme point. Using these information a depth-damage curve was generated as shown in **Figure 6.**

Damages to other sectors of the Khulna economy due to flood were also required for this analysis. In order to assess this, the study named "Strengthening the Resilience of the Water Sector in Khulna to Climate Change" conducted focused group discussion in the affected areas with representatives from a) the industrialists, b) the manufacturing firms, c) the government agencies, d) local hospitals, and so on. The objective was to assess the damage function in terms of % of output per year with different level of water logging. Based on several FGD results, the damage function for these sectors of the economy was estimated with hypothetical estimate of damages at different water logging levels in that study. Damage functions are shown in **Figure 7 to 11** for industry, manufacturing, commercial enterprises, agriculture and for public roads respectively.

12. Findings of Damage calculation

The calculated damage to different types of structure for both scenarios is provided in **Table 3**. The comparison between total damage and damage to different types of structures for both scenarios are shown in the **Figure 12 to 14.**

The result shows significant reduction of damage. The damage reduces by 1,739 million taka after deduction of cost of pumping to reduce the water level of the lake. The power consumption of five pumps of 5 cumec and 340 kw[5] costs about 1,54,224 taka.

13. Conclusion and recommendation

The early warning system is an advance system. This study shows that this system can be used to reduce damage due to flood. The runoff of the study area catchment will increase due to unplanned and rapid urban growth. The excess water from runoff can be handles by increasing the retention capacity of the Lakes with the help of early warning of heavy rainfall. The structural measures such as new pipelines, control structures and pumps can reduce the flood extent and damage but these options are extremely costly for a densely populated city like Dhaka. On the other hand, the use of early warning system can reduce the damage for very little cost. Therefore, it is the most cost effective solution for a country like Bangladesh and this system should be used by authorities to improve the flood situation.

The only hurdle is to ensure the co-operation between the agencies. This system requires high level of communication between the Bangladesh Meteorological Department (BMD) and Dhaka Water Supply and Sewerage Authority (DWASA). An emergency protocol can be developed through which the agencies will prepare a warning of heavy rainfall and respond accordingly to reduce the effect of flood.

14. Annex

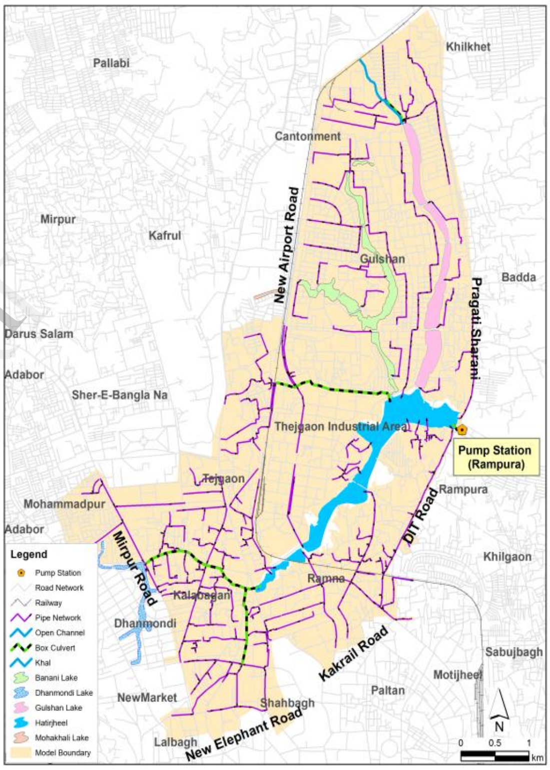

Figure 1: Drainage system of Hatirjheel Lake

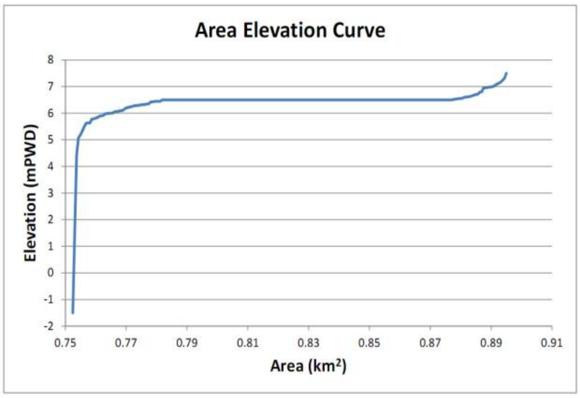

Figure 2: Area Elevation Curve of Hatirjheel Lake

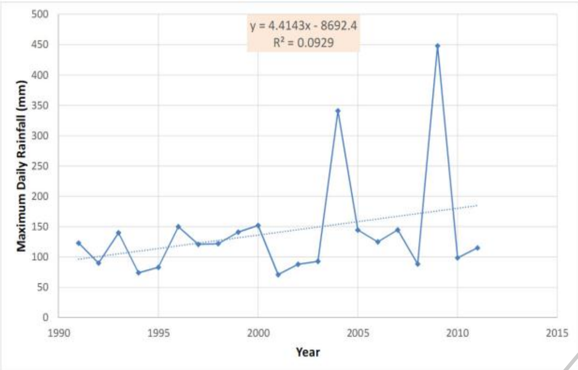

Figure 3: Maximum Daily Rainfall of Dhaka City

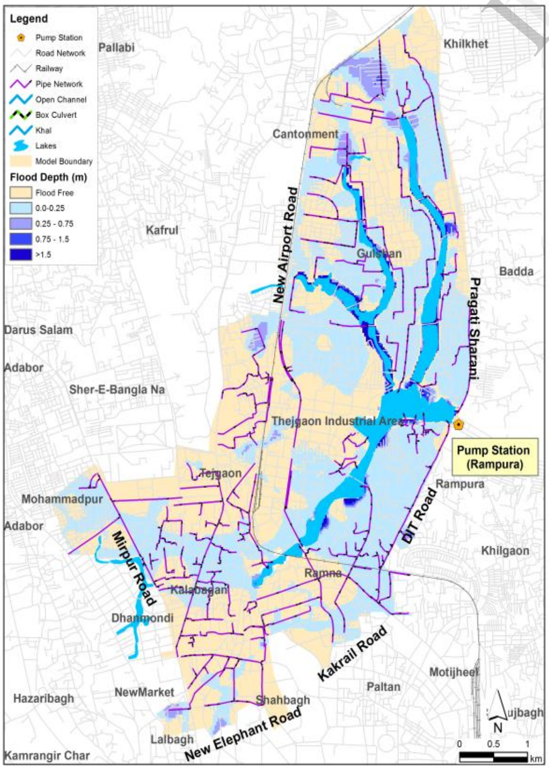

Figure 4: Flood map for scenario i

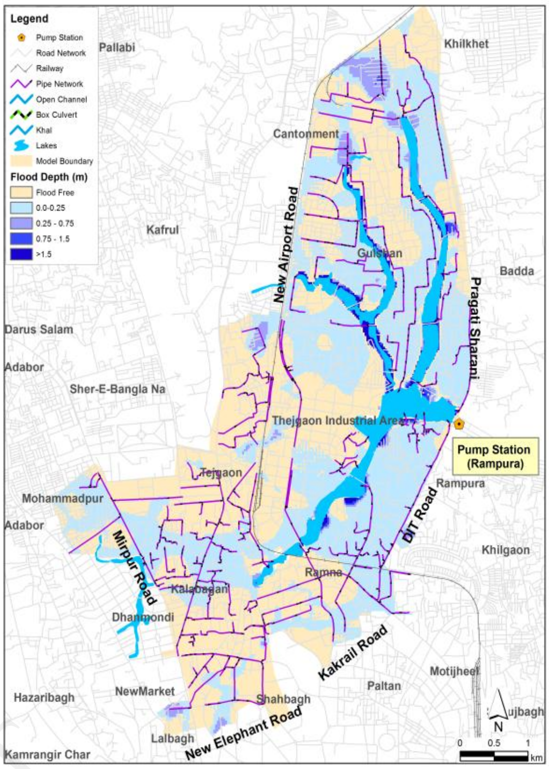

Figure 5: Flood map for scenario ii

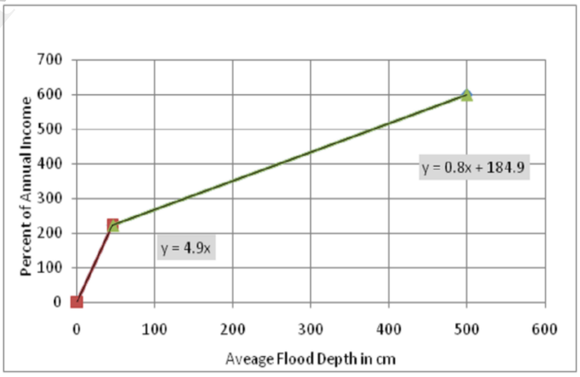

Figure 6: Depth Damage Curve for Residential Structures

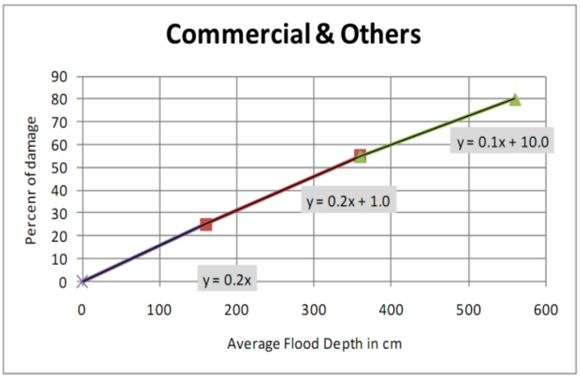

Figure 7: Depth Damage Curve for Commercial Structures

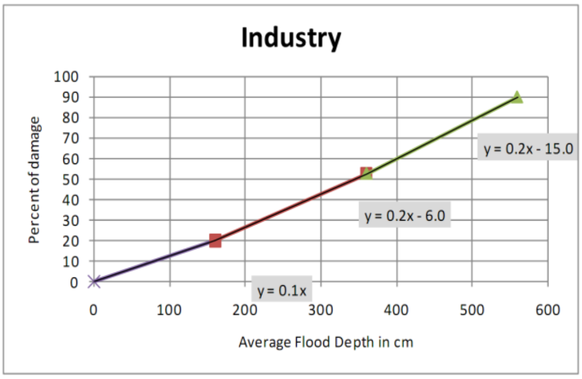

Figure 8: Depth Damage Curve for Industrial Structures

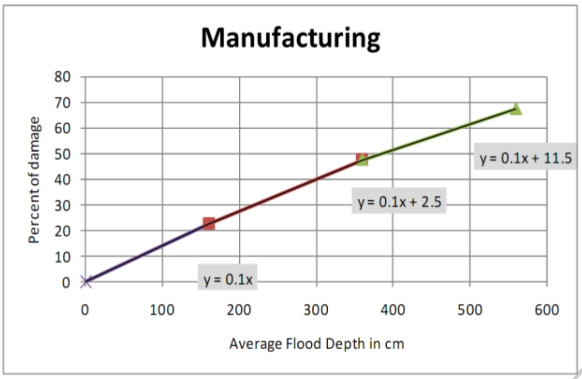

Figure 9: Depth Damage Curve for Manufacturing Structures

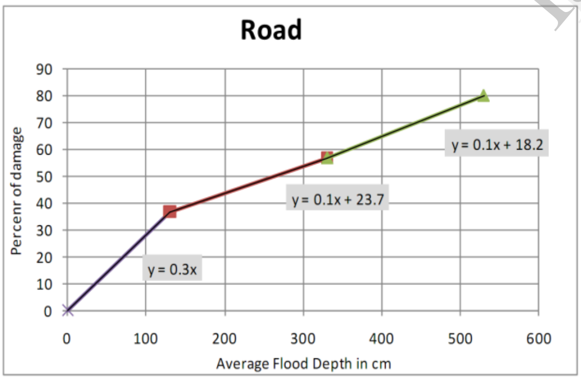

Figure 10: Depth Damage Curve for Roads

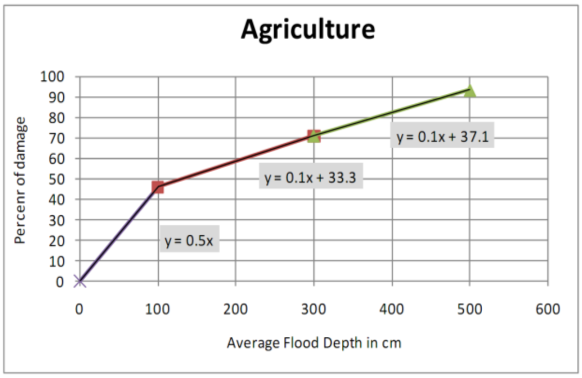

Figure 11: Depth Damage Curve for Agriculture

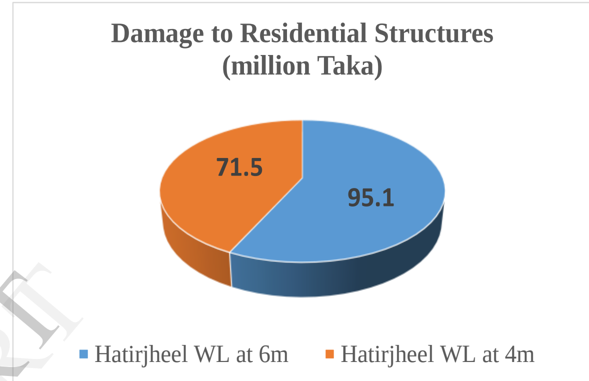

Figure 12: Damage Comparison for Residential Structures

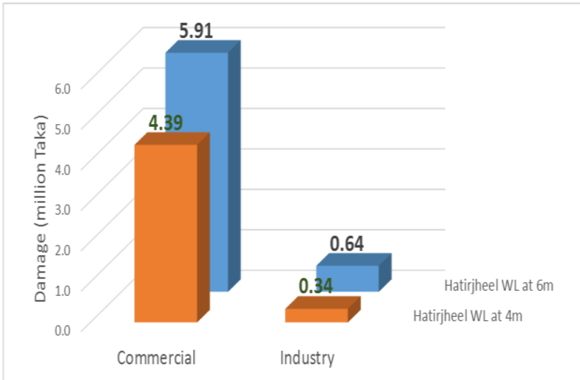

Figure 13: Damage Comparison for Commercial and Industrial Structures

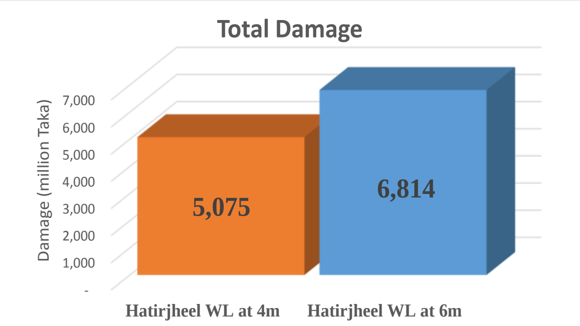

Figure 14: Comparison of Total Damage

Landuse	% of total area
Residential	39.15
Mixed Use	11.48
Circulation Network	10.84
Water Body	8.30
Restricted Area	7.46
Manufacturing and Processing Activity	6.13
Diplomatic	5.43
Recreational Facilities	3.83
Education & Research	2.76
Commercial Activity	2.18
Service Activity	1.50
Vacant Land	0.93

Table 1: Landuse as % of total model area

Structure Type	No. of effected Structure for different flood depth (scenario i)		No. of effected Structure for different flood depth (scenario ii)	
	0.0 to 0.25	0.25 to 0.75	0.0 to 0.25	0.25 to 0.75
Commercial Activity	492	19	609	53
Community Service	32	5	50	8
Education & Research	57	0	78	13
Governmental Services	2	0	5	1
Manufacturing & Processing Activity	51	13	90	30
Mixed Use	476	19	643	53
Non Governmental Services	4	0	4	0
Recreational Facilities	0	0	2	0
Residential	6180	538	7682	1132
Restricted Area	1	0	1	0
Service Activity	159	17	216	49
Transport & Communication	18	2	20	2

Table 2: No. of effected structures by type and for different flood depth

15. Reference

[1] Bangladesh: Strengthening the Resilience of the Water Sector in Khulna to Climate Change, Asian Development Bank (ADB), Dhaka, August 2010, Project Number: 42469-01.
[2] Sonia Binte Murshed, AKM Saiful Islam and M.Shah Alam Khan, Impact of Climate Change on Rainfall Intensity in Bangladesh, 3rd International Conference on Water and Flood Management, ICWFM, Dhaka, 2011.
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[4] Integrated Development of Hatirjheel Area Including Parts of Begunbari Khal, Rajdhani Unnayan Kartripakha (RAJUK), Dhaka, June 2008, Mid-Term Report.
[5] Feasibility Study on the Frainage Improvement of Dhaka-Narayanganj-Demra (DND) Project, River Reaserch Institute (RRI), Dhaka, February 2010, Draft Final Report (Volume-2).