A STUDY ON LAND USE POLICIES OF KHULNA STRUCTURE PLAN 2000-2020 IN THE LIGHT OF CLIMATE CHANGE INDUCED FLOOD SCENARIO

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Dedication

Dedicated to My Respected Parents, Beloved Wife and Daughter

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Abstract

Khulna, the third largest metropolis of Bangladesh has been identified as one of the 15 most vulnerable coastal cities under climate change. Approximately 20% to 25% territory of the country is inundated during the monsoon, which will be exacerbated due to the climate change, especially in the coastal region. Khulna City is home to around 1.3 million people and is within the Khulna Development Authority (KDA) area of which land use structure is consisted of 46% residential, 18% agriculture, 15% industrial, and 5% commercial. The land use pattern here has been substantially influenced by the flow of the Rupsha and Bhairab Rivers. The whole metropolitan area is poorly drained and approximately 2.5m above the mean sea level. Such low elevation of the city is an obstacle to the development of a proper land use plan. Climate change effect especially sea level rise and flooding is being added to this problem and the situation is supposed to be aggravated in the future. The structure plan prepared by Khulna Development Authority (KDA) in 2000 for regulating growth till 2020 considered a number of factors but it did not consider the climate change impacts. Therefore, it is pivotal to analyze the land use plan and policies of KDA development plan in the light of climate change induced flood effects. Flood damage analysis needs to be carried out with the help of Digital Elevation Model of Flood and stage-damage functions using Geographic Information System (GIS) grid-based approach for analyzing the proposed land use plan and policies. This approach is classified further into two namely aggregated land use based and object-oriented (building foot- print). Due to simplification and having lack of available data, aggregated land use based approach has been selected. Flood damage will provide better understating of the future flood risk, which facilitate the decision makers especially KDA in taking the appropriate actions on flood mitigations and preventions, and making any change on the on-going projects or assessing the Structure Plan and development needs of the city as well. Research findings show that the climate change will cause damage to property at different parts of the city depending on land use in 2020. Maximum damage is estimated to commerce sector (1937 million Taka) and next to industrial sector (124 million Taka). Minimum damage is estimated to agricultural sector after residential use. Proposed commercial land uses are recommended to be reviewed for relocation in flood free areas of the city.

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List of Acronyms and Abbreviations

ADB	Asian Development Bank
^{o}C	Celsius Degree
CRES	Center for Resource and Environmental Studies
DEM	Digital Elevation Model
FGD	Focus Group Discussion
GBM	Ganges-Brahmaputra-Meghna
GDP	Gross Domestic Product
GIS	Geographic Information System
KDA	Khulna Development Authority
KCC	Khulna City Corporation
KUD	Khulna Urban Drainage

LEDC	Less Economically Developed Countries
IWM	Institute of Water Modelling
NSF	National Science Foundation
SLR	Sea Level Rise
USACE	U.S. Army Corps of Engineers

List of Technical Terms

Beel	Closed larger Water body
Khal	Water channel
Kancha	Earthen
Pourashava	Municipality
Pucca	Concrete in case of building, bituminous in case of road
Upazila	Third tier in the administrative unit / Thana
Zila	Second tier in the administrative unit District

Chapter 1: Introduction

1.1 Background of the Research

Bangladesh consists of very low lying deltaic floodplains (80%), with 70% of its land area being less than one meter above sea level (LEDC, 2006). Approximately 20% to 25% of its territory is inundated during the monsoon season (Hossain, 2003). It is believed that this flood scenario will exacerbate due to climate change, especially in the coastal zone. Bangladesh is one of the most vulnerable countries of the world due to climate change. The southern part of Bangladesh is devastated by cyclone; high tidal wave sinks in the saline water of the sea permanently, submerging of the low-lying areas by sea level rise, tidal floods and, losing of biodiversity.

Khulna, the third largest metropolis (about 45 km^2) in Bangladesh (Khulna City Corporation, 1984) has been identified as one of the 15 most vulnerable cities under climate change impact and it has been considered as one the most vulnerable coastal cities (Roy, 2009). The city is home to around 1.3 million people (Khulna City Corporation, 1984). According to the land use survey undertaken for Khulnaǿs Master plan, about 46% of the Khulna City Corporation (KCC) area is occupied by residential use and about 18% of it is agriculture. Near about 15% lands is under industrial use, small percentage (about 5%) of land is under commercial use (Khulna Development Authority, 2002b). The land use pattern of Khulna City has been substantially influenced by the flow of the Rupsha and Bhairab Rivers (*See* Figure 4-2). As a deltaic plain the land is flat and poorly drained. The whole metropolitan area is approximately 2.5m above the mean sea level. Such low topography of the city is an obstacle to the development of a proper land use plan (Asian Development Bank, 2010). Climate change caused by sea level rise is adding to this problem and the situation is likely to be aggravated. Apart from this, the major concerns for Khulna City are frequent and increased level of floods, storm surges, intensity of cyclones, water logging, saline intrusion, and sedimentation and river erosion (Roy, 2009), which are expected to be particularly severe due to the consequences of climate change because of its geographical location. Lately, Institute of Water Modelling has carried out a study titled as ñBangladesh: Strengthening the Resilience of the Water Sector in Khulna to Climate Changeò financed by Asian Development Bank. The study was developed and analyzed several climate change scenarios in order to assess the impact of climate change on the water sector of Khulna using several mathematical models. The Urban Drainage Model was able to show different water logging conditions of Khulna City. It showed that for 2020, a plausible low scenario of 10cm was selected and a plausible high scenarios of 25cm (Asian Development Bank, 2010). The model was based on different input data viz. precipitation, surface runoff, existing drainage facilities, existing catchments, sea level rise, etc.

Khulna Development Authority (KDA) prepared the Urban Structure Plan in 2000 for the proper growth management of Khulna City till 2020 maintaining almost all possible factors namely transport, physical and social factors, land use etc. (Khulna Development Authority, 2002b). However, climate change issues were not considered. It is critical to analyze the plan in the light of climate change induced flooding as low-lying land could be severely imparted. Flood damage analysis needs to be carried out on the planǿs present land use policies and proposals to reduce the potential damage. Flood damage implies susceptibility to physical and economic damage. ñThe importance of assessing potential flooding becomes evident when policy makers and planners try to strike an optimal balance between the development needs of a particular area and the levels of flood risk society is ready to acceptò (Global Water Partnership & World Meteorological Organization, 2007). There is a pressing need to have sufficient understating of the future flood risk of this city, which can facilitate the decision makers in making timely changes in the policy of their structure plan, i.e. climate change adaptation planned.

1.2 Justification of the Research

Khulna City, headquarter of the south-west region of Bangladesh, is situated in the coastal region. It is the hub of political and socio-economic activities. The region is characterized by frequent and increased level of floods, storm surges, and intensity of cyclones, water logging, saline intrusion, sedimentation, and river erosion. Dimension of impact of these natural phenomena is different and is on different sector. These natural phenomena have been occurring for hundreds of years, where the region largely Khulna City is subsisting on and is growing larger. Climate change is added to the above and reduces the resilience of the region especially the Khulna City. Climate changes create some impacts especially sea level rise due to global warming firstly and secondly, mostly increase the degree of impact of the prevailing natural phenomenon viz. flooding especially urban flooding for the city. Sea level rise, tidal effects, and lack of maintenance of urban drainage are likely to worsen the urban flood situation of the city. Due to this flooding, different types of land use are being affected by varying degrees based on the spatial location of the use, and depth and duration of the flood. Within the same depth and duration of the flooding, different types of land uses is being damaged on differently especially industrial and commercial land uses is being damaged more. That is to say, different land uses have different amount of damage to the flood. This is why flood damage of different land uses is important to know in order to reduce the degree of damage by flooding by relocating the existing uses and proposes the futures uses in the safer places. Decision makers who are especially involved in the planning and development of the city, stakeholders, flood managers, climate change researchers, etc. will be benefited from the outcomes of this research.

1.3 Research Objectives

This research aims to assess the potential flood risks, which would help the planning authority to make necessary changes in the proposed plan. For this, the following two objectives have been developed.

1) To assess the potential flood damage in the KCC area due to projected climate change scenario based on selected damage functions.
2) To analyze the major land use policies and proposals within the Khulna City Corporation Area of the structure plan 2000-2020 for Khulna Development Authority in the light of the above objective.

1.4 Possible Outcomes

This research will provide better understanding to the planners and flood managers (Khulna Development Authority, Khulna City Corporation, etc.) in taking the appropriate actions on flood mitigations and preventions, making any change on the on-going projects or in the present plan and future development needs in this flood plain. This research will be helpful especially for the Khulna Development Authority to take any adaptation measure on its structure plan in light of climate change induced flood.

1.5 Scope and Limitations

Khulna Region is often affected by different natural phenomenon namely cyclone, tidal flood, storm surge, etc. and in some cases these disasters have interactive relationship among themselves. Each phenomenon has distinct dimension of impact with distinct characteristics. Climate change effect, a new dimension is added to these natural phenomena and worsens the situation. This research includes climate change induced potential flooding within the Khulna City Corporation area. Impact of this type of flooding is multifarious on different land uses. Only the tangible and economic damage caused by the flooding on the general land uses of the city have been selected to avoid the complexities of working with different complex variables, long-termed social impact, in-depth investigation of the intangible damage, etc. Flood impact on the general land use has been expressed as the flood damage, which includes only the physical and economic damage. Later on with the help of this flood damage, the existing structure plan of the Khulna Development Authority was assessed. Both the existing and future land use of the plan was assessed. Considering the climate change impact on different land use, the best possible alternative location of the land use having worst damage has been suggested.

The degree of impact of climate change induced flood on various sectors is diverse. The research therefore, should be conducted to get the more precise result. But due to a number of constraints, some selected parameters and tangible and economic impact of flooding were selected. Time constraints, resource scarcity, unavailability of primary and secondary data, lack of field investigations are mentionable. Considering the volume of work, frequent field investigation, extensive primary and secondary data collection, complex parameters, and finally assessment of the modeled result, structure plan and potential impact by the potential situation, the research actually should require much time and huge resources. In this regard, this research got less resources and time. Another major drawback of the research was technical especially the distance between the study area and the educational institution of the researcher was far, which was quite impossible to visit the study area frequently. For all these reasons, the research was conducted based on GIS-grid based methodology to overcome the major drawbacks getting the best results. If the constraints were eradicated really with great care, the research would expect better result.

1.6 Outline of the Thesis

This research intends to focus on the flood damage analysis in order to comprehending the potential loss caused by the climate change induced flood on different land uses. Spatial location of the potential losses at variant amount of both, existing and proposed land uses of the structure plan 2020 will be explored here that will help finding the best possible location of those land uses. This work has been organized and represented under seven chapters in this report. The content and structure of the chapters are briefly outlined below.

Chapter 1: Introduction **–** This described the background, justification of the study. It also aimed to state objectives of the study, possible outcomes and scope and limitations of the study.

Chapter 2: Conceptual Framework ï This is mainly comprised of literature reviews stating the theoretical and conceptual framework of the research. It helps understanding the background of the study by upbringing the aspects behind the backdrop of the study in a sequential manner. Various types of terminology associated with for making out as well as carrying out the research are discussed herein.

Chapter 3: Methodology of the Research **-** This chapter intended to portray the ways, methods and methodologies of the research sequentially. It also outlined the research questions that this study would answer.

Chapter 4: Study Area Profile ï This chapter concentrated on an overview of the study area incorporating its socio-economic, environmental, physical and demographic characteristics. Past flood events and subsequent losses are also embodied in this chapter.

Chapter 5: Review of Land Use Policies and Proposals ï Discussion of different land use policies of the Structure Plan 2020 for Khulna Development Authority within the study area has been provided herein.

Chapter 6: Estimating Flood Damage and Analyzing Polices and Proposals ï This outlined the spatial distribution of flood damage of different land use due to climate change and with this damage, assessed the compatibility of the existing and proposed land uses of the proposed plan.

Chapter 7: Research Findings, Recommendation and Conclusion ï This recommended some measures especially the best possible location of highly flood affected land uses with research findings.

Chapter 2: Conceptual Framework

This chapter explicates the theoretical and conceptual approach applied in this research, different types of technical terminologies, functions, limitations related to the flood damage development and assessment, Geographic Information System and its associated terms.

2.1 Flood Scenario of Bangladesh

Floods are common in Bangladesh, where floodplains constitute about four-fifths of the landmass. The country is situated at the end of the catchment area of the GBM (Ganges-Brahmaputra-Meghna) river systems, occupying only about 7.5 percent of the combined catchment area. Since this small fraction of the catchment area has to manage drainage of over 92 percent of the water volume, over 80 percent of it being discharged in about five months period during the monsoon, floods frequently hit and cause havoc in the deltaic plains. Every year, Bangladeshŝs low-lying areas get inundated by seasonal floods. From time immemorial, people living in the delta have been experiencing rainy season and have adapted to such annual events over the centuries and found ways to take advantage of it. The 1988 and 1998 floods were the two most severe in living memory, when over 60 percent land suffered flooding and about half the population was directly affected.

Types of Flood in Bangladesh

Four types of floods are often observed in Bangladesh, flash floods, riverine floods, rainfall-induced floods and storm surge floods. Figure 2-1: Flood Vulnerable Areas of Bangladesh shows flood prone areas of Bangladesh. In a hydrological year, the flooding season may start as early as May and can continue until November.

The flood season generally begins with flash floods occurring as early as in late April and early May. Generally observed in the northern and eastern parts of the country, flash floods usually occur after a heavy downpour in the neighboring hills and mountains and are characterized by a very sharp rise in the water level in rivers and subsequent overbank spillage with a high flow velocity. Flash floods are also marked by a relatively rapid recession of water from the floodplains.

With the onset of monsoon all the major rivers start swelling to the brim and bring flood water from upstream. When rising water levels cross riverbanks, spillage occurs. Such events are common in every hydrological year and termed as river induced flooding.

Localized floods are often triggered by heavy rainfall episodes, either within the sub-basin or in upper catchment areas. Bangladesh receives, on an average, some 2,200 mm rainfall annually, ranging from 1,100 mm in the west to 5,000 mm or more in the northeast. Local excessive rainfall often generates high volume of runoff in the rivers and creeks in excess of their drainage capacity and termed as rainfall induced flooding.

About 2.8 million hectares of the coastal areas of Bangladesh consist of large estuarine channels, extensive tidal flats and low-lying islands. Storm surges generated by tropical cyclones bring tidal bores of up to 9 meters high. Although numerous embankments protect most of the southern coastal, high tidal bores often overtop those and storm surge flood is occurred. Tropical cyclones are most likely to occur during pre- and post-monsoon periods (April-May and October-November, respectively) and this is shown in Figure 2-2: Areas Affected by Early Monsoon Floods (Early June - Mid July) and Figure 2-3: Areas Affected by Late Monsoon Floods (Early August - Mid September), but there have been episodes coinciding with monsoon flood peaks.

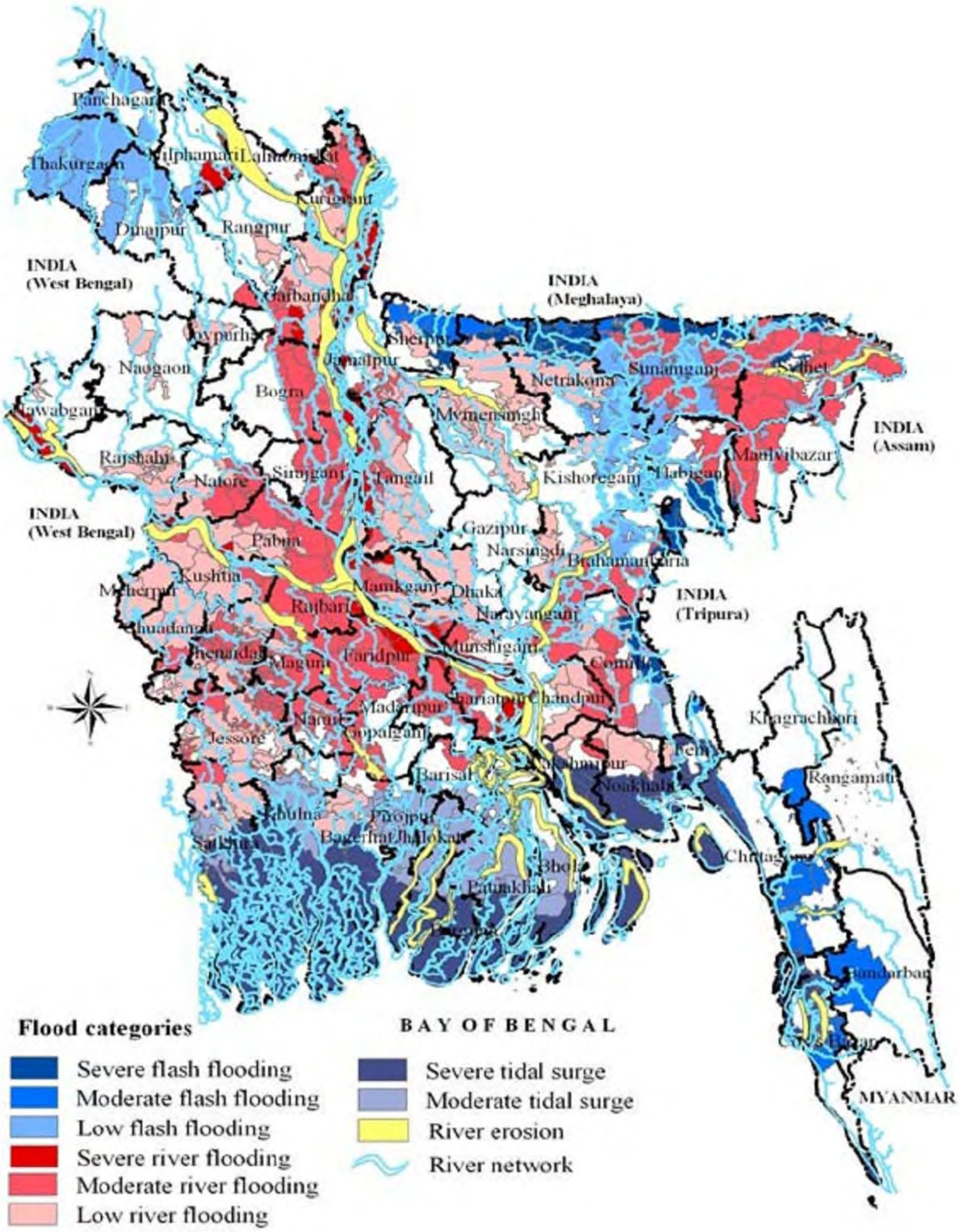


Figure 2-1: Flood Vulnerable Areas of Bangladesh

Source: (Department of Environment, 2006)

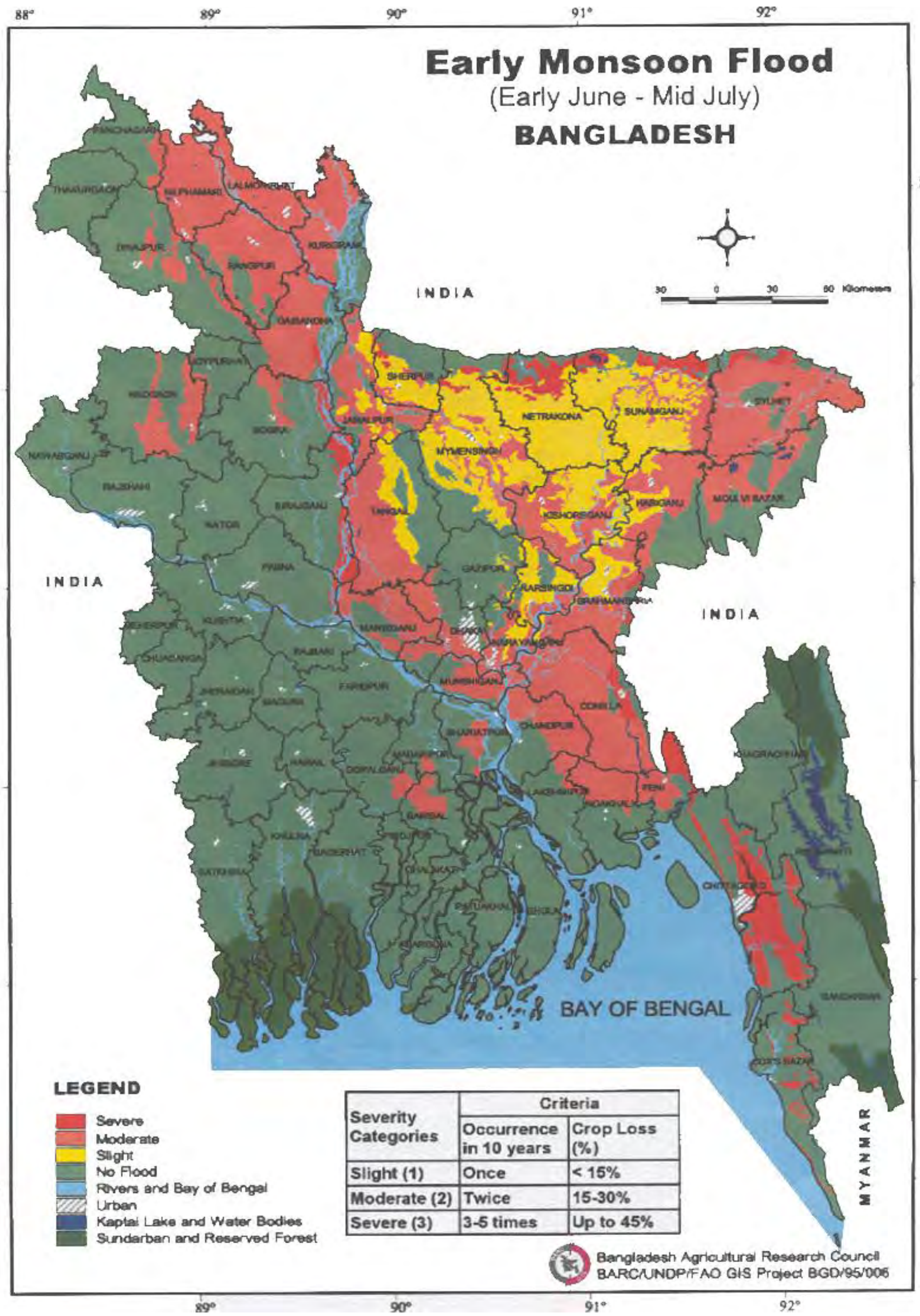


Figure 2-2: Areas Affected by Early Monsoon Floods (Early June - Mid July)

Source: (Manual for Community- Based Flood Management in Bangladesh, 2004)

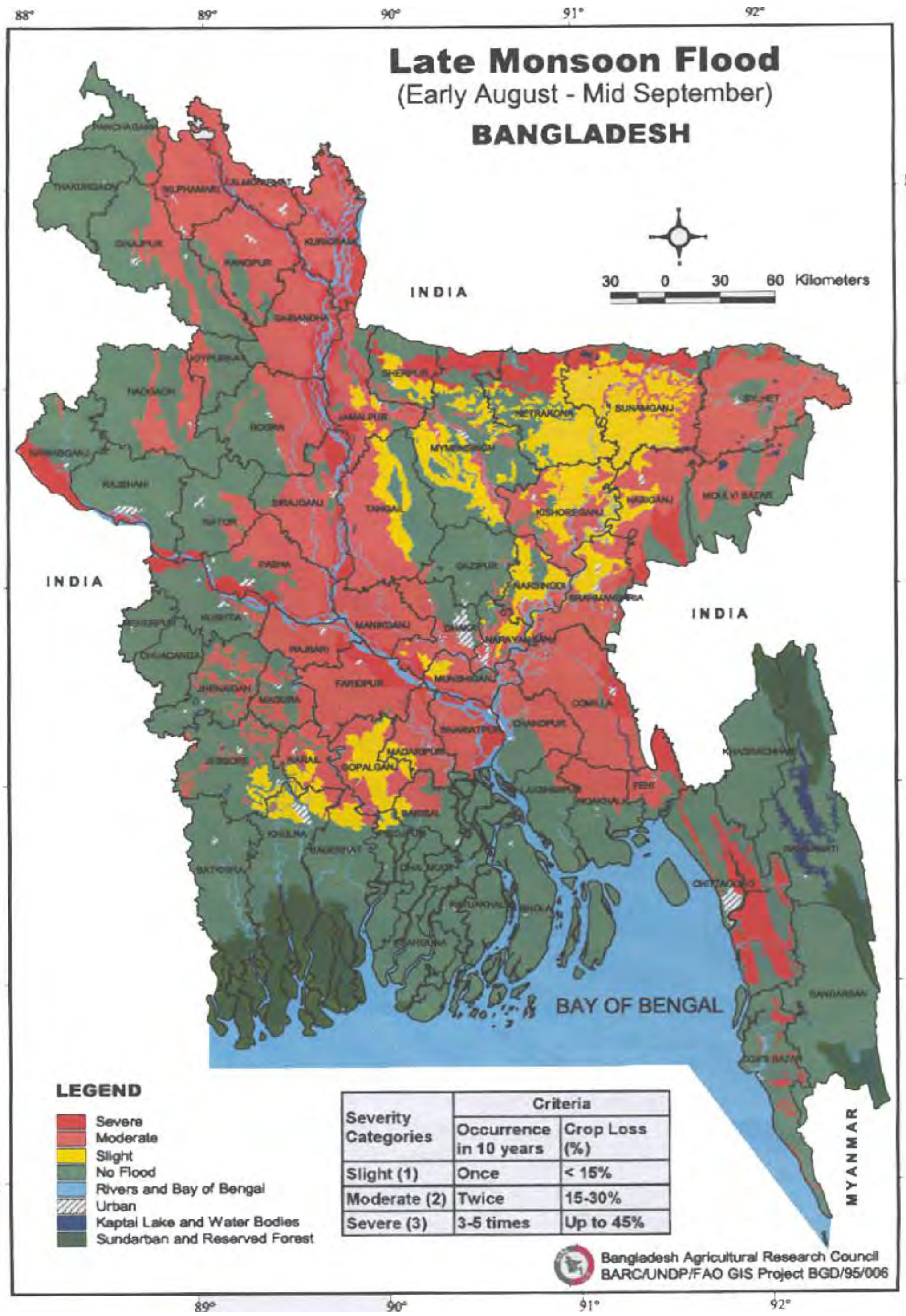


Figure 2-3: Areas Affected by Late Monsoon Floods (Early August - Mid September)

Source: (Manual for Community- Based Flood Management in Bangladesh, 2004)

2.2 Types of Flood in Bangladesh

2.2.1 Climate Change Induced Flood

The IPCC saw changing climate and floods as ñthe most widespread direct risk to human settlements, driven by projected increases in rainfall intensity and, in coastal areas, sea-level rise. Riverine and coastal settlements are particularly at risk, but urban flooding could be a problem anywhere that storm drains, water supply, and waste management systems have inadequate capacity. Flood magnitude and frequency could increase in many regions as a consequence of increased frequency of heavy precipitation events, which can increase runoff in most areas as well as groundwater recharge in some floodplains" (Global Green House Warming, 2010). Bangladesh is a very low lying country, (only 3-7 feet in most parts). Climate change and floods exacerbated by global warming in the last few years has set in motion the rise in sea water levels. At the narrow north tip of the Bay of Bengal, tropical storms can whip up wind speeds to 140 mph sending waves(up to 26 feet tall)crashing into the coast (Global Green House Warming, 2010). The shallow sea bed and the fact that water coming down from the rivers Ganges and Brahmaputra cannot escape when the water level raises all contribute to the severe flooding of the Bangladesh coastline (Global Green House Warming, 2010).

2.2.2 Flash Floods

Flash floods are rapid onset floods that occur 6-12 hours or less after the associated rainfall. Flash floods occur particularly in mountainous or hilly area with rather steep terrain gradients and high surface runoff. They can also be triggered by the failure of hydraulic infrastructure such as dams or levees, outburst of glacier lakes, ice-jams or log-jams. Due to the short lead time for advance preparation, warning and evacuation etc, the losses of human life can be substantial. Due to the force of rapidly flowing water, they pose serious threats to the structural integrity of buildings and infrastructure (Global Water Partnership & World Meteorological Organization, 2010). Damage associated with flash floods is unpredictable due to having difficulties with predicting the phenomenon and with the short warning lead times. In matter of damages this means there is less time for preparatory action, so that potential losses are closer to actual losses than with other flood types.

2.2.3 Riverine Flooding

Riverine flooding is of two types generally namely slow and fast riverine flooding. In slow riverine flooding, runoff from sustained rainfall or rapid snow melts exceeding the capacity of a river's channel due to heavy rains from monsoons, hurricanes and tropical depressions, foreign winds, warm rain affecting snow pack and unexpected drainage obstructions such as landslides, ice, or debris. On other hand, fast riverine flooding includes flash floods resulting from convective precipitation (intense thunderstorms) or sudden release from an upstream impoundment created behind a dam, landslide, or glacier, where terrain gradients are lower. However, prolonged inundation may result in foundation failures, particularly if the construction is old or not to standard. The main parameters influencing the magnitude of flood damage are the depth of inundation and for a number of sectors the inundation time especially for agriculture, sediment and pollution loads. Due to the heavy economic activity on floodplains in many part of the world, damages and losses of riverine flooding account for substantive parts of the overall flood losses (Global Water Partnership & World Meteorological Organization, 2010).

2.2.4 Coastal Flooding

Coastal flooding is occurred in coastal areas due to severe sea storms, or as a result of another hazard (e.g. tsunami or hurricane). Coastal flooding includes a storm surge as well, from either a tropical cyclone or an extra-tropical cyclone. The combination of damages induced by contact with flood waters, and wind damage to structures is characteristic for this type of floods.

2.3 Climate Change Scenario in Bangladesh

Bangladesh is extremely vulnerable to climate change impacts because of its geographical location, high population density, high levels of poverty, and the reliance of many livelihoods on climate-sensitive sectors, particularly rural agriculture and fisheries. Climate change therefore threatens both previous achievements and future efforts to reduce poverty in Bangladesh to date, particularly by reducing water and food security. This is due to potential damage to essential infrastructure during more frequent disaster events due to its geographical features and location, high influence of monsoon and regional flow patterns, too much water in monsoon and too little water in the dry season, etc. These have significant effects on the socio-economic realities, i.e. population density, inequity and deprivation, poverty and per capita resource endowment, and development practices. The overall impacts on Bangladesh already are and will be significant since climate variability and change will significantly affect the hydrology. The location of the country in the regional setting is in itself an element of damage by giving rise to climate extremes. Further, the regional aspects of water management put additional difficulty toward adaptation to climate change and climate variability. (Department of Environment, 2006)

The climate of the country is strongly influenced by monsoon. Though Bangladesh occupies only 7% of the combined catchment area of the Ganges-Brahmaputra-Meghna River basin, the country has to drain out 92% of the flow into the Bay of Bengal (Department of Environment, 2006). Too much water in the monsoon period affects different sectors, livelihoods and food security. Climate change scenario projections show mean monthly rainfall may significantly change over normal (i.e. current variability). Monsoon rainfall may increase by 11% by 2030 and 27% by 2070. Also, the general rise in surface average temperature will increase by 1.3 degree C by 2030 and 2.6 degree C by 2070 (Department of Environment, 2006). The number of rainy days will increase by about 20 days. During the post-monsoon to pre-monsoon cycle, rainfall diminishes while temperature increases. Low rainfall runoff reduces river flows; consequently salinity penetrates along the coastal rivers. A combination of increased temperature and reduced rainfall results in an increase in evapo-transpiration, detrimental to crop growth.

Implication of these climate change scenarios is that about 18 percent of current lowly flooded areas will be susceptible to higher levels of flooding while 12 to 16 percent new areas will be at risk to inundation. On an average about a quarter of the countryȇs landmass is currently flood prone in a normal hydrological year, which may increase to 39 percent, while the frequency of a catastrophic flood (affecting over two-third of the landmass of the country) could increase under climate change scenarios. Prolonged flooding can effectively reduce overall potential for Aman production (Department of Environment, 2006).

The projected sea level rise (SLR) along the coastal areas of Bangladesh will be about 88 cm by the year 2100 (Department of Environment, 2006). If this comes true, a majority of the low-lying non-embanked coastal areas may be completely inundated. There will be increasing risk of coastal salinity (both soil as well as surface water, including drinking water from wells). Scarcity of saline free drinking water will be even more pronounced. SLR will have compounding effects on coastal drainage and erosion. The mixing zone between fresh (sweet) water and saline water will also shift. Land use suitability, particularly in relation to current agricultural practices will change. Embanked coastal agricultural areas will be at higher risk of tidal surge and subsequent inundation with saline water. SLR will cause shoreline retreat, resulting in increase in basin area, which contributes to increasing the cyclone path length. This will allow the cyclone to remain more time in the water, acquire and release more latent heat, resulting in more energy, intensity and wind speed.

Water resources and hydrology of Bangladesh are highly sensitive to current climate variability. Within Bangladesh, climate variability has two major dimensions ï temporal and spatial. Both are highly significant. There are various elements of damage associated to current climate variability. Under climate change, observed climate variability will increase causing extreme climate conditions. Floods, droughts and salinity ingress will occur more frequently and with higher intensity.

The country has to implement adaptation measures in order to reduce its current variability and change. In relation to the southwest region of Bangladesh, the implications as the maximum impact zone is higher salinity, choking up of small rivers, water logging, embankment breaching and overtopping, cyclonic storm surges, and riverbank erosion. Agriculture will be severely affected. Upper reaches will face drought conditions. A major challenge will be to assure saline free drinking water to the population and ecosystem.

2.4 Approaches of Flood Damage Assessment

Flood damage estimation is an important issue in urban areas especially in the coastal urban areas for the decision makers in the field of flood control, mitigation, adaptation, insurance, taking any future projects that are likely to be affected by the potential flood, assessing the Structure Plan, etc. It has been shown that there is no standardization of future flood damage methodology. Various methods are used by different organizations for different purposes without any national consensus (Su et al., 2005). There are basically two methods in carrying out flood damage estimations. One is to carry out a thorough questionnaire survey of affected population and properties to estimate the incurred loss. The other is to use what are known as stage-damage functions which describe the damage extent to different types of property for a given inundation depth and inundation duration (Herath, 2003). In simplest word, approach to flood damage is generally of two types viz. parcel-based approach and GIS grid-based approach.

2.4.1 Parcel Based (Unit Loss) Approach

The parcel-based approach keeps detail information of the socio-economic activities, e.g. the family housing, factories and stores, etc. at parcel level. The respective stage-damage curve is then applied to each parcel with the estimated flood depth at that point for its damage assessment (Dutta & Herath, 1998). The regional damage is the loss sum of all parcels for the entire flooding area. The data needed for this approach including land parcel maps and socio-economic activities on each parcel. These data are multifarious and difficult to establish and maintain. This is especially true in the developing countries that suffer most often from the natural hazards like flood. This is comparatively difficult due to collecting and maintaining gigantic database of different types of data.

2.4.2 GIS Grid-Based Approach

GIS grid-based Flood Loss Estimation approach is comparatively newer, which is used for loss estimation of post and future floods as well as for real-time loss estimation. Although a parcel-based flood damage assessment is more accurate but is also not very practical because it needs gigantic and detailed information at the parcel level (Dutta & Herath, 1998). The grid-based approach requires data that are comparatively easier to collect. the grid-based approach is based on a grid data model which divides the region into grid cells of equal area. The socio-economic activities are considered to be homogeneous within each cell and are aggregated into a single value and assigned to that cell. The data needed for this model can be derived from the aggregated census data that is more available than the individual ones. The flood damage is then estimated from the average flood depth and the aggregated census data for each cell using the stage-damage curve. The regional flood damage is calculated from the summation of loss estimation of each cell.

2.5 Existing Flood Damage Methodologies in Different Countries

Several countries especially the developed countries have flood damage methodologies developed by their respective responsible organizations. It has been shown that there is no standardization of such flood damage methodologies. On other hand, there is no consensus on flood damage methodologies among the countries, even among the different organizations of a country. This is happening due to having different purpose of those methodologies. One of the major purposes is cost-benefit analysis of flood control measurements. However, looking at the flood damage assessment of various countries, some interesting differences can be observed, which are briefly described in the following.

In Japan, flood is being occurred over the years. Post and potential flood is evaluated and appraised by the Ministry of Construction based on a standard procedure. Direct and indirect, both types of damages are considered in damage estimation. Damages considered in the Japanese methodology are classified into three groups namely damage to general assets, damage to crops, and damage to public infrastructure. Business loss is considered as lump sum 6% of total general asset damage (Dutta et al., 2001).

In United Kingdom, for many years United Kingdom has employed a standard approach to flood damage assessment. Procedures developed in the mid 1970s, and continually refined since, are mandatory for agencies and local authorities wanting central government assistance with flood mitigation measures. Middlesex Polytechnic Flood Hazard Research Center has been to the vanguard in developing flood damage estimation methodology in UK. Their main results are contained in three manuals, are known as 'Blue Manual', 'Red Manual' and 'Yellow Manual'. In 1979, Middlesex Polytechnic Flood Hazard Research Center produced the 'blue Manual' provides assessment techniques and a range of depth-damage data for a wide range of common urban buildings and their contents. The Red Manual (Urban Flood Protection Benefits: A Project Appraisal Guide) was published in 1987, provides depth-damage data and assessment methods for most common types of indirect flood loss including those associated with manufacturing, retail, and road traffic, utilities and services, households and emergency services. Direct losses for all but residential properties are also considered. The 'Yellow Manual' (The Economics of Coastal Management - A Manual of Benefit Assessment Techniques) was produced in 1992, discusses assessment of coastal erosion and expands upon the other manuals, particularly with regard to assessment of environmental effects. The flood damage assessment methodologies described in these three manuals had two basic purposes. The first purpose was to facilitate the reliable assessment of the benefits of urban flood protection through providing new methods for assessing flood loss potential. The second purpose was to explain the principles of benefit-cost analysis, which were fundamental to the assessment of flood protection benefits, especially the indirect benefits (Dutta, et al., 2001).

In United States, U.S. Army Corps of Engineers (USACE) has nationwide responsibilities in water resources planning and management. One of the important tasks of USACE is to evaluate damage potential due to flooding with and without proposed plans of improvement. For this purpose, USACE has produced its own guidelines for urban flood damage measurement, the National Economic Development Procedures Manual. The methodology adopted in the manual is very comprehensive for estimation of damage to urban buildings and to agriculture. In the United States, as part of an attempt to develop standardized methodology of flood damage assessment for whole country, the US National Science Foundation (NSF) is developing a guidebook called 'Damage Handbook: A Uniform Framework and Measurement Guidelines for Damage from Natural and Related Man-made Hazards'. The NSF is also funding a major review of hazard research, which includes examination of economics (Dutta, et al., 2001).

In Australia, flood damage assessment methodologies have been developed by a number of organizations. These include the Center for Resource and Environmental Studies (CRES) at the Australian National University and University of New South Wales. There is no standard approach and most authorities make little attempt to achieve standard approach, nor is there any set of standard methodologies and consequently, data sets are very diverse and case specific.

The flood damage assessment methodologies adopted in different countries have large variation; some countries like UK have established detailed methodologies for estimation of tangible losses. However, in case of Japan, USA, etc., detailed damage estimation methodology is limited to urban damage. It can be noted that most of the countries have adopted similar approach in damage estimation known as unit loss approach, which is based on a property-by-property assessment of potential damage. From the various available reports, it is found that countrywide standard methodologies of flood damage assessment are available in Japan and UK, that is, for assessment of damage caused by floods in any part of the country, same standard methodologies are used. United States is in the process of developing a standardized methodology for the whole country. However in Australia and many other countries, damage assessment methodologies vary in different regions within the country according to individual studies (Dutta, et al., 2001).

2.6 Flood Associated Damages and Losses

Conceptually it is important to note the difference between flood damages and flood losses. The term ñflood damageò is related to the physical damage of public and private assets such as infrastructure, houses, vehicles, etc., resultant of contact with flood waters. The term ñflood lossò has a much broader meaning and depicts also secondary or tertiary losses, as well as intangible losses such as losses to human life and others. To arrive at realistic estimates about the impact of a flood, only considering flood damages, i.e. direct tangible losses, would usually not do justice to the purpose of assessment, and would probably arrive at misleading messages to policy makers about the true impact and consequences of a flood event (Global Water Partnership & World Meteorological Organization, 2010). Figure 2-4 illustrates the different type and categories of flood damages and Figure 2-5 describes the disaggregation of flood losses by sectors.

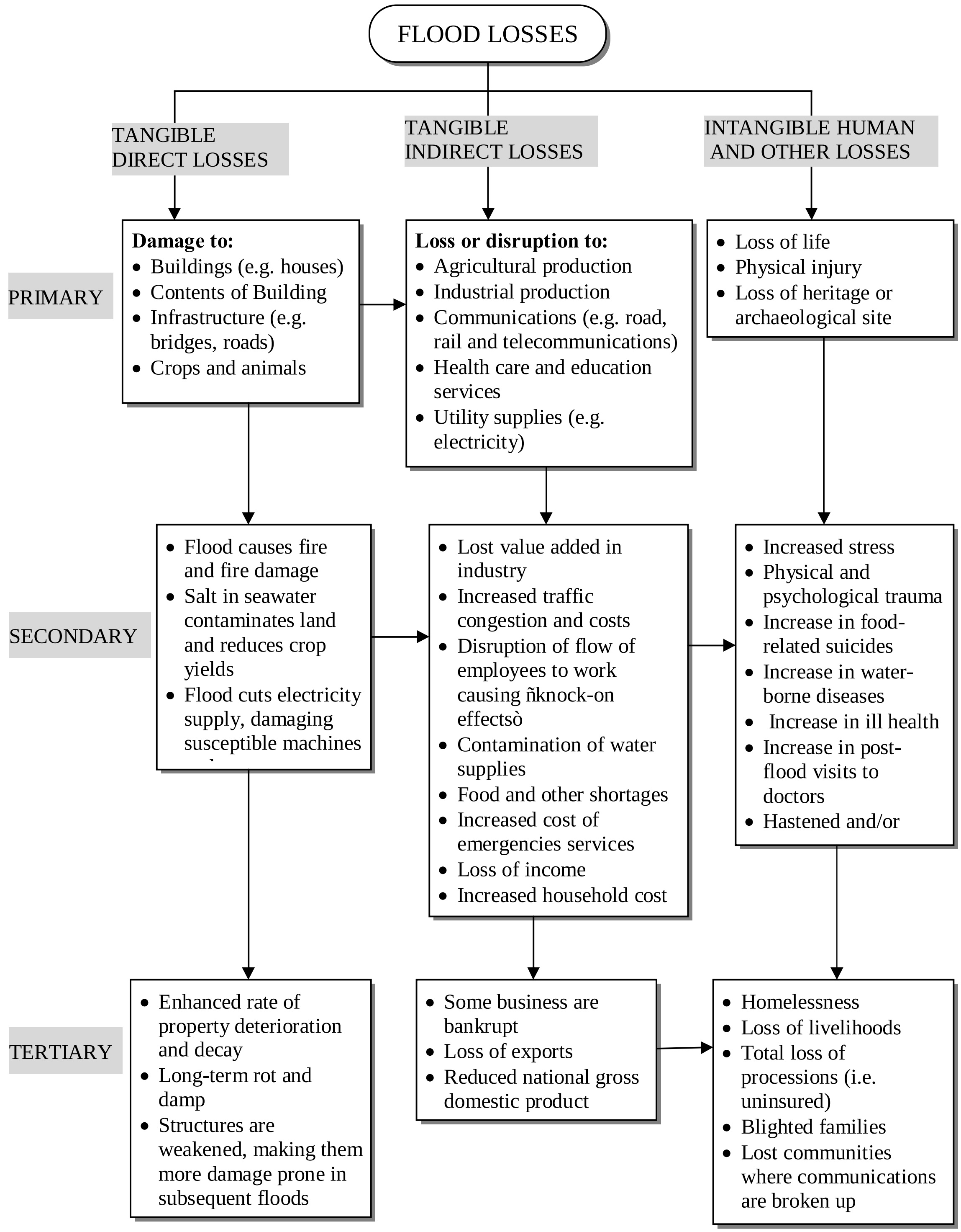


Figure 2-4: Different Types of Flood Losses

(*Source:* **(Global Water Partnership & World Meteorological Organization, 2010)**)

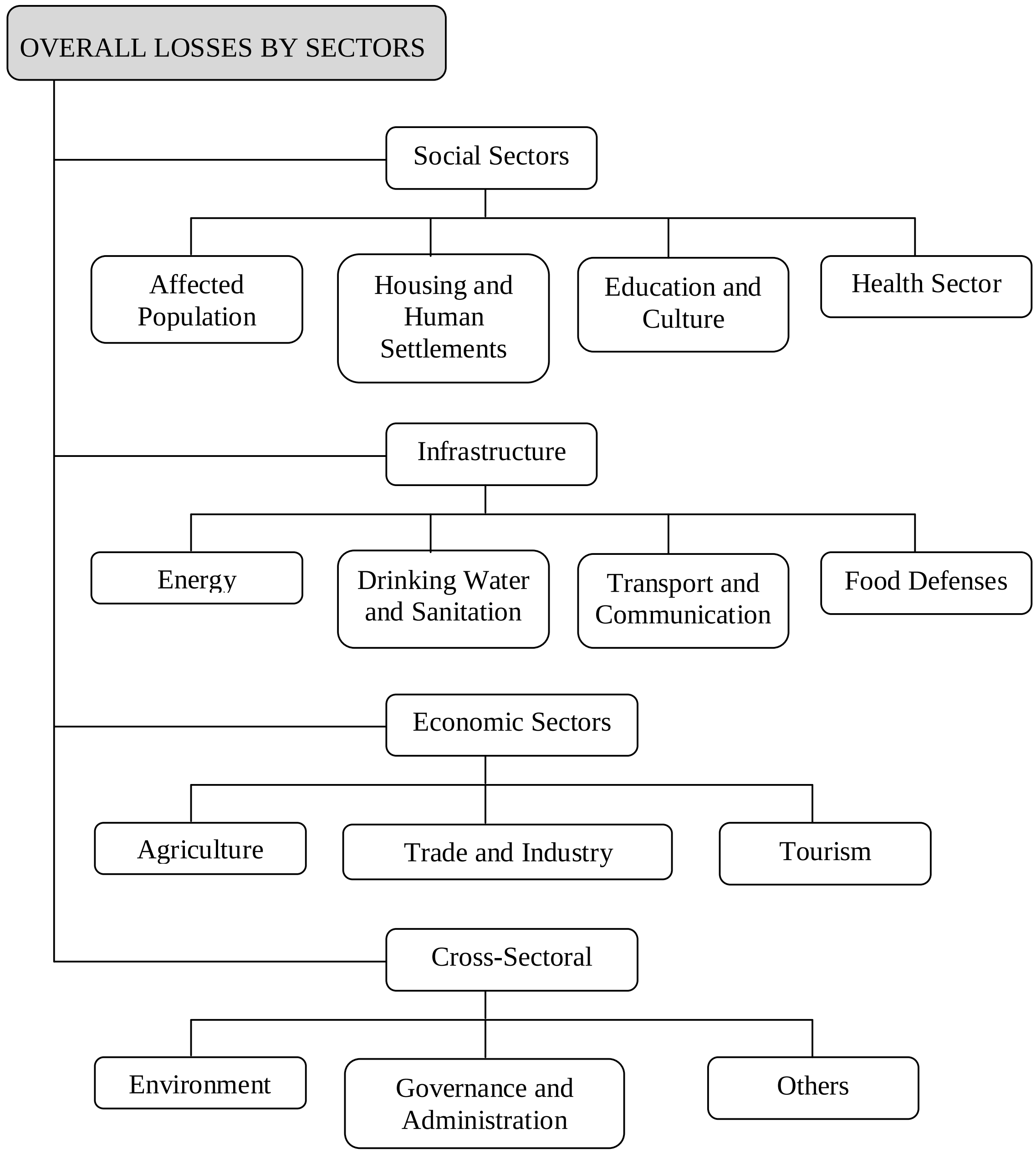


Figure 2-5: Disaggregation of Losses by Sectors
(*Source:* **(Global Water Partnership & World Meteorological Organization, 2010)**)

Flood damage has broadly four dimensions/parameters namely physical, socio-economic, environmental and institutional. There are different types of indicators for each type of parameter. Damage is being reflected through those indicators. An indicator, or set of indicators, can be defined as an inherent characteristic which quantitatively estimates the condition of a system; they usually focus on small, manageable, tangible and telling piece of a system that can give people a sense of the bigger picture. The damage indicators should provide additional information to set more precise and quantitative targets for damage reduction. Indicators facilitate the analysis of the relative state of the overall system and they should reflect the socio-economic, environmental, institutional and physical condition of the geographic region (UNESCO-IHE, 2010).

2.7 Stage Damage Function (Fragility Functions)

Stage damage functions are graphical representations of the losses expected to result at a specified depth of flood water. Such functions are typically used for housing and other structures of different land uses where the stage or depth refers to depth of water inside a building and the damage refers to the damage expected from that depth of water. In this research secondary data for stage damage functions were used.

Fragility functions (or stage-damage functions) are essential components of flood damage estimation methodology, which relate flood damage to flood inundation parameters for different classes of objects. In mathematical models for estimation of damage, stage-damage functions are used to calculate unit damage percentage to any object for given condition of flood (Dutta, et al., 2001). As depth of floodwater is the governing flood parameter for damage to urban buildings, in development of fragility functions for urban damage, only flood depth is considered.

For agriculture damage, both depth and duration factors are considered in fragility functions. For this purpose, depth is divided into several ranges and for each range of depth scale; fragility functions define the relationship between flood duration and damage. Crops and vegetables cultivated in different regions in Japan are grouped into a total of eight categories based on their nature of damage due to floods. For each of these categories, fragility functions were different (Dutta, et al., 2001).

2.7.1 Stage Damage Function Development

Synthetic stage-damage functions is based on land cover pattern, type of objects, information of questionnaire survey, etc (using information on losses measured following flooding combined with estimates of water depth) and Other Actual Stage-damage is based on damage data of past floods (building contents and structure repair costs), and other is from hypothetical analysis. The stage-damage function may be developed as a consequence of post-flood surveys or through personal interviews with plant managers, plant engineers, or other experts. Then, instead of employing dimensionless depth-percent damage functions, damages incurred at various water-surface elevations are approximated directly.

To describe uncertainty in these cases, the experts should be asked to estimate the most-likely damage for a range of depths, to provide a range of damages for each depth, and their confidence that the range contains the actual damage value that would occur. These opinions on the range and confidence can be used to estimate the parameters of a probability distribution that describes error for each depth. If the respondent cannot or will not provide information other than an estimated range, the analyst can use the mid-point of the range as the mean and one-fourth of the range as the standard deviation; this assumes a normal distribution of errors and inclusion of 95 percent of all damages in the stated range.

In some flood damage-reduction planning studies, data in the detail or format for proper analysis of uncertainty is not available, and the cost to enhance existing data to conduct an uncertainty analysis is not justified. In those cases, the planning team must take care to acknowledge likely sources of uncertainty and their impact.

The mean stage-damage function is likely most sensitive to error in the first-floor elevation, other things being equal. The error in damage at any stage is not symmetrically distributed around the mean damage. This is particularly true at the lower stages, because damage cannot be negative. Thus the probability of overestimating damage is greater.

Although the dispersion of damages about the mean, as measured by the standard deviation, increases with increasing stage, the coefficient of variation (standard deviation divided by mean) decreases with increases in stage. Thus, the error in damage, expressed as a fraction of the mean damage decreases as the stage (and hence, mean damage) increases. This is due, in part, to the truncation of damage at zero. Stage Damage Functions for Different Land Uses from Secondary Sources

2.7.1.1 Damages to the Household

Stage damage functions for household were used in this research which is developed by the Institute of Water Modelling (Asian Development Bank, 2010). The process of development is described below:

Surveyed data provided information about the damages incurred due to past events of disasters similar to climate changed induced natural disasters. Data from household 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 (for informal sectors), 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. Household survey data did not report the exact GIS-based information on location of the household and so it was not easy to directly estimate the damage function where damage = function of depth of water logging and duration of water logging. In absence of such information, the average water logging depth for the ward was used to estimate a damage function. This substitution of average water logging depth or duration with individual household level damages significantly reduced the degrees of freedom during estimation. Regression equations, perhaps, therefore, did not provide any significant statistical relationship between damage and water logging depth. The following steps used to arrive at an average damage estimate (Asian Development Bank, 2010).

Step 1: Based on the sample householdôs reports on damages (by year) and the annual income, percent of damage in terms of annual income is estimated for the sample households.

Step 2: The calibrated model is used to estimate the average depth of water logging in each ward for the years reported in the household samples, and the sample damage data to estimate the corresponding average damage as a percent of household income.

Step 3: Based on the model estimated water logging depth, estimated damage and estimate affected household (in percent), the following damage function was used:

Y = aX, where Y is the percent of damage (in terms of annual income) and X is the water logging depth. The slope coefficient is calculated for the Khulna city. The equation is shown in Figure 2-6 below.

Step 4: For estimation of the damage function above beyond the level of water logging reported in the data, it is needed to use a pseudo-damage function using 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 from surveyed data carried out by the Institute of Water Modelling, that duration of water logging did 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, Focus Group Discussion (FGD) is used with the households in the affected areas to estimate an extreme point (water logging depth of 500 cm). In actual analysis however, it was observed that water logging depth under different climate change scenarios is only marginally above the past water logging depth and so this assumption from the FGD is unlikely to affect the results (Asian Development Bank, 2010). This information is used to estimate the second part of the damage function shown in Figure 2-6: Damage functions for Households.

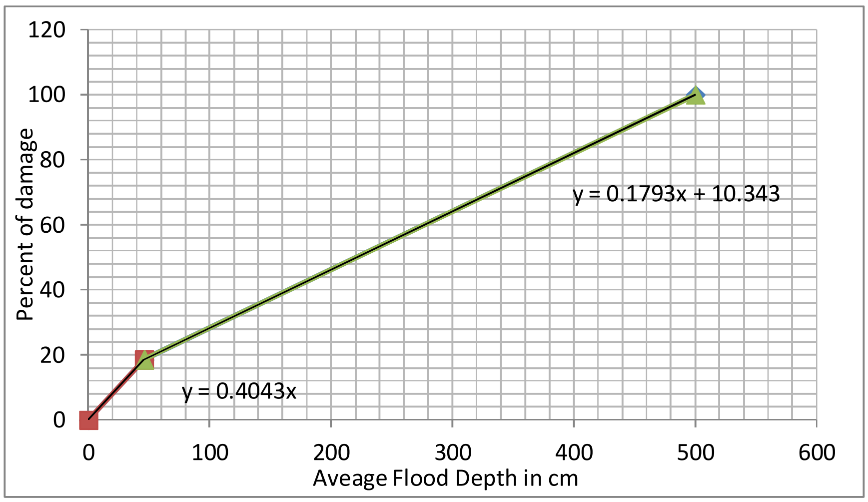


Figure 2-6: Damage functions for Households

2.7.1.2 Damages to Industry, Manufacturing and Other sectors

Stage damage functions for industry, manufacturing and commercial uses are also used form the secondary sources. Development process developed by the Institute of Water Modelling is described below:

Damages to other sectors of the Khulna economy due to climate change are also required for the analysis of avoided benefits from climate proofing the urban drainage infrastructure. In order to assess this, focused group discussion in the affected areas was resorted with representatives from a) the industrialists, b) the manufacturing firms, c) the government agencies, d) local hospitals, and so on. One of the objectives was to assess the points on a damage function in terms of percent of output per year with different level of water logging. An illustration of water logging to ensure proper understanding of the water logging depth was used. Based on several FGD results, the damage function for these sectors of the economy is estimated with hypothetical estimate of damages at different water logging levels. Damage functions are shown in Figure 2-7: Damage functions for Agriculture (Damage is in terms of yields) to Figure 2-11: Damage functions for Roads (Damage is in terms of physical damage) for agriculture, commercial enterprises, industry, manufacturing and for public roads respectively (Asian Development Bank, 2010).

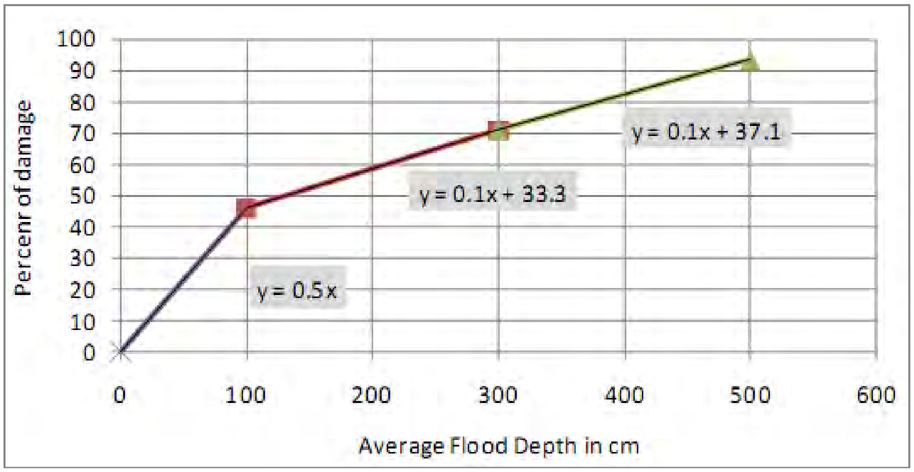


Figure 2-7: Damage functions for Agriculture (Damage is in terms of yields)

Source: (Asian Development Bank, 2010)

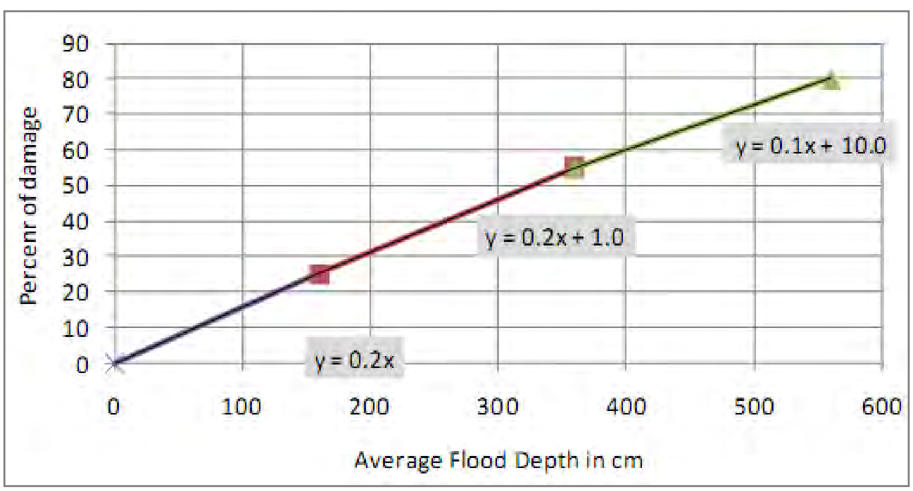


Figure 2-8: Damage functions for Commercial and Others (Damage is in terms of value of assets)

Source: (Asian Development Bank, 2010)

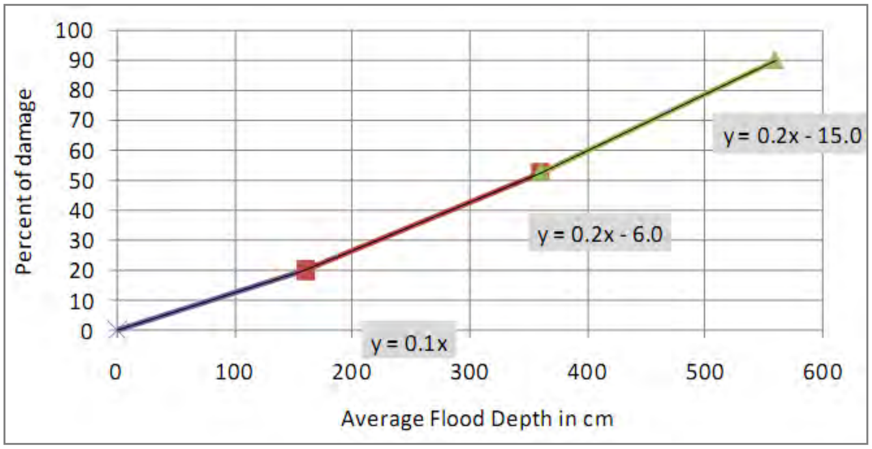


Figure 2-9: Damage functions for Industry (Damage is in terms of value of assets)

Source: (Asian Development Bank, 2010)

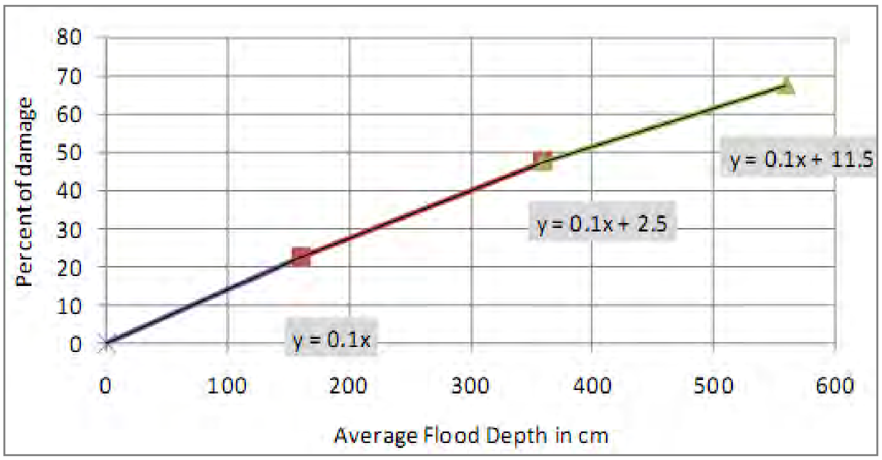


Figure 2-10: Damage functions for Manufacturing (in terms of value of assets)

Source: (Asian Development Bank, 2010)

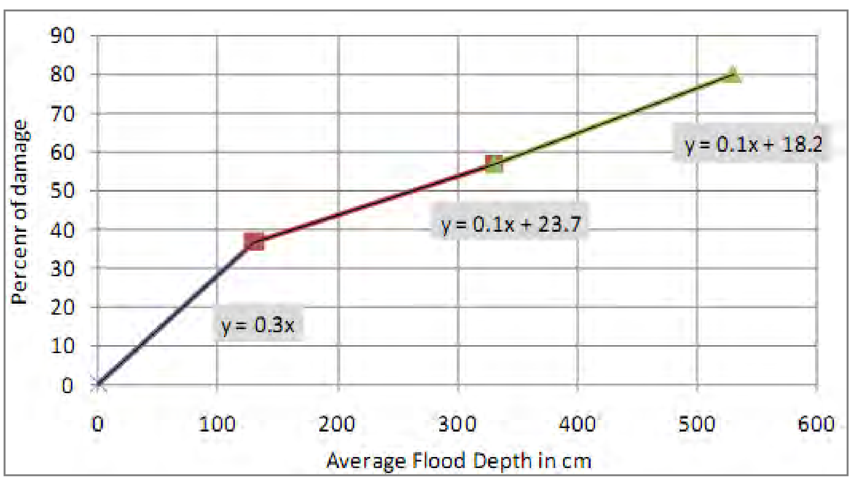


Figure 2-11: Damage functions for Roads (Damage is in terms of physical damage)

Source: (Asian Development Bank, 2010)

2.8 Limitations to the Flood Damage Estimates

The method used to estimate the damage functions above suffer from some limitations in terms of the extent of the estimates because of following facts (Asian Development Bank, 2010).

- While making the average estimates of the damages from floods, the actual damage data at the household level could not be collated with the water logging depth at that location for the corresponding household. As a result, a damage function revealing the true relationship between water logging depth and the amount of damages could not be estimated at the household level. This has limited our ability to simulate damages for future water logging levels.
- The damage function for other economic agents was estimated from the information based on FGD and so these damages are likely damages. In the actual cost benefit analysis these damages found to be much higher than damages at the household level. As such in future studies actual damage data should be collected based on experience of water logging along with the depth of water logging.
- Damage estimates for public infrastructure was estimated using an account approach whereby costs of repair and maintenance based on municipal budgets were used for this study. In future, actual repair costs after water logging damages could be used (if available from public offices) to make the estimates closure to reality.

Chapter 3: Methodology of the Research

This chapter starts with the research questions and then discusses the methodologies of the research sequentially. The method used, methodology applied and steps followed are explained elaborately in this chapter.

3.1 Research Questions

The research questions, from which the objectives have been corresponded, are summarized in the following Table 3-1.

Table 3-1: Research Questions, from which research objectives have been developed.

No.	Objectives	Research Questions
1	To assess the potential flood damage in the KCC area due to projected climate change scenario based on selected damage functions.	• What is the potential flooding Scenario of the Khulna City? • What are the appropriate major land uses at risk? • What are the relationship between flood-depth, flood duration and flood damage for each major land use at risk (four distinct types of land use viz. agriculture, commercial, industrial and residential)? • What is the spatial distribution of damage for those major land uses at risk? • What is the potential damage (in monetary term) for each major land use at risk?
2	To analyze the major land use policies and proposals within the Khulna City Corporation Area of the structure plan 2000-2020 for Khulna Development Authority in the light of the above objective.	• What are the major land use policies and proposals of the Structure Plan 2000-2020 for KDA within the KCC Area? • What are the relationship between the spatial distribution of flood damage and existing and proposed land uses? • How much monetary damage will be incurred for each major land use at risk? • Where will be the best alternative suitable location of the possibly highly damaged land uses? • Which major land uses will get highest priority in relocating?

3.2 Methodology

The research is carried out based on specific methods and approach, which includes certain steps. These steps are consecutive generally with some simultaneous works, is shown in Figure 3-1: Methodological Approach of the Research.

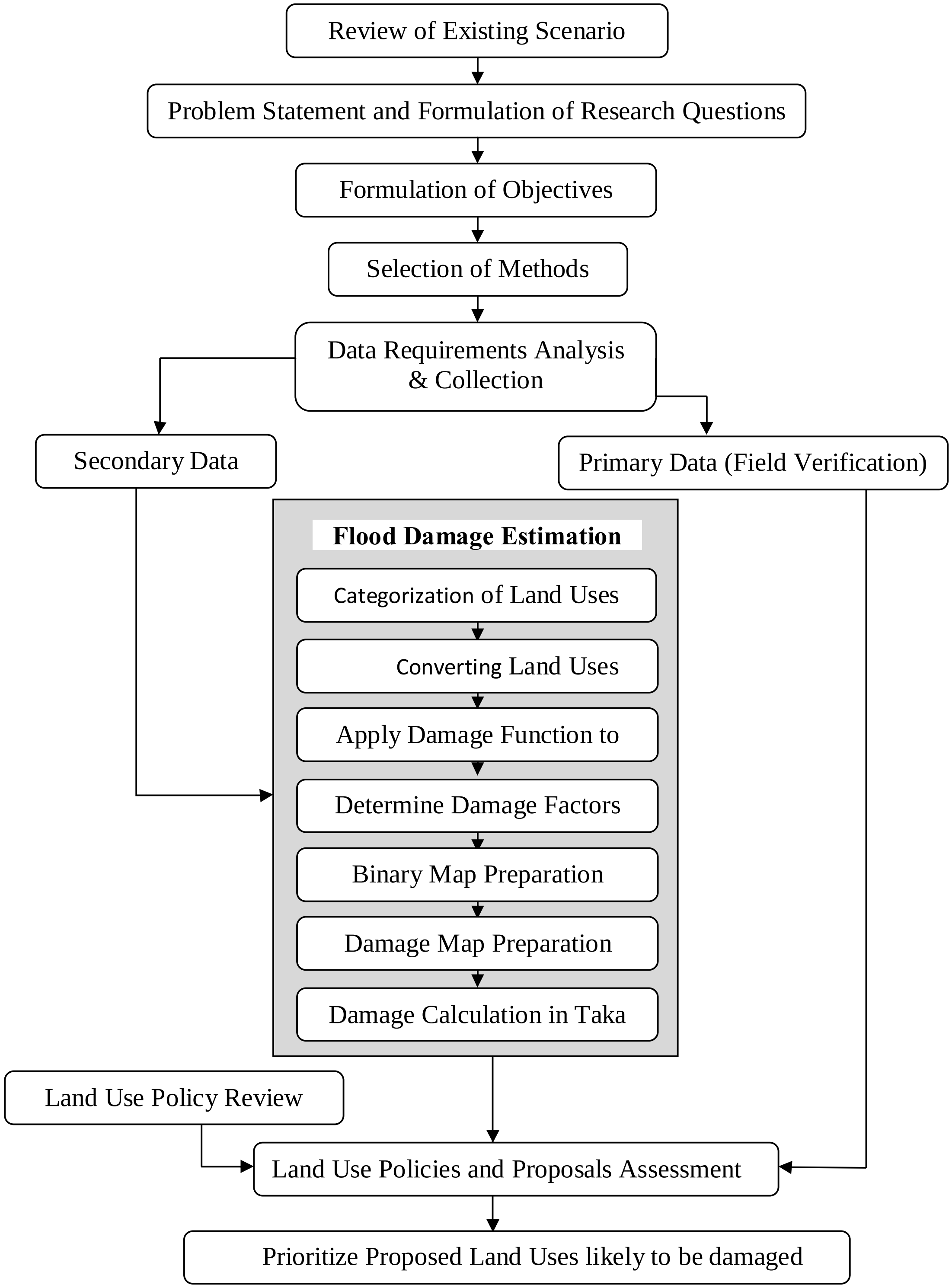


Figure 3-1: Methodological Approach of the Research

3.2.1 Methods

GIS grid-based Flood Loss Estimation approach is comparatively new, which is used for loss estimation of past and future floods as well as for real-time loss estimation. Although a parcel-based flood damage assessment is more accurate but is not very practical because it needs considerable amount of detailed information at the parcel level (Dutta & Herath, 1998). The grid-based approach requires data that are comparatively easier to collect. This research is based on secondary data. Beyond this, it required some primary data, which was collected through primary survey, interpersonal communications, etc. The grid-based approach is taken because parcel data are difficult to establish or access due to the concern of privacy and significant volume of data. The aggregated data are easier to get even in developing countries. Another reason for employing the grid-based model in this study is because flood hazard potential maps generated from computer modeling are usually in grid data format.

3.2.2 Sources of Data Collection

This research is largely based on data and information from secondary sources. This includes spatial distribution of potential flood due to climate change, stage-damage function curves for different land uses, land use plan and policies enunciated in the Structure Plan for Khulna Development Authority, the existing land uses and any other relevant information of the study area. At the end of the research, the outcome is validated and check by the primary data especially the field survey on different potential flood affected areas of the city and taking interviews with the city stakeholders and managers.

The key principles behind the damage assessment need to be considered carefully. Often, two approaches such as a financial and an economic viewpoint are considered. The financial viewpoint takes into consideration the losses incurred to individual households or businesses. An economic viewpoint takes a broader perspective, considering as it does the net change in welfare to a country or a region (University of Exeter, 2011). Here the financial perspective is considered. In this research, damage obviously direct tangible flood damage, is defined as ñloss of value of elements at risk (buildings, inventories, infrastructure, goods, cultural and ecological assets) compared to pre-flood conditions and loss of production caused by a floodò. Direct tangible damage can be defined as the ñdamage caused by direct contact with flood water that can be readily quantified in monetary termsò (University of Exeter, 2011). It is the most studied type of damage. There are three steps in the calculation of direct tangible damage. These three steps broadly as follows:

a) Classification of the elements at risk by pooling them into homogeneous classes.

b) Exposure analysis and asset assessment by describing the number and type of elements at risk and by estimating their asset value

c) Susceptibility analysis by relating the relative damage of the elements at risk to the flood impact.

The estimation of direct tangible damage is the collection of the data, are highly dependent on the data that are available, which is highly variable between the cities. Data types that the researcher must consider are a) inundation characteristics, b) land-use data and c) asset value data and relative damage functions or absolute damage functions.

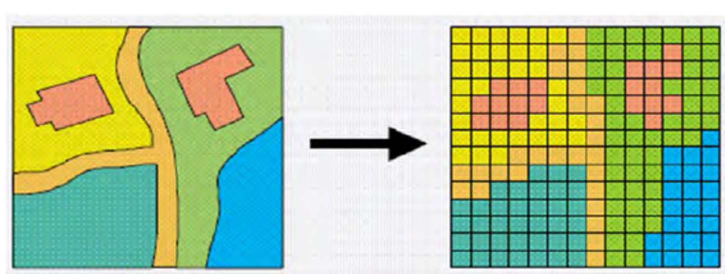
3.2.3 Data Preparation

3.2.3.1 General Land Use Classification

Depending on the type of land use, the extent of flood damage varies to a great extent. This is why it is necessary to categorize the land uses of similar characteristics, which will at the end acts as damage categories. In this research, detailed land use information was created through categorizing the land uses into major four classes: agricultural, residential, industrial and commercial, which encompass mostly all types of land uses of economic value.

3.2.3.2 Assigning land use into 20m x 20m grid cell

The grid-based approach is based on grid data model, which divides the given area into grid cells of equal area. Considering data on flood map was prepared 20m x 20m grid cell. In connection with this, the whole land use area was divided into 20m x 20m grid cell. Smaller cell size would make the processes slow and larger cell size would reduce accuracy. This is why a moderate cell size was chosen. Each grid cell is supposed to be homogenous land use depending on major share of land use category; each cell was assigned a single land use category.



20m x 20m grid Cell

Figure 3-2: Converting Land Use Spatial Vector Data to Raster Data (20x20m)

3.2.3.3 Determination of Damage Value for Specific Land Use

For estimating the damage, it is necessary to assign damage functions in each grid cell. According to the land use category, damage function was assigned to each grid cell.

3.2.3.4 Create Binary Maps for each Land Use

Maps for each land use were created. Each land use on the map was showed by 0 and 1. 1 stands for the presence of a particular land use and 0 for its absence on the other hand.

3.2.3.5 Spatial Distribution of Potential Flood and Land Use

The Spatial distribution of the potential flooding along with its depth and duration is important for determining potential damage for a particular land use and presented as digital elevation model (DEM). Damage functions will be applicable only in the areas of potential flooding areas in estimating the potential maximum loss. The maximum extent of flooding depth and duration must be taken into the account of determining damage from stage-damage functions.

The damage caused by flooding has been linked to many different inundations. Damage depends on the extent of the flooding, the flood depth, the flow velocity, the flooded duration, the time of its occurrence, and the debris load. The most commonly used characteristic is flooded depth, which has led to the development and use of depth-damage curves alongside the extent of flooding. Information on the damage functions is normally based on published government estimates, insured losses and typical insurance damage curves or any other authenticated information. In this research, flooded extent, depth, and land uses are considered. Because stage-damage functions for different land uses from secondary data used only flood depth, extent and land uses.

3.2.4 Data Analysis

3.2.4.1 Create Damage Map for each Land Use Applying the respective Stage-Damage Function

Four damage maps for each land use were created using stage-damage function for the respective land use. It is resulted from the functions of land use, flood depth and duration and flood damage.

3.2.4.2 Add all Damages to get overall Flood Damage Maps

Flood damage maps are the resultant from adding four damage maps, which represents the probability of a particular type of land use being damaged from flooding of certain depth and duration.

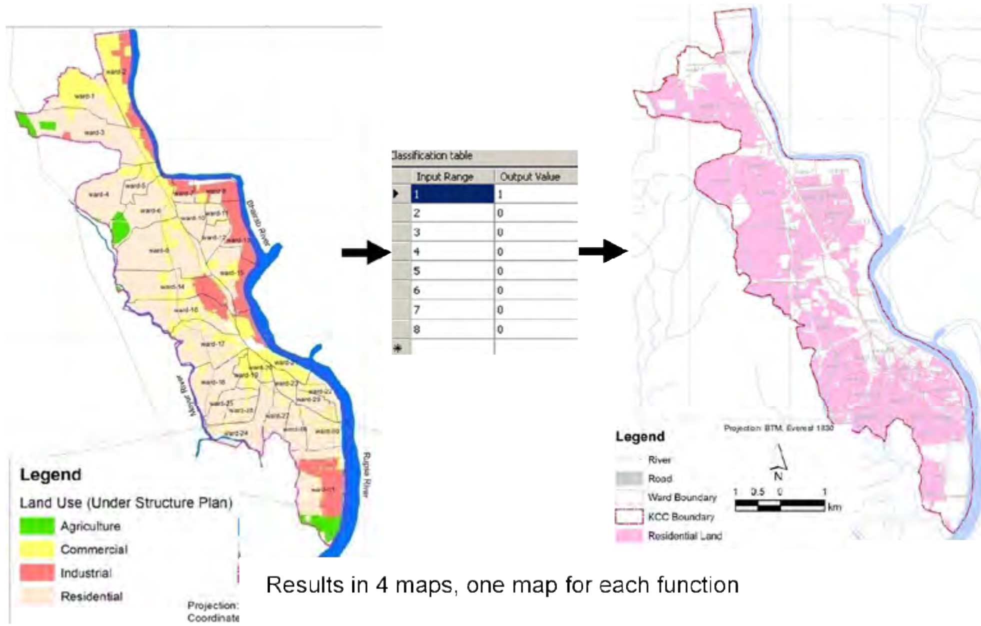


Figure 3-3: Binary Maps for all Damage Functions

3.2.4.3 To Investigate Land use policy of the Structure Plan 2000-2020 of Khulna Development Authority within the KCC Area

Overlaying flood damage maps for 2020 upon the proposed land use of the existing plan, the appropriateness of the policies and proposals in regards to climate change induced flood effects were analyzed. In this connection, land use plan, policies and proposals were examined.

3.2.4.4 To Prioritize the Proposed Land Uses likely to be Damaged to Potential Flood

At the same depth of inundation and duration, damages to the different land uses are different. Some land uses have more damage than others. This is why, depending on the calculated amount of damage due to potential flood for four major land uses, preferable land uses are proposed for minimizing loss. Finally this research provided a set of guidelines to take necessary adaptation measures regarding the development of KCC area.

Chapter 4: Study Area Profile

This chapter provides an overview of the study area focusing its socio-economic, environmental, physical and demographic characteristics. Past flood events and subsequent losses are also discussed in this chapter.

4.1 Introduction

Khulna is the third largest city in Bangladesh. It is located on the banks of the Rupsha and Bhairab Rivers in Khulna District. It is the divisional headquarters of Khulna Division and a major industrial and commercial center. It is the second port entry in Bangladesh. The city is entrusted with a plethora of positivity counter-balanced with lots of potential threats especially sea level rise, cyclone, tidal effects etc.

4.2 Location and Historical Facts of the Study Area

Khulna City is located in the southwest of Bangladesh with its surrounding bounded by the longitude 89°28N to 89°37E East and latitude 22°46N to 22°58N North. The Bhairab on northern side, Rupsha River in the middle part, Pasur on the southern side flows along eastern margin of the city, Mayur on the northern side and Hatia River on the southern side flow along the western side of the city. The location of the study area is shown in Figure 4-2.

Khulna, the south-western divisional city in Bangladesh, is named after its headquarters. As per myth, there was a shrine called Khullaneswari temple on the bank of the river Bhairab, about one and a half kilometers to the east of the present Khulna city, and the town is called Khulna after the name of Khullaneswari. The district was formed in 1882 comprising of the then Khulna and Bagerhat subdivisions of Jessore district, Satkhira subdivision of 24 Parganas district (India) and the Sundarbans. Khulna, a subdivision of Jessore district, was formed as the first subdivision in Bengal in 1842. The jurisdiction of Khulna Sub-division was then extended over the present Khulna district and a great part of the present Bagerhat district. This City is intersected by a network of channels and creeks. The ebb and flow tides control the formation of the land (Khulna City Corporation, 1984).

4.3 General Information of the Study Area

Khulna Municipality was established in 1884 during the British colonial regime. The area within which municipal limits was 12 square kilometers. In 1990, Khulna Municipality was declared as City Corporation.

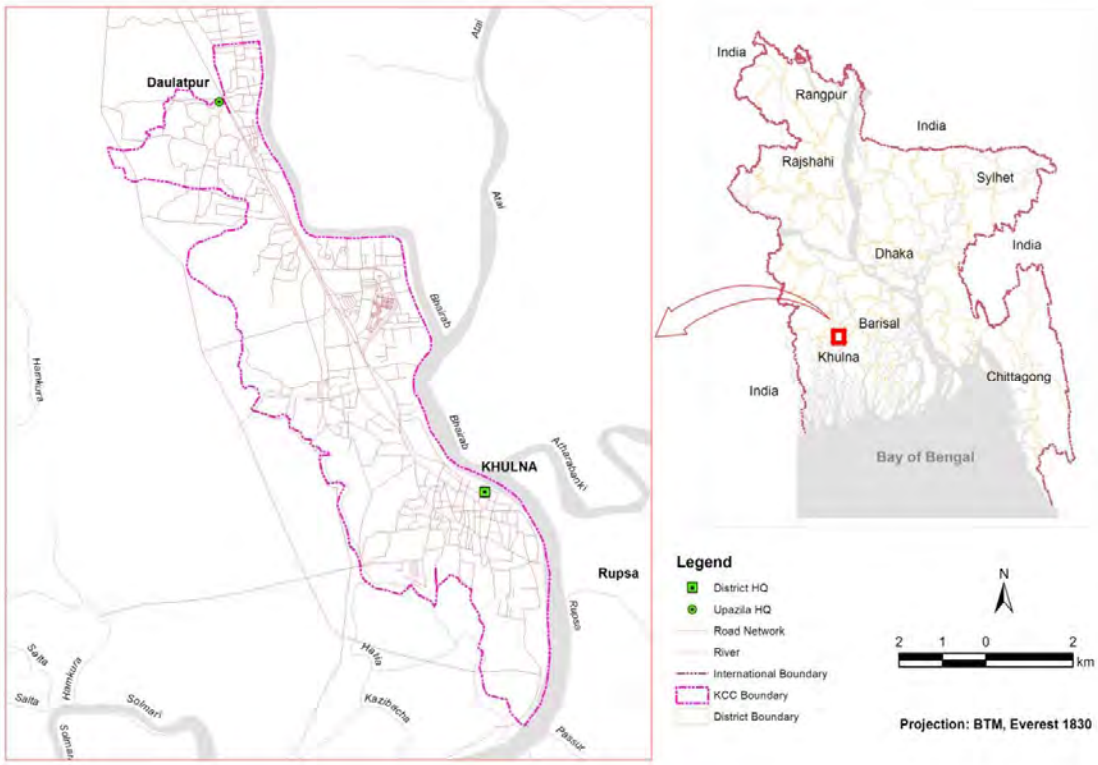


Figure 4-1: Location of Khulna City with Respect to Bangladesh

Source: The map is prepared by the researcher

Khulna City comprises of 31 wards within 5 Thanas (*See* **Table 4-1** and **Figure 4-1**). From the table, it is shown that Khalishpur and Khulna Sadar Thana equally comprise highest number of wards (13) and lowest number of ward (5) in Daulatpur Thana on other hand. Previously mentioned two Thanas are also largest in terms of their occupancy (Area in sq. km) within the city corporation area and they are 12.73 sq. km (28%) and 11.25 sq. km (25%) respectively. Daulatpur Thana is also lowest in terms of area (4.60 sq. km) and it is 9% of the total city corporation area.

Table 4-1 : Thanas Comprising of Different Wards of Khulna City

Thana Name	Within the Thana Boundary		Area (sq. km) with the KCC Boundary	Percent (%)
	No. of Ward	Ward No.		
Daulatpur	5	1, 2, 3, 4, 5	4.06	9
Khalishpur	13	5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 21	12.73	28
Khanjahan Ali	9	1, 2, 3, 4, 5, 6, 9, 14, 16	9.22	21
Khulna Sadar	13	19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31	11.25	25
Sonadanga	10	14, 16, 17, 18, 19, 20, 21, 24, 25, 26	7.63	17
5	**31**		**44.89**	**100**

Source: (Khulna Development Authority, 2002b)

Table 4-2 : Area of Different Wards of Khulna City

Ward No	Area (sq. km)	Percent (%)	Ward No	Area (sq. km)	Percent (%)
1	2.10	5	17	2.29	5
2	2.12	5	18	1.58	4
3	3.73	8	19	0.49	1
4	1.98	4	20	0.50	1
5	0.74	2	21	1.37	3
6	2.15	5	22	0.66	1
7	0.46	1	23	0.51	1
8	0.91	2	24	1.52	3
9	3.54	8	25	0.76	2
10	0.81	2	26	0.66	1
11	0.37	1	27	0.83	2
12	0.66	1	28	0.76	2
13	1.01	2	29	0.66	1
14	2.69	6	30	1.18	3
15	1.57	4	31	3.66	8
16	2.27	5	**Total**	**44.55**	**100**

Source: (Khulna Development Authority, 2002b)

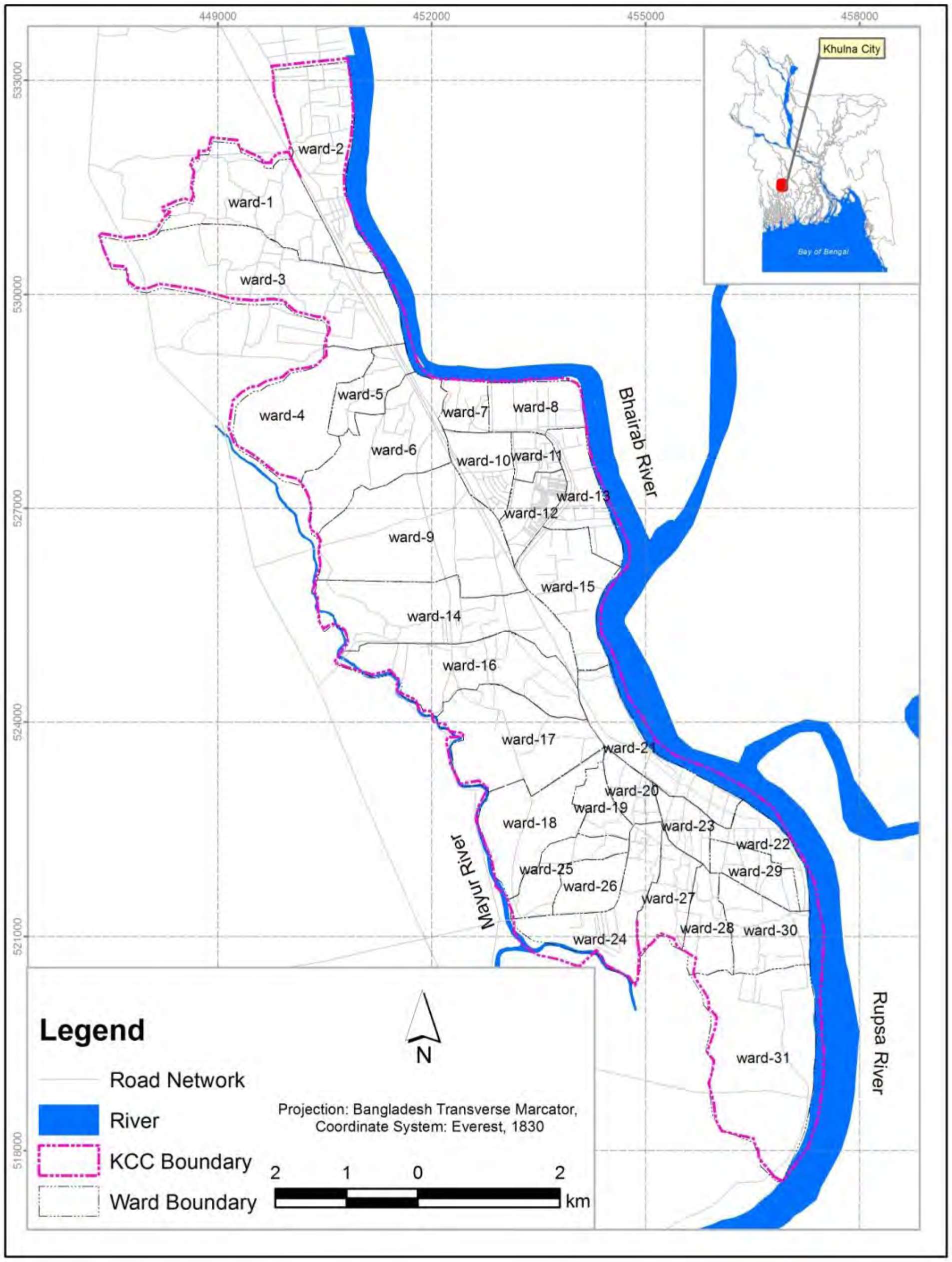


Figure 4-2: Base Map of Khulna City

Source: The map is prepared by the researcher

Table 4-2 depicts occupancies of different wards within Khulna City. It has been shown that ward 3, 9 and 31 take up highest coverage of the city and it is 8% each of ward. These are mostly peripheral wards. On other hand, 7, 11, 12, 19, 20, 22, 23, 26 and 29 wards have the lowest coverage of area (1%) and these are mostly located in the central parts of the city (*See* **Figure 4-2**).

4.4 Study Area Information

4.4.1 Geographical Setting

Khulna is located in the south-west of Bangladesh. Khulna district has an area of about 4,394 km² (BBS, 1995). It lies south of Jessore and Narail, East of Satkhira, West of Bagerhat and North of the Bay of Bengal. It is part of the largest delta in the world. In the southern part of the delta lies the Sundarban, the world's largest mangrove forest. The city of Khulna is situated in the northern part of the district, and is mainly an expansion of trade centers close to the Rupsha and Bhairab Rivers. Khulna City Corporation is consisted of 31 wards, which is shown in Figure 4-2: Base Map of Khulna City.

4.4.2 Topography

Natural environment has a profound impact on a city in shaping its physical setting and its pattern of growth. With the characteristics of a moribund delta and tidal environment, Khulna City has some specific conditions that need to be considered for any spatial and physical planning exercise. Khulna City is consisted of the largest delta in the world, which has been developed and influenced by the process of siltation from a network of rivers. Because of its location in a moribund delta and tidal environment, the city has specific characteristics on land, soil, climate, hydrology, rainfall and salinity. The physiography of Khulna region can be broadly characterized by the Ganges-tidal floodplain having lower relief and being crisscrossed by innumerable tidal rivers and channels. This physiographic unit is nearly flat and the surface is poorly drained.

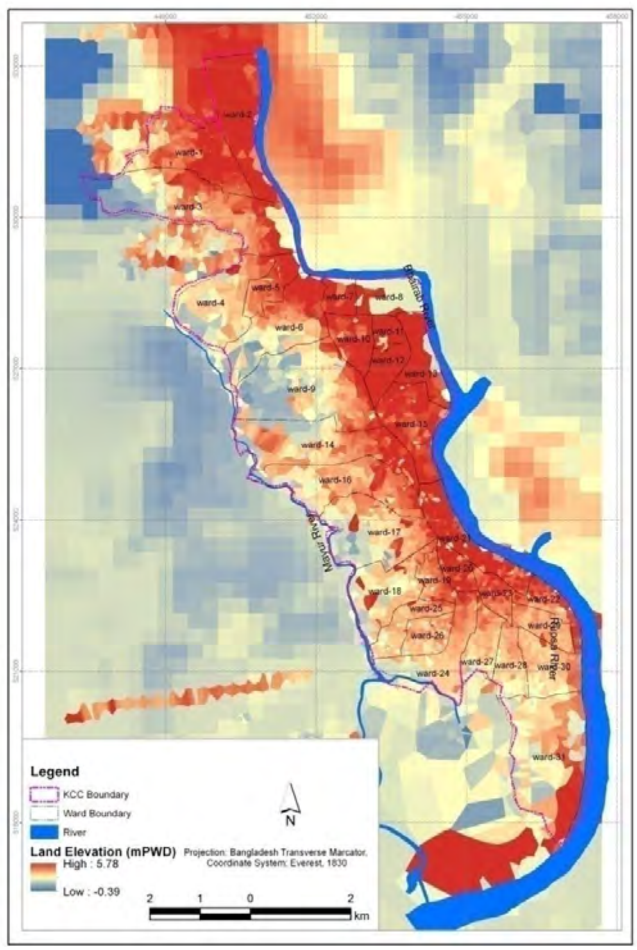


Figure 4-3 : Topographic Condition of KCC Area

(Based on data from national DEM of Bangladesh)

Khulna City is not perfectly leveled over the whole area and is characterized by some major units viz. natural levees, floodplains, old meander complex, bar, tidal marsh and back swamps. Natural levees are well developed along the Bhairab-Rupsha banks (mostly on the west bank) and are occupied mainly by the present built-up area of the city. Each of these above units has different land levels. It can be observed that elevation of land decreases sharply to the east and west direction from the main city or more appropriately, from the rivers Rupsha and Bhairab. However, along the north-south direction land levels moderately decreases towards the south. This part of the city is 4 m above the mean sea level (MSL). The low-lying areas extend mainly towards the fringe areas of the city characterized by swampy areas, currently used for agricultural purpose that are poorly drained and suffer persistent water logging problems. Figure 4-3 shows Digital Elevation Model of Khulna City representing land elevation. The average altitude of this area is less than 2m above MSL (Khulna Development Authority, 2002b). Apart from these topographic conditions the city has the following natural peculiarities:

- Khulna City has a unique linear shape, extending from southeast to northwest along the Bhairab-Rupsha Rivers. Also the railway line and Khulna-Jessore Road played a dominant role in shaping the city in a linear one.
- Khulna City experiences high impact of salinity in its surface and ground water. This poses a problem because of a saline natural environment around the city.
- The city is almost free from natural disasters like flood, cyclone and earthquake. Both, frequency and intensity of disasters are also low in Khulna.

4.4.3 Hydrology

Khulna is located on the bank of the confluence of the two major rivers, the Bhairab and the Rupsha. The Bhairab borders the north-west part of the city, after which the river Atai connects with Bhairab and goes forward to as Rupsha. At the

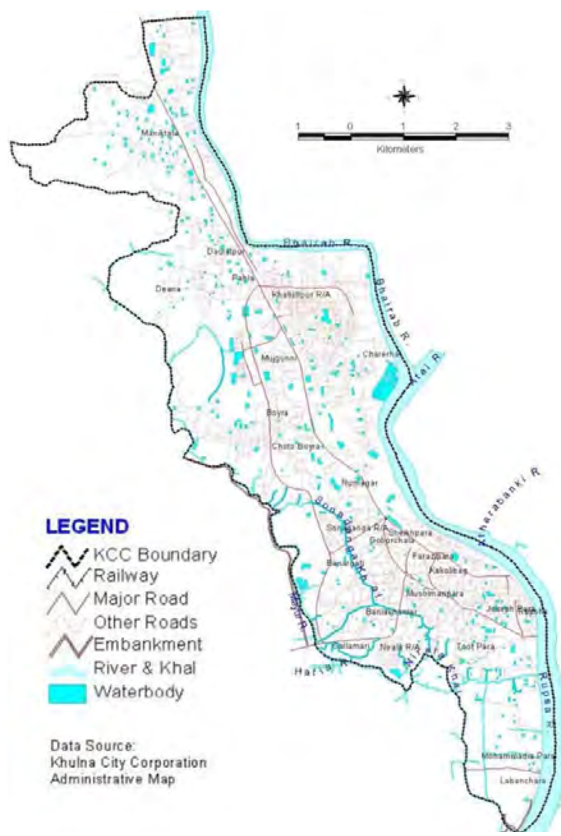


Figure 4-4 : Water bodies of Khulna City

upstream the river system is connected to the Ganges through the Gorai River. Besides the Bhairab and Rupsha Rivers, few other rivers namely Chitra, Nabaganga, Atharobanki and Modhumati are also of relevance to Khulna City concerning the surface water hydrology (*See* Figure 4-4). Majority (80%) of the rainfall occurs during the monsoon (June to October). So the main source of fresh water for Khulna City during dry season is the flow diverted from the Ganges to the Gorai River. Downstream of Khulna City, the Rupsha River meets with the Pasur River and falls into the Bay Bengal. Tidal flow from the Bay has daily, seasonal and annual variation. The effect of this tidal flow is observed throughout the system. Salinity intrusion from the Bay of Bengal into the river system around the Khulna City is influenced by the surface water hydrology prevailing around the City (Asian Development Bank, 2010). Figure 4-5 shows the total hydrological system of the south-west region (covering the whole area of Khulna Region) of Bangladesh.

Figure 4-5 : River System of Khulna Region

Source: The map is prepared by the researcher

4.4.4 Land Use Activities

As mentioned earlier, because of physiographic setting, Khulna has grown along the west bank of the river Bhairab in a linear pattern. Because of the non-availability of buildable land and having hinter land on the west, the westward growth of the city has been restricted, making the city a narrow strip of urbanized land, 16 km in north-south and a maximum of 4 km in east-west direction. According to the Khulna Structure Plan 2000, about 28% of the land is occupied by housing. Near about 5% land is under industrial use, small percentage (about 2%) of land is under commercial use. Land use pattern of Khulna has been substantially influenced by the flow of the Rupsha and Bhairab rivers. As a deltaic plain the land is flat and poorly drained. The whole metropolitan area is approximately 2.5 meter above the mean sea level where such low configuration of the city surface acts as an obstacle to the development of proper land use structure.

Table 4-3: Land Use Pattern of KCC in 1998

Land Use	Area in sq km	Percentage
Settlement Area	23.50	51.1
Agricultural Land	9.77	21.2
Mixed Built up Area	6.58	14.3
Industrial Area	3.07	6.7
Commercial Area	0.48	1.1
Education	0.35	0.8
Shipyard	0.32	0.7
Government Institutions	0.13	0.3
Grave Yard	0.07	0.1
Others	1.73	3.80
Total	**46**	**100**

Source: (Khulna Development Authority, 2002b)

Figure 4-6: Land Use Pattern of Khulna City in 1998

On the other hand, if the proportions of different types of land uses were calculated from the gross built-up areas, a more meaningful picture is observed. In this case, the most dominant type of use is urban residential category (61 percent) followed by industrial uses (14 percent). Health, education and community facilities covered 7 percent of the built-up areas, the third dominant use. Almost similar proportion of land, 6 percent, was used by the public authorities for its various usages. For commercial activities, about 6 percent of the urbanized land was used. The lowest proportion was found to be for recreation purpose, 3 percent, which is highly inadequate by any standard. It is interesting to note that even with the gross built-up areas, there are about 2 percent of the land was used for non-urban type of uses.

Land use under transport and communication show only the type of use such as terminals and stations, etc. If land use under road network is considered, which was not shown on Table 4-3, it constitutes about 8 percent of the gross built-up area. This seems also to be inadequate for a proper circulation system of the city.

Individual category wise, mixed residential areas for middle and lower income people occupied the largest proportion of land, 49 percent, followed by land use for heavy industries, which accounted for only 7 percent of the built-up area. A generalized pattern of land use is shown in Figure 4-6.

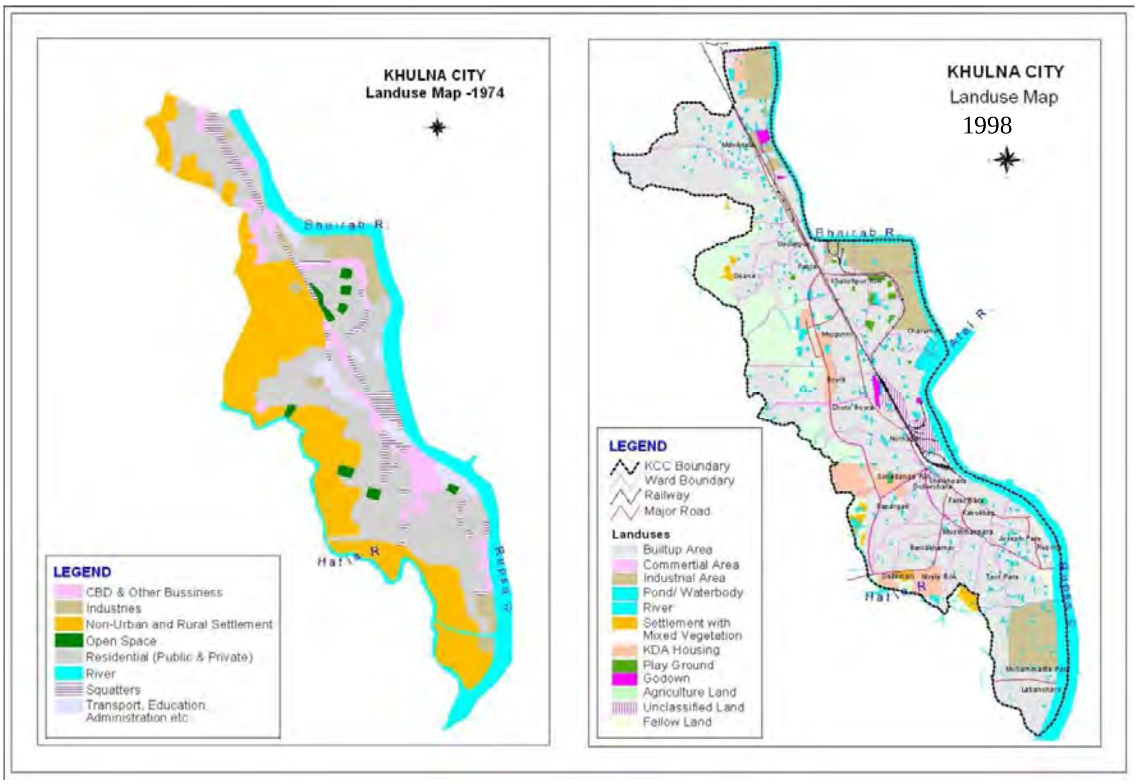


Figure 4-7 : Pattern of Land Use Change in Khulna City Corporation Area in 1974 and 1998.

Source: (Khulna Development Authority, 2002b)

Land use change from 1974 to 1998 is shown in the above Figure 4-7. It is noticed that a significant amount of agriculture land has decreased from that time interval. On other hand, urban land (majorly commercial, residential and industrial land) has taken place replacing agricultural land. Within the city corporation area, the city has expanded in the westward and outside the city corporation area the city has expanded northward.

4.4.5 Economic Characteristics

A linear economic corridor from Jessore to Mongla has been developed over the period due to transport network, road, railway and water. Following this, Khulna City was flourished as a major centre of jute processing and trading. This has played a significant role in the growth of the city during the 1960s. However, the City no longer depends on such important industrial base. Several new dimensions have been added to its economy. Khulna is emerging as a major shrimp processing and exporting centre in the country. Already the sector made a significant contribution to the regeneration of the city (Khulna Development Authority, 2002b).

Khulna City was famous for two basic industries Shipyard and Newsprint Mill. But in course of time both the industries declined to play an important potential role. Despite the closure of major nationalized industries in Khulna, the city still has a lion share of labor force in the industrial sector. Such basic characteristics indicate the potentiality of further growth of the city. Shrimp processing industry have grown profoundly in and around the city. This may be considered as resource base for the city. Low net density but high gross density in Khulna City indicates a lack of open space and a large non- built up areas (Khulna Development Authority, 2002b). Climate-induced natural phenomenon like increased salinity, water logging, cyclone, etc. would directly affect the income of nearly 80 percent of the people (non-wage income group). A number of large scale industrial units were set up in this district during the period of 1950-70, where Khulna Newsprint Mills Ltd, Khulna Hardboard Mills Ltd, Khulna Textile Mills Ltd, Khulna Power Station and seventeen jute mills are mentionable. Another important industrial unit Khulna shipyard Ltd was established in 1957. But now, Khulna Newsprint Mills, Textile Mills and a number of jute mills have already been closed as per government decision. On the other hand, Khulna shipyard Ltd was handed over to Bangladesh Navy for running its operation.

At present, economic activities in Khulna City are mainly centered on its rich natural resources ï fisheries and forestry. Around 1.9% of the population of Bangladesh lives in Khulna but it contributes a slightly higher percent in terms of GDP (2.5% of national GDP). The service sector dominates the economic activities of the area (54%). Agriculture is next contributing to 26% of the GDP of Khulna, while industries contribute to 20% (BBS, 2005).

4.4.6 Existing Drainage Condition

Unplanned spatial activities and habitation cause encroachment on water retention areas and natural drainage paths with little or no care for natural drainage system. Inadequate drain sections, natural siltation, absence of outlets, indefinite drainage outlets, lack of proper maintenance of the existing drainage system and over and above disposal of solid wastes into the drains and drainage paths are responsible for the prime causes of blockage in drainage system and water logging. In addition, seasonal tidal effect and flat topography of land also cause water logging, especially in the southern part of the city.

There is about 528 kilometers of drainage network in KCC area. Of this about 64 km is pucca, about 52 km semi-pucca and about 38l km is kancha. Except natural drains there is no man made drainage stem outside municipal areas. From the household survey of the Master Plan of Khulna City shows that about 68 percent of the households have no planned drainage facilities in and around their premises, while only 32 percent have some sort of drainage facilities. The existing drains in KCC area discharge into the nearby khals, rivers, low-lying areas and beels. There is no underground storm water drainage system within the city. Existing drainage facilities in the fringe and sub-urban areas are inadequate and unsatisfactory. The KDA or KCC areas in the town are not subject to direct flooding from the Bhairab-Rupsha River, but the low-lying areas situated on the western and southern part of the city are flooded by the rain and tidal flooding during monsoon season. There are 6 regulators and 8 sluice gates which drain out storm water from KCC. 4 regulators drain out storm water into the Rupsha River and the other two regulators drain into the Khudir Khal, the upstream of Gollamari River. Existing drainage network is shown in Figure 4-8. Topographical features, existing internal network of khals and the river system in and around the Structure Plan area shows the following five drainage zones:

a. Long- Narrow Strip of Flat Highland along Bhairab-Rupsha River (Right Bank).

There is a long and narrow strip of flat highland along the Bhairab and Rupsha Rivers and stretching along northwest to southeast direction; this strip consists of KCC core and urbanized area. The ground elevation of this narrow strip decreases towards west and south direction and gradually turns into a flood plain and swampy lands/beels comprising flat and low-lying areas, crisscrossed by numerous tidal rivers and channels. The drainage water is discharged into the Bhairab and Rupsha rivers through sluices/ regulators lying on the embankment cum road.

b. Strip on the Eastern Side of the Bhairab and Rupsha River (left bank)

These areas are drained through natural drains, borrow-pits and ground profiles sloping towards adjacent low-lying areas/flood plain and ultimately into the outfall river/khals, viz., Bhairab, Rupsha, Atharobanki, Atai, Majudkhali, etc. These areas comprise the fringe area of the town.

c. South and South-eastern Area on the Left Bank of Rupsha, Kazibacha River

These are fringe areas and drained through numerous tidal creeks, low-lying areas/beels and flat land situated in the flood plain of the major rivers, which ultimately drained into the adjacent Rupsha, Kazibacha and Atharobanki Rivers.

d. Western Part of KCC Area along Left Bank of Gollamari River and Khudir Khal

The western part of KCC between Daulatpur and Kazibacha river is drained by the upstream of Gollamari River or Khudir Khal and downstream of Gollamari River and ultimately through a regulator at Alutala which discharges into the Kazibacha-Rupsha River. A small part of the catchment area adjoining Khulna University, on the right side of the Gollamari River used to drain by two sluices, but now drains towards west and into the lower Sholmari River due to occurrence of siltation problem in the Gollamari River and Khudir Khal.

e. Northwestern Part of KCC and Structure Plan Area, Western Part of the Plan Area.

This catchment is falling in drainage area along Khulna-Jessore Road and Dakatia Beel. North and northwestern part of Structure Plan area between Daulatpur, Phultala and Avoynagar. The storm water runoff from these areas is discharged into the Dakatia Beel, Koyar Beel and Daira Beel through numerous khals comprising a complex system of khals and low-lying areas and ultimately the runoff is discharged into the upper Sholmari River through a regulator at Salua which finally discharges into its outfall Kazibacha River at Jalma. Inundation and inadequate drainage in the Structure Plan area occur due to localized storm rainfall (internal flood) affecting drainage system. External flood is not likely to occur since the Structure Plan is situated in the tidal zone. The areas suffering from drainage congestion has been identified during moderate to heavy rainfall. The inundated areas associated with drainage congestion are Natun Bazar, Rupsha, Tutpara, Shipyard areas, East Bania Khamar, Boyra, Rayer Mohal, Khan-A-Sabur Road (in front of KDA building), Nodal Point of Khan Jahan Ali and KDA Avenue (nearby and surrounding Royal Hotel). Water logging areas based on wards within the studied area is shown in Figure 4-10. The reasons for water logging have been identified as improper operation and maintenance of khals/drains, blockage in the existing khals/drains, absence of integrated network comprising secondary and side drains, haphazard expansion of the settlements which obstructs the natural drainage system, uncontrolled and haphazard disposal of solid waste into the drainage system and siltation in drainage channels with consequent reduction of discharge capacity.

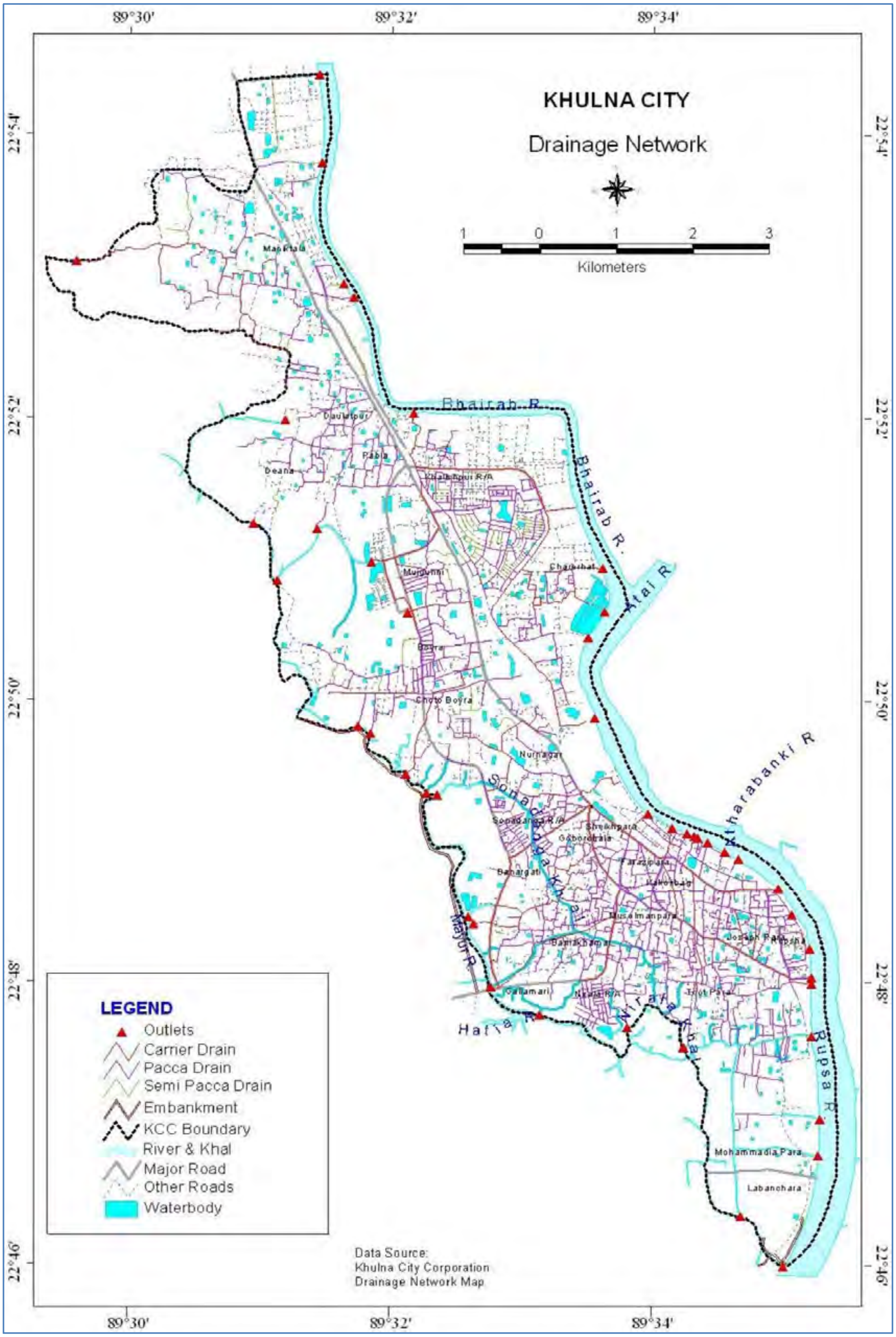


Figure 4-8: Existing Drainage Network within KCC Area in 2011

Source: Khulna City Corporation

4.4.7 Environmental Characteristics

The whole Khulna city is becoming unsuitable for living because of environment degradation. There is a major threat to the environment continuously polluting air, water and soil of the areas. Of them, water logging problem is severe. Khulna City receives an average rainfall of about 1800mm (Billah, 2001). There is insufficient drainage system handling this rainfall within the city area. There is a total of 652 km drain, of which 291.23 km pacca, 55.5 km semi pacca, and 305.25 km kancha drain (muddy). There is no underground drainage system in the city (Rahman, 2005). The major drainage problems of the city are encroachment on drainage path, inadequate drain sections, inadequate outlets, lack of proper maintenance of existing drainage system, and disposal of waste into drainage paths. This is why different parts of the city especially the downtown have to face the water logging problems. In this connection, major water logging areas are Ward 8, 9, 12, 21 and 18 which is shown in Figure 4-9 and Figure 4-10.

Industrial units at Khalishpur and Daulatpur in Khulna are posing a threat to the environment continuously polluting air, water and soil of the areas. Local physicians claim people of the Khalishpur and Daulatpur industrial area who are exposed to constant sounds of mills and factories are losing hearing capacity day by day. They are also affected by water pollution caused by the industrial units. Waste from different mills and factories are falling in the Rupsha and Bhairab and polluting the river water. A recent report said, there were 58 industrial units in this area in 2001. But now, there are about 350 industrial units in the region. Of them, 230, including jute mills, power plants, soybean mills, saw mills, shrimp processing plants and cement factories are on the banks of the Bhairab (The Financial Express, 2010).

Urban Flooding in front of KDA building

Urban Flooding in the hub of the City

Urban Flooding

Urban Flooding in the terminal of KCC

Figure 4-9 : Environmental Conditions in Different Parts of Khulna City

More than 22 shrimp processing factories are also polluting the environment of Khulna and Rupsha areas. Chemical wastes and bleaching powder, disposed by the industries and plants are polluting water and soil to a great extent. Brickfields in Rupsha, Abhaynagor and Phultala Upazilas are polluting air on a large scale. The brickfields used firewood instead of coal emitting huge volume of black smoke.

The air is contaminated with different harmful gases including carbon dioxide and carbon monoxide, which are detrimental to health. Consequently, diseases like lung cancer, respiratory problems, asthma and hypertension have become common among the people of the region. The drainage system of Khulna and Khalishpur is in a poor condition. A large number of latrines are connected to drains that constantly produce obnoxious smell. Due to lack of a sound water management, water logging has also become a regular phenomenon, particularly in rainy season.

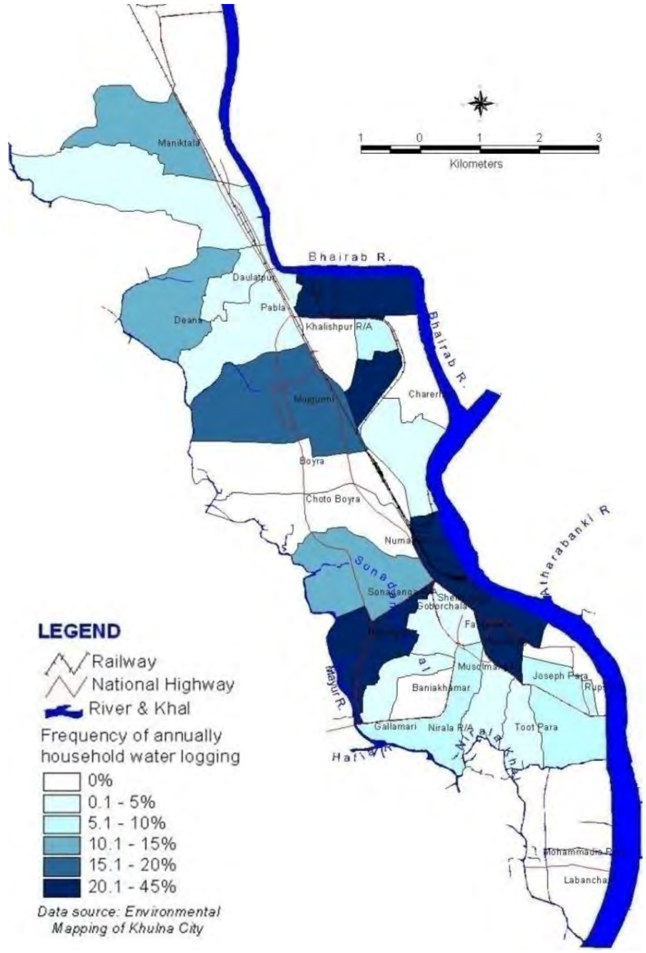


Figure 4-10 : Water Logging Areas in Different Wards of Khulna City
Source: (Rahman, 2005)

Climate change has left an adverse impact on the coastal belt of the country where storm, cyclone, tidal surge, drought, river erosion and water logging have become the regular affairs. For example, Sidr on November 15, 2007 and Aila on May 25, 2009 battered southern districts. Disasters hit people are still living miserable life under the open sky and in makeshift camps amid acute scarcity of food and safe drinking water. The coastal rivers are getting swelled with tidewater due to the effect of climate change and the water flowing over the river banks are entering the arable land with adverse effects causing loss of fertility, said Makhon Lal Das, DAE of Khulna office. He added that it is also severely affecting aqua life, bio-diversity and threatening food security in the coastal belt. Fishermen and farmers are now searching for alternative livelihood and urging the authorities to find out salinity resistant varieties of crops to save them from crop losses and the burden of loans. (The Independent, 2010)

4.5 Past Incidents and Probable Disasters

Bangladesh stands to suffer a high risk of damage from climate change for several reasons. Geologically and geographically, Bangladesh is a low-lying active delta interlaced by rivers and waterways, the outlet of three gigantic Himalayan rivers into the Bay of Bengal. It lies on a geological fault line and has a high risk of earthquakes. It is prone to tropical cyclones. In the southern coastal belt, cyclones are often accompanied by storm surges or tidal bores where sea water travels up canals and rivers with deadly force. Near the coast saltwater also seeps up the freshwater channels and makes potable water scarce. Such risks are set to increase with climate change. However, the demographics of Bangladesh also stand to exacerbate its effects. (Lönnqvist et al., 2010)

Bangladesh faces lots of disasters due to geographical location over the thousands years. It is situated in the mouth of the funnel of the Bay of Bengal and its coastal zone take up significant amount of areas. In this connection, coastal areas are more vulnerable by marine related disasters viz. cyclone, tidal flooding, storm surge, salinity intrusion, river erosion, etc. rather than others. Recently frequency of those disasters is increased and expected to be exacerbated. Factors behind this are both man-made and natural. Of the natural factors, climate change is advertent and it has left an adverse impact on the coastal belt of the country where storm, cyclone, tidal surge, drought, river erosion and water logging have become the regular affairs. Maximum hazards and disasters are supposed to be direct and indirect effects and repercussion of climate change. In this connection, Sidr on November 15, 2007 and Aila on May 25, 2009 are the paradigm that battered southern districts. Climate change related problems are increased flood frequency and level, increased frequency and extent of storm surge, increased intensity and frequency of cyclone, water logging, salt water intrusion, sedimentation and river bank erosion (Rahman, 2005). Apart from this, vulnerable sectors are health, water and sanitation, energy, settlements, waste and waste management, and road and transport (Rahman, 2005).

Khulna City is situated around 125km west from the shore. Though it has less chance to be affected directly by the major disasters namely cyclone, storm surge etc. rather than coastal and near coastal areas. But it is at grave risk under salinity intrusion, flooding (urban, riverine and urban flooding), river erosion, sedimentation and water logging. Due to having intense land use and infrastructures in urban areas, amount of damage caused by the disasters is greater than in the rural areas and agricultural land.

Chapter 5: Review of Land Use Policies and Proposals

This chapter reviews the land use policies and proposals stated in the Structure Plan and Master Plan of Khulna Development Authority. Four major land use policies namely agriculture, commercial, industrial and residential land uses are discussed here.

5.1 Introduction

Land use planning is a part of the development plan, which is encompassing various disciplines which seek to order and regulate land use in an efficient and ethical way, thus preventing land use conflicts. Authorities especially the city managers use land use policies and proposals portrayed to manage the development of land for the needs of the community while safeguarding natural resources. A land use plan, an element of a comprehensive plan, provides a vision for the future possibilities of development in neighborhoods, districts, cities, or any defined planning area.

5.2 Nature of Development, Constraints and Opportunities of Khulna City

Every city has its some own uniqueness from different perspectives. In the same way, it has some similarities. Along with this, every city has its own history from which it has been flourished. Khulna City is characterized by linear development along the bank of the Rupsha and Bhairab River. The physical growth of the city is constrained by its geographical conditions. Due to low lying back swamp areas at east-west direction lateral growth is highly constrained. The soil condition is also not favorable at these locations. Thus, the physical planning of the city must consider this factor (Khulna Development Authority, 2002a).

The physiography and natural environment of Khulna City have profound impact in shaping its physical growth and pattern of development. The natural levees along the rivers Rupsha and Bhairab are the most ideal lands for urban development. The linear shape is also influenced by transport route that is Khulna-Jessore highway and it may expand north up to Jessore. However, such as obvious linear shape (in north-south direction) seems too dysfunctional and less efficient for more than one reason especially the transport cost for receiving administrative and other social services which is much higher under the present circumstances. Thus, the recent trend of growth towards southeast and southwest seems to be encouraging for a more balanced and integrated spatial development of natural growth of the city west and southwestward will take place as the Rupsha Bridge is constructed with the approach road running west of Khulna. The aspect of the lateral growth option should also be explored it the city could spill over across Rupsha to Dighalia, provided a second bridge could he constructed in the medium term (Khulna Development Authority, 2002a).

Observation on the past trends of growth reveal that physical expansion of Khulna City was highly influenced by two main factors ï topography and communication route. The first ever settlement took shape on the natural levee by the riverbank and over the years, the settlements continued to extend on the levee along the River Bhairab-Rupsha. During early days rivers served as the key route of transport, which also became one of the key factors in location decisions. Later on, when road system was developed, particularly the Khulna-Jessore Road also followed the higher topography along the river. The entire settlement pattern, was, thus dictated by the land level and the transport route. Apart from the above two factors, establishments providing major sources of employment also served as impetus to the development of residences and other supporting services in their close proximity. Survey of the city and surroundings areas show that land under natural levee is already occupied by settlements, though there are scope for densification in outer areas. Natural levee on the western part of the Bhairab-Rupsha is more intensively built. The eastern section is more of rural character and offer further opportunities for growth. Next to the levee is the flood plain, where settlement can grow without being raised much. Because these places are not inundated and thus are free from flood. The land under flood plains is near the amount of land under natural level. Next to flood plain is tidal marsh, a vast area characterized by silty clay and peat located in the southwestern part of the city periphery. This category of land is unsuitable for development due the low drainage and load bearing capacity of the soil.

Observation of recent trend suggests that immediate growth is likely to take place along the corridors created by the highways leading to Satkhira and Bagerhat-Mongla and Khulna-Jessore. Contiguous growth along Khulna-Satkhira Road is influenced by,

- The establishment of Khulna University,
- Construction of a bridge on the river Rupsha and developing a Bypass Road, and
- Improvement of Khulna-Satkhira Road.

Khulna-Bagerhat-Mongla triangle is an important for industrial agglomeration. Growth in these areas is highly influenced by the proposed EPZ and export and import through Mongla Port. Comparatively slow growth is expected along Khulna-Jessore Road. The growth along the Khulna-Jessore is expected to result in a linear conurbation linking Noapara-Rajarhat-Fultala with Khulna. Residential development is expected to be higher on the southwestern fringe due to better infrastructure and good accessibility to CBD facilities and other urban services. The old Satkhira Road or the road linking Daulatpur with Chuknagar will also offer some opportunities for growth. But this would depend on the quality of improvement of the road to make it an attractive alternative to Khulna-Satkhira Road. On the left bank of the river, the development prospect seems to be limited unless (a) city bridge is constructed to link both sides and (b) municipal services are extended to the region. However, Rupsha and Dighalia show very high potentials for urban growth, since suitable land and good communication.

The process of urban land development in Khulna City has been extremely slow due to the stagnant and slow growth of the economy of Khulna, low investment, sick industries, lack of vital infrastructure and deteriorating law and order situation. The housing areas in Khulna City are characterized both by very low and high densities depending on the location and the area. Except around the central city area, most of the residential areas have vacant land, water bodies and non-residential usage. Agricultural uses of land in many residential areas are common in Khulna. Lack of affordability, low demand for housing, absence of housing loan are perhaps other important reasons for slow growth. Even in some high-income areas, like Nirala and Sonadanga, development is rather slow. Other major constraints for development are lack of awareness of the people for planned development and people's participation, lack of political commitment, Poor adherence to planning laws and regulatory measures or reinforcement of planning laws and regulation and lack of cooperation and coordination among the parastatal organizations involved in the physical development activities in the city areas.

There can be debate about the method and approach to planned development, but there is no scope to discard the necessity and importance of such development to ensure a congenial urban environment in a civilized world. One of the pre-conditions for planed development is the availability of large tracts of undeveloped or less developed land. Development on such lands can help minimize the cost of development by avoiding demolition, and providing compensation and rehabilitation. With the re-delineation of KDA boundary, vast non-built areas (currently used as poor farmlands) are included within the prospective city boundary. This will offer new opportunities for planned urban development. There are a range of opportunities of various natures which might be utilized for the planned growth of cities where applicable. It is the responsibility of the authorities to use such opportunities. The main such opportunities are as follows.

- Flood free land, especially in the north, east and some of the areas of south and south east region of the Plan area

- Low land price (if compared with other metropolitan cities) is also an opportunity for its development

- Availability of technical assistance for development from Khulna University and Khulna University of Engineering and Technology

- Goods transport network in and around Khulna City which connects all important places in the region.

- There are still ample scopes for densification of population within the limit of the city. This will facilitate providing services to the people with reasonable development cost.

- There are a number of NGOs involved in the activities and development of Khulna City. This may also be considered as an opportunity as they are active partners of city development

- Innumerable water bodies of different sizes and shape punctuate the city landscape. Preservation and management of these bodies would contribute to plan city growth with preservation of Sound City environment.

Figure 5-1: Satellite Image Showing Khulna City Corporation Area

Source: Google Earth, 2011 (The map is prepared by the researcher)

The spatial growth of Khulna City is explained by its topography. There exist natural levee on either side of the Bhairab-Rupsha River. Height of the levee varies from 7 to 14 feet above MSL and offer excellent opportunities for human settlement development. This levee extends about ½ km to 4 km inside from the river on both sides. The original Khulna city grew up on the western side of the Bhairab-Rupsha River near the southern end of the levee and extended towards northwest. After creation of Khulna-Jessore Road and development of economic activities, the city started to take shape along Khulna-Jessore corridor. Next to levee follows flood plains, about 4 km inside (western side) from the river, following the river alignment. The height of the flood plains, on average, is about 4 ft to 5 ft above MSL. Beyond the flood plains exist back swamp and tidal marsh, unsuitable for settlement development (*See* Figure 5-2). The physiography of Khulna is broadly characterized by tidal flood plains having lower relief and crisscrossed by innumerable river channels. Khulna is situated on the natural levee of the Rupsha-Bhairab River and its elevation sharply decreases to the east and west directions. In the north south direction, the city finds its way to expand naturally on moderately elevated lands. From topographic point of view, it is projected that the city`s growth will follow the levee and flood plains northward and southwest. Due to existence of the same categories of land on the eastern side of the Bhairab-Rupsha River, there is a potential for overspill. This will however, depend on development of infrastructure and municipal services including several bridges across the river. (Khulna Development Authority, 2002a)

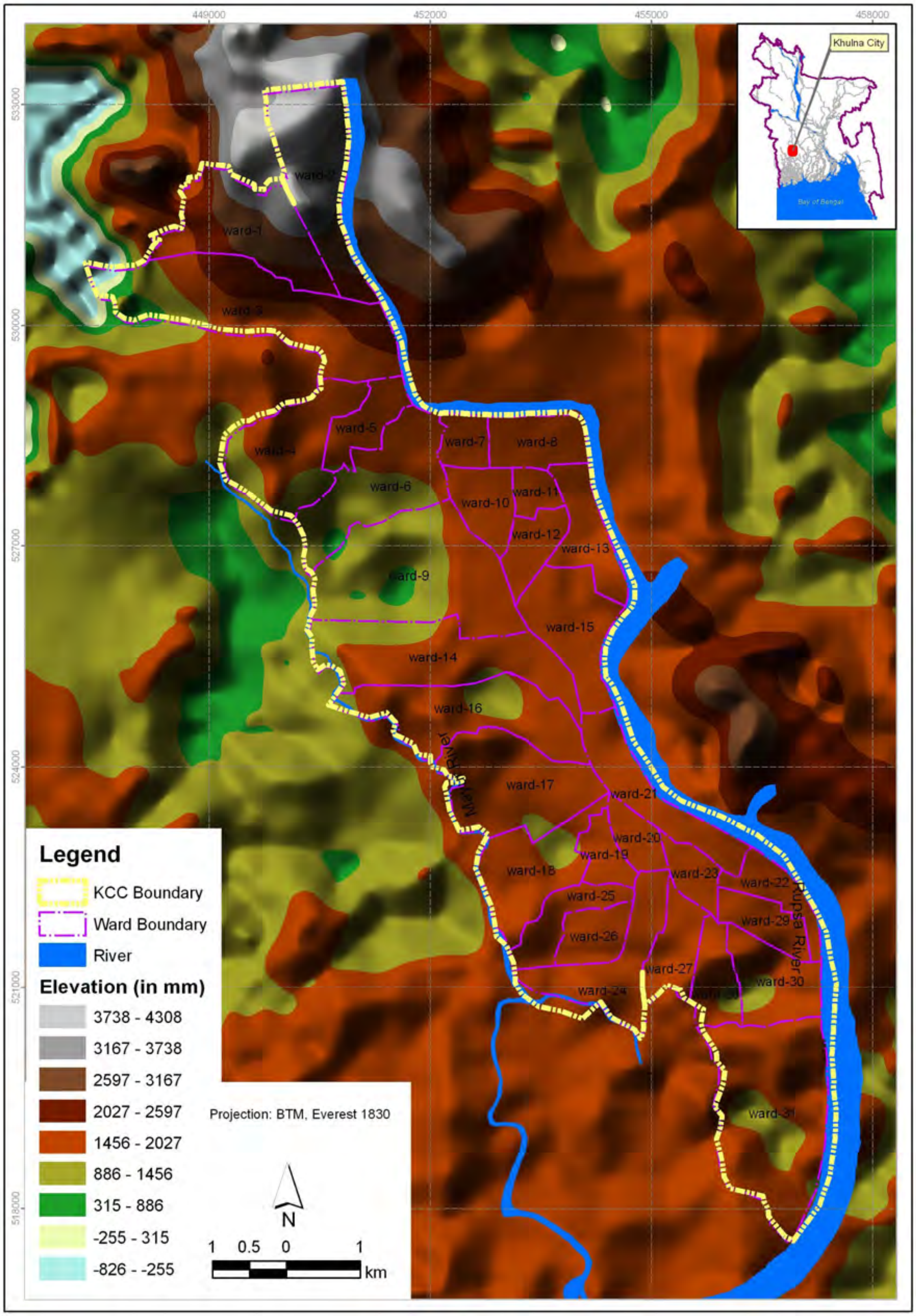


Figure 5-2: Digital Elevation Model (in terms of TIN) for KCC Area (mPWD datum)

Source: The map is prepared by the researcher

5.3 Major Land Use Policies with Proposal

5.3.1 Agriculture

The broad agriculture sector comprises about 18.64% of the total GDP. The overall growth rate of the broad agriculture sector for FY 2008-09 is provisionally estimated at 4.8% in real terms over FY 2007-08. Most Bangladeshis earn their living from agriculture directly or indirectly. The agriculture and forestry sector contributed about 16.03% of the total GDP in FY 2008-09, includes four sectors namely crops and horticulture, animal farming, forest and related services, and fisheries (Shakilah, 2011). This sector in the country contributes to ensure crops as staple food, fish and livestock as the sources of protein, and forestry as the protector of the earth especially the coastal areas from climate change etc. With this, agricultural land especially the high value agricultural land is normally hinter land, which acts as flood flow zone and the sources of wetland, contains the rainfall surface runoff, water from any type of flooding.

Agriculturally, the hinterland of Khulna City is highly rich in production of paddy, vegetables and horticulture of almost all varieties. Land is fertile for growing almost any crop. The greater Khulna District occupies 4^{th} position in contributing gross value added to national agriculture. In terms of sectoral share in district GDP share agriculture declined from 37.4 percent to 33.7 percent over the period 1990-91 to 1994 ï 1995 (Khulna Development Authority, 2002a). In the year 1993-1994, it contributed Tk. 21.197 million gross value added to national agriculture inclusive of crop, livestock and poultry, fishery and forestry. In forestry Khulna is the 2nd highest contributor to the gross value added in agriculture. The greater Khulna has 2170 thousand acres of total cropped land occupying 6th positron among former districts (BBS, 1995).

A substantial part of agricultural land of greater Khulna district has been put under brackish water shrimp cultivation in 1993-94. Almost entire production is exported. Bangladeshôs annual shrimp export amounts to about Tk. 9210 million (1993-94) and about half of which is contributed by Khulna region. In 1993-94, about 95000 hectares of land was under shrimp farms, which are about 76 percent of total shrimp land (Khulna Development Authority, 2002a). Supplies of agricultural consumables for the Khulna City come from its hinterland. Agro-products of the Khulna sub-region are marketed through Khulna City.

Structure plan area of KDA covers 451 sq. km where a clear dominance of rural and agricultural land use is observed in the existing land use pattern. In 1998, according to the survey of the structure plan, of the total 70,798 acres (or 28,663 ha.) of land studied, nearly

80 percent were used for cultivation, fishing, rural housing, as low land and water bodies (Khulna Development Authority, 2002b). On other hand, KCC area comprises of 46 sq. km. In 1998, within KCC Area, agricultural land was around 22% and 15% in 2010. In 2020, as per the Structure Plan, Agricultural land will be decreased to around 3%.

Khulna city experiences almost all the ills of environmental problems as usually does by growing urban centers of developing countries. Rapid growth and concentration of population and unplanned activities, over exploitation and irrational use of natural resources failure of management and control of unplanned development interacts each other to produce a situation of degenerated environment in the city and its surrounding areas. Basic resources like land, water and air are adversity affected, particularly in urban areas due to industrial activity. The development of land and housing is quite slow in Khulna.

The physical growth of Khulna City is constrained by its geographical conditions. Due to low lying back swamp areas at east-west direction lateral growth is highly constrained. The soil condition is also not favorable at these locations. Thus, the physical planning of the city considered this factor. There are vast agricultural land in the periphery and outskirts of the urban centers within the Khulna Development Authority Area. These lands have been allowed to remain in their current use not only as a source of food supply but also as reserve land for future urban use. Total land under agriculture has been estimated as 1276.05 acres. This land can also be used for future urban land use and hence can also be termed as urban deferred.

In fine, it has been drawn as the agricultural land was given due importance as the source of food supply and for future urban expansion within KDA Area. But there is no fixed policy to protect agricultural land within the urban area. The Structure plan shows some areas that are not suitable for development and it is small in amount.

5.3.2 Commercial

Commercial activities are termed as the life line of a city as it is a major form of economic activities. The growth and decay of city is determined, primarily, by the level of economic activities carried out. The l96l Master Plan of Khulna city proposed an area of about l44 acres as commercial land use (general business area and special office and shopping area). Proposals on commerce were presented as two broad headings for central area and for neighborhood centers. The plan proposed about 117 acres for general business purpose and 27 acres for special office and shopping area. Besides, a town centre was proposed at

Daulatpur over an area of 87 acres. A city town square was proposed on railway land near ferry Ghat area. However, only a handful of Master Plan commercial proposals were implemented. KDA failed to implement either Daulatpur Town Centre or City Town Square proposal at Ferry Ghat area. Spontaneous development dominates the land use of these areas now. Apart from land use zoning the plan also made some specific development proposals.

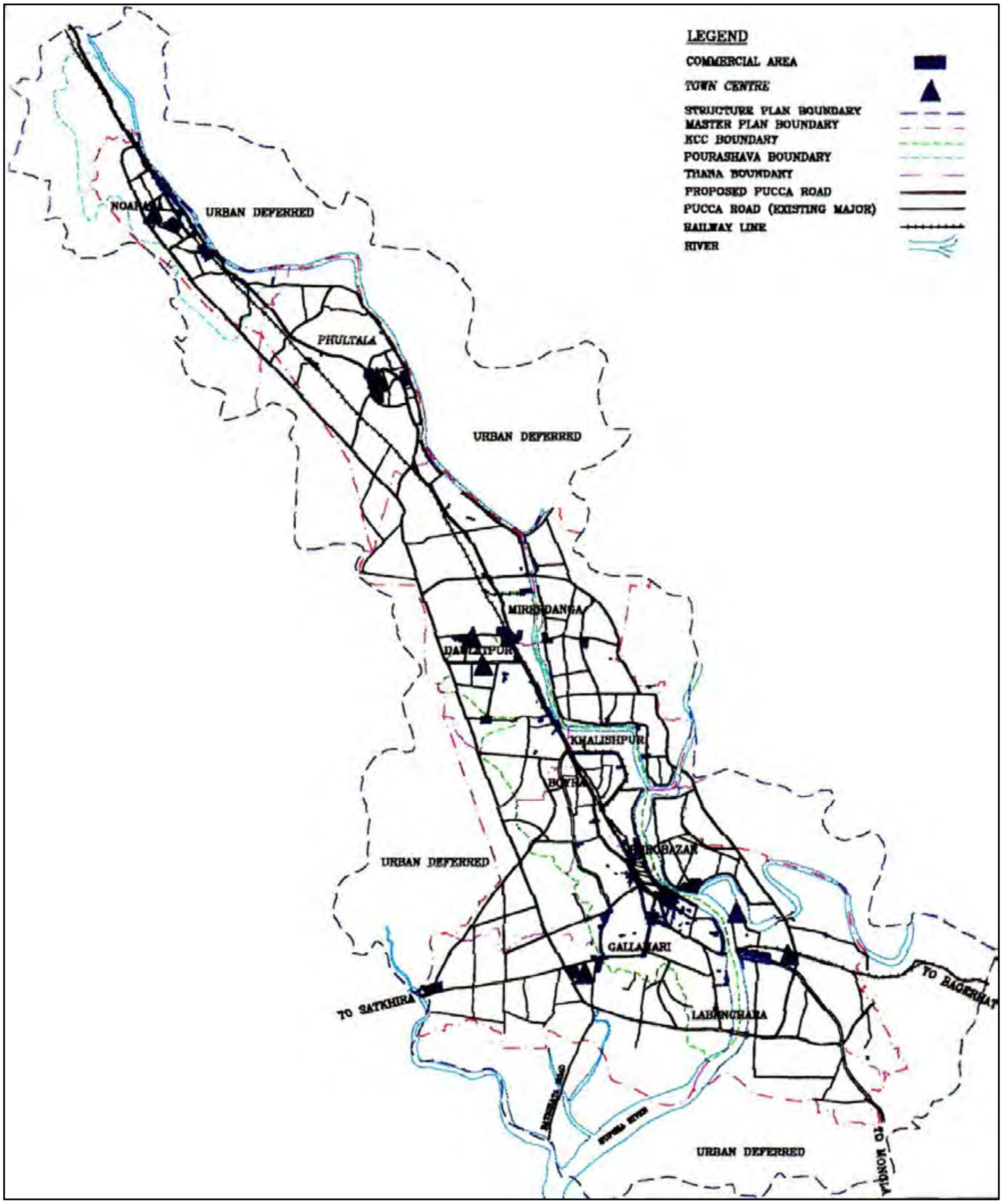


Figure 5-3: Master Plan Land Use Zoning Commercial Area

Source: (Khulna Development Authority, 2002b)

At the time of structure plan preparation in 1998, the major commercial area is about 120 acres (*see* Figure 5-5), which is existed in the KCC areas. Noapara accommodates wholesale and retail business while small urban centers like, Phultala, Rupsha and Dighalia area have retail businesses only. Apart from wholesale and retail businesses there are a large variety of commercial activities, like hotel and other services, trading houses taking place as commercial activities. The most important area lies in the central area of the city extending from Hadis Park area in the cast up to the Railway land on the west and the river Bhairab on the north up to Khan-E-Sabur Road on the south. Large commercial establishments of different categories are concentrated in this area over an area of about 70 acres. Other large concentrations are at Rupsha, Daulatpur and Noapara area. There are huge ribbon commercial developments along roads, like Sie Iqbal Road, Khan-E-Jahan Ali Road, Symmetry Road, Khan-E-Sabur Road, KDA Avenue, Sher-e-Bangla Road.

The Master Plan (*see* Figure 5-7) proposes commercial uses in those areas that are suitable for commercial development in the Khulna Development Authority Area. Provision has also been kept to enable commercial development in mixed areas. Locations with good accessibility and scope of public gathering have, particularly, been given importance in delineating commercial use areas. The plan proposes to develop commercial hubs in potential areas within the Master Plan. About 1088.81 acres of land have been proposed as commercial use (including Town Centers) within the Master Plan area with about 762 acres in KCC area. About 362.81 acres have been proposed within the extended area. Important commercial developments are expected in Shiromoni, Phulbari gate, Gaslamari, New Market-Shibbari area, Aranghata area, Teligati area, Noapara, Rupsha and Dighalia area. In Phultala area the existing main commercial development is by the riverside. Other commercial developments are clustered. New commercial development in the area will include town centre, bazaar and other commercial development around the town centre and existing commercial establishments. In Noapara area new commercial proposals include a new town centre, a bazaar and surrounding commercial development generated through extension. The existing commercial developments are located as ribbon development along the existing highway which is major reason for traffic congestion in the area. The new developments on the western side of the railway line will transfer the focus of the town from the existing town area. The proposed town centre will play the key role in this regard. If found encouraging the commercial land use in the area may be extended further during revision of the Master Plan. With the development of new western bypass road it is expected that congestion on Jessore-

Khulna Road will be reduced and business activities in the area will gear up further. A significant amount of land has been allocated for making an Information Technology (IT) village in the existing Textile industries land behind New Market. This will be an important area in terms of commerce and business in Khulna City.

The Master Plan proposed around 1100 acres commercial land including the existing one, which was expected to be grown up in 2010. But practically, it has been shown that there is a huge gap from the proposal and only around 700 acres of land has been developed (*see* Figure 5-6). Because, Service sector remained more or less stagnant, while shares of both industry and manufacturing increased (Khulna Development Authority, 2002a).

In terms of sectoral share in district GDP in Khulna, agriculture declined from 37.4 percent to 33.7 percent over the period 1990-91 to 1994 ï 1995 (Khulna Development Authority, 2002a). In the Structure Plan in 2020, around 1600 acres of land has been proposed as urban expansion (see Figure 5-8). This also decreased 1600 acres of agricultural land. In this expansion, commercial use take a significant amount of land and proposals are already mentioned above.

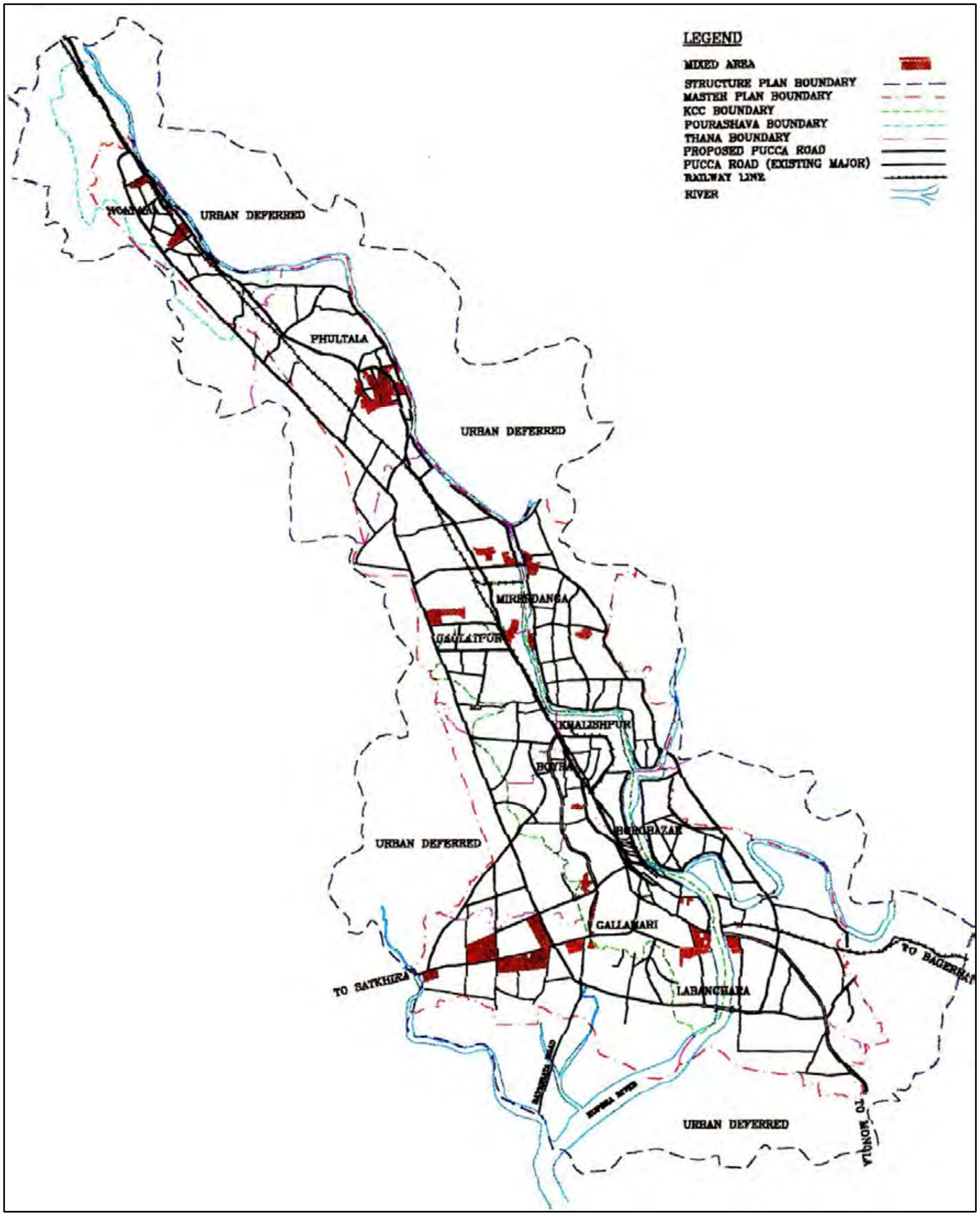


Figure 5-4: Master Plan Land Use Zoning Mixed Use Area

Source: (Khulna Development Authority, 2002b)

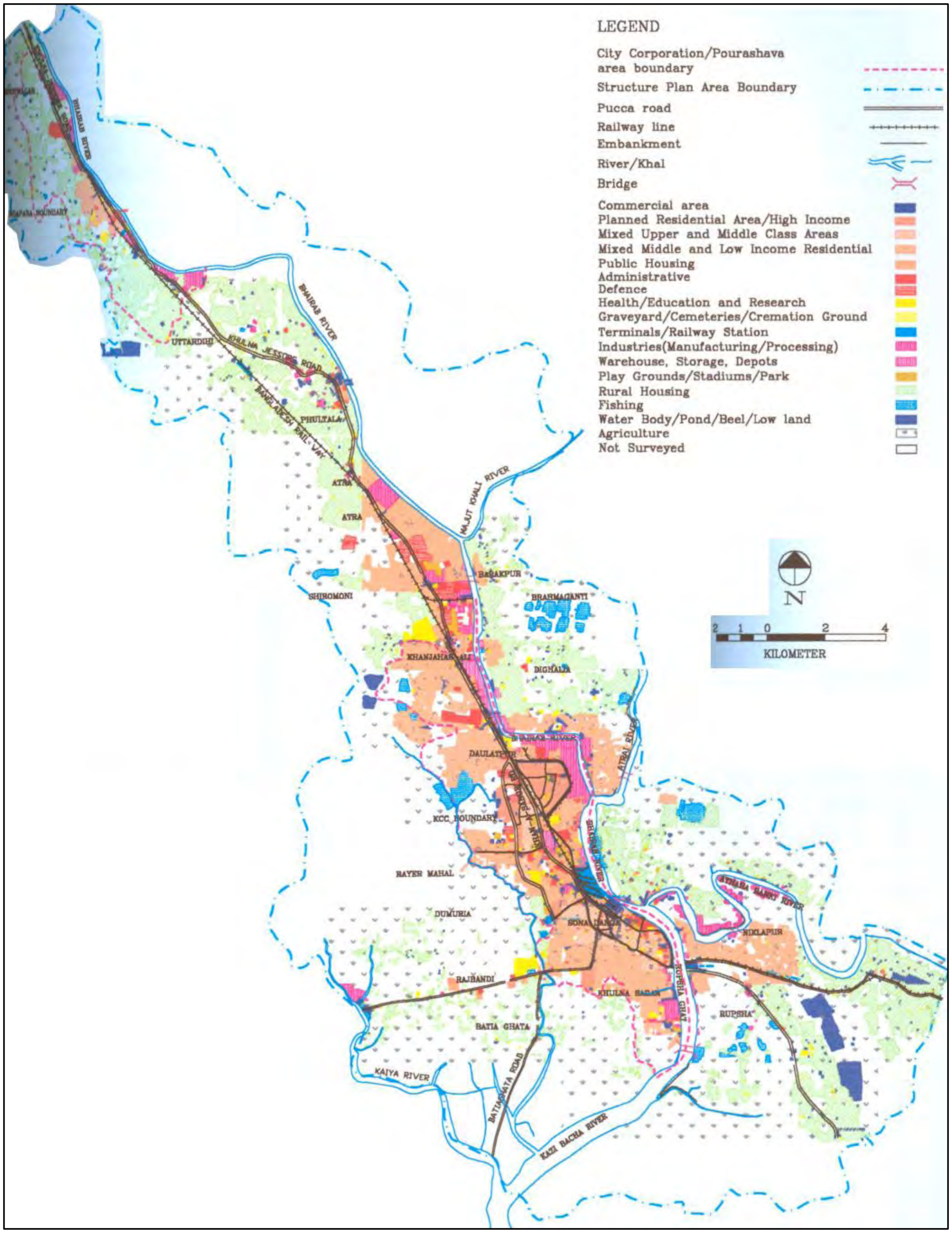


Figure 5-5: Land Use Pattern of KCC Area in 1998

Source: (Khulna Development Authority, 2002b)

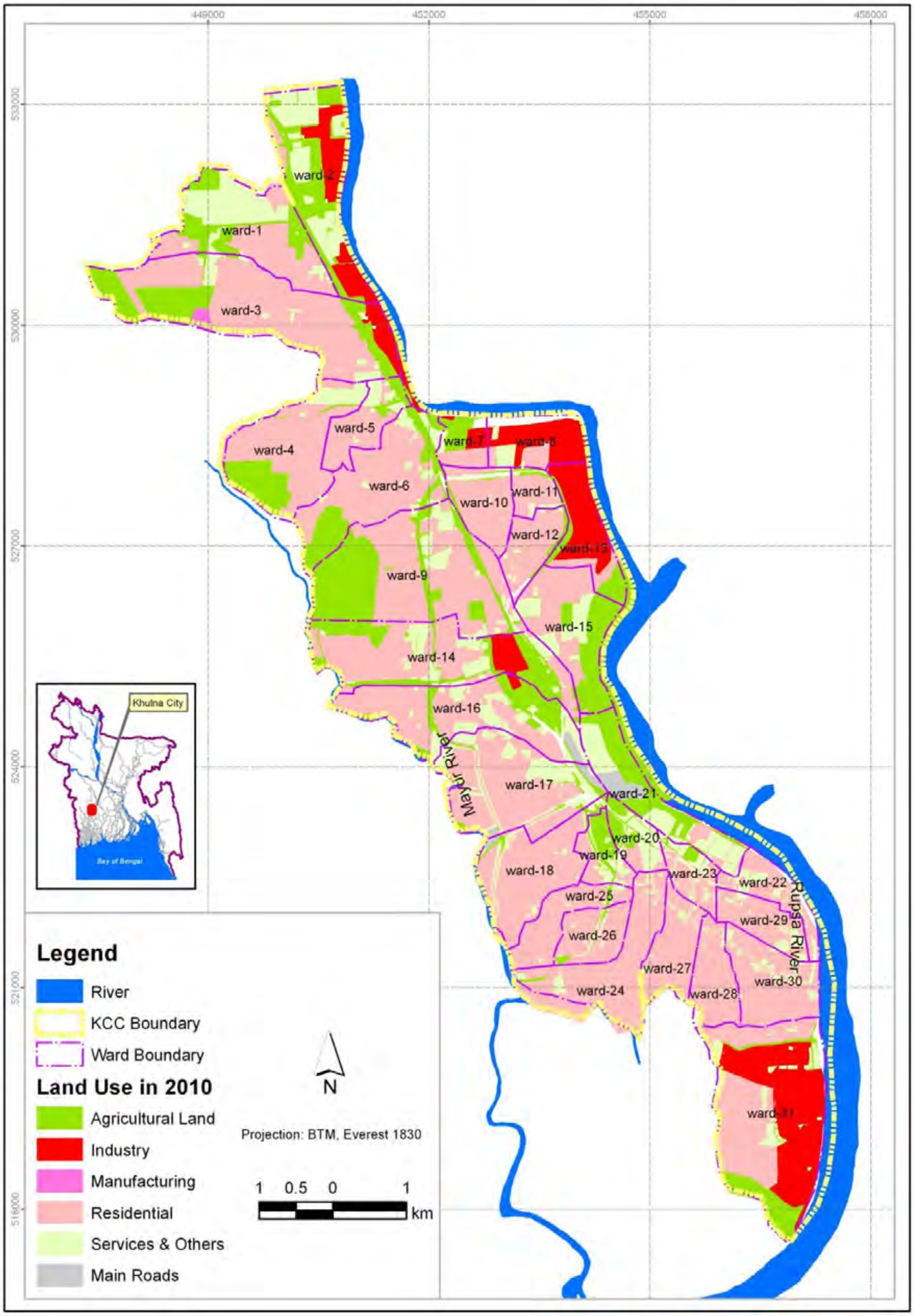


Figure 5-6: Land Use Pattern of KCC Area in 2010

Source: (Asian Development Bank, 2010)

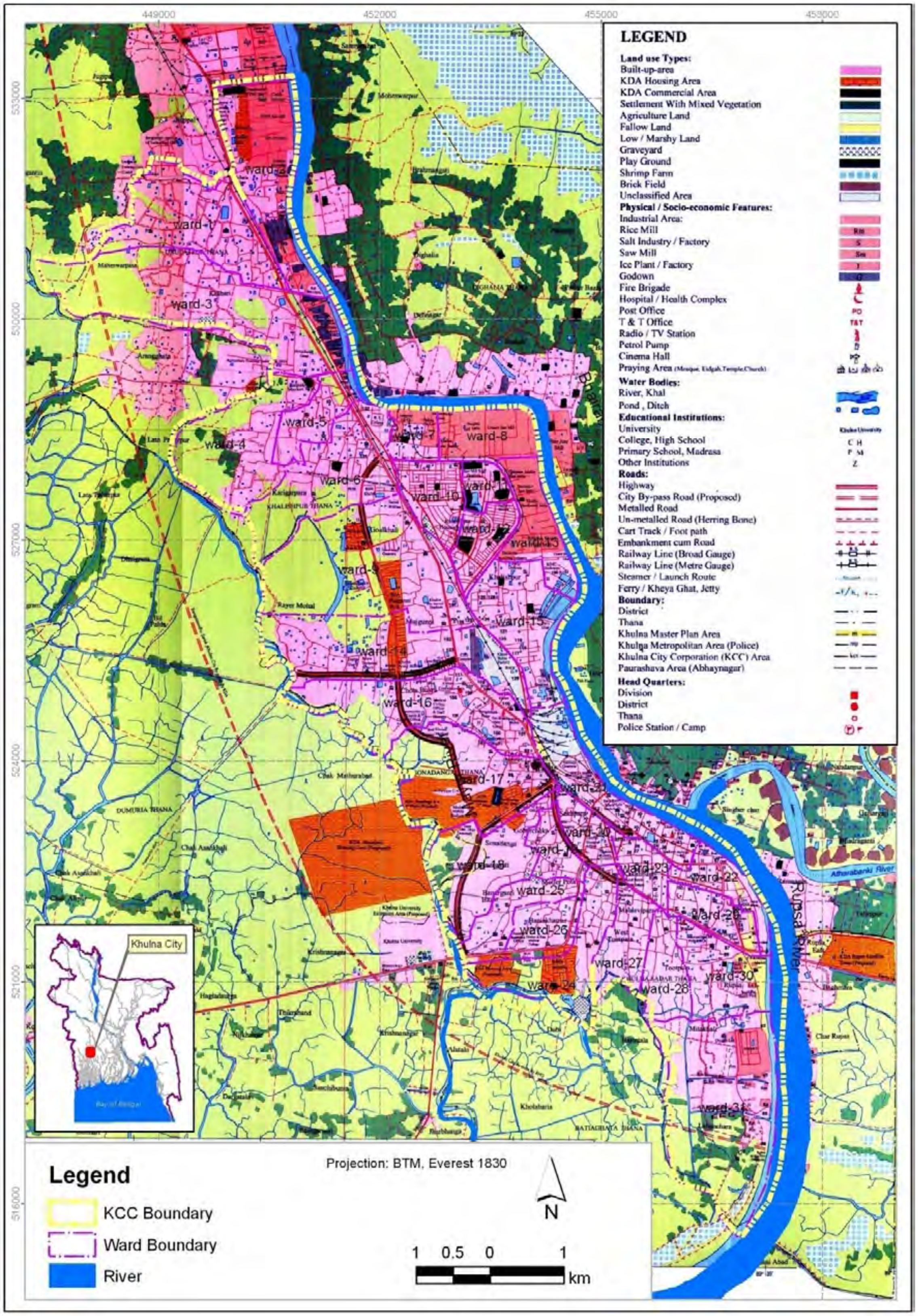


Figure 5-7: Master Plan (2000-2010) of KDA Showing KCC Area

Source: (Khulna Development Authority, 2002c)

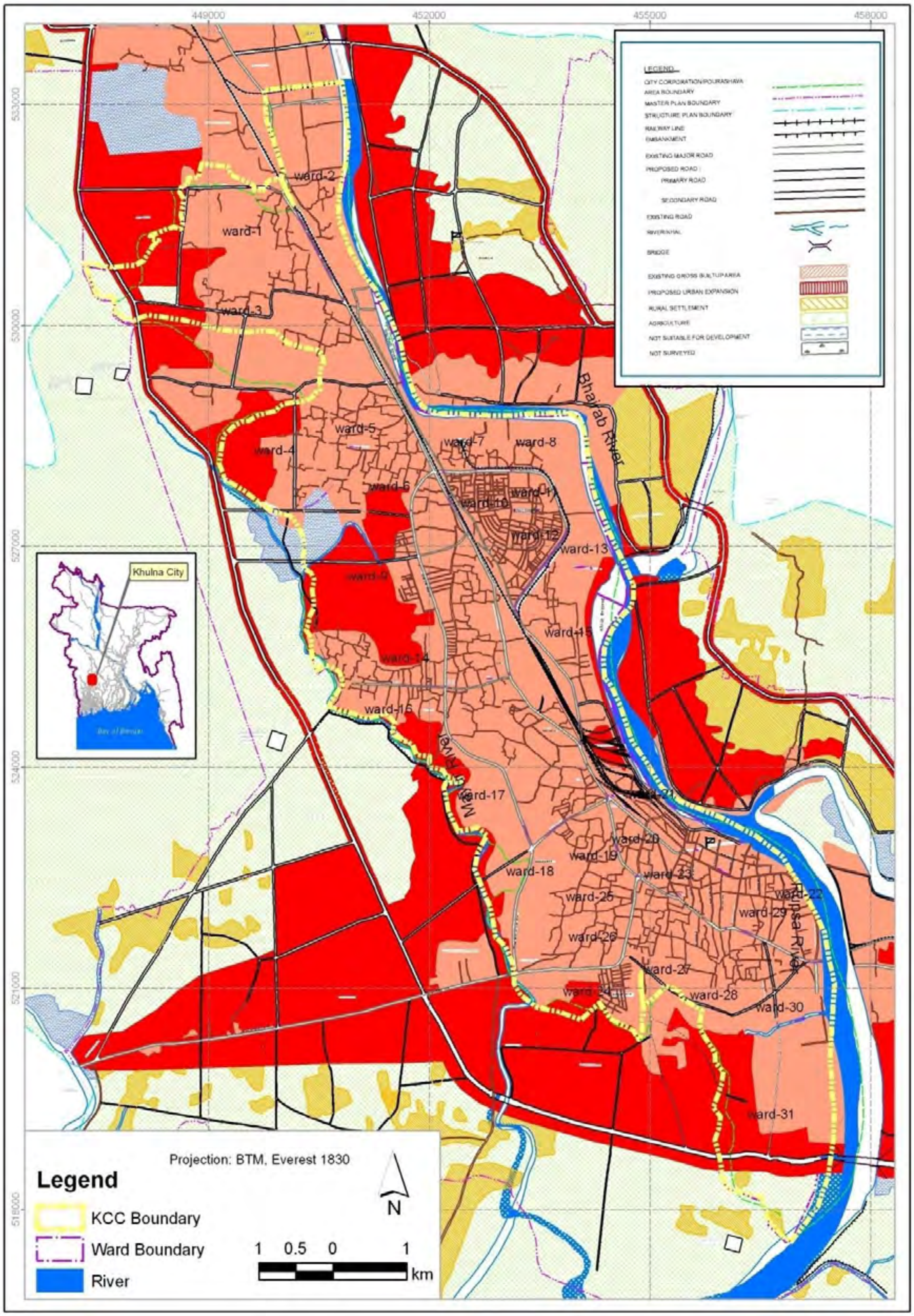


Figure 5-8: Structure Plan (2000-2020) of KDA Showing KCC Area

Source: (Khulna Development Authority, 2002b)

5.3.3 Industrial

Industrial policies and proposals are offered for facilitating industrial promotion through infrastructure development, zoning and other policy recommendations emphasizing on the role of private sector. The 1961 Master Plan which was the first plan for Khulna City, anticipating an industrial boom with an area of about 5443 acres for industrial use, where there was 12.15% of the total master plan area. Besides 127 acres was proposed for godown and light industries and 22 acres for workshop and light industry. The 1961 Master Plan placed the noxious industries southward on the river Rupsha, outside the Master Plan boundary. On review of implementation of the Master Plan provisions on the industrial land development it is revealed that except KDA industrial estate at Shiromoni and BSClC industrial estate nearby no other organized industrial area was developed. KDA industrial estate at Shiromoni has an area of 575 acres, while that of BSCIC covers an area of 44.43 acres. Besides, large areas were designated for industrial use at Labonchora and and Gilatala but no major industrial agglomeration took shape at those areas. Debnagar and Chandnimahal on the other side of the Bhairab-Rupsha designated as industrial use also did not flourish as per expectation of the Master Plan. The plan assumptions for industrialization were upset due to socioeconomic changes following liberation. Besides, the economic depression that gripped the city during 1970s, 1980s and 1990s may also be marked as a major factor responsible for failure of the industrial sector.

Khulna is a leading industrial town with its rich heritage. Though early industries took shape here during the British period, industrial development flourished in the city in the late sixties and early seventies. However, the industrial base started to decay after the liberation of Bangladesh. Khulna City still holds 3rd largest position with respect to the number of industries and industrial labor force. Following is a brief overview on the status of industrial sector in Khulna city and its surroundings in 1998.

Major Industrial Locations - Though small scale manufacturing industries are spread all over the city and surrounding areas covered by master plan boundary, large industries are found to be located only at selected areas.

Noapara- Rajghat-Phultala Area accommodates industrial agglomeration that has developed in the recent past. The area accommodates jute and jute goods, textile, leather processing, cement, salt, wood processing (saw mill) and few other manufacturing.

Atra-Shiromoni Area has two planned industrial estates developed by BSCIC on an area of 44.43 acres and KDA on an area of 575 acres. But in both the estates only a handful of factories have developed.

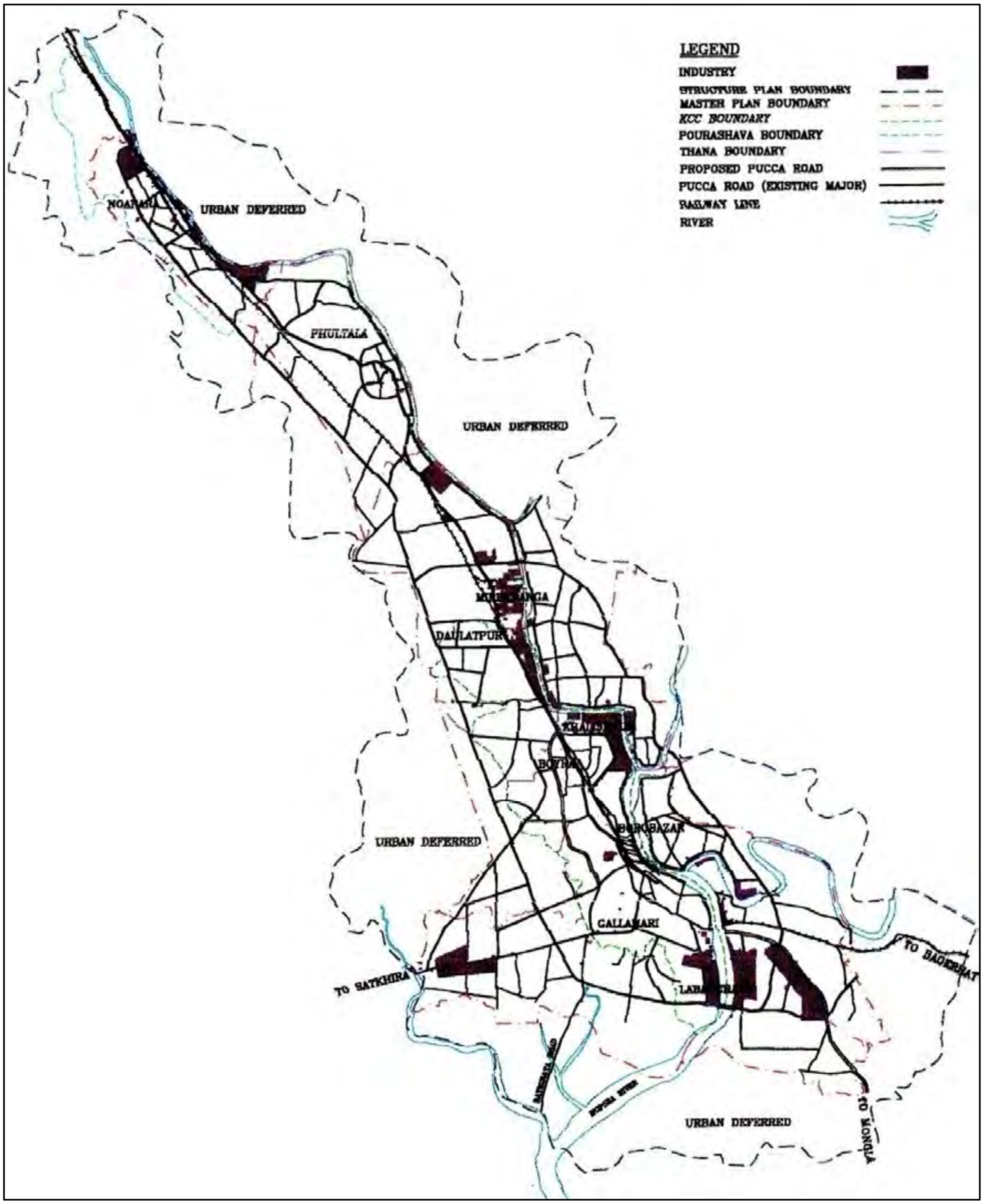


Figure 5-9: Master Plan Land Use Zoning Industrial Area

Source: (Khulna Development Authority, 2002b)

According to land use survey by the current Master Plan (*see* Figure 5-7), industrial land use within Master Plan area covers about 1,731.37 acres which is 4.25% of the total study area. Power crisis, problem of access to formal credit, tree import policy and smuggling are found to be the major handicaps towards industrial promotion.

Proposed industrial Land use – in 2000, the Master Plan has estimated 1,735 acres of land for industrial use. These lands are clustered mainly at Khalishpur, Daulatpur, Dighalia, Shiromoni, Noapara and Phultala-Rajghat area and by industries scattered all over the Plan area. The Master Plan besides extension of existing industrial zones proposes some new areas for industrial growth. About most of new areas are on the eastern side of the river Rupsha. About 647.97 acres of new land have been proposed at Ramnagar, Rajapur, Nandanpur-Bhadragati and Jabusha. Additional 230 acres have been proposed at Labanchara area. Altogether total additional industrial land use will be about 1,172.62 acres. Adding the existing 1,735 acres the total land proposed for industrial use would be 1,896.37 acre, which is about 5.25 percent of the total Master Plan area.

Proposal for Industrial Areas The current section sets forth proposals for industrial area that include extension of existing one and proposal for development of new industrial sites, which are as follows.

Rupsha Strand-Labanchara Area **-** Rupsha Strand Road area has a match factory, few other manufacturing and a large number of saw mills along the river. Labanchara area accommodates an oxygen factory and the only shipyard of the country. Having easy access to the River Rupsha and the proposed Rupsha bypass road, this area offers excellent opportunity for development of industry. There is about 84 acres under industrial use in the area at present. An additional 230 acres of land is recommended at this area around shipyard which will give a total area of 311 acres (l25.9l ha.) of land in this site for industries. Mainly export oriented industries can come up here taking advantage of water and road access to Mongla Port.

Eastern Rupsha **-** At Ramnagar there is a dockyard and few fish processing units on an area of about 8.12 acres. This is a potential area for industry due to its location on the riverbank and presence of industries. The study team suggests an additional area of 39.88 acres. This will give a total area of 48 acres for industries in the area.

Jabusha by the Rupsha on the eastern Rupsha is an important industrial site for fish processing. This site is proposed to be extended towards east and south to accommodate large number of industries over an area of about 540 acres. This will be the major industrial site for Khulna in future. However, the area might need raising of land to some extent.

Rajapur, Rupsha on the bank of the river Atharobanki has a number of salt and fish processing plants, workshop and godowns on an area of about 18.28 acres. The study team suggests additional 6.72 acres of land in this area giving a total area of 25 acres for industrial use.

Nandanpur-Bhadragati areas at the northern confluence of the Rupsha and Atharobanki Rivers have been selected for noxious industries. An area of 6l.25 acres has been earmarked for such industrial concerns.

Mirerdanga is the northward extension of` Daulatpur industrial belt. Total area is about 127.50 acres. Large numbers of industries are operating here. There are little opportunities for further expansion of the site.

Debnagar, Dighalia area by the river Bhairab there exist an industrial site (86.25 acres) accommodating jute mills and godowns. An extended area of about 18.36 acres is proposed for new industries giving a total area of 104.60 acres of industrial land for the area.

Chandrimahal on the eastern bank of the river Bhairab accommodates a jute mill and a number of godowns on an area of about 41.40 acres. The study team proposes to extend the site on an additional area of 22.28 acres, which will give a total area of 63.68 acres.

Daulatpur area accommodates large number of jute processing, manufacturing units and godowns/warehouses. Total industrial area stands on about 112.50 acres. The industrial area cannot be physically extended. Since most of the jute processing units are unutilized there are opportunities to replace them by new industries.

Atra-Shiromoni Area accommodates two industrial estates - one of KDA and another of BISIC on 575 acres and 44.43 acres respectively. Both of these estates are highly underutilized large number of industries can be accommodated in this site.

Phultala-Rajghat have some large industrial units in this area cover an area of about 42 acres. The industrial site here can be further expanded at least by 10 acres. This will give a total area of 52 acres for industrial use in this site.

Noapara North- there is a textile mill and two jute mills in Noapara North within the boundary of the Master Plan over an area of about 57 acres. The study team recommends additional area of 140 acres on the bank of the Bhairab for next industries to avail of the good transportation facilities. This will give a total industrial in the area l97.80 acres.

Noapara Central North- A few jute mills, cement and textile mills are scattered situated here on an area of about 21 acres. For localization of industries in the northern and southern part of the Master Plan it would be better not to allow further industries on the southern part of the township around the existing ones.

Service and Processing Industries - There is large number of service and processing industries spread around the Master Plan area. Some of these industries, like, all kinds of furniture making, bakery, printing press, laundry, small-scale readymade garments flour/rice mills are non-polluting as well as their services are used by citizenry in their everyday life. These service and processing units should be treated liberally and can be accommodated in mixed as well as in commercial area. On the other hand polluting industries, like, sawmill, metal fabricating, engineering workshop should be carefully sited. The study team has selected Rupsha Strand Road-North and South, Rupsha area, Daulatpur area, Sonadanga Bus and Truck Terminal area for such units. No additional, however, has been suggested for this purpose.

Noxious Industries - The study team has earmarked 61.25 acres of land on the northern confluence of the Rupsha-Atharobanki Rivers for establishment of noxious industries.

Justification for Selection of Industrial Areas - The industrial sites described above are all well established spontaneously developed industrial areas. Establishment of new industries within and extended areas of these sites will enable them to enjoy economies of scale in the form of:

- Infrastructure facilities like power, road, loading and unloading.
- Facilities for transportation of raw materials and finished goods by road, water way as well as railway at some places.
- Enjoying marketing facilities due to the availability of brokers and agents,
- Support from linkage industries warehouse facilities already existing there.

To avail all the above opportunities the new industrial entrepreneurs would prefer to set up their industrial ventures in those areas. The extension of the existing industrial areas will enable them to avail of this opportunity in a better way. The place has been found appropriate because it lies outside the main city. The areas around the site belong to low density rural settlement and agricultural use. Therefore, there is possibility of minimum loss of life and property due to any hazard or environmental ecological degradation caused by noxious industries. Besides, the plants can discharge their affluent into the river, which will be carried to the sea downward without polluting the upstream areas. To exercise development control regulations it would be appropriate to place the noxious industrial area within the Master Plan boundary.

5.3.4 Residential

The City Corporation area has about 150,000 households with 106,700 housing units. There were housing backlogs of 8,300 units in KCC area in 1991. Considering a moderate growth rate of`3.3 percent per year, the number of households in KCC was estimated to be 144,700 in 1998 with 129,300 dwelling units, which shows a backlog of 15,000 housing units. Considering this trend in the growth of households and backlog, it is estimated the requirement of new housing units in the Master Plan period, i.e. in 2010. It should be noted here that 20 percent replacement of the existing housing units has also been considered while estimating future needs. It has been estimated that by the year 2020, the Structure Plan area will require additional 224,376 new dwelling units with another 90,000 units as replacement. Of these, roughly about 70 percent of the units will be constructed in the Master Plan area. Thus, estimated 1,611,000 units will have to be provided in Master Plan area. Most of the units will be constructed by the private informal sector, while the public sector along with the formal private sector will play an important role in the planned residential area. Apart from rural and agricultural use, urban residential use accounted for 12 percent of the study land, the highest proportion among the urban use categories. Other urban categories such as industrial, commercial transport and communication, public use and social facilities constitute respectively 3.75, 1.50, 4.38, 1.69 and 1.80 percent. Recreational use was found to be about one percent of the total land (Khulna Urban Structure Plan 2000-2020, 2002b).

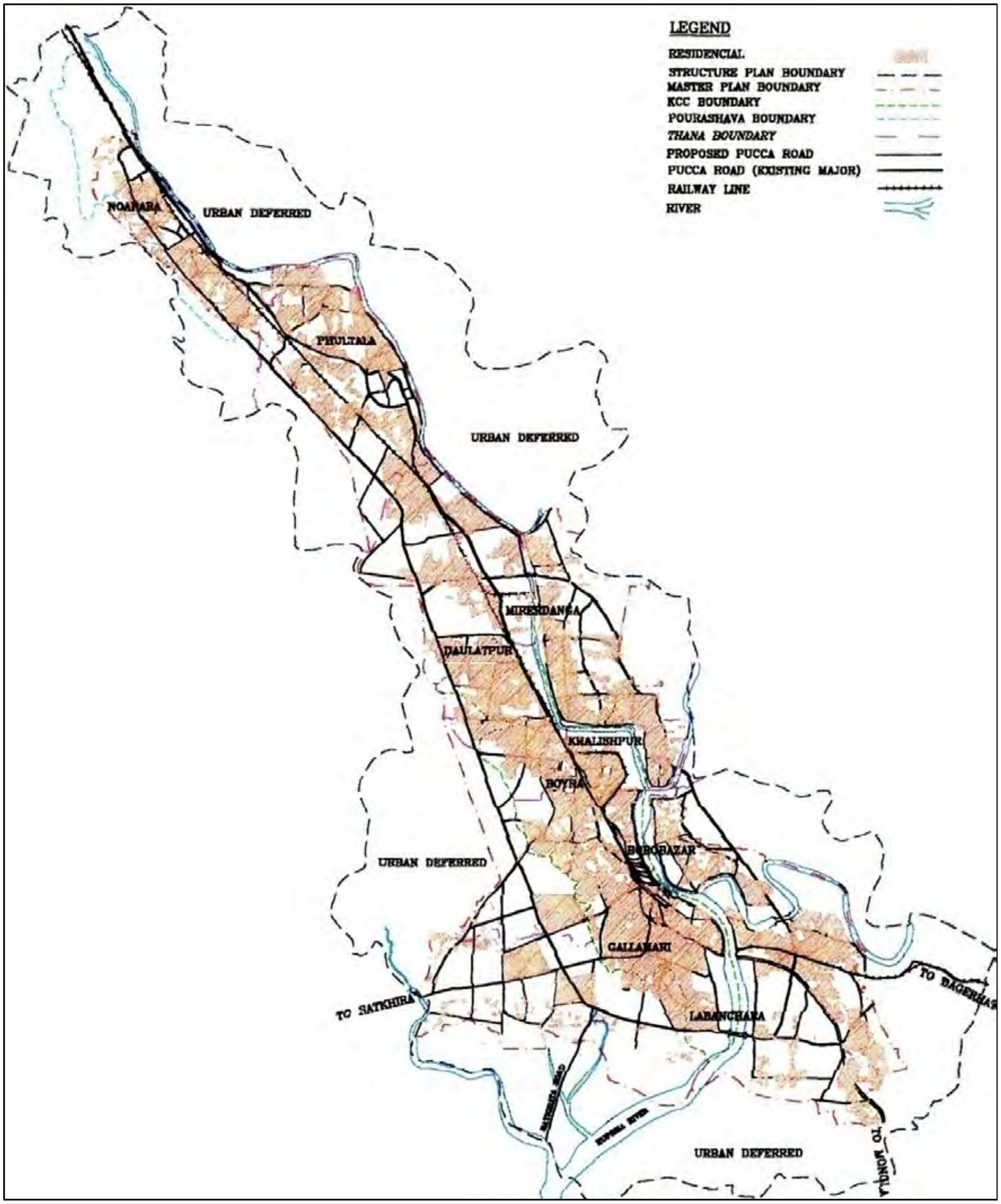


Figure 5-10: Master Plan Land Use Zoning Residential Area

Source: (Khulna Development Authority, 2002b)

The development of land and housing is quite slow in Khulna. On the other hand, the quality of housing, both in terms of structure and environment is also poor. The proliferation of slums and squatter settlements are moderately rapid in Khulna. Under the circumstance, institutional supports, by providing adequate infrastructure and credit are necessary. At the same time the private sector should be encouraged to play their desired role within the framework of planned development (Khulna Development Authority, 2002a).

Housing situation in Khulna, if considered in the national context, seems to be not a serious problem, as the condition cannot be explained by its critical shortages. However, the poor quality of housing apparently seems to be more serious than the number of units required. Study reveals that not more than a quarter of housing units were made of concrete, if roof materials are considered. Thus, an overwhelming majority of housing units were made of temporary materials.

The second problem, which seems to be more serious in Khulna, is the lack of effective demands for housing. Despite a moderate growth of households in the city, the growth or housing units cannot cope with needs, mainly because of low demands. Economic stagnation, low income, lack of housing finance and credits demands are not growing. However, if the economy of the city turns into a positive direction and the policies of the public agencies support properly, the effective demands seem to be created.

Third, as a third of cityôs households live in poverty who cannot afford proper housing and thus they live either in slums and squatter settlements or in substandard housing environment. It is shown from the survey that about 18 percent of the people in Khulna City Corporation area live in slums and squatter settlements. The existing policy of the government and the traditional system of housing production in the city do not help these poor people much. The poor housing condition can also be explained by room occupancy by households, floor area and environmental amenities and facilities. Nearly one third of the households live in one room house and about 70 percent of the households use less than 800 sq. ft. as floor area. The average size of floor area in slums was found to be further below, 400 sq. ft. only.

Fourth, in terms of housing units available and needs, Khulna seems to be in a better position if compared with the national situation. Our survey shows that housing shortages were roughly about 8 percent in 1991. The corresponding figure for national urban housing shortages were 20 percent during the same period. However, with the growth of population and low production of housing units shortages are increasing over time.

Fifth, like in other cities of Bangladesh, the private informal system of housing delivery is the dominant process in Khulna with 90 percent of the total housing units produced under such system. Against such huge production of housing, the public authorities produced only about 5.5 percent under its sites and services and public housing construction schemes. Slums and squatters accounted for another 4 percent of the total housing stock.

Sixth, the housing areas in Khulna area characterized by low and high density residential areas depend on location. Most planned areas are low density type, while the spontaneously developed middle class areas along with poor areas are high density type. In most cases, housing areas are mixed in nature, where the poor and middle class and middle class and the rich live together. Over all, there is little planning control over the development of housing areas. The planning authority seems to be more concerned with approval of building rather than planned development of residential areas. Although, KDA has developed several planned residential areas, but compared with all housing areas in the city, the effort is highly insignificant.

Seventh, the majority of the people finance housing horn their own sources. Public finance in housing goes mainly to the rich and for the public servants. There are hardly any financial facilities for the low-income people. Thus, the lower income groups, who constitute more than 70 percent of the city dwellers, rely mainly on their own sources and informal credits. This is reflected in two important features of housing. One, the poor quality of housing and two, housing units are being built over a long period of time through a gradual development. Against this back drop, it can be said that housing financial market is extremely limited and is confined to upper income people.

Chapter 6: Estimating Flood Damage and Analyzing Polices and Proposals

This chapter depicts potential flood damages for different type of major land uses (both existing and proposed) within the study area using depth-damage curves which is expressed as percentage. Later on, compatibility of those major land uses is analyzed from the flood damages perspective.

6.1 Introduction

Flood damage is understood as the extent of harm expected on certain conditions of exposure, susceptibility and resilience and it is expressed as index. Under the same conditions, damages of different land uses or elements at risk are different. Flood damage index enables the assessment of damage to flood and finally to recognize correct actions that can be taken to reduce damage before the possible harm is realized.

6.2 Physical Element at Risk and Their Attributes

During flood disaster, different type of elements (land uses) which is largely under social, infrastructural and economic sector is affected (*See* Figure 2-4 and Figure 2-5). Elements at risk during flooding are attributed as tangible (physical) and intangible. Each of these three elements is further classified as primary, secondary, and tertiary (*See* Figure 2-4). In this study, tangible, primary and direct losses of the elements at risk are undertaken. In this connection, four major land-uses viz. agriculture, commercial, industrial and residential have been studied to find out their respective flood damage to understand the extent of possible damage under a specific flood condition.

6.3 Potential Climate Change Induced Flood Scenario in 2020

Though climate change is a global issue, its effects are not equally spread over the world. All nations are not equally hampered and not in the same way due to ability to confront the climate change effects. Apart from these, geographical and climatic settings are different in different places, which is another important factor to make a particular area vulnerable to climate change. Many hazards and disasters especially sea level rise, salinity intrusion, flooding, cyclone, submerging coastal area etc. are found and will increase in the future due to climate change. Flooding specially urban flooding of all the coming disasters is mentionable in urban areas due to the extent of possible damage.

Khulna is a coastal city entrusted with all types of functions is supposed to have urban flooding/water logging problems due to climate change. This is why Institute of Water Modeling developed a model named as ñKhulna Urban Drainage (KUD)ò for Khulna Region to predict the urban flooding within the city area on behalf of the project of Asian Development Bank. This model is able to show the water logging conditions of Khulna City. This is developed on the basis of the past time series data of rainfall, evaporation, water level, surface runoff, catchment areas, sea level rise, drainage capacity, drainage insufficiency with its blockage, river and canal systems, water bodies and the complex tidal system of the South-West Region of Bangladesh. The rainfall and evaporation data from historical records were used for the base condition and the climate model generated data were used for 2020. Several flood scenarios due to climate change have been developed by the institute of water modeling on 10 and 5 years return period under different conditions (with climate change, without climate change, with improved drainage system, with adaptation and without adaptation). Flood scenario (extent and degree of inundation) for 2020 with Climate Change in Khulna City (10 in 1 Year) is shown in Figure 6-3 which is under with climate change and without improvement and adaptation on 10 years return period.

Distribution for the potential urban flooding under climate change in 2020 is shown in Figure 6-1. It has been observed that maximum and minimum range of the potential water logging is 10cm and 220cm respectively. Maximum inundation area is 6.64 sq. km (37.82% of the inundation area) lies between 41cm to 70cm and found at all wards except 1 and 2. Average inundation flood depth is 109cm and it is found that maximum area under inundation is between minimum (10cm) to average (109cm) flood depth. On other hand, area under inundation depth between 130cm to the maximum (220cm) is small but its effects in terms of damage are higher (*see* damages for different land uses in section 6.6).

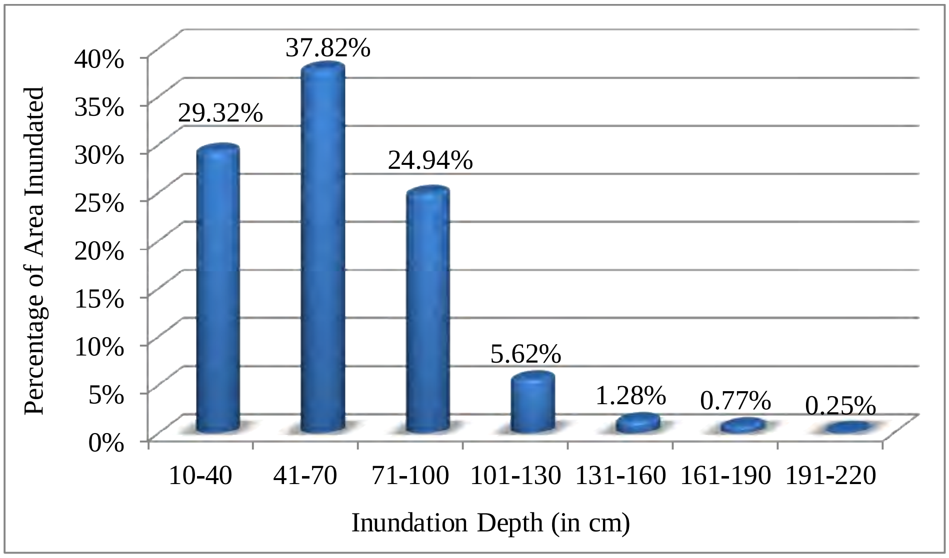


Figure 6-1 : Distribution of (Inundation Depth) Potential Flood in 2020

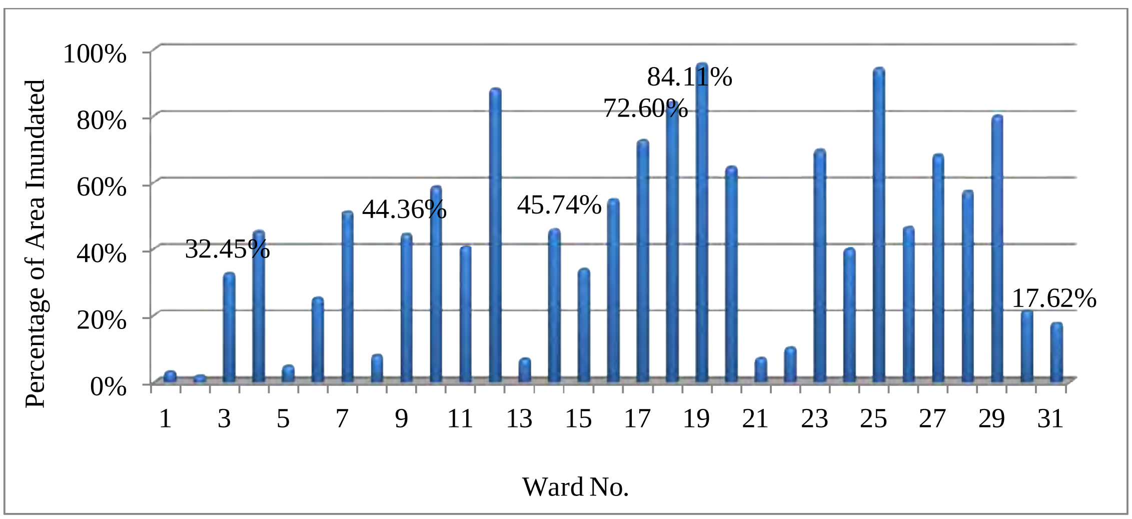


Figure 6-2: Ward Wise Distribution of Area Inundated for Potential Flood in 2020

Wards having maximum area under inundation are found at 3, 4, 9, 14, 16, 17, and 18, which are shown in Figure 6-2 and Figure 6-3 and Table 6-1. It is observed that all these wards are situated in the western low-lying area of the city. Maximum inundated ward is 17 located in the western low-lying area and near the city hub, which is 9.51% of the inundated area. Wards having minimum inundation are 1, 2, 5, 8, 11, 13, 21, and 22. On other hand, wards having medium inundation are 6, 7, 10, 12, 15, 19, 23, 24, 25, 26, 27, 28, 29, 30, and 31, which are largely situated southern part of the city. It is noticed that all the wards lie under inundation though the extents of their inundation is different.

Figure 6-3 and Table 6-1 shows the water logging condition under climate change scenario if no adaptation measures or improvement measures are taken in the water logging area which causes damage covers 38% area of the City. It has been noticed from the table that ward 12, 18, 19 and 25 are inundated most and it is 88, 84 95 and 94 percent consecutively of their total area (*See* Table 6-1). Maximum wards are inundated at average depth except 1 and 2. On other hand, wards 3, 7, 9, 10, 11, 14, 15, 18, 21, 25, and 27 are inundated highly (above the average inundation depth). It is also evident that percentage of the inundated area above the average inundated depth is low and it is 2.3%. On the contrary, the rest of the percentage of the total inundated area is at below average depth.

Table 6-1: Ward Wise Area (sq. km) under Different Inundation (cm) Level in 2020

Ward No.	Area (sq. km)	Area (sq. km) under Different Inundation (cm) Level									Ward Area Inundated (%)
		10-40	41-70	71-100	101-130	131-160	161-190	191-220	Total	Percent	
1	2.23	0.070	0	0	0	0	0	0	**0.07**	**0.40**	**3.12**
2	2.18	0.039	0	0	0	0	0	0	**0.04**	**0.22**	**1.78**
3	3.66	0.614	0.500	0.068	0.003	0.001	0.001	0	**1.19**	**6.76**	**32.45**
4	2.03	0.309	0.378	0.184	0.052	0	0	0	**0.92**	**5.26**	**45.40**
5	0.78	0.007	0.017	0.013	0	0	0	0	**0.04**	**0.21**	**4.75**
6	2.16	0.266	0.207	0.066	0.004	0	0	0	**0.54**	**3.09**	**25.14**
7	0.47	0.029	0.070	0.089	0.053	0.001	0	0	**0.24**	**1.37**	**51.13**
8	0.94	0.0004	0.074	0.001	0	0	0	0	**0.07**	**0.43**	**7.92**
9	3.54	0.207	0.683	0.564	0.104	0.011	0.0004	0.002	**1.57**	**8.95**	**44.36**
10	0.81	0.008	0.108	0.169	0.138	0.039	0.013	0	**0.47**	**2.71**	**58.63**
11	0.36	0.043	0.066	0.034	0.004	0.0004	0	0	**0.15**	**0.84**	**40.45**
12	0.66	0.163	0.388	0.029	0.0004	0	0	0	**0.58**	**3.31**	**88.07**
13	1.12	0.057	0.020	0	0	0	0	0	**0.08**	**0.44**	**6.90**
14	2.69	0.470	0.288	0.340	0.051	0.046	0.036	0.0004	**1.23**	**7.02**	**45.74**
15	1.66	0.132	0.127	0.078	0.043	0.061	0.078	0.042	**0.56**	**3.19**	**33.77**
16	2.25	0.236	0.531	0.457	0.012	0	0	0	**1.24**	**7.04**	**54.85**
17	2.30	0.395	0.476	0.732	0.066	0	0	0	**1.67**	**9.51**	**72.60**
18	1.62	0.226	0.469	0.457	0.172	0.036	0.0004	0	**1.36**	**7.76**	**84.11**
19	0.49	0.082	0.217	0.138	0.034	0	0	0	**0.47**	**2.68**	**95.57**
20	0.50	0.159	0.128	0.032	0.003	0	0	0	**0.32**	**1.84**	**64.60**
21	1.73	0.014	0.024	0.042	0.029	0.008	0.006	0	**0.12**	**0.70**	**7.10**
22	0.83	0.074	0.008	0.002	0	0	0	0	**0.08**	**0.48**	**10.22**
23	0.51	0.079	0.185	0.090	0.001	0	0	0	**0.36**	**2.03**	**69.79**

Ward No.	Area (sq. km)	Area (sq. km) under Different Inundation (cm) Level									Ward Area Inundated (%)
		10-40	41-70	71-100	101-130	131-160	161-190	191-220	Total	Percent	
24	1.68	0.198	0.246	0.141	0.083	0	0	0	**0.67**	**3.81**	**39.80**
25	0.76	0.140	0.254	0.216	0.090	0.018	0.0004	0	**0.72**	**4.09**	**94.26**
26	0.66	0.048	0.122	0.118	0.021	0	0	0	**0.31**	**1.76**	**46.44**
27	0.81	0.106	0.216	0.210	0.020	0.002	0	0	**0.55**	**3.16**	**68.19**
28	0.74	0.231	0.172	0.019	0.001	0	0	0	**0.42**	**2.41**	**57.40**
29	0.66	0.358	0.166	0.002	0.0004	0	0	0	**0.53**	**3.00**	**79.90**
30	1.32	0.028	0.235	0.018	0	0	0	0	**0.28**	**1.60**	**21.32**
31	3.90	0.358	0.263	0.066	0.0004	0	0	0	**0.69**	**3.92**	**17.62**
Total	**46.05**	**5.14**	**6.64**	**4.38**	**0.99**	**0.22**	**0.13**	**0.04**	**17.55**	**100**	**38.10**
Percent		**29.32**	**37.82**	**24.94**	**5.62**	**1.28**	**0.77**	**0.25**	**100**		

Table 6-2: Ward Wise Area (sq. km) under Different Inundation (cm) Level in 2010 (base year) and 2020

Ward No.	Area (sq. km)	Inundation in 2010	Percentage of inundation in 2010	Inundation in 2020	Percentage of inundation in 2010	Changes in Percentages
1	2.23	0.004	0.20	0.070	3.12	2.93
2	2.18	0.048	2.22	0.039	1.78	-0.44
3	3.66	0.102	2.78	1.187	32.45	29.67
4	2.03	0.387	19.02	0.924	45.40	26.39
5	0.78	0.014	1.81	0.037	4.75	2.94
6	2.16	0.191	8.85	0.543	25.14	16.28
7	0.47	0.233	49.35	0.241	51.13	1.78
8	0.94	0.047	4.96	0.075	7.92	2.97
9	3.54	0.852	24.07	1.570	44.36	20.29
10	0.81	0.329	40.65	0.475	58.63	17.98
11	0.36			0.148	40.45	40.45

Ward No.	Area (sq. km)	Inundation in 2010	Percentage of inundation in 2010	Inundation in 2020	Percentage of inundation in 2010	Changes in Percentages
12	0.66	0.141	21.42	0.580	88.07	66.64
13	1.12	0.006	0.50	0.077	6.90	6.40
14	2.69	0.564	20.97	1.231	45.74	24.77
15	1.66	0.082	4.92	0.560	33.77	28.86
16	2.25	0.228	10.10	1.236	54.85	44.75
17	2.30	1.396	60.71	1.669	72.60	11.88
18	1.62	0.907	56.05	1.361	84.11	28.06
19	0.49	0.254	51.61	0.470	95.57	43.97
20	0.50	0.170	34.02	0.323	64.60	30.58
21	1.73	0.068	3.92	0.122	7.10	3.18
22	0.83	0.043	5.18	0.084	10.22	5.04
23	0.51	0.305	59.75	0.356	69.79	10.04
24	1.68	0.294	17.49	0.668	39.80	22.31
25	0.76	0.408	53.48	0.718	94.26	40.78
26	0.66	0.115	17.33	0.309	46.44	29.12
27	0.81	0.273	33.65	0.554	68.19	34.54
28	0.74	0.147	20.00	0.422	57.40	37.40
29	0.66	0.368	55.87	0.527	79.90	24.02
30	1.32	0.138	10.45	0.282	21.32	10.87
31	3.90	0.292	7.49	0.688	17.62	10.13
Total	46.05	8.405	18.25	17.545	38.10	19.85

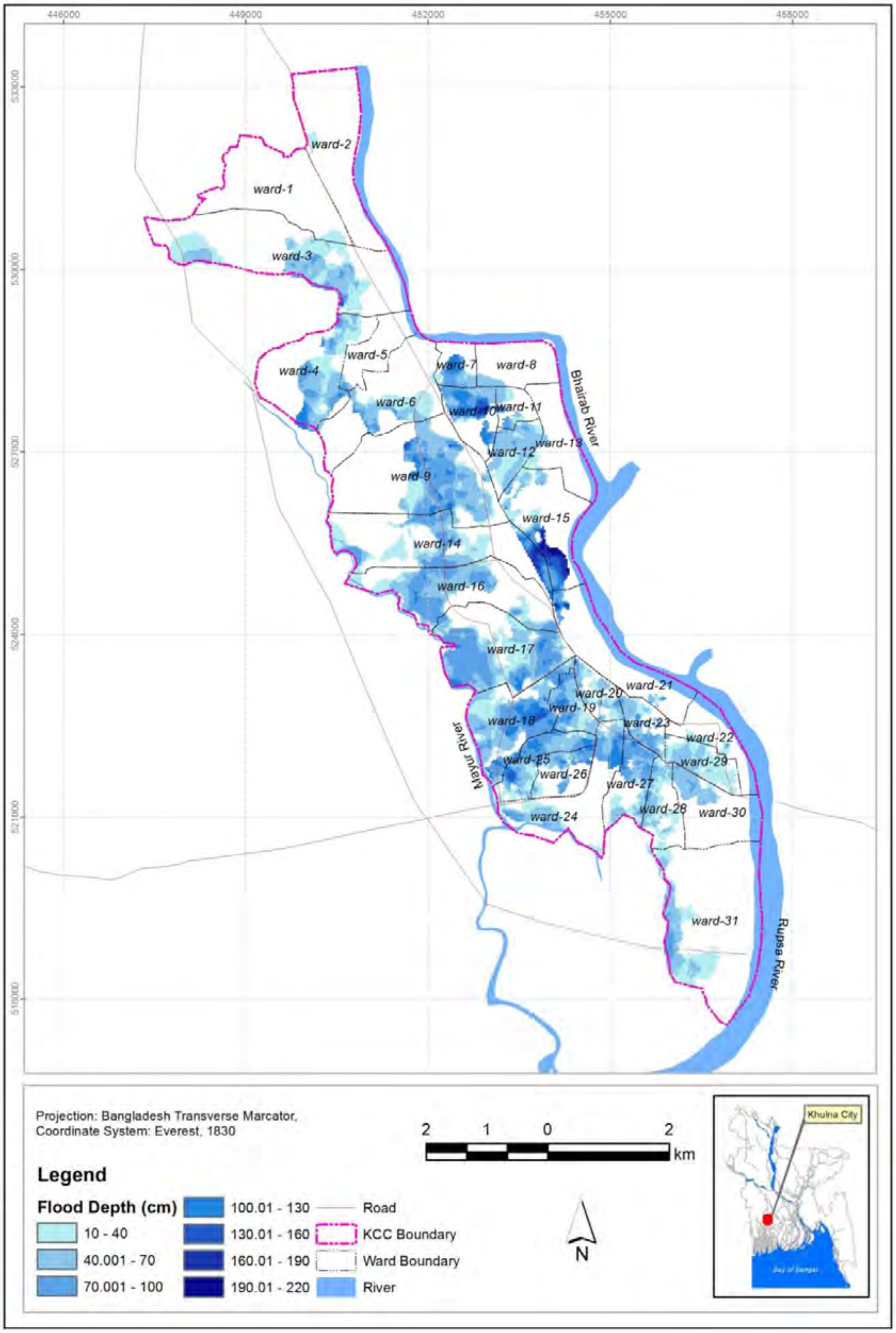


Figure 6-3: Flood Scenario for 2020 with Climate Change in Khulna City (10 in 1 Year)

Source: (Asian Development Bank, 2010)

Figure 6-4 shows the base year flood extent and inundation over Khulna City Corporation area in 2010. Based on this flood scenario, flood for 2020 was predicted incorporating different climate change oriented parameters. Table 6-2 shows the comparison of inundation extent and degree for the projected and base year. From these two figures, it is apparent that except ward 11 in 2010, all other wards are under climate change induced floods for both years. Maximum inundated ward for base case is 17 (61%) and 96% for projected year for ward 19. Ward 12 had would have been affected more than the base year and in the opposite way ward 2 would have been affected least.

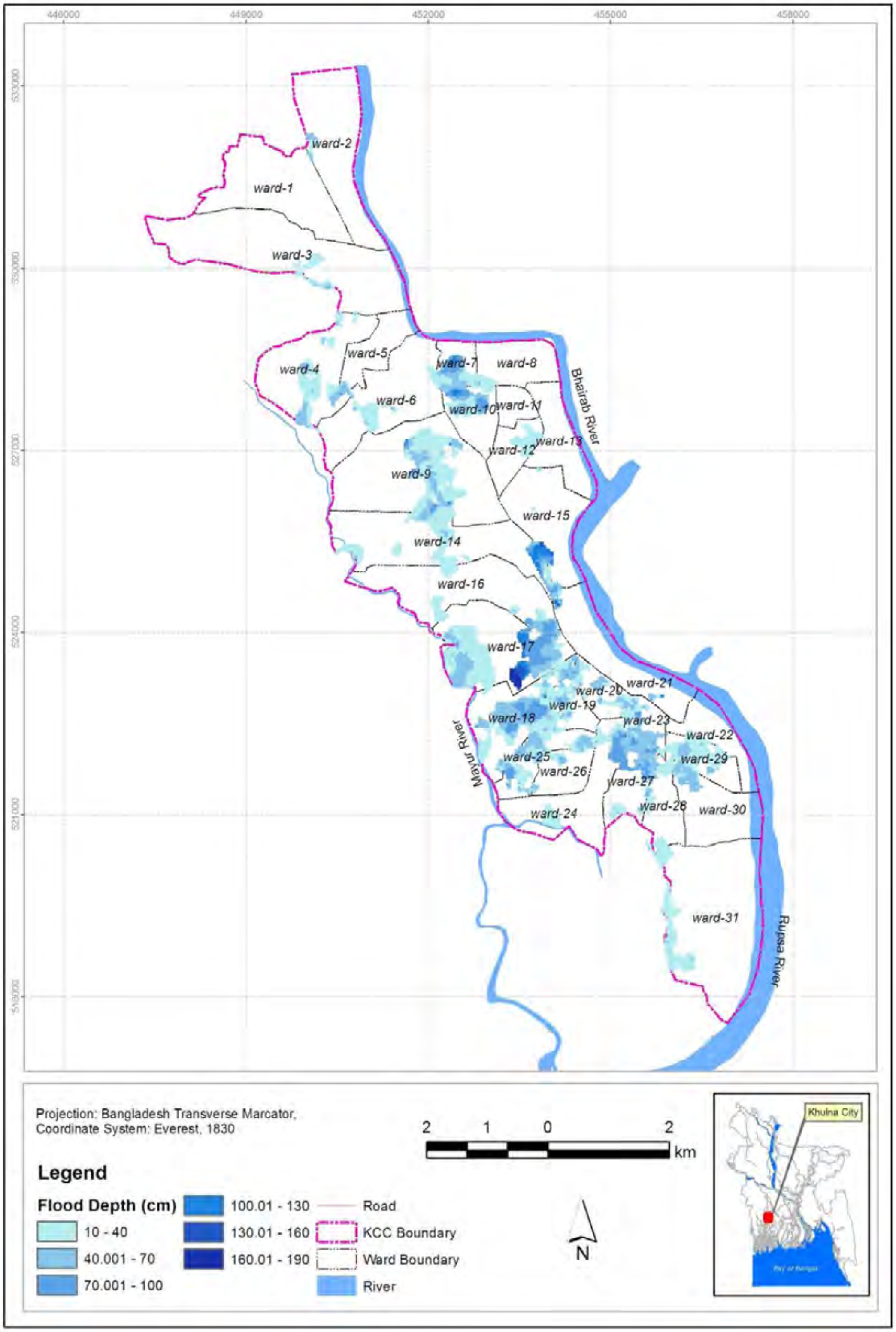


Figure 6-4: Flood Base Scenario for 2010 with Climate Change in Khulna City (5 in 1 Year)

Source: (Asian Development Bank, 2010)

6.4 Potential Flood Damages and Depth Damage Curves

Elements at flood risk are Households, economic enterprises (commercial, industrial, social), urban infrastructure, agriculture and industrial units are likely to be affected with urban flooding and water logging. Degree of damages of those elements depends on the depth, duration and velocity of flooding incurred. For the sake of simplification, only inundation depth is considered for calculating the damages of the elements. Depth-damages curves for different land uses have been collected from secondary sources and used in this research to calculate the respective land usesô damages. In the ADB study, Depth-damage was developed from the socio-economic survey where damages incurred on different land uses during past 10 years of events related to climate change related events - like flood, water logging, salinity intrusion, and cyclone were collected.

From the survey (Asian Development Bank, 2010); it is found that increased water level in river caused lot of problems. It caused flooding and water backflow in the residential areas. In the rainy season, when incessant rain occurred, the runoff did not flow to the river which lead to water congestion. It was a big problem in some parts of the Khulna city. Duration of this water congestion remained for 2-3 days. Different types of problems were emanating from water congestion which included affect to work, movement, sanitation, business and even schooling which got suspended. Also poor people took shelter at different places and different types of water borne diseases occurred in that monsoon period. The rain water remained 1-1.5 ft but it did not last for long time - roughly 4-5 hours. In the rainy season, water congestion was a major problem. If the water level rises up slightly in the river, then whole Khulna city used to go under water. Cause of water congestion lies with unplanned construction even by government and river occupants. Plinth level of some houses was raised so that water did not flow up to the bed room or some people constructed water blocking wall around their houses.

6.5 Land Use and Potential Climate Change Induced Flood in 2020

Damage to land uses is sensitive to the depth, duration and velocity of the potential flood. In the opposite way, the degree of damages to different land uses is different to the same depth, duration and velocity of the flooding. Table 6-3 shows distribution of different land uses of the structure plan under different wards with their respective degree of inundation. It has been noticed that residential and commercial land uses are spread over all wards whereas agricultural land uses are limited to wards 3, 4, 6, 14 and 31. Industrial Land uses are distributed over wards 2, 3, 5-9, 11, 13-16, 21 and 31.

Table 6-3: Ward wise Distribution of Different Land Uses under the Structure Plan with Inundation for 2020

Ward No.	Different Land Uses in 2020 (in sq. km)					Inundated Land use Area (in sq. km)	Percent of Inundated Land uses Area
	Agriculture	Commercial	Industrial	Residential	Total		
1	0	1.20	0	0.96	**2.16**	**0.07**	**3.22**
2	0	1.33	0.69	0.08	**2.10**	**0.04**	**1.84**
3	0.32	0.42	0.31	2.60	**3.65**	**1.19**	**32.54**
4	0.06	0.19	0	1.76	**2.01**	**0.92**	**45.85**
5	0	0.23	0.03	0.51	**0.77**	**0.04**	**4.75**
6	0.34	0.36	0.05	1.39	**2.14**	**0.54**	**25.39**
7	0	0.02	0.24	0.16	**0.42**	**0.24**	**57.25**
8	0	0.10	0.55	0.14	**0.78**	**0.07**	**9.54**
9	0	0.57	0.02	2.93	**3.52**	**1.57**	**44.63**
10	0	0.07	0	0.71	**0.78**	**0.47**	**61.12**
11	0	0.05	0.001	0.31	**0.36**	**0.15**	**40.88**
12	0	0.03	0	0.61	**0.65**	**0.58**	**89.92**
13	0	0.00	0.92	0.19	**1.10**	**0.08**	**7.00**
14	0.02	0.53	0.52	1.62	**2.69**	**1.23**	**45.82**
15	0	0.33	0.63	0.69	**1.65**	**0.56**	**33.91**
16	0	0.50	0.32	1.33	**2.15**	**1.24**	**57.47**
17	0	0.60	0	1.60	**2.21**	**1.67**	**75.55**
18	0	0.20	0	1.41	**1.61**	**1.36**	**84.66**
19	0	0.31	0	0.18	**0.50**	**0.47**	**94.21**
20	0	0.41	0	0.10	**0.51**	**0.32**	**63.42**
21	0	0.84	0.39	0.11	**1.34**	**0.12**	**9.15**
22	0	0.19	0	0.45	**0.64**	**0.08**	**13.26**
23	0	0.24	0	0.30	**0.54**	**0.36**	**65.91**
24	0	0.12	0	1.58	**1.70**	**0.67**	**39.32**
25	0	0.05	0	0.71	**0.76**	**0.72**	**94.10**
26	0	0.07	0	0.59	**0.66**	**0.31**	**46.44**
27	0	0.04	0	0.77	**0.81**	**0.55**	**68.21**
28	0	0.04	0	0.71	**0.75**	**0.42**	**56.00**
29	0	0.17	0	0.53	**0.70**	**0.53**	**75.00**
30	0	0.14	0	1.04	**1.18**	**0.28**	**23.81**
31	0.61	0.19	1.46	1.37	**3.63**	**0.69**	**18.92**
Total	**1.36**	**9.56**	**6.11**	**27.45**	**44.49**	**17.55**	**39.44**
Inundated Land Use (in sq. km)	**0.20**	**2.65**	**0.12**	**14.57**	**17.55**		
Percent of Inundated Land Use	**14.86**	**27.69**	**2.03**	**53.08**	**39.44**		

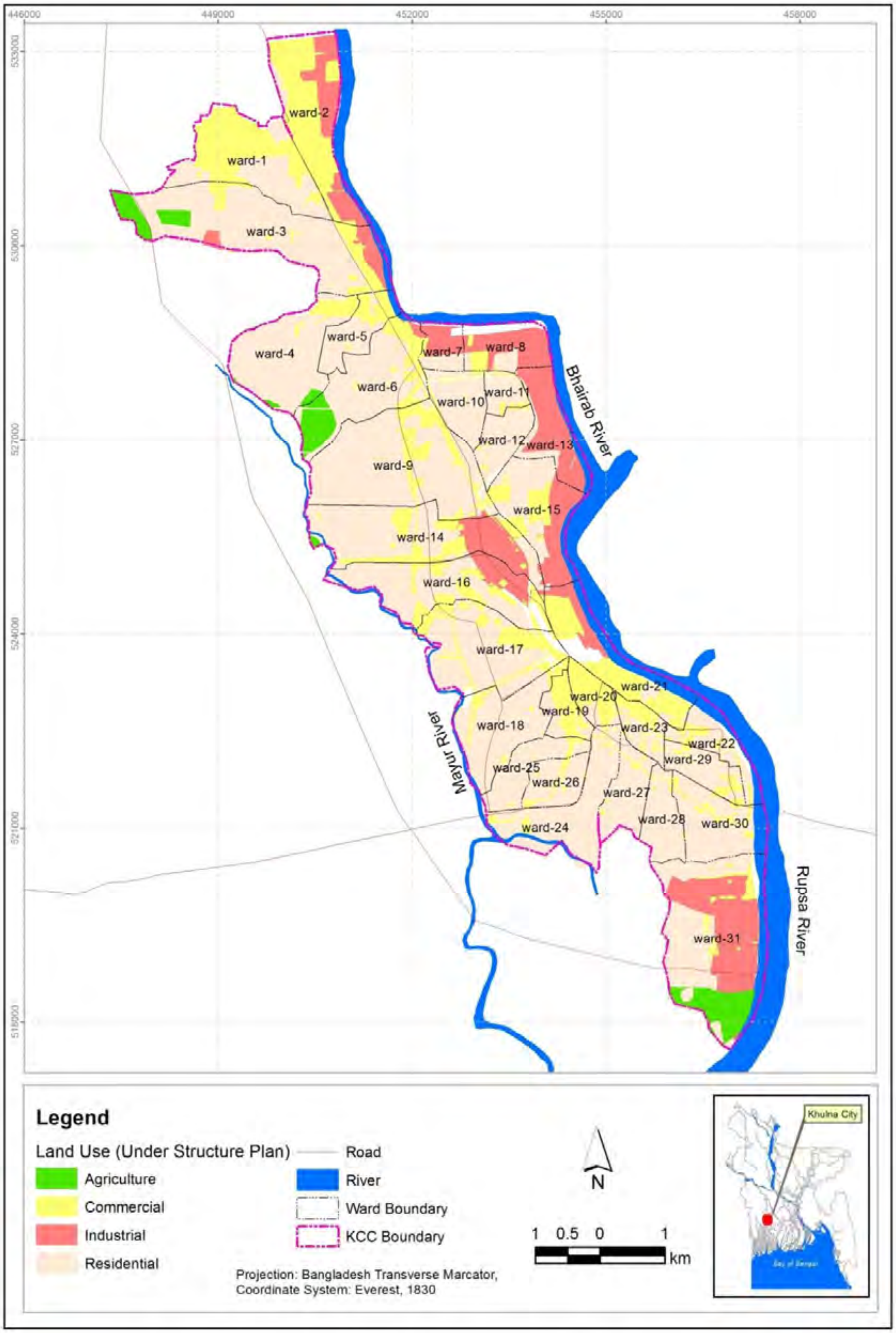


Figure 6-5: General Land Uses under the Structure Plan 2020.

Source: (Khulna Development Authority, 2002b)

Figure 6-5 shows the future general land uses under the structure plan, 2020. It is noticed that major industrial land uses are laid besides the Rupsha-Bhairab River and commercial land uses in the main hub of the city along the major road sides. Agricultural land uses are scanty and located at the western and southern low-lying area. Residential land uses are dominant and spread over the whole city. From Table 6-3, it has been observed that residential use is high and it is 27.45 sq. km. it is also noted that around 53% of the residential land uses and 28% for commercial land use will be inundated in 2020. Wards 12, 18, 19, and 25 will have more water logging problems rather than other wards.

Table 6-4 depicted ward wise distribution of different Land use under potential inundation and Figure 6-7 expresses the extent of different land uses of the structure plan under inundation. From the table, it has been observed that residential land uses occupies 83%, and commercial 15% of the total inundated land. Distribution of different inundated land uses are shown in Figure 6-6. Agriculture and industrial land uses take up very small portion of the total water logging areas. On other hand, ward 3, 4, 9, 14, 16, 17, and 18 occupies most of the inundated area.

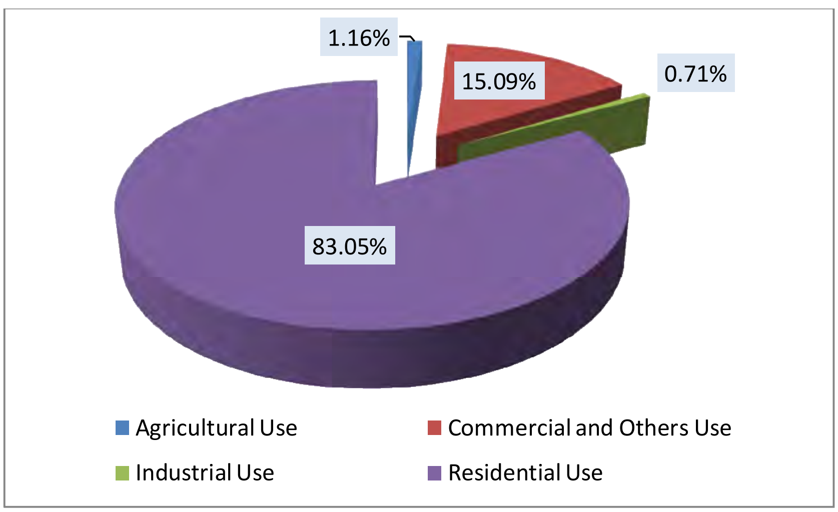


Figure 6-6: Distribution of Land Uses under Inundation in 2020

Table 6-4: Ward Wise Distribution of Different Land Uses under Indation in 2020

Ward	Different Land Use (sq. km) Under Inundation					
	Agricultural Use	Commercial and Others Use	Industrial Use	Residential Use	Total	Percentage
1	0	0	0	0.07	**0.07**	**0.40**
2	0	0.01	0.02	0.01	**0.04**	**0.22**
3	0.12	0.02	0	1.05	**1.19**	**6.76**
4	0	0.10	0	0.83	**0.92**	**5.26**
5	0	0	0	0.04	**0.04**	**0.21**
6	0	0.05	0	0.49	**0.54**	**3.09**
7	0	0.04	0.05	0.14	**0.24**	**1.37**
8	0	0.04	0.01	0.02	**0.07**	**0.43**
9	0	0.22	0	1.35	**1.57**	**8.95**
10	0	0.06	0	0.42	**0.47**	**2.71**
11	0	0.04	0.001	0.10	**0.15**	**0.84**
12	0	0.06	0	0.52	**0.58**	**3.31**
13	0	0.04	0.01	0.02	**0.08**	**0.44**
14	0.02	0.29	0	0.92	**1.23**	**7.02**
15	0	0.11	0	0.45	**0.56**	**3.19**
16	0	0.17	0	1.07	**1.24**	**7.04**
17	0	0.30	0.03	1.33	**1.67**	**9.51**
18	0	0.11	0	1.25	**1.36**	**7.76**
19	0	0.13	0	0.34	**0.47**	**2.68**
20	0	0.22	0	0.11	**0.32**	**1.84**
21	0	0.05	0	0.07	**0.12**	**0.70**
22	0	0.04	0	0.04	**0.08**	**0.48**
23	0	0.16	0	0.20	**0.36**	**2.03**
24	0	0.09	0	0.57	**0.67**	**3.81**
25	0	0.03	0	0.69	**0.72**	**4.09**
26	0	0.02	0	0.29	**0.31**	**1.76**
27	0	0.03	0	0.52	**0.55**	**3.16**
28	0	0.02	0	0.40	**0.42**	**2.41**
29	0	0.11	0	0.41	**0.53**	**3.00**
30	0	0.06	0	0.22	**0.28**	**1.60**
31	0.06	0	0	0.63	**0.69**	**3.92**
Total	**0.20**	**2.65**	**0.12**	**14.57**	**17.55**	**100**
Percentage	**1.16**	**15.09**	**0.71**	**83.05**	**100**	

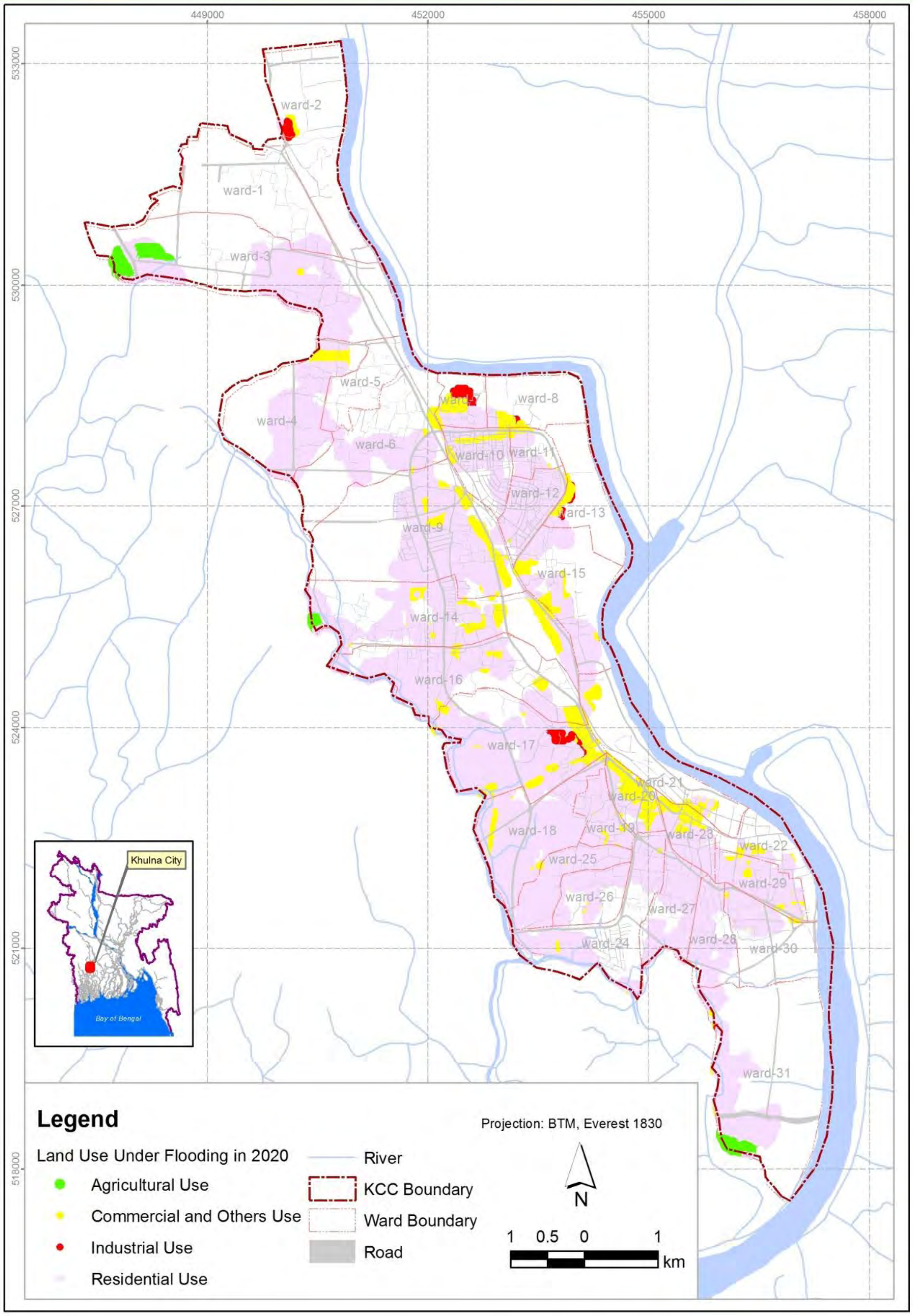


Figure 6-7: Extent of Four General Land Uses Under Inundation in 2020

Source: The map is prepared by the researcher based on (Khulna Development Authority, 2002b)

Table 6-5 shows the condition of four general land uses under different inundation depth and it has been pointed out that agricultural land use is inundated up to 70cm whereas commercial is up to 190 and industrial up to 160cm. Residential land use is inundated between lowest to maximum inundation depth. Depth range 41-70cm covers around 38% of the total inundation and it is gradually decreased to the maximum depth.

Table 6-5: Land Uses (in sq. km) at Different Inundation Depth

Land Use	Area (sq. km) under Different Inundation (cm) Level								
	10-40	41-70	71-100	101-130	131-160	161-190	191-220	Total	Percentage
Agricultural Use	0.18	0.02	0	0	0	0	0	**0.20**	**1.16**
Commercial and Others Use	0.90	0.92	0.67	0.13	0.02	0.02	0	**2.65**	**15.09**
Industrial Use	0.04	0.02	0.03	0.03	0.00	0	0	**0.12**	**0.71**
Residential Use	4.02	5.68	3.68	0.83	0.21	0.12	0.04	**14.57**	**83.05**
Total	**5.14**	**6.64**	**4.38**	**0.99**	**0.22**	**0.13**	**0.04**	**17.55**	**100**
Percentage	**29.32**	**37.82**	**24.94**	**5.62**	**1.28**	**0.77**	**0.25**	**100**	

To assess damage to land use, it is sometimes very important to know that how much land for different land uses is proposed in non-urban area and how much land for different land uses is existed in the urban built-up area. Table 6-6 shows the amount of land uses at urban and non-urban areas under the potential inundation in 2020. It has been pointed out that 6.37 sq. km land is proposed for commercial, industrial and residential land uses in the agriculture area, of which around 32% of the residential and 5% of the commercial land use will be inundated. In the proposed area no industrial land will be inundated. On other hand, in the built-up areas around 57% of the residential and 29% of the commercial land will be inundated. Only 2.35% of the industrial land use will be flooded in the built environment of the city.

Table 6-6: Land Uses (sq. km) at Urban and Non-Urban Area under Inundation

Land Use	Urban Area						Non-Urban Area		
	Expanded Area			Built-up Area			Agriculture		
	Total	Under Flood	%	Total	Under Flood	%	Total	Under Flood	%
Commercial	0.45	0.02	**4.63**	9.11	2.63	**28.83**	1.36	0.20	**14.71**
Industrial	0.81			5.30	0.12	**2.35**			
Residential	5.11	1.61	**31.59**	22.34	12.86	**57.58**			
Total	**6.37**	**1.64**	**25.67**	**36.75**	**15.61**	**42.48**	**1.36**	**0.20**	**14.71**

6.6 Potential Flood Damages of Different land Uses

6.6.1 Agricultural Damage

Extent and degree of damage to agriculture (percentage of the yields to be damaged) is shown in Figure 6-9 and Table 6-7. It is noticed that agricultural crops are inundated at a depth of maximum 70cm through the lowest 10cm which causes the maximum 35% damage of the yields. It is also pointed out that 90% of the agricultural land is under the depth of 10-40cm inundation. It has been remarked from Figure 6-8 that maximum agricultural area is under damage between 11% and 23%. With the increase of depth and duration, agricultural damage is increasing (*See* Figure 2-7) and up to 100cm depth, damage follows 0.4583 multiplied by inundation depth.

Table 6-7: Area (sq. km) under Different Damage (%) Level of Agricultural Use under Different Inundation Depth

Damage to Agriculture (%)	Area (sq. km) under Different Inundation (cm) Level								
	10-40	41-70	71-100	101-130	131-160	161-190	191-220	Total	Percentage
5 - 11	0.043	0	0	0	0	0	0	**0.043**	**21.30**
11.01 - 17	0.074	0	0	0	0	0	0	**0.074**	**36.69**
17.01 - 23	0.064	0.013	0	0	0	0	0	**0.077**	**38.07**
23.01 - 29	0	0.007	0	0	0	0	0	**0.007**	**3.55**
29.01 - 35	0	0.001	0	0	0	0	0	**0.001**	**0.39**
Total	**0.18**	**0.021**	0	0	0	0	0	**0.203**	**100**
Percentage	**90**	**10**	0	0	0	0	0	**100**	

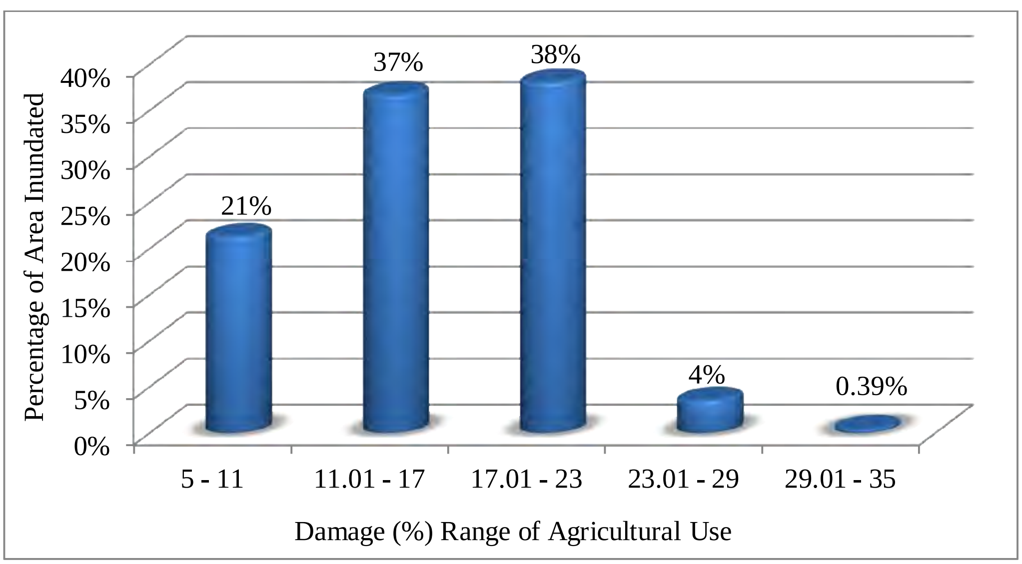


Figure 6-8: Percentage of Area Inundated Under Agricultural Use at Different Damage (%) Level

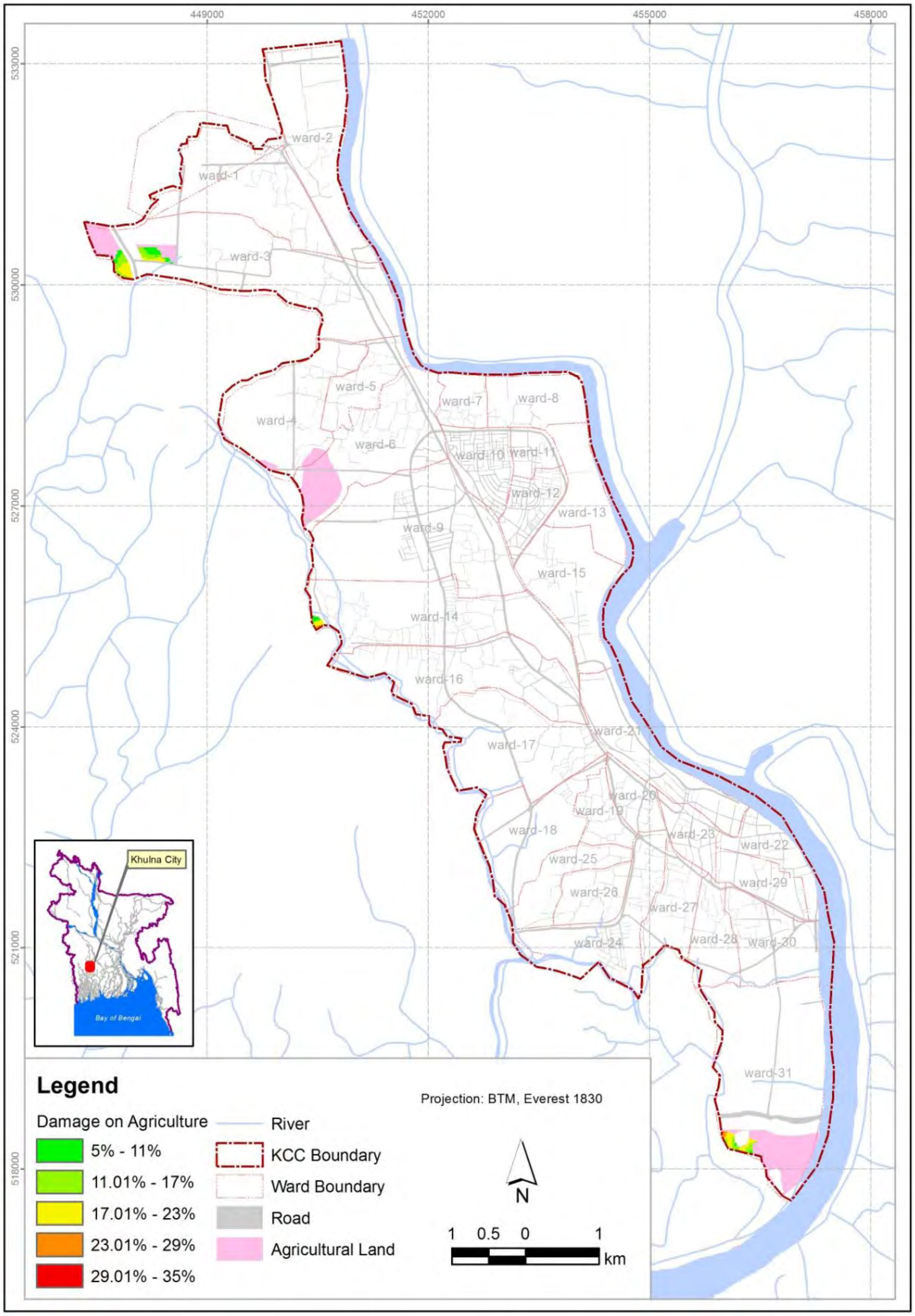


Figure 6-9: Extent and Degree of Damage (%) of Agricultural Use

Source: The map is prepared by the researcher

6.6.2 Commercial and Other Damage

Commercial land other land use basically mixed land uses are grouped together to find out their extent and degree of damages and shown in Figure 6-11and Table 6-8. It is observed that contents to commercial use are inundated at a depth of maximum 190cm through the lowest 10cm which causes the maximum 35% damage of the commercial contents. 60% of the inundated commercial area lies between 41cm to 100cm depth (shown in Table 6-8) and on other hand, 84% inundated commercial area having 2% to 17% damage to the commercial contents is shown in Figure 6-10. Figure 2-8 points out that commercial damage is increasing with the increase of depth and duration.

Table 6-8: Area (sq. km) under Different Damage (%) Level of Commercial and Other Use under Different Inundation Depth

Damage to Commerce &Others (%)	Area (sq. km) under Different Inundation (cm) Level								
	10-40	41-70	71-100	101-130	131-160	161-190	191-220	Total	Percentage
2 - 9	0.90	0.19	0	0	0	0	0	**1.09**	**41.16**
9.01 - 17	0	0.73	0.41	0	0	0	0	**1.14**	**43.16**
17.01 - 24	0	0	0.25	0.10	0	0	0	**0.36**	**13.51**
24.01 - 32	0	0	0	0.02	0.02	0	0	**0.04**	**1.47**
32.01 - 39	0	0	0	0	0	0.02	0	**0.02**	**0.71**
Total	**0.90**	**0.92**	**0.67**	**0.13**	**0.02**	**0.02**	0	**2.65**	**100**
Percentage	**34**	**35**	**25**	**5**	**1**	**1**	0	**100**	

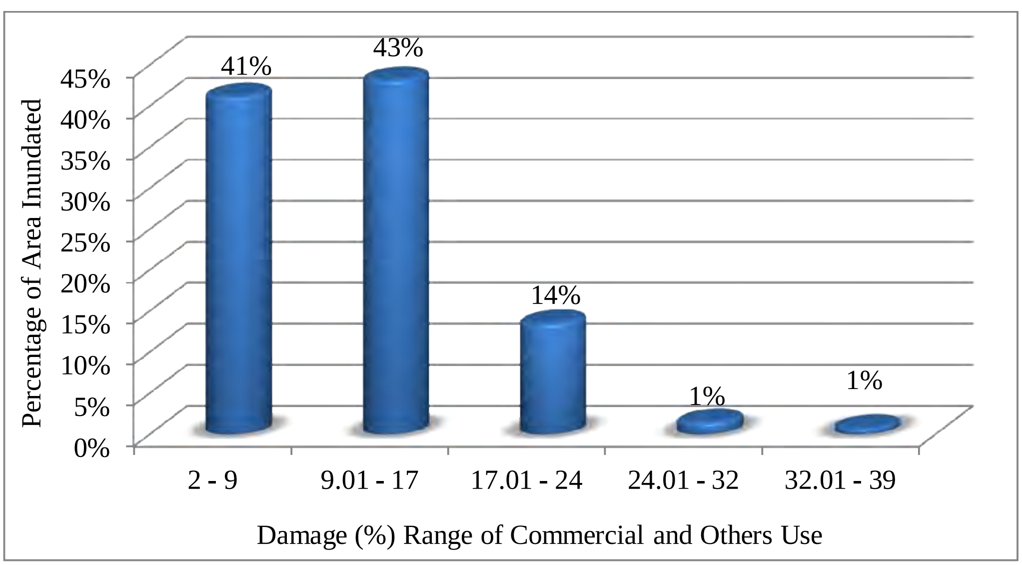


Figure 6-10: Percentage of Area Inundated Under Commercial and Others Use at Different Damage (%) Level

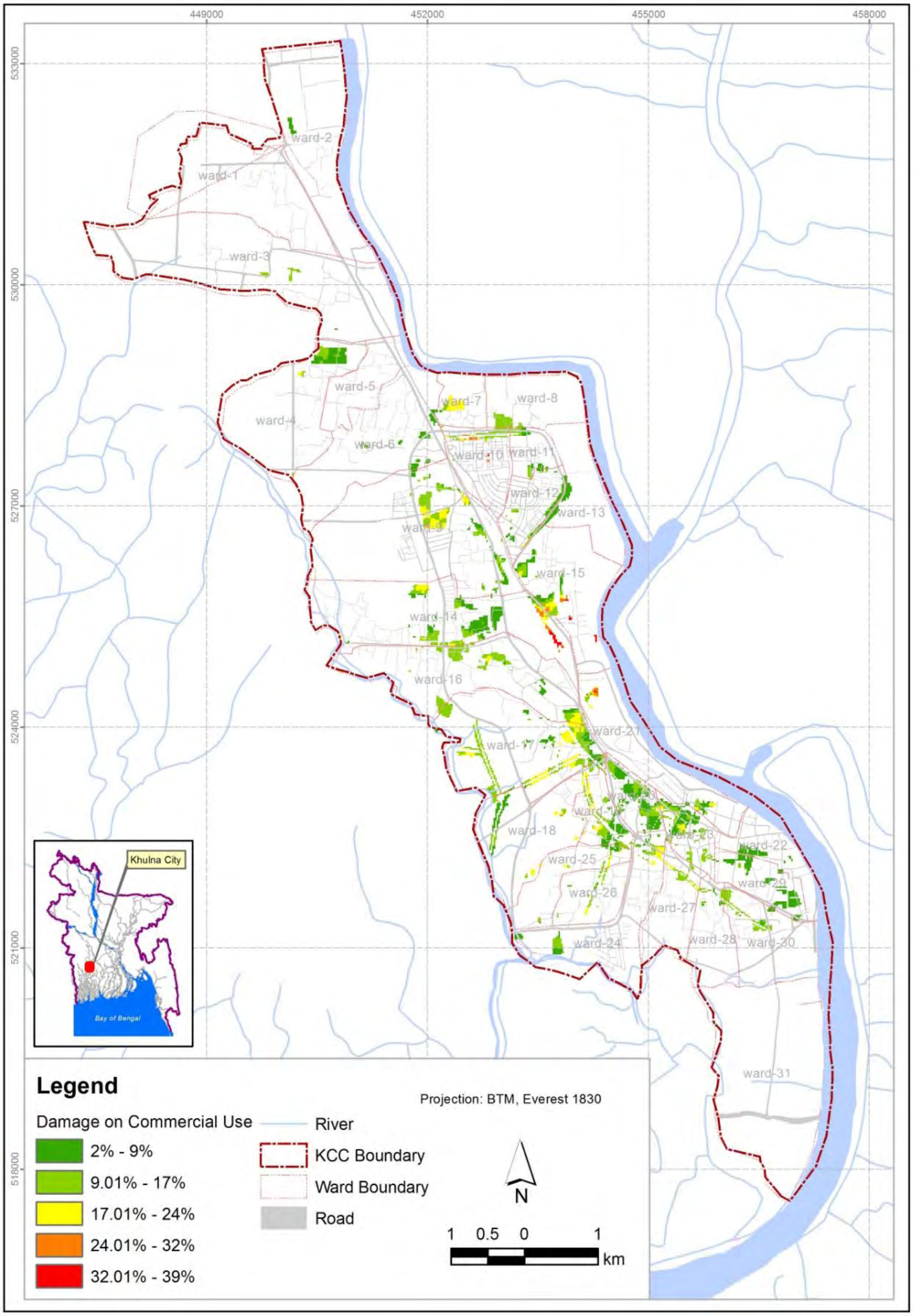


Figure 6-11: Extent and Degree of Damage (%) of Commercial and Other Use

Source: The map is prepared by the researcher

6.6.3 Industrial Damage

Around 2% industrial land will be inundated in 2020 (*See* Table 6-3) and it is the lowest from other three major land uses. Table 6-9 and Figure 6-13 shows the extent and degree of damage in terms of percentage to the industrial contents. It is noticed that contents to industrial use are inundated at a depth of maximum 160cm through the lowest 10cm which causes the maximum 14% damage of the industrial contents. Maximum damage to the industrial contents is lowest from other three land uses in terms of their respective percentage. Most damages in terms of percentage of area (99%) under inundation is occurred at a depth of 10cm to 130cm. Figure 6-12 points out that all ranges of damages (%) are significantly responsible but 8.01% to 11% damages covers highest area (34%) under inundation.

Table 6-9: Area (sq. km) under Different Damage (%) Level of Industrial Use under Different Inundation Depth

Damage to Industry (%)	Area (sq. km) under Different Inundation (cm) Level								
	10-40	41-70	71-100	101-130	131-160	161-190	191-220	Total	Percentage
1 - 3	0.02	0	0	0	0	0	0	**0.02**	**18**
3.01 - 5	0.01	0.01	0	0	0	0	0	**0.02**	**17**
5.01 - 8	0	0.01	0.01	0	0	0	0	**0.02**	**20**
8.01 - 11	0	0	0.02	0.020	0	0	0	**0.04**	**34**
11.01 - 14	0	0	0	0.01	0.001	0	0	**0.01**	**12**
Total	**0.04**	**0.02**	**0.03**	**0.03**	**0.001**	0	0	**0.12**	**100**
Percentage	**29**	**17**	**26**	**27**	**1**	0	0	**100**	

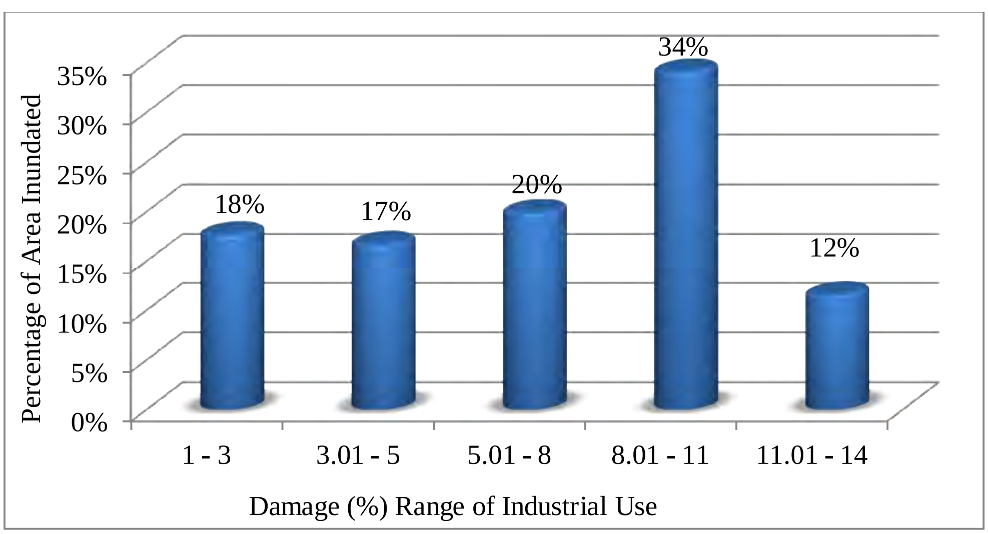


Figure 6-12: Percentage of Area Inundated Under Industrial Use at Different Damage (%) Level

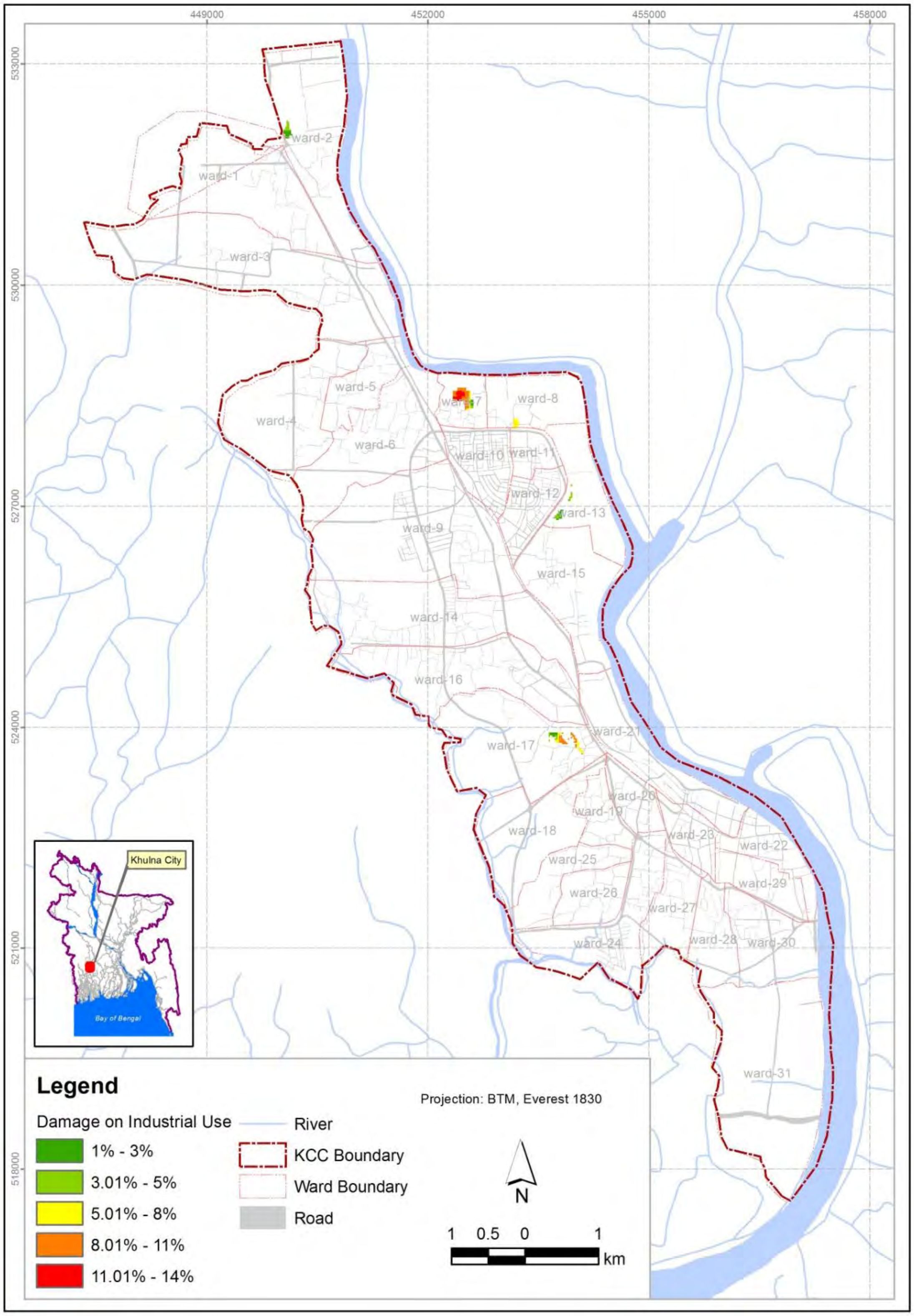


Figure 6-13: Extent and Degree of Damage (%) of Industrial Use

Source: The map is prepared by the researcher

6.6.4 Residential Damage

Extent and degree of damage to residential use (percentage of the contents to be damaged) is shown in Figure 6-15 and Table 6-10. It is noticed that at all inundation depth, residential damages is occurred and it is highest in terms of area inundated and damage percentage from other three major land uses. Around 39% of the inundated residential area is highest among the different inundation depth and it is 41cm to 70cm. On other hand maximum 42% areas under residential use having 13% to 22% damage is highest (*See* Figure 6-14).

Table 6-10: Area (sq. km) under Different Damage (%) Level of Residential Use under Different Inundation Depth

Damage to Industry (%)	Area (sq. km) under Different Inundation (cm) Level								
	10-40	**41-70**	**71-100**	**101-130**	**131-160**	**161-190**	**191-220**	**Total**	**Percentage**
4 - 13	2.61	0	0	0	0	0	0	2.61	**18**
13.01 - 22	1.41	4.73	0	0	0	0	0	6.14	**42**
22.01 - 31	0	0.95	3.68	0.62	0	0	0	5.25	**36**
31.01 - 40	0	0	0	0.21	0.21	0.03	0	0.44	**3**
40.01 - 49	0	0	0	0	0	0.09	0.04	0.13	**1**
Total	**4.02**	**5.68**	**3.68**	**0.83**	**0.21**	**0.12**	**0.04**	**14.57**	**100**
Percentage	**27.6**	**39.0**	**25.2**	**5.7**	**1.4**	**0.8**	**0.3**	**100**	

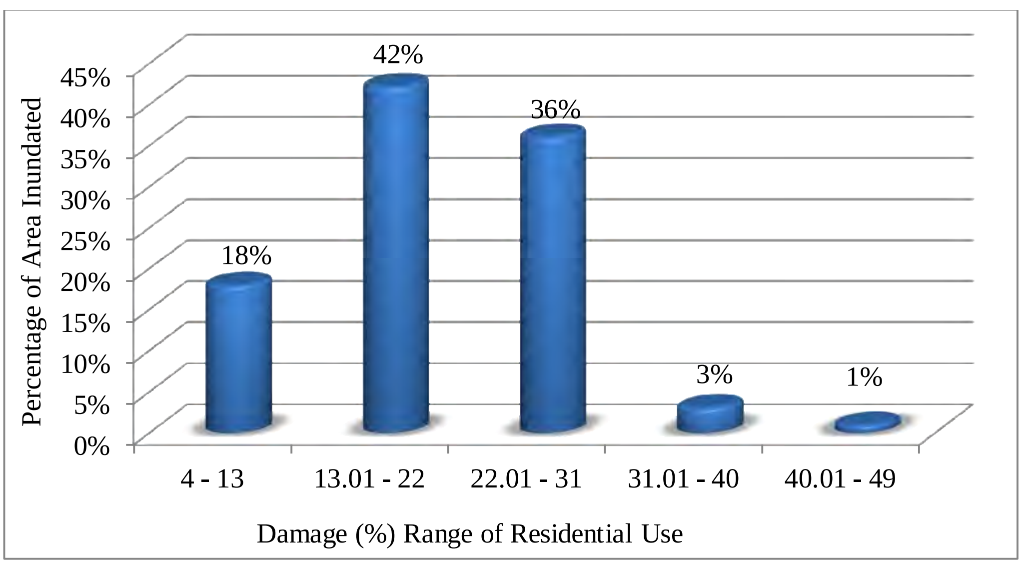


Figure 6-14: Percentage of Area Inundated Under Residential Use at Different Damage (%) Level

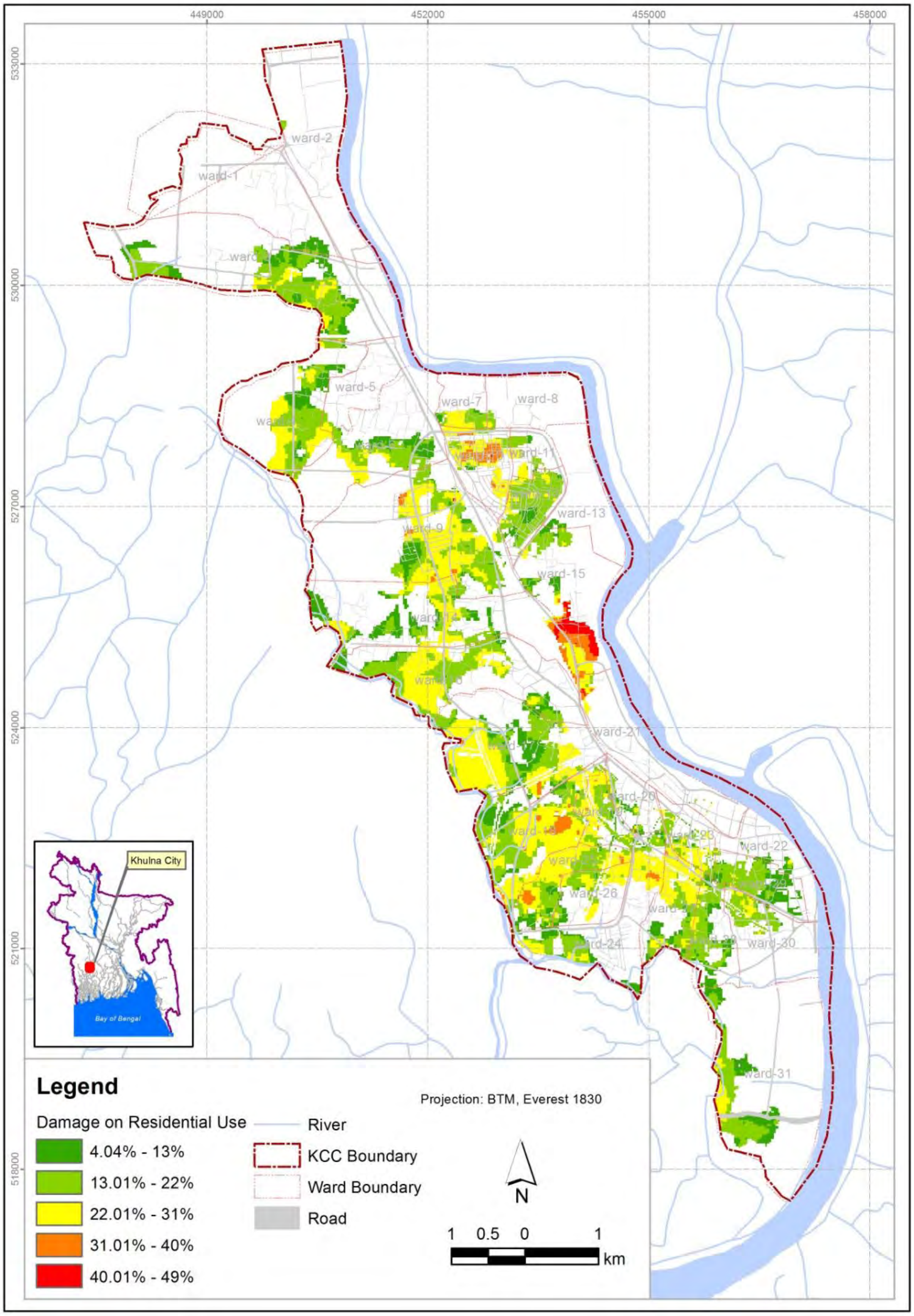


Figure 6-15: Extent and Degree of Damage (%) of Residential Use

Source: The map is prepared by the researcher

6.7 Comparative Analysis of the damages of different land uses

Damages to the different land uses by inundations are different as they have different degree of sensitivity to various inundations depth and duration. Even, within the same depth and duration of inundations for same amount of area, damages of different land uses are different. Various land uses associate different things, some are expensive than others that define the degree of damage to that particular land use. Total estimated damage on different land uses is Tk. 1959 million. This is significant amount of damage is more than the budget for 2011-2012 (Tk. 1800 million) and around one-third of the budget for 2012-2013 (Tk. 3090 million). Table 6-11 points out the unit damage of four major land uses for 2020 in regards of the base year damages. It has been noticed that unit damage (per sq. km) to industrial use is much higher than others and it is 1040 million Tk. with compound interest at the rate of 11.97% inflation. Khulna City is associates with different type of small, medium and large scale industries, which includes various types of costly parts that might be damaged under inundations. Along with this, during inundation production of the affected industries will be hampered which will augmented the degree f damage. Commercial unit damage is immediately after the industrial use and it is around 731 million Tk., which includes different commercial goods both in the shops or commercial areas and warehouses. Agricultural unit damage is third in position before residential among the major four land uses.

Table 6-11: Damage Costs (million Tk) in 1-10 Year, Realistic Scenario

1 in 10 year Water Logging Event	**Average water logging depth (cm)**	**Residential**	**Industry**	**Commercial & Others**	**Agriculture**	**Total**
Base Case (mTk for 2010)	41	5	23.5	564	3	595.5
Inundated Area (sq. km)		12.22	0.07	2.39	1.59	16.52
mTk / sq. km		0.41	335.71	235.98	1.89	36.05
Projection for 2020 (Calculated Based on the Above Data)*						
Projection (mTk for 2020)	59					
Inundated Area (sq. km)		14.57	0.12	2.65	0.20	17.54
Total mTk for the inundated area (in respect of present value)		5.96	40.29	625.36	0.38	632.27
Total mTk for the inundated area @11.97% Inflation Rate		**18.46**	**124.80**	**1937.08**	**1.18**	**1958.48**
mTk / sq. km @11.97% Inflation Rate on March, 2012		**1.27**	**1040.00**	**730.97**	**5.90**	**111.66**

* Case with Socio-Economic (SE) changes and with climate changes (CC), Calculations for 2020 is done based on damage mTk per sq km for 2010 (Base Case)

Source: (Asian Development Bank, 2010)

6.8 Compatibility of the Land Use Policies and Proposals

6.8.1 Agriculture

Agricultural land has been decreased substantially from the initiation of the existing development plan. In 1998, within the Khulna City Corporation, agricultural land was 22%, and 15% in 2010 as per Master Plan. But it is alarming that the agricultural land will be decreased to 3%. Form Figure 6-9 and Table 6-7, it has been shown that around 96% of the inundated agricultural land is under 5% and 23% damage. This does mean that under the potential flood, agricultural yields will be damaged up to 23% in those areas and this occurs largely in Kartikerkul (Ward-3) and Labanchara (Ward-31) area. These are the major sources of agricultural land within the city corporation area with areas near Karigarpara (Ward-6). As per the Structure Plan, these areas are solely dedicated to agricultural land due to unsuitability for development being low-lying areas, acting as wetland/reservoir which retains the surface runoff, providing senses of open spaces within the city area and finally being high value agricultural land which contributes the rice production of the country.

Three major sources of agricultural land within the Structure Plan lie near the bypass road of Khulna City. These lands are dedicated to agriculture as per Structure Plan due to being low-lying areas and no development has been suggested on those lands. Talking with the local peoples, planners and engineers, it has been shown that many of these agricultural land is about to encroach by the people to be settled there and some places has already been occupied by settlement with high plinth structures from getting rid of from the inundation (*See* Figure 5-1). It has also been come out from talking with the local people that Bypass Road has increased the accessibility and finally land price which provokes the people to purchase the land to be profited in the future. City Authority (KDA) is almost unaware about the issue, which has been expressed talking with one of the planners of the city authority. Potential damage to agricultural land is limited to up to 23%. On other hand, agricultural land has more advantages apropos of acting as wetland, open spaces, etc. Inundation to the agricultural land helps to deposit silt which increases the crops production. Considering all these factors, it has drawn that these land is suitable for high value agricultural land and not suitable for any development. Form field survey, it has also observed that there are some other low-lying areas (areas near Bastohara Colony) which has been proposed in the structure plan.

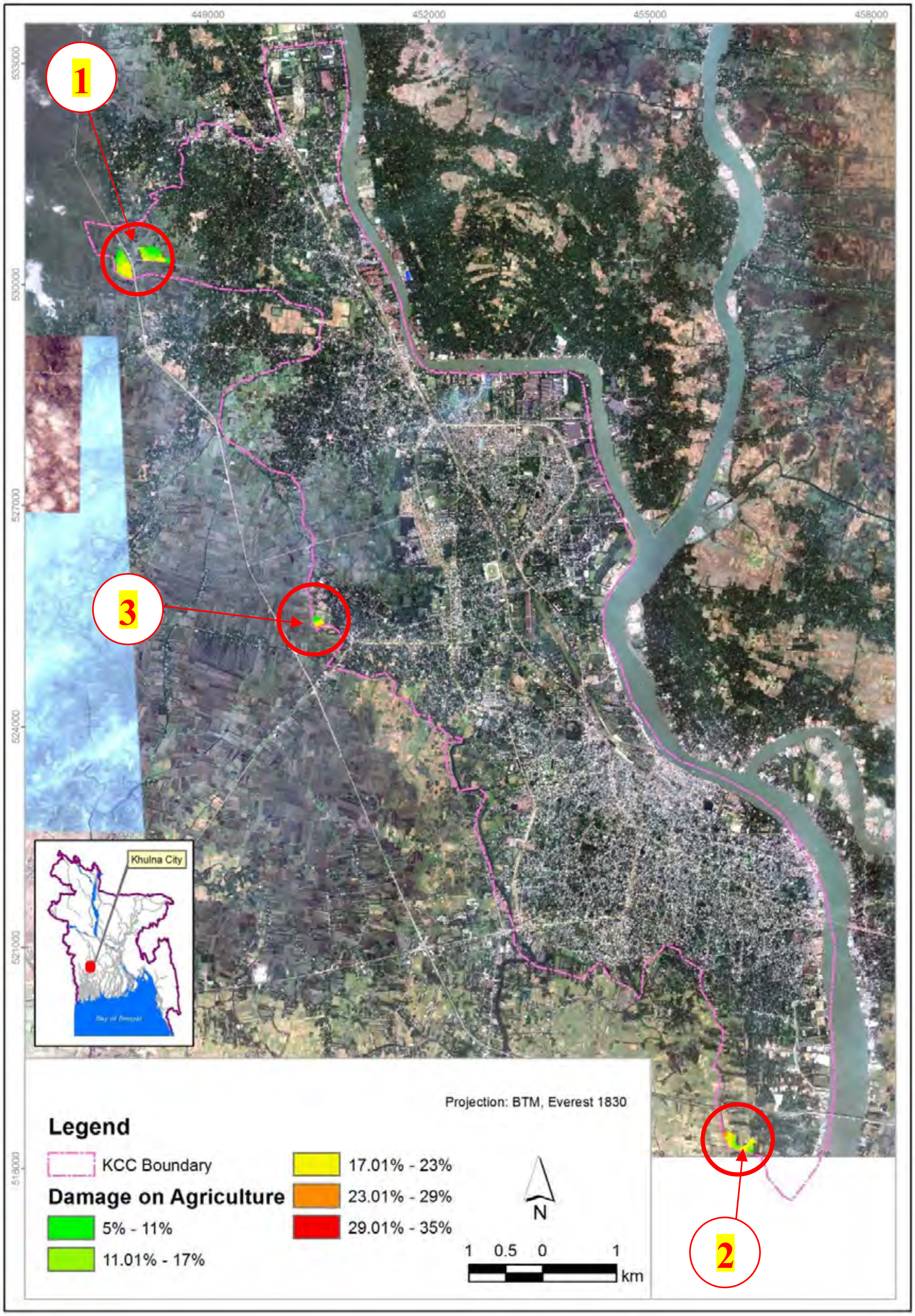


Figure 6-16: Extent and Degree of Damage on Agricultural Use with respect to Satellite Image (Google Earth, 2010)

Source: The map is prepared by the researcher

6.8.2 Commercial

A judiciously worked out land use plan showing commercial use areas can enable systematic growth and balanced growth of commercial establishment. The Existing Structure Plan and Master Plan of Khulna City proposed commercial areas in those areas that are suitable for commercial development. Khulna is a linear City mainly guided by the major road along north-west (Khulna-Jessore Road) and all establishments especially commercial, industrial land uses largely follow that road. Large commercial establishments of different categories are concentrated in city hub (Barobazar, Sonadanga, etc.). Other large concentrations within the city corporation area are at Daulatpur, Khalishpur, Mujgunni, Boyra, Sheikhpara, Natun Bazar, Nirala, Banargati, Mistripara, Rupsha, Labanchara, Wahab Avenue, New Market, Joragate. Important commercial developments are expected in Shiromoni, Gollamari, New Market-Shibbari area, Aranghata area, Teligati area, Rupsha and Dighalia area. New commercial development in the area will include town centre, bazaar and other commercial development around the town centre and existing commercial establishments. There are huge ribbon commercial developments along roads, like Sie Iqbal Road, Khan-E-Jahan Ali Road, Symmetry Road, Khan-E-Sabur Road, KDA Avenue, Sher-e-Bangla Road.

Figure 6-17 shows the extent and degree of damage of commercial land use. The damage map [1] shows the highest degree of damage. This area comprises of wholesale market, warehouses and other shops on the existing built-up area. With the help of the satellite image and field survey, it has been observed that this commercial area is situated along the old Jessore Road and bounded by this and the railway on other side. It has also been observed that there some significant numbers of water bodies. Despite having those water bodies, significant potential inundation (*See* Figure 6-3) due to insufficient drainage (*See* Figure 4-8), drainage blockage and having no outgoing channel, which cause the highest degree of damage on commercial use.

Damage map [2] comprises of the Kotowali and Sonadanga Thana of Khulna City which is the hub of commercial activities. These areas are mostly built-up areas which have more drainage facilities compared with other areas but deemed to be insufficient. Potential flood facilities proved the insufficiency of drainage facilities or inefficiency of the existing drainage due to blockage of drains or limited facilities of draining out the surface runoff.

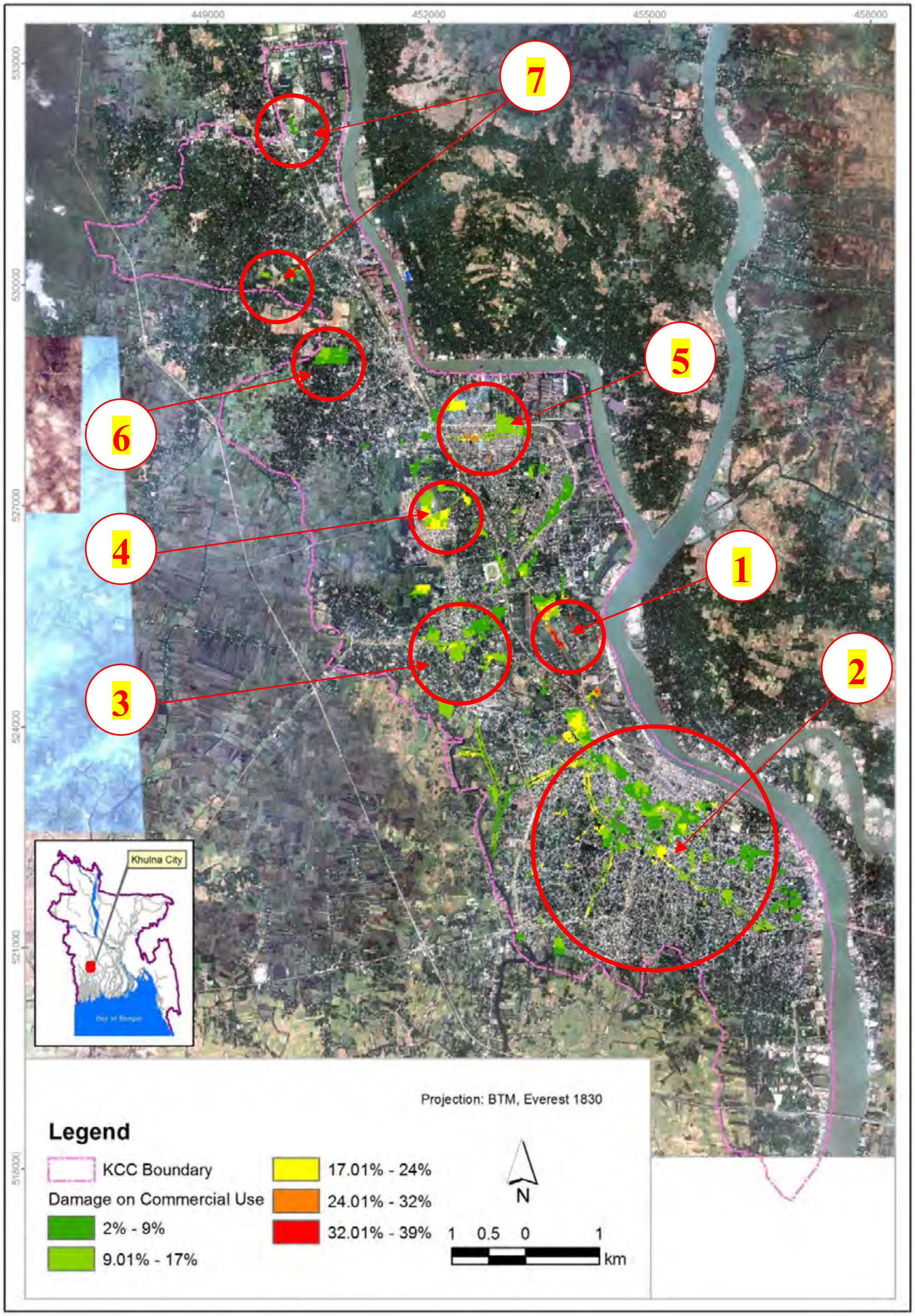


Figure 6-17: Extent and Degree of Damage on Commercial Use with respect to Satellite Image (Google Earth, 2010)

Source: The map is prepared by the researcher

Damage map [3] is the sub town centre of Khulna City which comprises of largely Mujgunni, Boyra, Rayar Mahal Area. This is a highly built-up area which has well connected with the town center. There is a large amount of hinterland just besides the area in the north-west. Commercial activities are near the roads and other parts are mostly residential. Due to being high built-up area, water logging is a severe problem here (*See* Figure 6-3). Figure 4-8 shows that drainage facilities are comparatively less despite being built-up area. There is a good chance to get rid of from this situation by draining out the surface runoff to the hinterland and finally to the Mayur River on the west.

Damage Map [4] shows clearly the area bounded by the hinterland area. This is a newly developed area comprises of Daspara and Part of Mujgunni area. Due to being low-lying area, commercial uses are predicted here to be damaged significantly though drainage facilities are deemed to be better.

Damage map [5] comprises of some commercial areas at Khalishpur Housing Estate. This is the first more or less planned residential area (quarter) ever built in Khulna City acts as Jute Millôs Staff. Marked commercial areas are vulnerable, though drainage facilities (*See* Figure 4-8) are deemed to be good enough due to having draining out facilities being nearer to the river. There is a great chance to be affected by the sea level rise due to climate change.

Damage map [6] shows a developing commercial area within the Daulatpur Thana, which comprises of existing and proposed commercial areas. Drainage facilities are insufficient here and surrounded by the hinter land. Due to having lower topography, this area is prone to be damaged in the future.

Damage map [7] comprises of existing and proposed commercial areas. These are the remote commercial areas of the city. These areas have low probable damage on commercial use due to having comparatively higher topography.

6.8.3 Industrial

Khulna Cityôs development was based on industrial sectors with its rich history. Khulna City holds 3rd largest position with respect to the number of industries and industrial labor force. As there was no master plan or land use zone at the inception of flourishing industrial sector, different types of industries was developed spontaneously. It has been noticed that though spontaneous industrial development was occurred, mostly were on and near of the western bank of the Rupsha and Bhairab River. Industrial zoning has been clearly defined in the present Structure Plan. All possible factors were considered at the time of plan preparation except the impacts of climate change. So the policies and proposals of different land uses might have deficiencies in the preparation.

Figure 6-18 shows the extent and degree of damage of industrial use. Damage map [1] shows Meghna and Padma Oil Company Area and itôs nearer between Khalishpur and Daulatpur, which highest degree of industrial damage has been occurred. Some small and medium level industries are existed here. A significant number of water bodies especially ponds are available in this area with limited draining out facilities which causes significant potential inundations (*See* Figure 6-3). Figure 4-8 shows drainage facilities. It has been noticed that drains are not well connected that leads to the outfall in the river.

Damage map [2] shows Khulna Textiles Mills area (behind the New Market Area) where significant industrial damage is predicted. This area is of comparatively lower topography in respect of its surroundings. Internal drainage facilities (from the drainage map) seem to be better but draining out capacity is worse. This area is connected to the lower topographic area on the west but huge developments hinder the draining out facilities.

Damage map [3] shows the highly built-up area at Khalishpur with small level industries. Drainage facilities in number are good but draining out condition is worst due to blockage, discordant connections to each another and finally unwell connections with the outfall.

Damage map [4] shows the built-up area on the western bank of the Bhairab River and near Khalishpur Housing Estate, where small industries with some warehouses are existed. Draining facilities are very poor here.

Damage map [5] shows Mirerdanga area, where some existing and some proposed industrial uses are existed. Itôs a remote area of the city corporation. Drainage facilities and drainage conditions are very poor here.

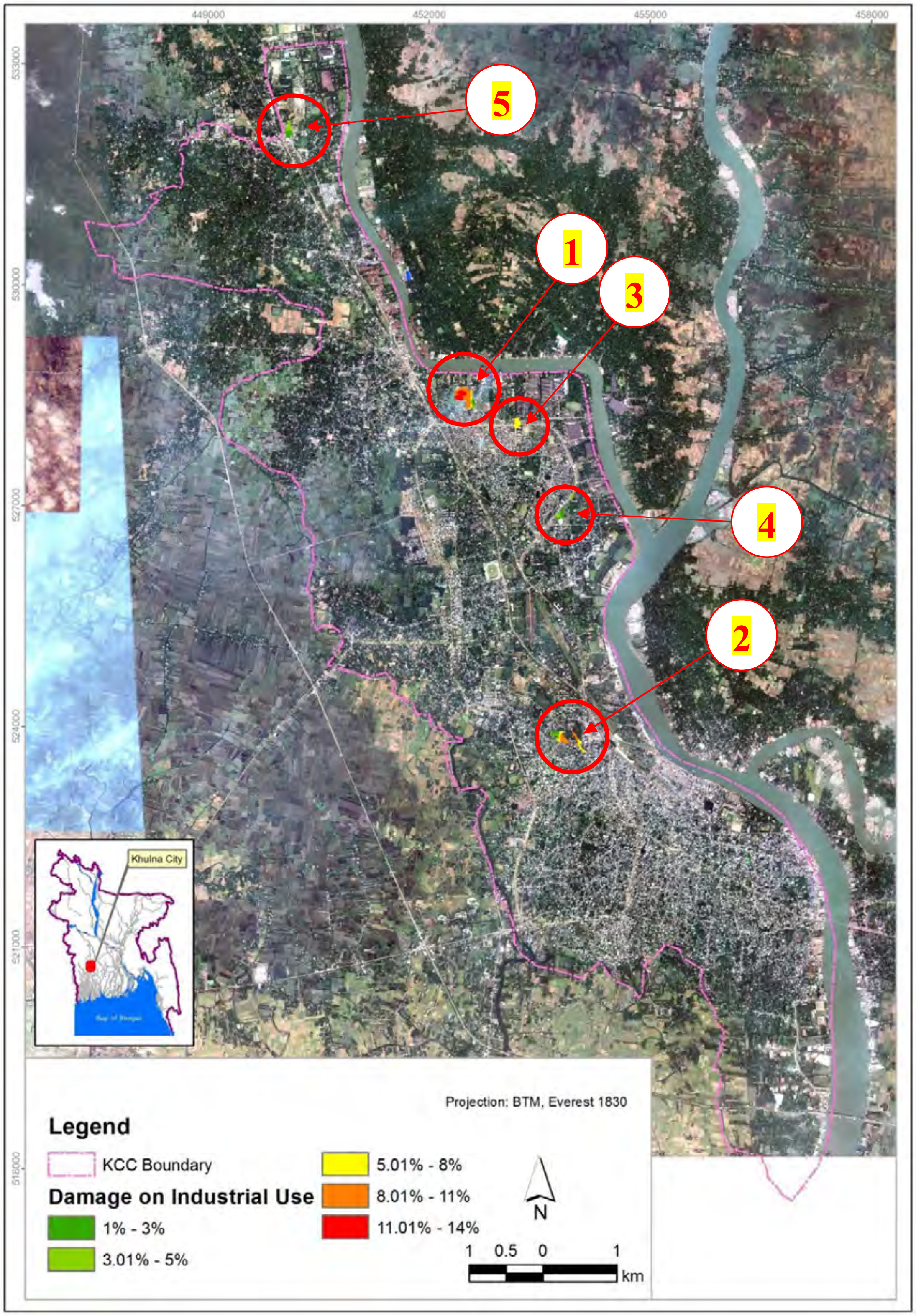


Figure 6-18: Extent and Degree of Damage on Industrial Use with respect to Satellite Image (Google Earth, 2010)

Source: The map is prepared by the researcher

6.8.4 Residential

Residential is a dominant land use in Khulna City (*See* Figure 4-6). Residential land use is largely spontaneous development over the city area. On other hand, there are some pure residential areas for the sake of having some big industries especially Khalispur Housing Estate, which is the first planned residential area which includes the Jute Mills Staff Quarters, Nirala Residential Area, etc. Figure 6-19 depicts the extent and degree of potential residential damages.

Damage map [1] shows Mongla Port Authority Residential Area which is situated besides the western bank of the Rupsha River. The highest degree of residential damage will have occurred here. Drainage facilities (*See* Figure 4-8) and its conditions what existed here are very poor in this residential area. On other hand it is vulnerable to the potential inundation due to being sited besides the river due to sea level rise and urban flooding (*See* Figure 6-3). Probable hazards and impacts of climate changes especially urban flooding with poor drainage facilities and conditions make this area more vulnerable.

Damage map [2] shows Largely Nirala Residential Area, Mohammad Nagar, Boro Bazar, Sonadanga, Arambag, Denarabag, Mollapara, Kotowali, which are existing built up area. Drainage facilities are mainly concentrated in this area. Major developments are centered on this area and density of different uses is comparatively quite high. Whatever the drainage facilities are, their condition seems to be worst from the potential urban flooding. It has been noticed from the field survey that maintenance of the existing drainage facilities has lacking of the respective authority.

Damage map [3] shows Khalispur Housing Estate, Mujgunni Residential Area, Daspara, Goalkhali and part of Rayermahal. These areas are mostly built-up with some proposed residential areas. Khalishpur is planned residential areas with significant drainage facilities but their conditions are quite worse. On other hand, the western part of the planned residential area which includes Daspara, Goalkhali are of lower topography prone to have attacked by the urban flooding. A major portion of land has been proposed here for residential use. These areas mainly act as catchment for the surface runoff with its nearer areas. Future development might hamper the drainage conditions of these areas.

Damage map [4] shows Daulatpur area which includes built-up and proposed residential use. Nayapara, Islambag, Maheshwar Pasha, Shah Para, Gaikur, Munshi Para, Kalibari, Maniktala Area are mentionable. It has been noticed from the drainage map that the drainage facilities are lesser with poor conditions. Areas nearer to the Jessore-Khulna highway are of comparatively higher topography that the areas on the western sides of these areas. It is interesting noticing from the field survey that housings are developed continuously making the plinth level at high from getting rid of from the damage occurred.

Apart from the above mentioned areas, there are some other residential areas viz. north-west part and Labanchara under the damage by the potential inundations. In different parts of the city, residential land is being developed. On the other hand, slums area (*See* Figure 6-20) are more vulnerable as there have limited facilities especially drainage facilities. From the residential damage map and potential urban inundation map, it is shown that the slum areas near Khalishpur are prone to be damaged.

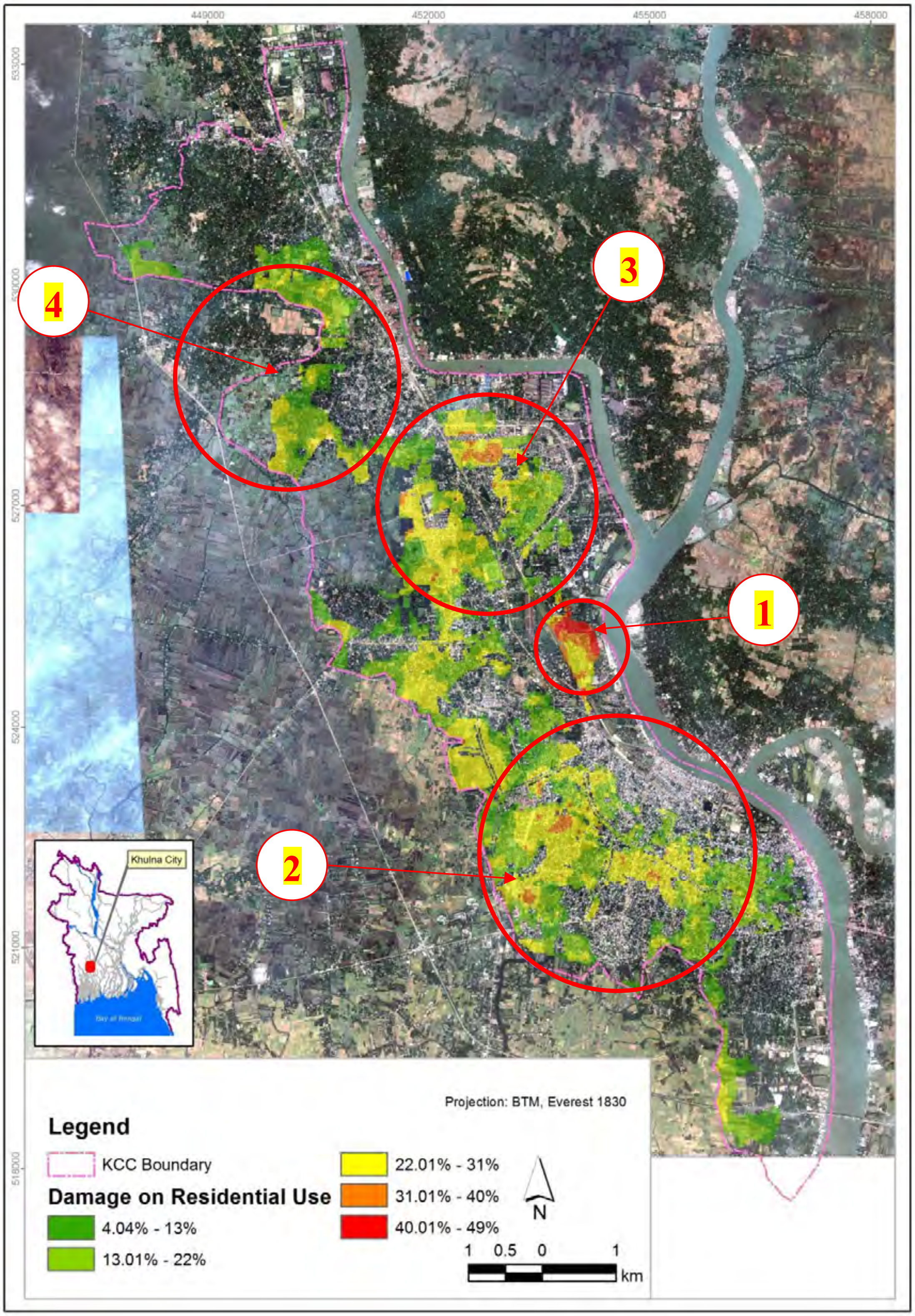


Figure 6-19: Extent and Degree of Damage on Residential Use with respect to Satellite Image (Google Earth, 2010)

Source: The map is prepared by the researcher

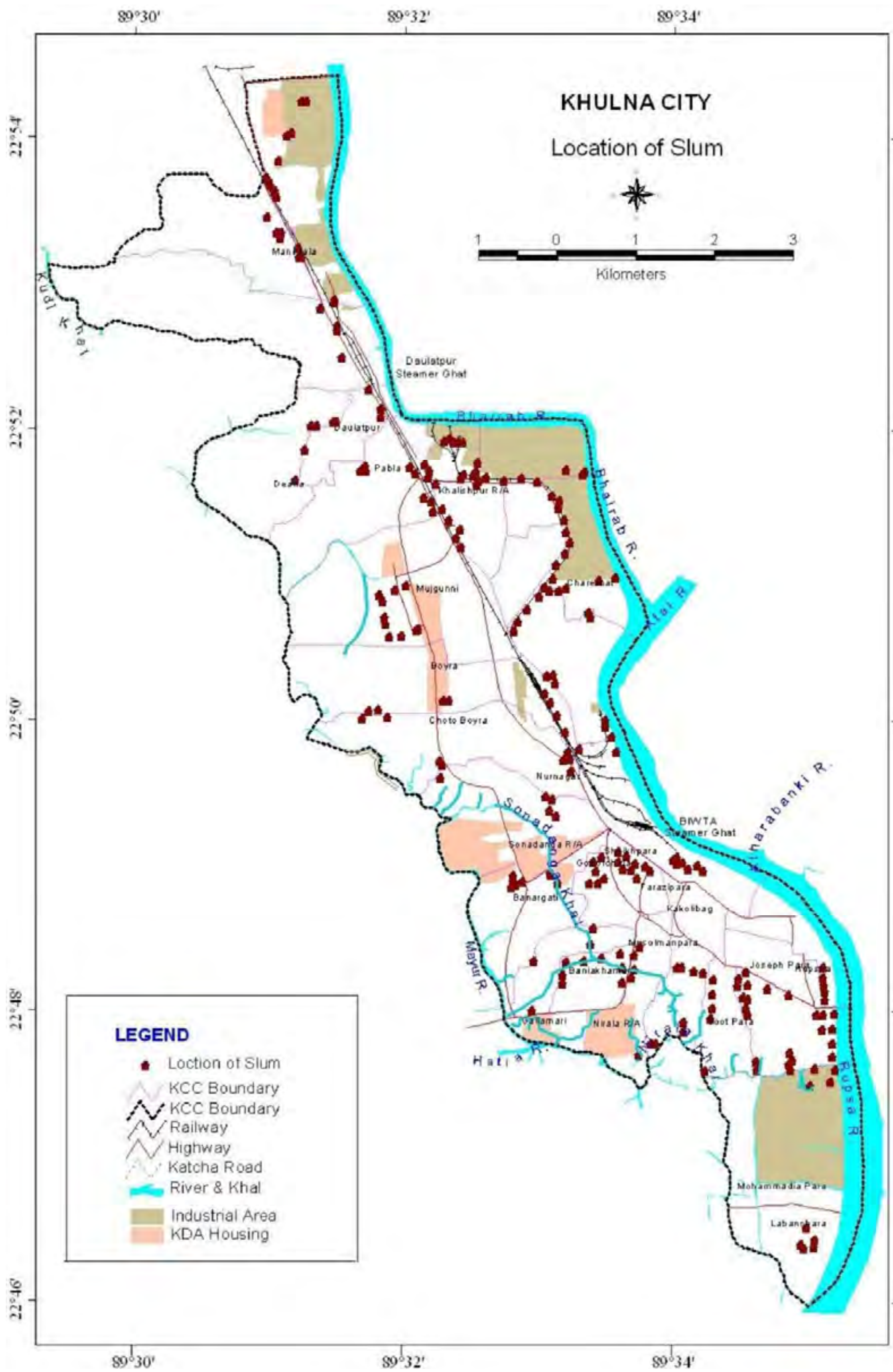


Figure 6-20: Location of Slums with reference to KDA and Industrial Location

Source: (Khulna Development Authority, 2002b)

Chapter 7: Research Findings, Recommendation and Conclusion

This chapter portrays summary findings based on the analysis carried out in the previous chapters. With this, some recommendations are proposed in the light of findings and finally conclusion as well.

7.1 Introduction

Findings of the research will help in taking decisions regarding any sort of development within the plan area. Degree and extent of damage of different land uses will guide the future development of the city and will help in adopting different measures to reduce the potential costs.

Four major land uses namely agricultural, commercial, industrial and residential are considered for this research. First one is non-urban and remaining three is urban land use. Findings from each land use have come out through analysis and field survey. Following are some important findings of the research..

7.2 Overall Findings

Several supporting statements in the decision making process have come out from different perspective viz. drainage system, potential flooding, land use scenario, etc. All these findings express its performance especially the strength and weakness of the city, which will determine its future operations. Findings are outlined in the following.

a) Drainage facilities are concentrated in the core areas and its surroundings. Except natural drains there is no man made drainage stem outside municipal areas. Drainage network is not well connected to each another.

b) There is no underground storm water drainage system within the city. Existing drainage facilities in the fringe and sub-urban areas are inadequate and unsatisfactory.

c) The KDA or KCC areas in the town are not subject to direct flooding from the Bhairab-Rupsha River, but the low-lying areas situated on the western and southern part of the city are flooded by the rain and tidal flooding during monsoon season.

d) The areas suffering from drainage congestion has been identified during moderate to heavy rainfall. The inundated areas associated with drainage congestion are Natun Bazar, Rupsha, Tutpara, Shipyard areas, East Bania Khamar, Boyra, Rayer Mohal, Khan-A-Sabur Road (in front of KDA building), Nodal Point of Khan Jahan Ali and KDA Avenue (nearby and surrounding Royal Hotel).

e) The reasons for water logging have been identified as improper operation and maintenance of khals/drains, blockage in the existing khals/drains, absence of integrated network comprising secondary and side drains, haphazard expansion of the settlements which obstructs the natural drainage system, uncontrolled and haphazard disposal of solid waste into the drainage system and siltation in drainage channels with consequent reduction of discharge capacity.

f) Range of the potential water logging is 10cm and 220cm respectively. Maximum inundation area is 6.64 sq. km (37.82% of the total inundated area within the city) lies between 41cm to 70cm and found at all wards except 1 and 2. Average inundation flood depth is 109 cm.

g) Wards having maximum area under inundation are found at 3, 4, 9, 14, 16, 17, and 18 which are situated in the western low-lying area of the city. Maximum inundated ward is 17 located in the western low-lying area and near the city hub, which is 9.51% of the inundated area. Wards having minimum inundation are 1, 2, 5, 8, 11, 13, 21, and 22.

h) Water logging area which causes damage covers 38% area of the City. Ward 12, 18, 19 and 23 are inundated most and it is 88, 84, 95 and 94 percent consecutively of their total area. Maximum wards are inundated at average depth except 1 and 2. Percentage of the inundated area above the average inundated depth is low.

i) In the rainy season, when incessant rain occurred, the runoff did not flow to the river which entailed water congestion. Duration of this water congestion remained for 2-3 days. Plinth level of some houses was raised so that water did not flow up to the bed room or some people constructed water blocking wall around their houses.

j) Residential and commercial land uses are spread over all wards whereas agricultural land uses are limited to wards 3, 4, 6, 14 and 31. Industrial Land uses are distributed over wards 2, 3, 5-9, 11, 13-16, 21 and 31.

k) Major industrial land uses are laid besides the Rupsha-Bhairab River and commercial land uses in the main hub of the city along the major road sides. Agricultural land uses are scanty and located at the western and southern low-lying areas.

l) Agricultural land use is inundated up to 70cm whereas commercial is up to 190 and industrial up to 160cm. Residential land use is inundated between lowest to maximum inundation depth.

m) 6.37 sq. km land is proposed for commercial, industrial and residential land uses in the agriculture area in 2020, of which around 32% of the residential and 5% of the commercial land use will be inundated. In the proposed area of the structure plan no industrial land will be inundated. In the built-up areas around 57% of the residential and 29% of the commercial land will be inundated. 2.35% of the industrial land use will be flooded in the built environment of the city.

7.3 Findings based on Major Land Use

7.3.1 Commercial

a) Important commercial developments are expected in Shiromoni, Phulbari gate, Gaslamari, New Market-Shibbari area, Aranghata area, Teligati area, Noapara, Rupsha and Dighalia area in 2020.

b) The Master Plan proposed around 1100 acres commercial land including the existing one expected to be grown up in 2010. But practically, there is a huge gap from the proposal and only around 700 acres of land has been developed in 2010. Because, Service sector remained more or less stagnant, while shares of both industry and manufacturing increased.

c) Commercial use is inundated at a depth of maximum 190cm through the lowest 10cm which causes the maximum 35% damage of the commercial contents in 2020. 60% of the inundated commercial area lies between 41cm to 100cm depth.

d) Commercial unit damage is immediately after the industrial use and it is around 731 million Tk. in 2020 with 11.97% inflation rate, and 236 million Tk. in 2010.

7.3.2 Industrial

a) In 2000, the Master Plan has estimated 1,735 acres of land for industrial use. These lands are clustered mainly at Khalishpur, Daulatpur, Dighalia, Shiromoni, Noapara and Phultala-Rajghat area.

b) Around 2% industrial land will be inundated in 2020, which is the lowest from other three major land uses. Industrial use is inundated at a depth of maximum 160cm through the lowest 10cm which causes the maximum 14% damage of the industrial contents.

c) Industrial unit damage (per sq. km) is much higher than others and it is 1,040 million Tk. with compound interest at the rate of 11.97% inflation in 2020 and 336 million Tk. in 2010.

7.3.3 Residential

a) Around 39% of the inundated residential area is highest among the different inundation depth and it is 41cm to 70cm. Maximum 42% areas under residential use having 13% to 22% damage.

b) Residential land uses are dominant and spread over the whole city and it is 27.45 sq. km. Around 53% of the residential land uses and 28% for commercial land use will be inundated in 2020.

c) Residential land uses occupies 83%, and commercial 15% of the total inundated land. Agriculture and industrial land uses take up very small portion of the total water logging areas.

d) Least unit damage (damage in million taka per sq km) by inundation is occurred in the residential unit damage and it is 1.27 million Tk. with compound interest at the rate of 11.97% inflation in 2020 and 0.41 million Tk. in 2010.

7.3.4 Agriculture

a) Due to low lying back swamp areas used as agricultural land at east-west direction, lateral growth is highly constrained.

b) KCC area comprises of 46 sq. km. In 1998, within KCC Area, agricultural land was around 22% and 15% in 2010. In 2020, as per the Structure Plan, Agricultural land will be decreased to around 3%.

c) Agricultural crops are inundated at a depth of maximum 70cm through the lowest 10cm which causes the maximum 35% damage of the yields. Maximum agricultural area is under damage between 11% and 23%.

d) Agricultural unit damage is third in position among the major four land uses. In 2010, agricultural damage per sq. km. is 1.89 million Tk. and 5.90 million Tk. in 2020 with 11.97% inflation rate on March, 2012.

7.4 Recommendation

As per the Structure Plan, some low-lying areas in the western side of the city are declared as areas not suitable for future development and retained the present land use which is agriculture. Practically it has been noticed that those areas are being encroached by the people for bringing up residence and some areas have already been developed. In this context, it is necessary to strengthening the monitoring system of the city authority which will stringently take care of the policies and proposals clearly mentioned in the structure plan.

Total estimated damage on different land uses (both existing and proposed land uses) for 2020 by climate change induced flooding is Tk. 1959 million and it was estimated in 2012. This is significant amount of damage is more than the budget for 2011-2012 (Tk. 1800 million) and around one-third of the budget for 2012-2013 (Tk. 3090 million). Climate change induced flood was projected without improved drainage system. It was recommended that drainage system should be improved to tackle over drainage problems to reduce the potential damage.

Damage for four major land uses has been assessed for two scenarios viz. existing built-up areas and another is proposed areas of which the present land use is agriculture. Both areas are concern for potential urban flooding. Existing built-up areas have drainage facilities with other many facilities especially road, infrastructure, etc. To reduce the potential damage, it is not feasible to relocate the existing use in many cases. But some uses from a particular area may shift considering the potential damage. In this regard, mitigation and adaptation measures should be taken, though the net impact does not get reduced to zero after implementation of adaptation measures. As such, it is important to use other auxiliary method to reduce the impact of climate change on economic and social enterprises as well as on households. Feasibility of such measures shall be studied carefully during the feasibility studies of the project to be taken and a detailed plan needs to be chalked out to reduce the impacts further. Along with these, drainage conditions and drainage facilities must be augmented. Planned development is the precondition to ensure the better drainage condition with drainage facilities and finally minimizing the potential damage. On other hand, proposed areas to be damaged should be reviewed further before implementation as at the time of policy and proposal under the structure plan preparation, climate change impact was not studied. It is good to state that no industrial locations fall under the proposed areas to be damaged by the potential flood.

Potential flood is predicted with climate change without taking any adaptation measures. This implies that potential urban flooding is predicted with taking no improvement in the future. Damage is calculated on the general land use in regards of the potential flood. If object oriented land use (building foot print areas only) is taken into the damage calculation, potential damage might be more realistic and more specific areas (building foot print) under damage will come out rather than aggregated areas. Damage is calculated based on the potential urban inundation depth for major land uses. It has been noticed from the field survey that practically in the low-lying areas people are building with plinth level high to be safe from urban flooding. As a result damage calculated in this research for those areas will be overestimated.

7.5 Conclusion

Every research has some strength with some limitations. In this connection, entire scope of the research was not achieved due to some technical limitations. Some limitations of this study can be addressed by future research works. Potential damage estimation is the toughest job due to uncertainty in the future. More precise potential damage means the damage to be occurred in future will be nearer to the reality. Potential damage is quite impossible to meet the reality in the future. To the best of knowledge and experience, the researcher tried to incorporate the maximum possible uncertain factor in predicting the potential damage. What has been carried out in this research will be the great help of other researchers who will do works in this arena.

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