Delineation of Hydrologically Sensitive Area of Sitakundu Upazila

Urban Development Directorate
Ministry of Housing and Public Works
Government of the People's Republic of Bangladesh
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1. Chapter 1 Introduction

1.1 General

Water is the most important natural resources in our country but this resource can be interrupted by several ways such as facing high population growth, scarcity of freshwater, irregularity of rain-fall, excessive land use change and increasing vulnerability to risks such of drought, flash flood desertification and pollution. Thus, the availability and the sustainable use of this resource become the core of the local and national strategies.

Sitakunda is the third biggest upazila of Chottogram District of Bangladesh that came into existence as a thana in 1899 and was upgraded to upazila in 1983. It is believed in Hinduism that, God Ram along with his wife Sita and younger brother Laxman resided in the Chandranath hills near the present Sitakunda upazila. Eventually, the hills were named Sitakunda. It is the home of the country's first eco-park, as well as alternative energy projects, specifically wind energy and geothermal power. Chandranath Mandir, Baskunda at Sitakunda Sadar, Bara Aulia Dargah Sharif at Sonaichhari, Harmadia Jami Mosque at Kumira is well known place for all.

About 5 kilometres north of Sitakunda Town is the Labanakhya saltwater hot spring, which has been proposed as a source of geothermal energy. There are two waterfalls in the hills: Sahasradhara (thousand streams) and Suptadhara (hidden stream). Both have been identified as sites requiring special attention for protection and preservation by the National Heritage Foundation of Bangladesh.

Sitakundu serves as a water divide between the Halda Valley and the Sandwip Channel. The 88 kilometres long Halda flows from Khagrachari to the Bay of Bangal, and is one of the six tributaries of Karnafuli, the major river in the area. Sandwip Channel represents the northern end of the western part of the Chittagong-Tripura Folded Belt. A lot of canal or perennial channels have flown through this upazila and any interruption or haphazard growth may fetch alarming situation for this region. Hydrological analysis has been done in this research for Sitakudnu Upazila to understand the present scenario of natural channels and possible outcome from this situation. Generally, Hydrology is defined as the science dealing with the interrelationship between water on and under the earth and in the atmosphere.

1.2 Goal and Objectives

The goal of this research is to delineate hydrologically sensitive area thus identifying major stream channel which will promote sustainable development. To achieve it, the following objectives have been considered:

- Preventing deterioration of existing relationships between the use of natural resources within a watershed
- Restoring sustainable relationships which had been destroyed due to actions in the past

1.3 Rationale of the Study

Sitakundu Upazila has the characteristics of flat and hilly region and has situated at the Bay of Bengal which is experiencing now as an industrial area having Ship breaking yard of Bangladesh. Recently, it is milking by flash flood as a result of haphazard unplanned growth and encroachment of natural channels. However, it's mandatory to preserve the natural channel for sustainability of this region as this region acts as pathway between rivers and Bay of Bengal. Moreover, the research will help to analyze the impact of agriculture and water resources, available channel and probable water reservoir for urban areas, achieving predictive capabilities of land surface hydrology.

1.4 Limitation of The Study

The research has few limitations as follows:

- Data collected from secondary sources have few limitations such as spot height is not enough well distributed due to hilly regions.
- Temperature, precipitation and soil profile have not considered in this research.
- Data validation in field level has not done due to time constraints.
- Administrative Boundary has not delineated primarily, achieved from secondary sources.

2 Chapter 2 Methodology

2.1 Introduction

Methodology means the way by which a study is accomplished with a chronological order. It represents the way by which the objectives are full filled in different stages. It can be varied with the purpose, types etc. of the study. Actually, it is a set of procedures by which one can get idea about the study. A proper methodology is always necessary for a study, which helps to organize experiences, observations, examinations, analysis of data and information and their logical expression in a systematic process to achieve the ultimate goals and objectives of the study. It identifies the method to be best used in the research study. To carry out the entire study, the total stages were divided into two phases namely Phase I and Phase II. These phases are illustrated below:

2.2 Phase One

'Phase I' was comprised by the following stages:

- Problem Statement
- Conceptualization
- Define Objectives and Scope of the Research

2.2.1 Problem Statement

Today, Bangladesh is poor densely populated country. The continuous upgrading of population and development in Bangladesh creates a severe pressure on the land creating new phenomenon like surface water problem, flash flood, drainage problem etc. As a consequence, urban area is facing the drainage problem most. However, it's mandatory to keep the drainage system viable according to the nature. This study has been conducted on evaluation of present condition focusing the drainage channel of Sitakundu Upazila in Chattogram District and research problem has selected on drainage problem focusing the delineation of stream channel and catchment area and provide suggestions to keep viable it's nature.

2.2.2 Conceptualization

To conceptualize the research problem, various subjects were considered to develop the knowledge. At first the present situation of Sitakundu Upazila and data availability were understood. After understanding, the present developing trend, concept of watershed was got emphasis where delineation of Stream channel and catchment area of drainage basin was highlighted to unambiguous the concept on research problem.

2.2.3 Define Objectives and Scope of the Research

In order to meet the demand of the study, different methodological approaches were adopted to fulfill the stated objectives of the study. To identify the existing condition of drainage, relevant data was gathered from Survey of Bangladesh (SOB). The reasons of problems regarding drainage were identified through the secondary and primary sources. To enhance the sustainability of the project, drainage plan of the project has also proposed.

2.3 Phase Two

'Phase II' was comprised by the following stages:

- Data Collection
- Data Analysis, Interpretation and Tabulation

2.3.1 Data Collection

Secondary data includes Survey of Bangladesh (SOB) Data such as road, structure, spot height, stream data, river, waterbody etc. These data have been summarized in Thematic maps.

2.3.2 Data Analysis, Interpretation and Tabulation

After completing the data collection, the data were represented in tabular form and were cross checked for several times. Then it was shown to the supervisor for further modification. Then tabular data were transformed into charts and graphs. The result of data was summarized in map. Finally, by analyzing all the information and by studying the problems and finding all potentiality, the final research paper was prepared.

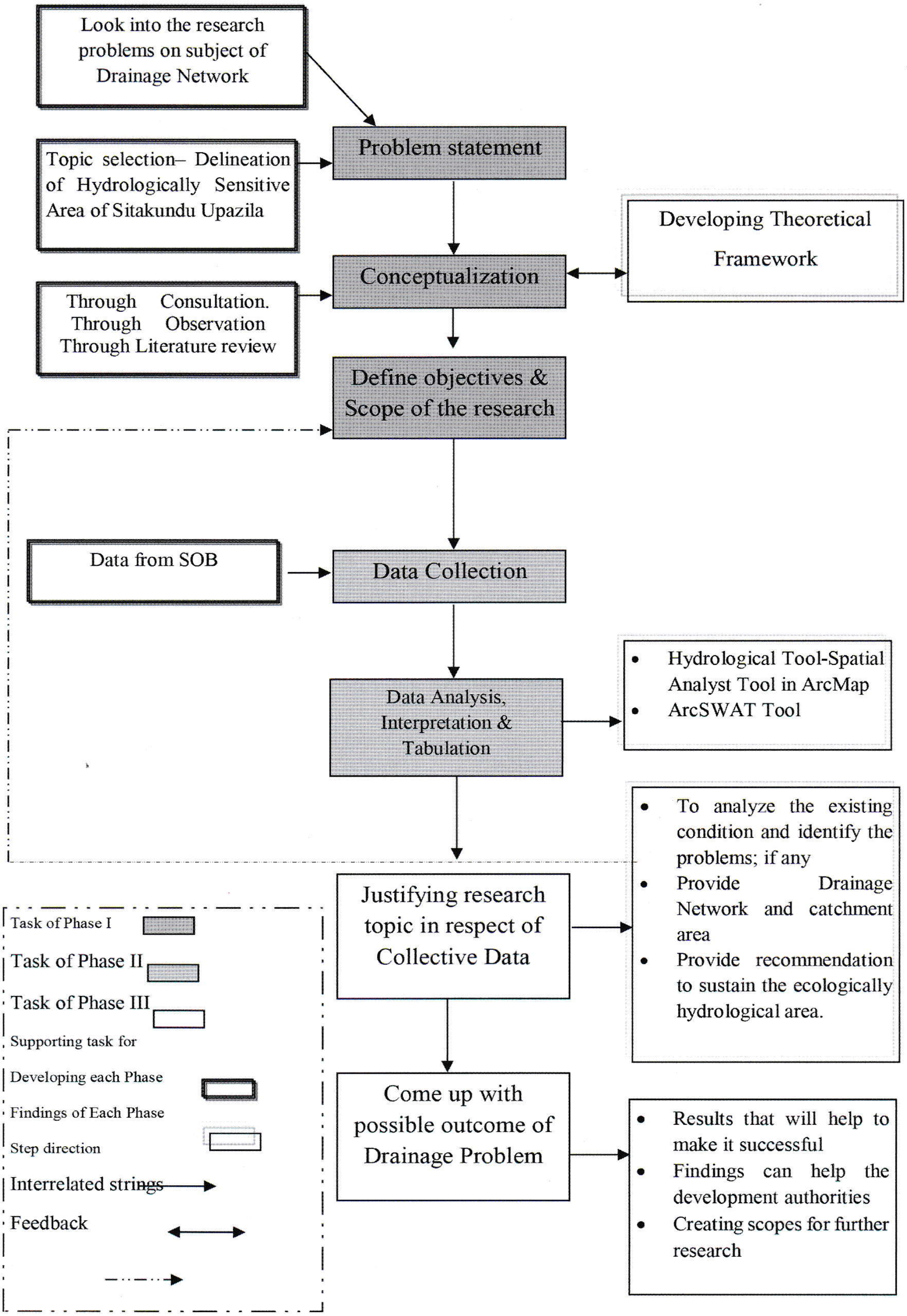


Figure 1: Working Methodology in Flow Chart

3 Chapter 3 Literature Review

3.1 Introduction

A review of the pertinent documents will require rapid digestion and summary, focusing attention on those that offer essential information and those that help formulate a vision or visions for future action. Since comprehensive knowledge of the literature of the field is necessary to start a study, it is part of every scientific work. It tries to review the current state and critical points of study and provide a solid background for further investigation. To achieve the goal, the study has conducted an extensive literature review of common practices to analyze GIS techniques and terms to combine the hypothesis.

3.2 Basic Terminology

Spatial Analysis

Spatial analysis is the process of manipulating spatial information to extract new information and meaning from the original data. Usually spatial analysis is carried out with a Geographic Information System (GIS). A GIS usually provides spatial analysis tools for calculating feature statistics and carrying out geoprocessing activities as data interpolation. In hydrology, users will likely emphasize the importance of terrain analysis and hydrological modelling.

Spatial interpolation

Spatial interpolation is the process of using points with known values to estimate values at other unknown points. For example, to make a precipitation (rainfall) map for a country, one will not find enough evenly spread weather stations to cover the entire region. Spatial interpolation can estimate the temperatures at locations without recorded data by using known temperature readings at nearby weather stations. This type of interpolated surface is often called a statistical surface. Elevation data, precipitation, snow accumulation, water table and population density are other types of data that can be computed using interpolation.

Sink and Fill

Sinks (and peaks) are often errors due to the resolution of the data or rounding of elevations to the nearest integer value. Sinks should be filled to ensure proper delineation of basins and streams. If the sinks are not filled, a derived drainage network may be discontinuous. In ArcMap, The Fill tool uses the equivalents of several tools, such as Focal Flow, Flow Direction, Sink, Watershed, and Zonal Fill, to locate and fill sinks. The tool iterates until all sinks within the specified z limit are filled. As sinks are filled, others can be created at the boundaries of the filled areas, which are removed in the next iteration.

Flow Direction

One of the keys to deriving hydrologic characteristics of a surface is the ability to determine the direction of flow from every cell in the raster. This is done with the Flow Direction tool. This tool takes a surface as input and outputs a raster showing the direction of flow out of each cell.

Flow Accumulation

In ArcMap, The Flow Accumulation tool calculates accumulated flow as the accumulated weight of all cells flowing into each downslope cell in the output raster. If no weight raster is provided, a weight of 1 is applied to each cell, and the value of cells in the output raster is the number of cells that flow into each cell. A sample usage of the Flow Accumulation tool with an input weight raster might be to determine how much rain has fallen within a given watershed. In such a case, the weight raster may be a continuous raster representing average rainfall during a given storm. The output from the tool would then represent the amount of rain that would flow through each cell, assuming that all rain became runoff and there was no interception, evapotranspiration, or loss to groundwater. This could also be viewed as the amount of rain that fell on the surface, upslope from each cell. The results of Flow Accumulation can be used to create a stream network by applying a threshold value to select cells with a high accumulated flow.

Stream Link

Assigns unique values to sections of a raster linear network between intersections. Links are the sections of a stream channel connecting two successive junctions, a junction and the outlet, or a junction and the drainage divide.

Stream Order

Assigns a numeric order to segments of a raster representing branches of a linear network. In ArcMap, the results are characterized by the following issues.

- The output of Stream Order will be of higher quality if the input stream raster and input flow direction raster are derived from the same surface. If the stream raster is derived from a rasterized streams dataset, the output may not be usable because, on a cell-by-cell basis, the direction will not correspond with the location of stream cells.

- The results of the Flow Accumulation tool can be used to create a raster stream network by applying a threshold value to select cells with a high accumulated flow.

Basin

It creates a raster delineating all drainage basins. In ArcMap, the following procedures apply:

- The drainage basins are delineated within the analysis window by identifying ridge lines between basins. The input flow direction raster is analyzed to find all sets of connected cells that belong to the same drainage basin. The drainage basins are created by locating the pour points at the edges of the analysis window (where water would pour out of the raster), as well as sinks, then identifying the contributing area above each pour point. This results in a raster of drainage basins.

- The best results will be obtained if when the input Flow Direction raster was created.

- All cells in the raster will belong to a basin, even if that basin is only one cell.

Watershed

A watershed is the upslope area that contributes flow generally water to a common outlet as concentrated drainage. It can be part of a larger watershed and can also contain smaller watersheds, called sub basins. The boundaries between watersheds are termed drainage divides. The outlet, or pour point, is the point on the surface at which water flows out of an area. It is the lowest point along the boundary of a watershed.

Watersheds can be delineated from a DEM by computing the flow direction and using it in the Watershed tool. To determine the contributing area, a raster representing the direction of flow must first be created with the Flow Direction tool. You will then need to provide the locations you wish to determine the catchment area. Source locations may be features, such as dams or stream gauges, for which you want to determine characteristics of the contributing area. You can also use a flow accumulation threshold. When the threshold is used to define a watershed, the pour points for the watershed will be the junctions of a stream network derived from flow accumulation. Therefore, a flow accumulation raster must be specified as well as the minimum number of cells that constitute a stream (the threshold value).

4 Chapter 4 Study Area Profile

4.1 Location and Administrative

Sitakundu upazila is situated on 9 kilometers north-west of Chottogram and located between 22°22' and 22°42' north latitudes and between 91°34' and 92°48' east longitudes (Map 1). It occupies an area of 483.96 sq. km and bounded on the north by Mirsharai Upazila, east by Fatikchhari and Hathazari Upazilas, south by Pahartali Thana and west by the Sandwip channel, Sandwip Upazila and the Bay of Bengal. The upazila consists of 1 Urban Settlement namely paurashava, 9 wards, 23 mahallas, 9 unions, 60 populated mauzas and 88 villages.

4.2 Demography

According to Population and Housing Census 2011, the total population of the upazila is 387832 of which 202137 are males and 185695 are females. The sex ratio of the upazila is 109 which has been tremendously decreased in 2011 as against 119 in 2001. In the upazila, there are 77279 households and the average household size for the upazila is 4.96 persons, for rural area the size is also 5.02 and for urban area the size is slightly lower such as 4.92 persons. The decadal population growth rate for the upazila is 15.71% and the annual compound growth rate is 1.45%. Population Density in this upazila is 801 inhabitants per sq. km. The average size of population of each ward and mahalla are 5016 and 1963 respectively. On the other hand, the average size of population of each union, mauza and village are 38076, 5711 and 3894 respectively. The overall literacy rate is 59.2% population aged 7 and above which is distributed in male and female by respectively 62.2 5 and 55.9%. The population ratio based on religion is 90.17% Muslim, 8.86% Hindu, 0.008% Christian, 0.915% Buddhist and 0.047% Others.

Source of Drinking Water: In Sitakunda upazila, 87.4% general households get the facilities of drinking water from tube-well, 8.1% from tap and the remaining 4.5% households get water from other sources.

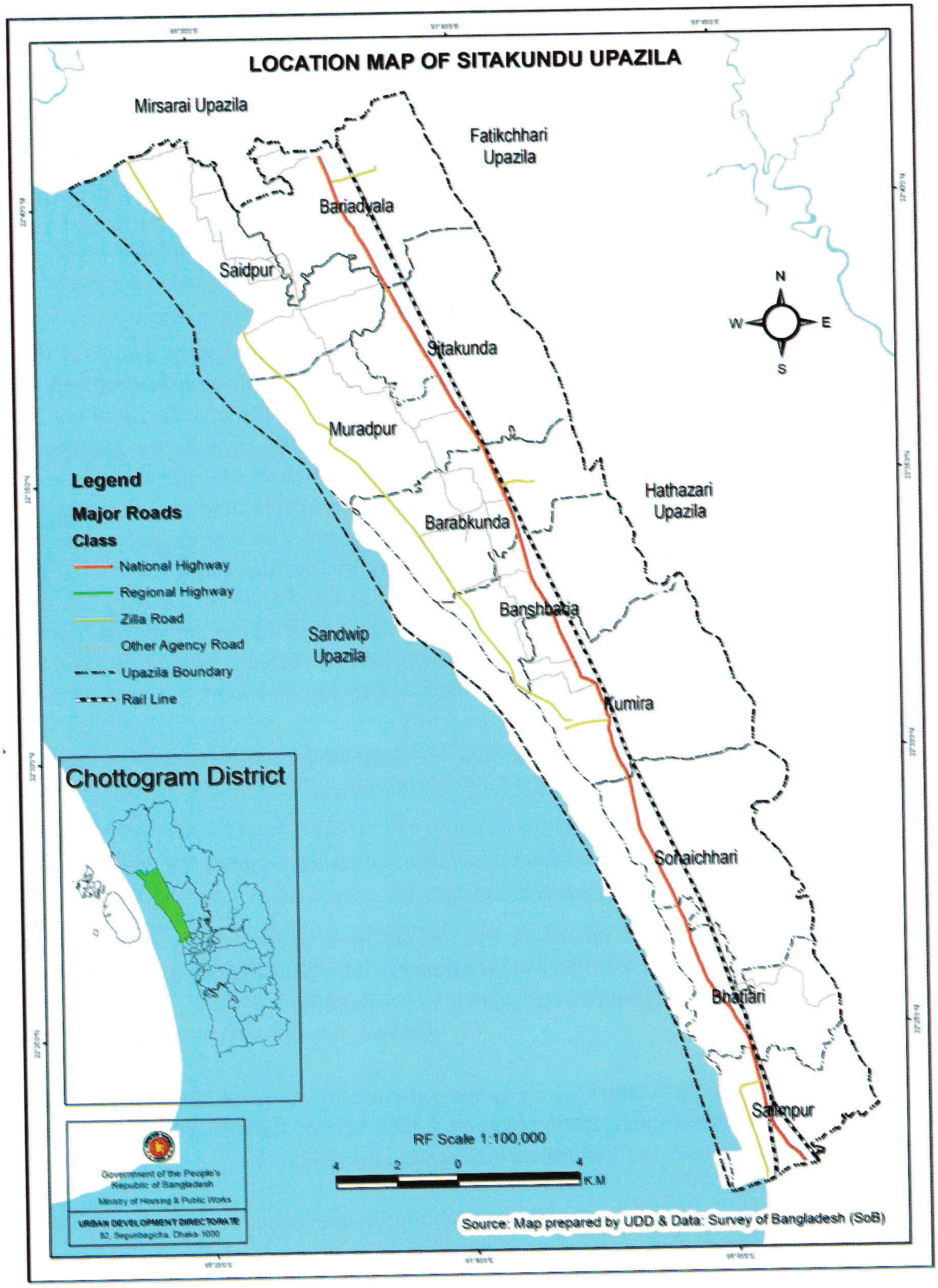
Sanitation: In the upazila, 81.3% general households use sanitary latrine, 17.7% non-sanitary latrine and the remaining 1.0% have no toilet facilities.

Access to Electricity: All the 9 unions of the upazila have been brought under the Rural Electrification Program. However, a total of 81.8% general households reported to have electricity connection in the entire upazila in 2011 as against 59.0% in 2001.

4.3 Economy

Main sources of income Agriculture 24.12%, non-agricultural laborer 4.27%, industry 2.82%, commerce 15.43%, transport and communication 4.32%, service 28.76%, construction 1.56%, religious service 0.29%, rent and remittance 6.10% and others 12.33%.

The most important economic features Chittagong Ship Breaking Yard is located in Faujdarhat, Sitakunda Upazila, Bangladesh along the 18 kilometres Sitakunda coastal strip, 20 kilometres north-west of Chittagong. Handling about a fifth of the world's total, it is the world's largest ship breaking industry, employs over 200,000 Bangladeshis, and accounts for around one-half of all the steel in Bangladesh.



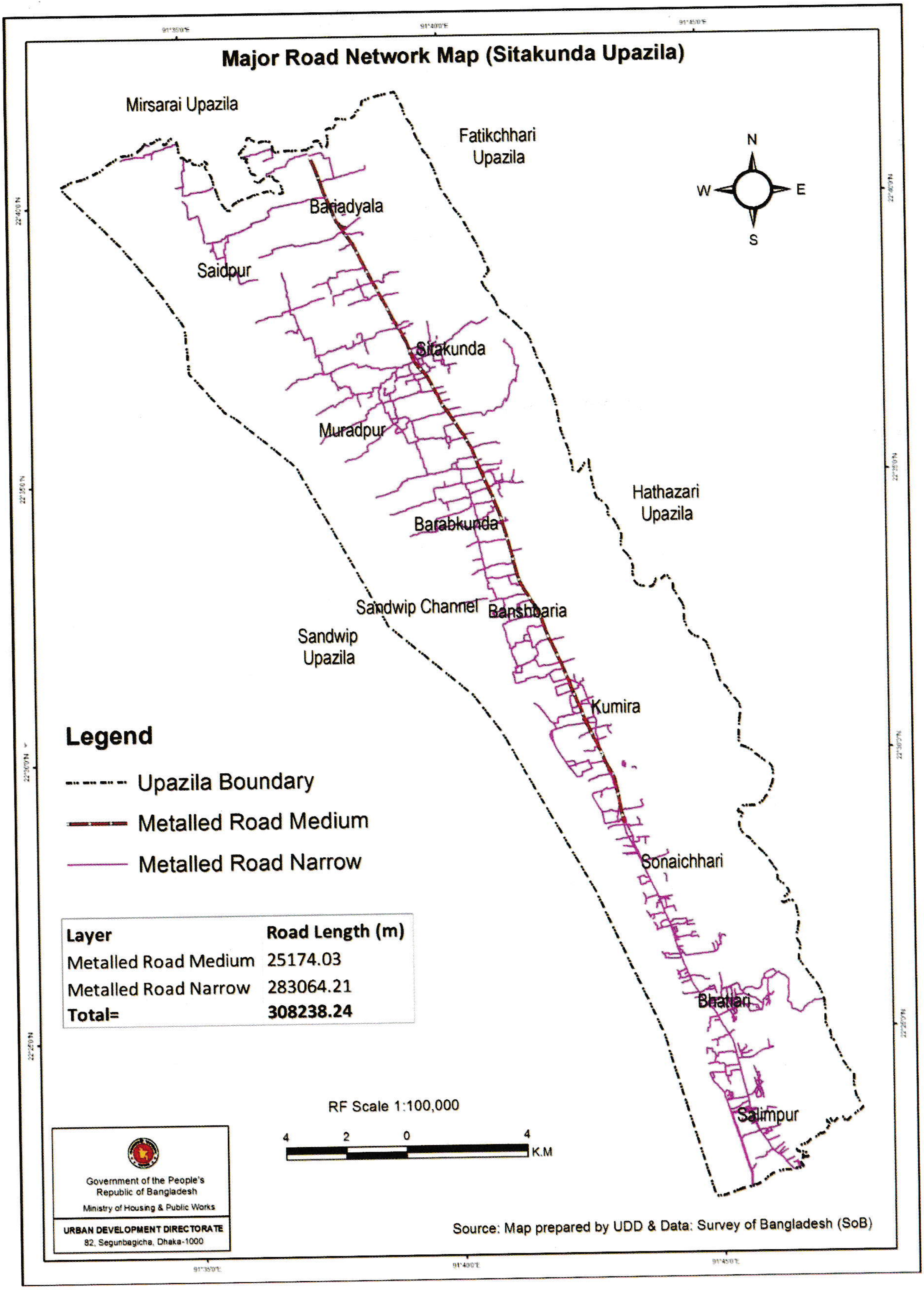
Map 1: Location Map of Study Area

5 Chapter 5 Existing Scenario and Hydrological Analysis

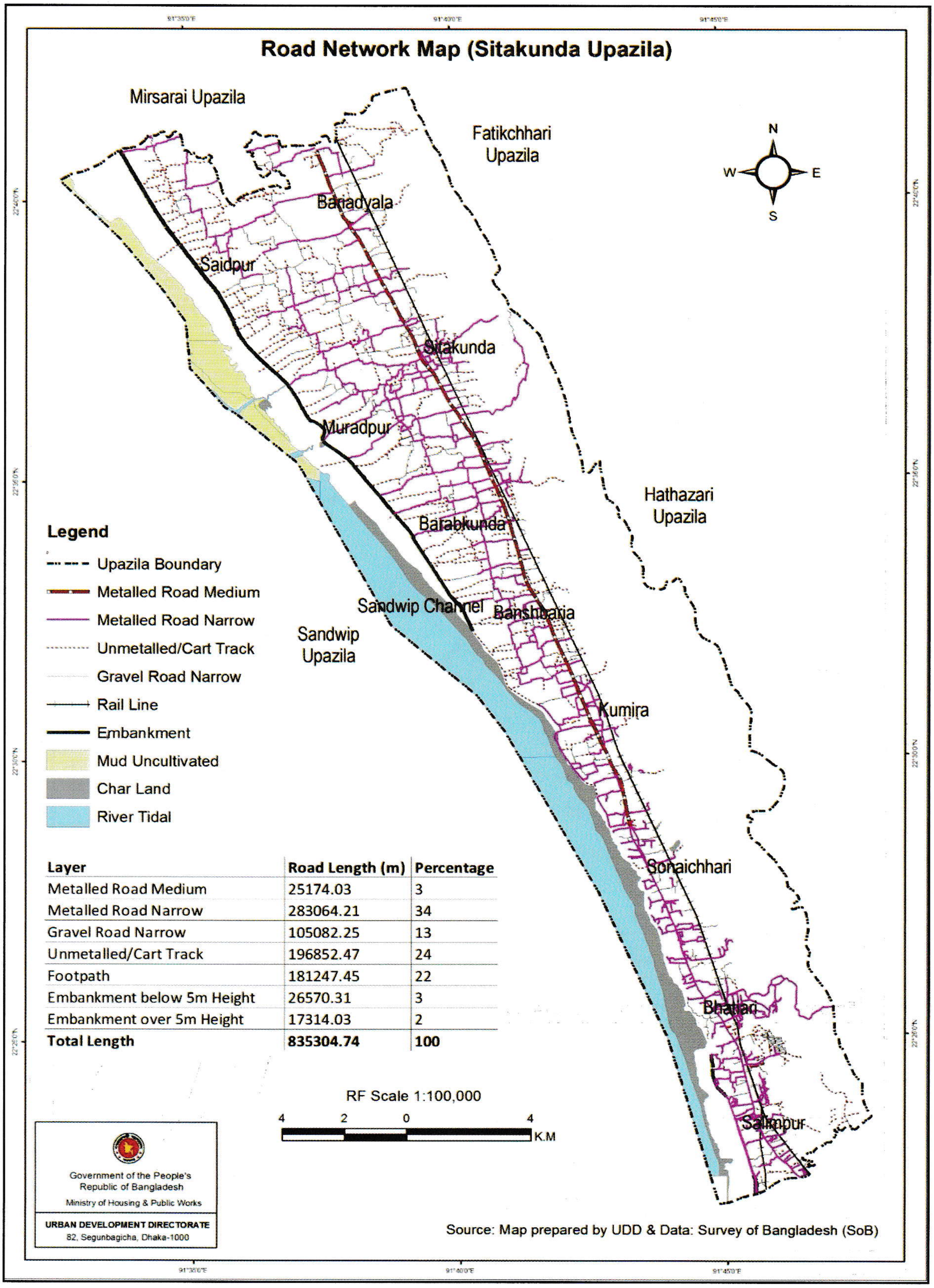
5.1 Existing Road Network

SOB data has been arranged to produce different scenario map of existing condition. From road data, there are two types of major road according to SOB data where metaled road medium and metaled road narrow occupy the length respectively 25.17 km and 283.06 km. (Map 2). The other road category includes Gravel Road, unmetalled Road, Footpath, Embankment road. Metaled Road Narrow, Unmetalled, Footpath take the more visible percentage than others such as 345, 24% and 22%. (Map 3) Moreover, Embankment road have two categories like 5m above and 5m below which are mainly in Saidpur and Muradpur Union along Sandip Channel (Map 4).

There are 92 bridges dividing into 5 categories such as bridge medium width, bridge narrow width, bridge unmetalled/cart track, bridge footpath/culvert and railway bridge. (Map 5)

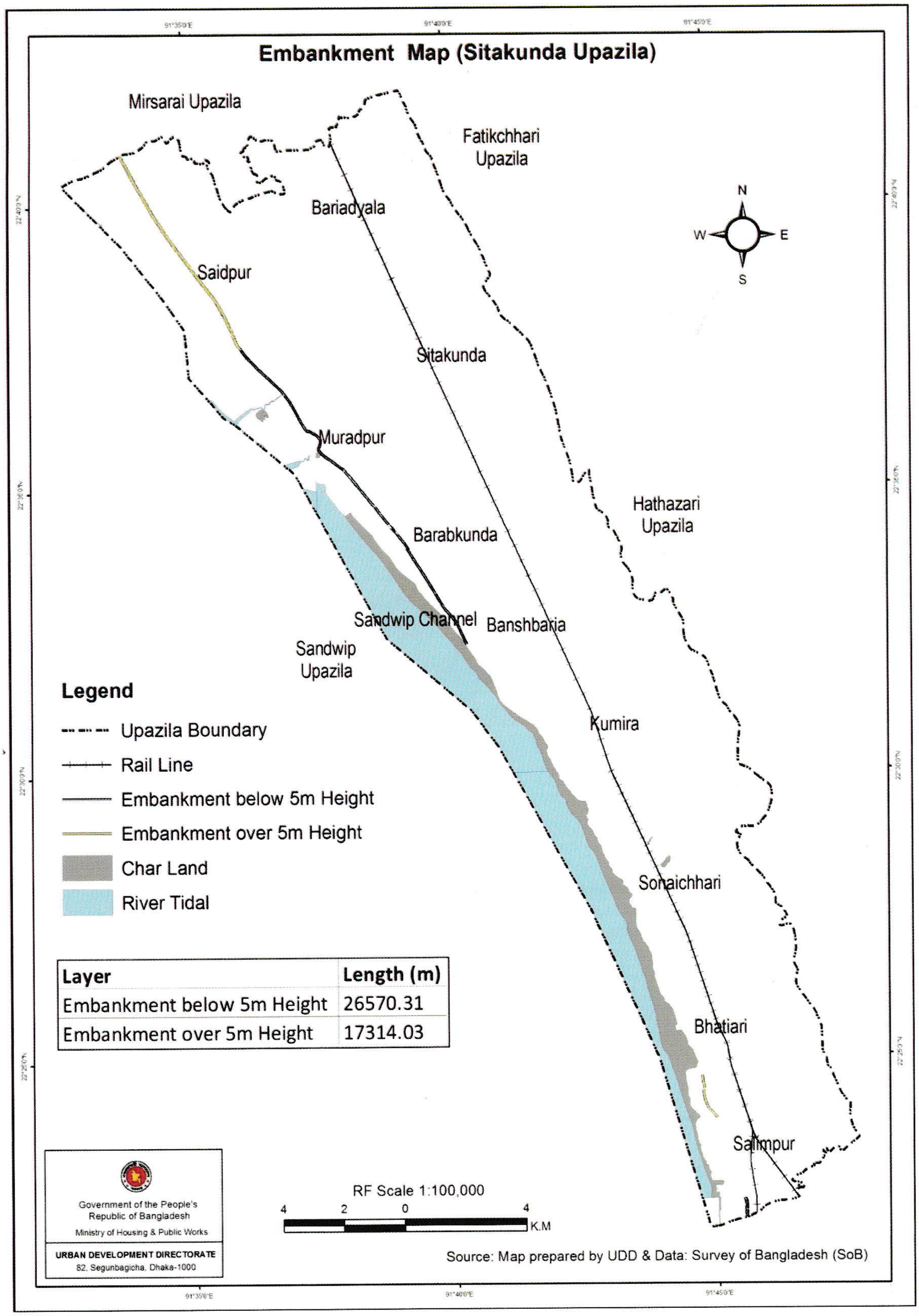


Map 2: Major Road Network Map



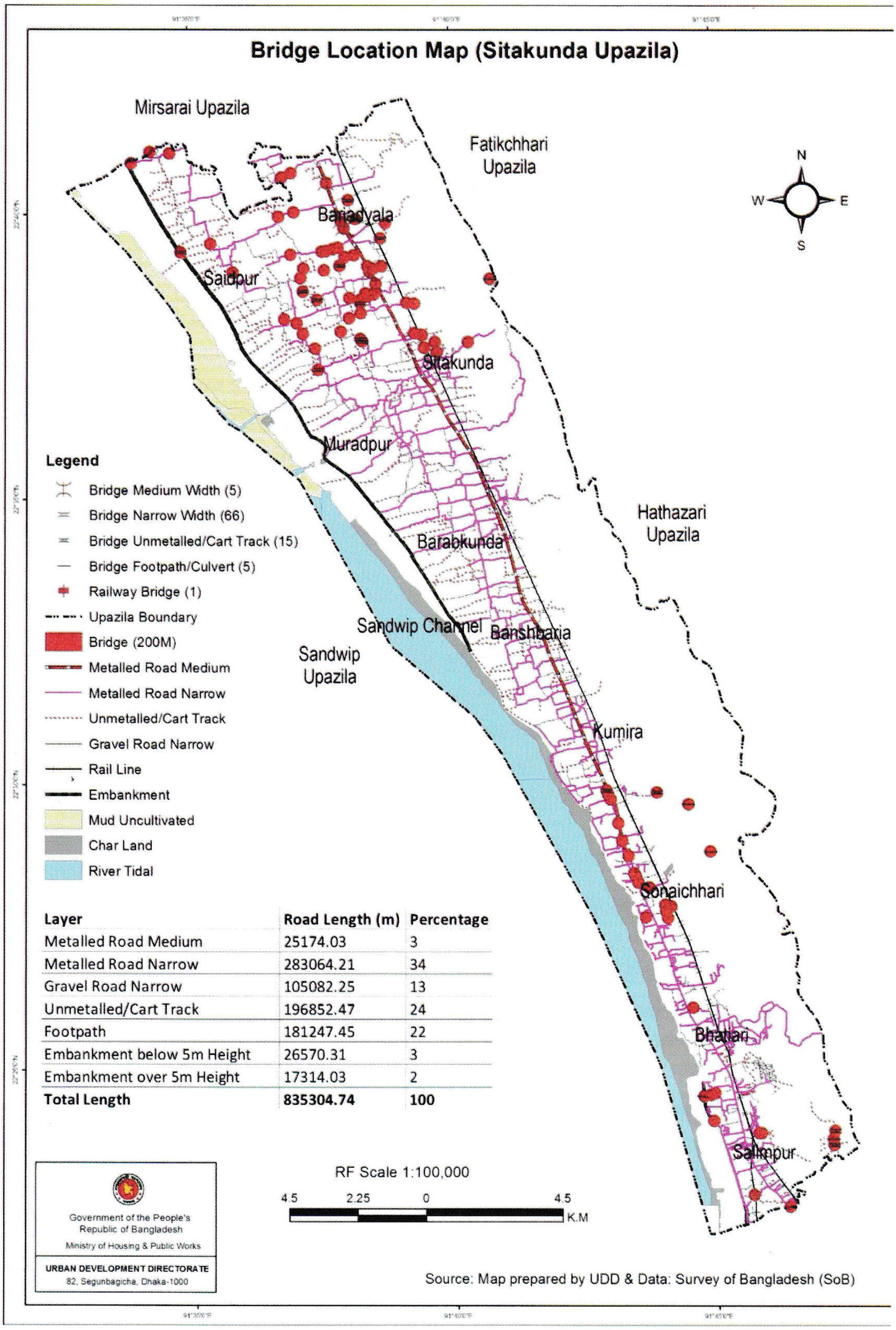
Layer	Road Length (m)	Percentage
Metalled Road Medium	25174.03	3
Metalled Road Narrow	283064.21	34
Gravel Road Narrow	105082.25	13
Unmetalled/Cart Track	196852.47	24
Footpath	181247.45	22
Embankment below 5m Height	26570.31	3
Embankment over 5m Height	17314.03	2
Total Length	**835304.74**	**100**

Map 3: Road Network Map



Layer	Length (m)
Embankment below 5m Height	26570.31
Embankment over 5m Height	17314.03

Map 4: Embankment Map



Layer	Road Length (m)	Percentage
Metalled Road Medium	25174.03	3
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Footpath	181247.45	22
Embankment below 5m Height	26570.31	3
Embankment over 5m Height	17314.03	2
Total Length	**835304.74**	**100**

Map 5: Location Map of Bridge

5.2 Structure Density

Structure data is important to understand the development growth of a region. In Sitakundu, there are 29963 structure which has been presented as a point feature (Map 6). The development follows the linear pattern along the national highway. Important structure counted as 1028 has been as polygon feature in Map 7. The structure distribution is highest in Sitakundu, Sonaichari, Bhatiari.

5.3 Landuse & Waterbody

The overall landuse of Sitakundu Upazila include 14 categories. Around 40% of total area has been occupied by forest area. Agricultural or Cultivation land dominates in this area as 23.20%. Homestead settlement and River tidal share the area respectively 20.63% and 7.75%. (Map 8) There are a lot of water channel and perennial sources in the study area. River tidal covers 84% of waterbody. Canal Perennial and Non-perennial distributes respectively 272.57 km and 733.35 km. (Map 9).

5.4 DEM & Contour

DEM reconditioning is a process of adjusting the DEM so that elevations direct drainage towards the vector information on stream position, which in this case are the blue line stream features obtained from SOB. DEM reconditioning is only suggested when the vector stream information is more reliable than the raster DEM information. This may not be the case here, but reconditioning is done nevertheless to illustrate the process. DEM reconditioning as done here involves a sequence of ArcGIS geoprocessing functions. The strategy is to first convert vector stream features to a raster dataset of grid cells on the streams that has exactly the same dimensions (rows, columns, cell size) as the DEM raster. This exposes you to a number of new geoprocessing tools (Feature to Raster, Greater Than, Reclassify) as well as Environment Settings to control raster cell size, extent and snapping. By doing this you get some experience using the ArcGIS geoprocessing tools to derive new spatial data from the original spot height and vector streams and a small glimpse into the powerful geospatial analytical capability that these functions enable.

Contour map has been prepared for 0.5-meter interval (Map 10). And DEM has prepared based on spot height, contour, stream line, road network which has been further use for watershed delineation (Map 11). The grossly land elevation pattern according to Natural Beak has shown in below table.

Table 1: Land Elevation of Sitakundu Upazila

Sl. No.	Elevation (m)	Area (Sq. km)	Percentage
1	-5.34 to 0	23.0679	7.96
2	0 to 5.81	88.6889	30.59
3	5.81-17.09	72.6352	25.06
4	17.09-30.56	11.5979	4.00
5	30.56 to 48.02	15.6582	5.40
6	48.02 to 61.31	12.7343	4.39
7	61.31 to 78.77	17.1855	5.93
8	78.77 to 91.15	10.9035	3.76
9	91.15 to 123.89	18.3863	6.34
10	123.89 to 365.56	19.0237	6.56

Source: Reclassification of Reconditioned DEM

5.5 Delineation of Drainage Network

Hydrology Analysis is important to extract the information about where water comes from and where it is going across on any cell of a raster data. Defined by topographic divides, a watershed is an area that drains surface water to a common outlet. A watershed is a hydrologic unit that is often used for the management and planning of natural resources. Watershed Analysis refers to the process of using of DEM and raster data operations to delineate watersheds and to derive topographic features such as stream networks. The works have been the following ways:

- Creation of Compatible Database
- Presentation of Analyzed Data and Existing Scenario
- Hydrological Analysis-Spatial Analyst Tool
- ArcSWAT Tool for identifying the main channel and tributary channel

Firstly, Contour and DEM have been prepared based on spot height, channel, road, waterbody. Then, Hydrological analysis includes Fill, Flow Direction, Flow Accumulation, Stream Link, Stream Order and Stream to Feature.

Moreover, ArcSWAT is used to cross checked the result. The Soil and Water Assessment Tool (SWAT) is an agro-hydrological watershed scale model developed by Agricultural Research Services of United States Department of Agriculture. SWAT allows simulating the major watershed processes as hydrology, sedimentation, nutrients transfer, crop growth, environment and climate change. The aim is to depict the physical functioning of different components and decision making of large catchments management. From the analysis, there has been identified 137 sub basins and their relative main channel and tributary channel which are the basis for detailing drainage network of that certain basin or area. The result has been depicted below:

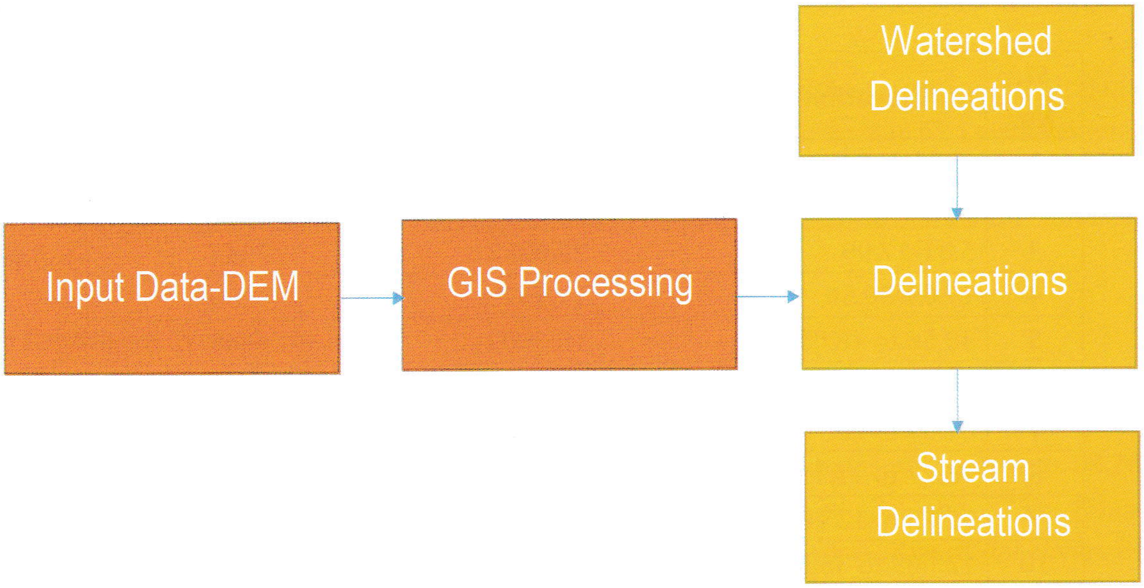
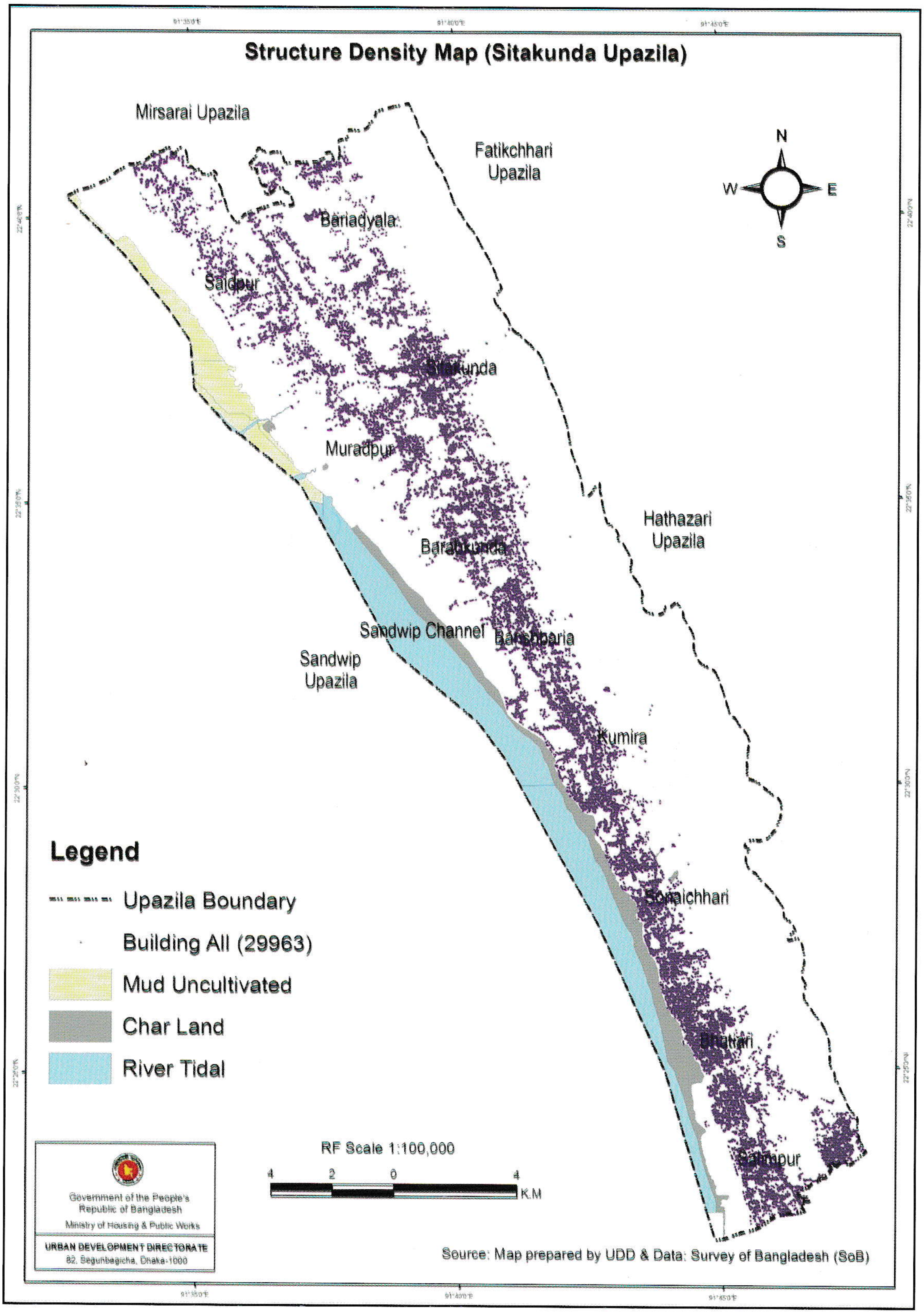
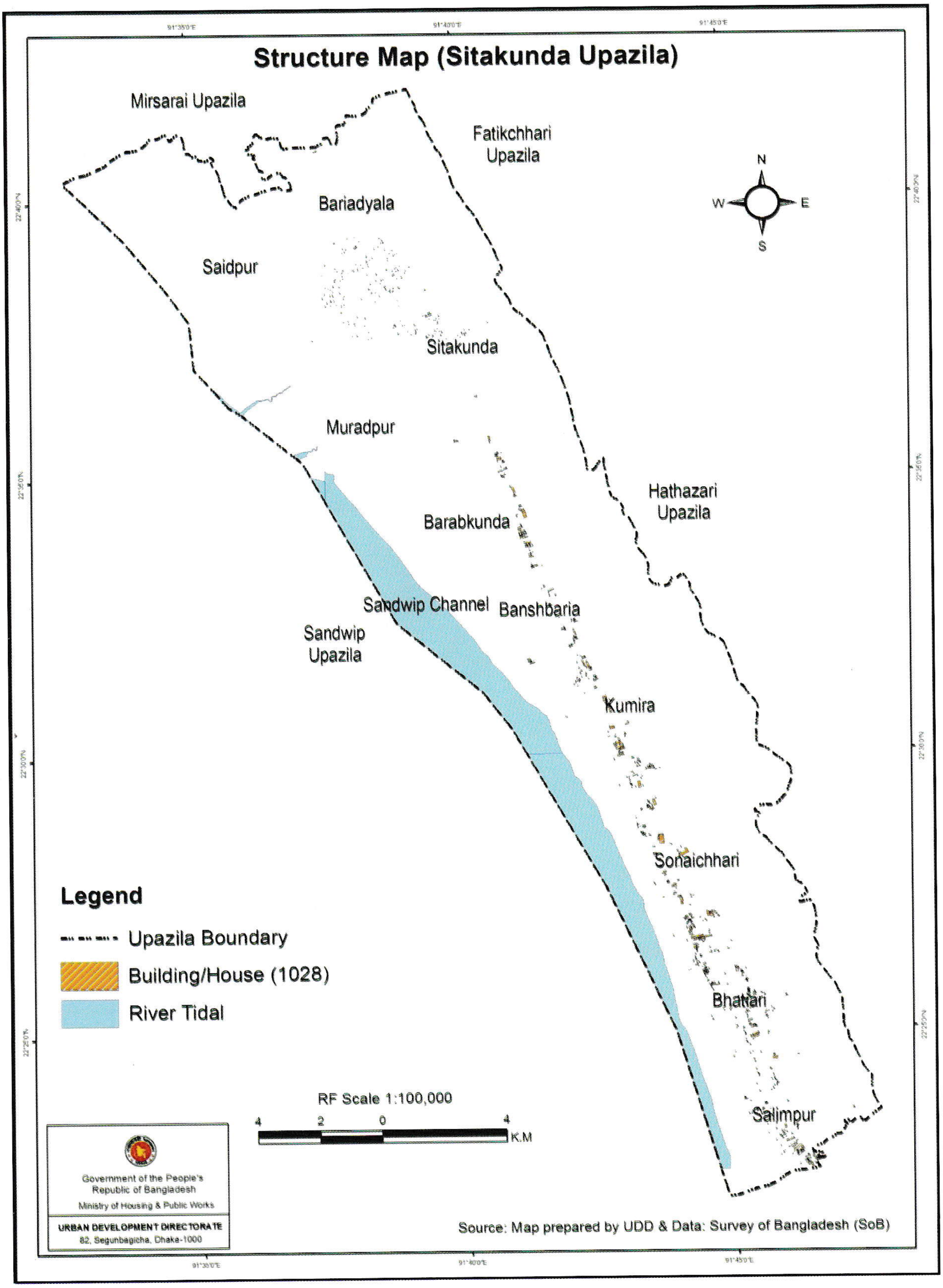


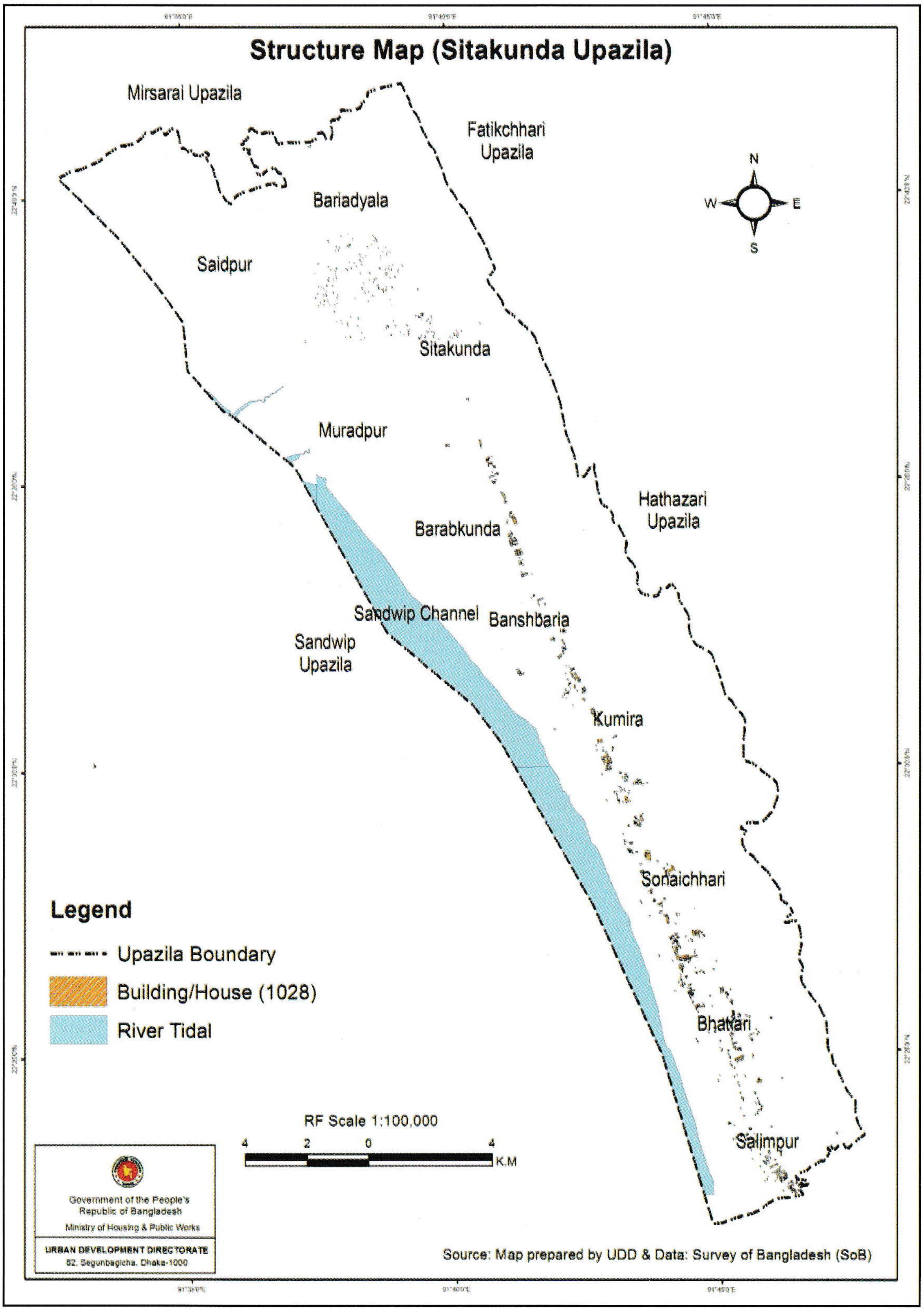
Figure 2: Steps in ArcSWAT Model



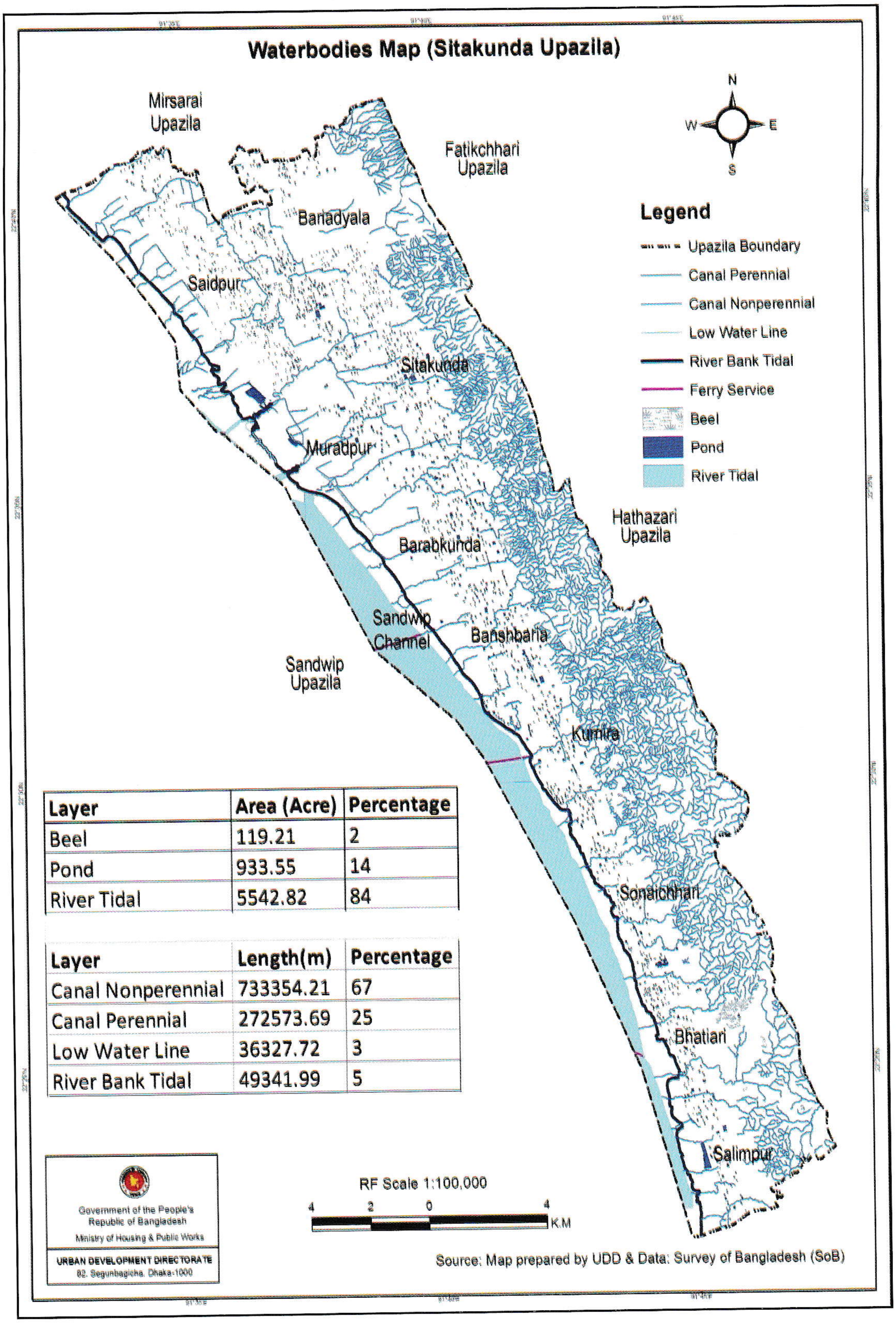
Map 6: Structure Density Map



Map 7: Major Structure Map



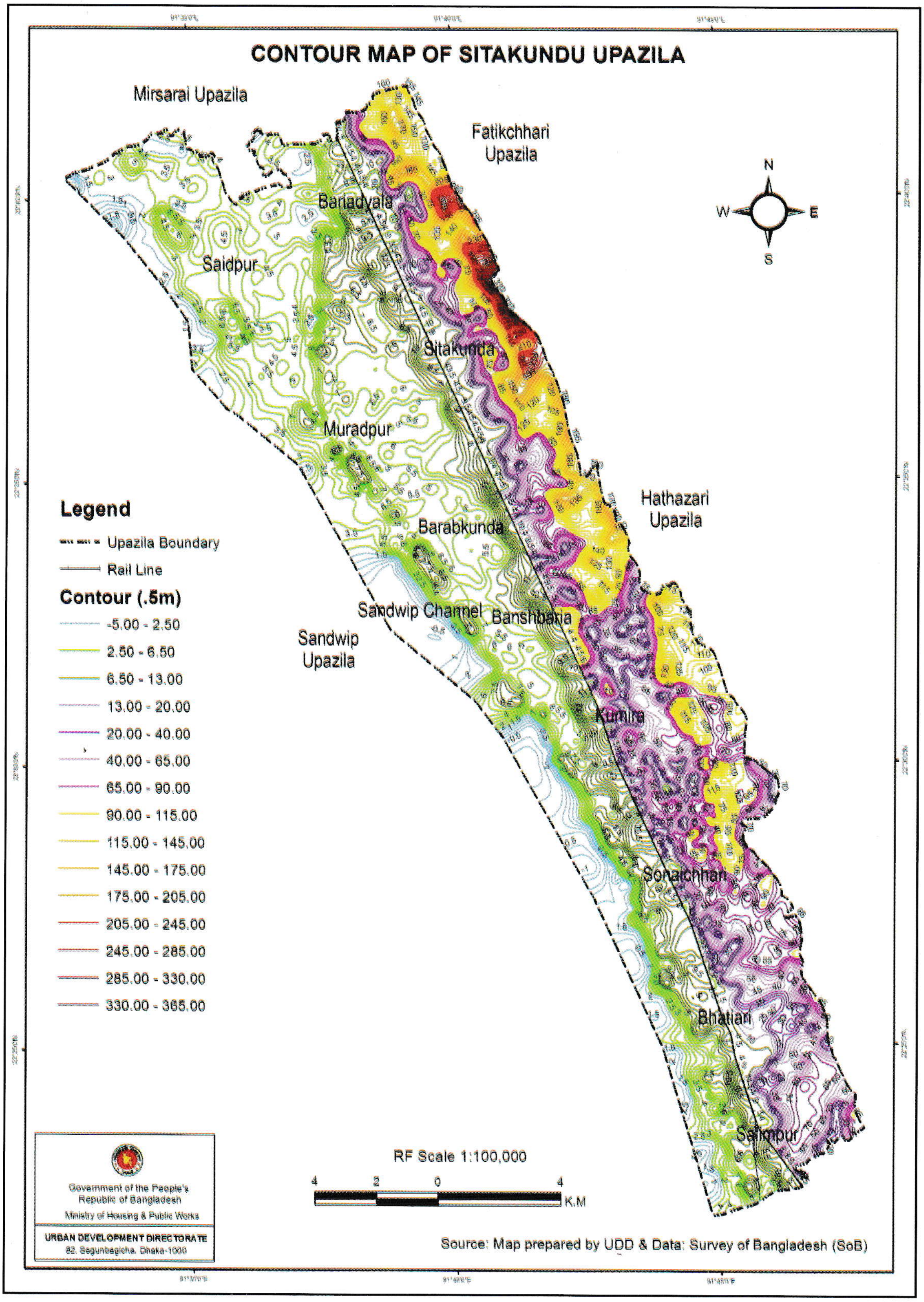
Map 8: Landuse Map of Sitakundu Upazila



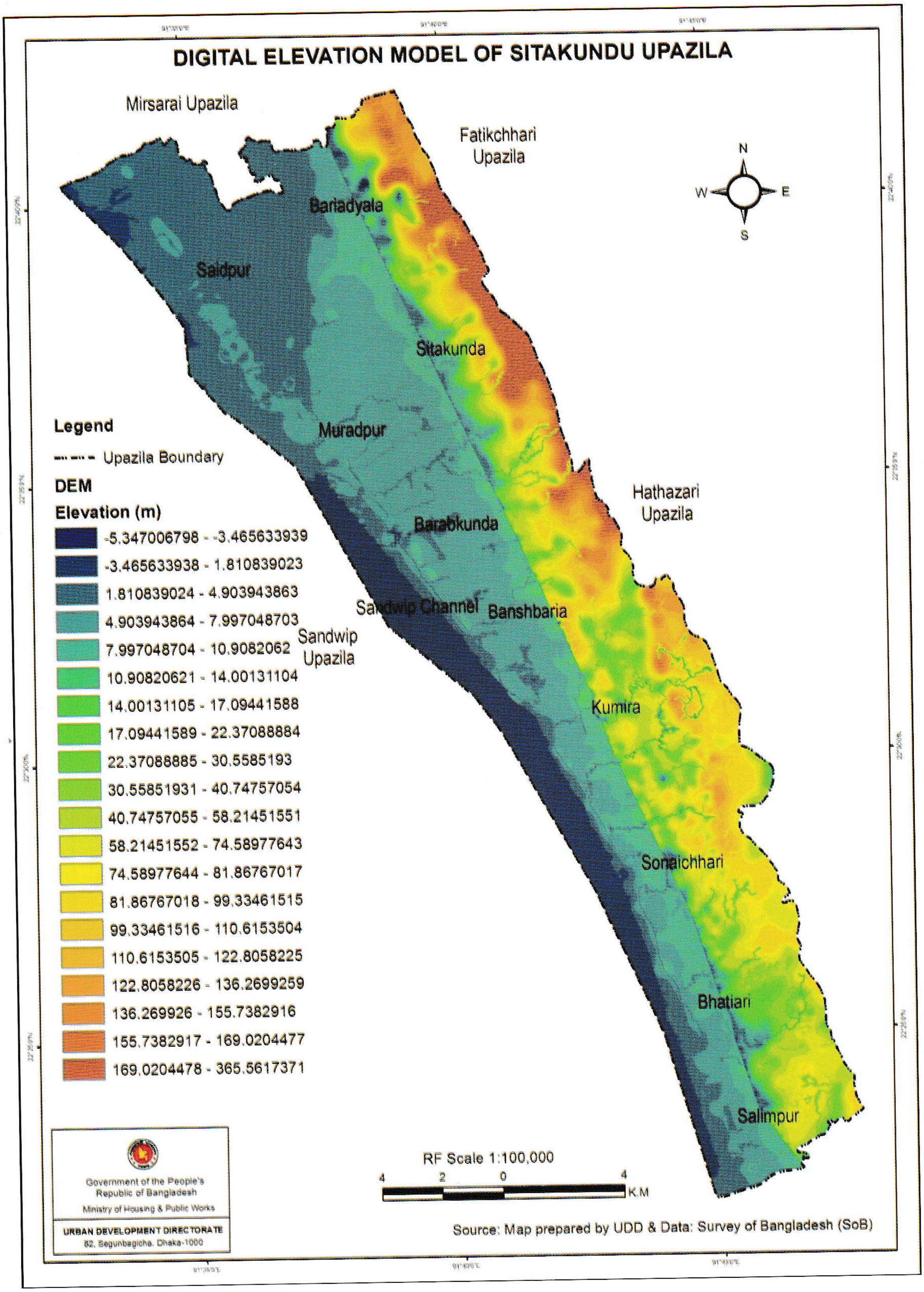
Layer	Area (Acre)	Percentage
Beel	119.21	2
Pond	933.55	14
River Tidal	5542.82	84

Layer	Length(m)	Percentage
Canal Nonperennial	733354.21	67
Canal Perennial	272573.69	25
Low Water Line	36327.72	3
River Bank Tidal	49341.99	5

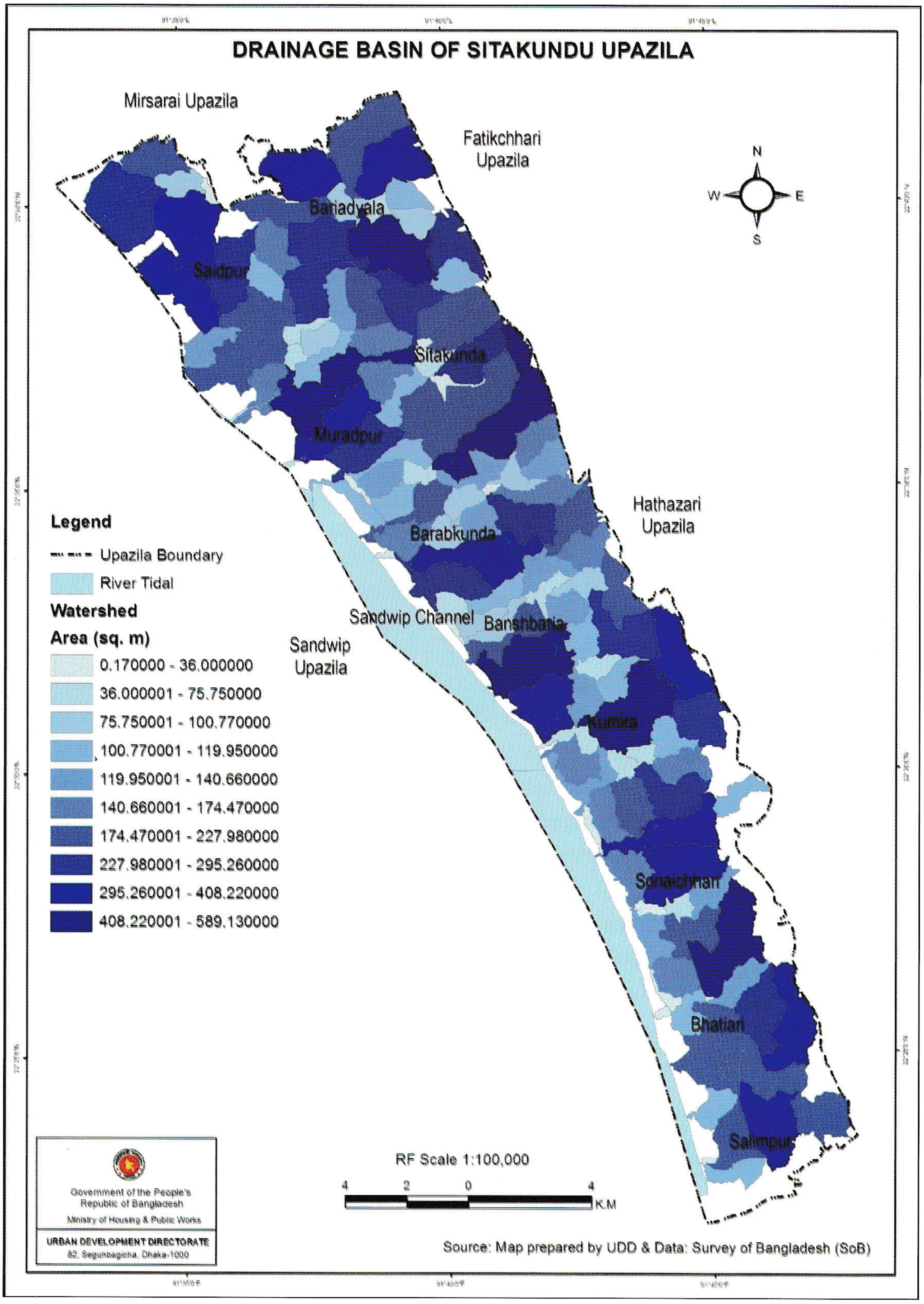
Map 9: Waterbody Map



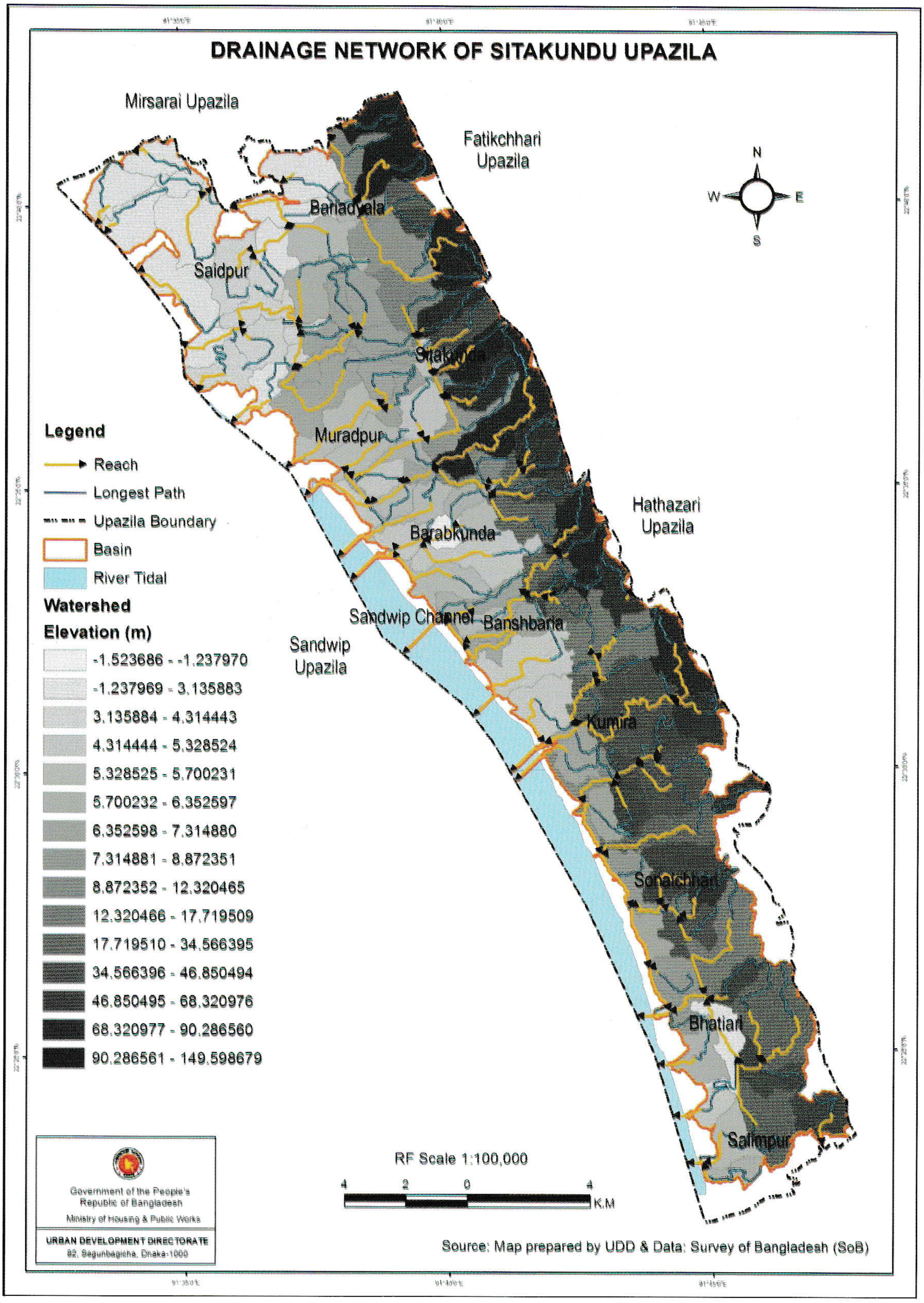
Map 10: Contour Map



Map 11: Digital Elevation Model of Sitakundu Upazila



Map 12: Drainage Sub basin Map of Sitakundu Upazila



Map 13: Drainage Network Map of Sitakundu Upazila

6 Way Forward

The quality of the data must be carefully monitored to determine whether they require validation, ground truthing or editing. For hydrological applications, apart from precipitation, the most significant climatological factors are temperature, evaporation and evapotranspiration. Before reviewing the processing tasks, is useful to consider the means by which most climatological data are observed and recorded, because this has a significant impact on subsequent operations. However, the conducted research is the basis of further applications and detailing which has already verified the natural sources. It will be helpful for further application of integrated water resources development and management, water resources assessment and impacts of climate change on water resources, protection of water resources, water quality and aquatic ecosystems, water and sustainable urban development and drinking water supply and sanitation in the urban context, water for sustainable food production and rural development, and drinking water supply and sanitation in the rural context, mechanisms for implementation and coordination at the global, national, regional and local levels.

7 Conclusion

Water related phenomenon like scarcity is one of the emerging problems faced by our country. Surface water flow resulting from the runoff is the major source for the increasing fresh water demand. Correct quantification of the stream from land system will require simulation of the contributing component in to hydrologic model. Modeling required determining its parameters, which will ultimately act as a key determination fact of the accuracy of the model result. All these hydrological parameters are spatially and temporally variables. Remote Sensing and GIS are the only technology available to estimate the model parameters, which yield the model to simulate more or less close to real nature. Our analysis on distributed subarea basis compared to the analysis as a whole gives better results, which is more similar to actual values. Moreover, the study of water resources at watershed scale is widely adopted as approach to manage, assess and simulate the important natural resources. Indeed, the major constraint that has hindered the expansion use of these Remote Sensing and GIS tools is the unavailability or scarcity of data especially in our country.

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