Abbreviations

ArcGIS	Spatial Date Analysis Software by ESRI
BADC	Bangladesh Agricultural Development Corporation
BM	Benchmark
BMD	Bangladesh Meteorological Department
BWDB	Bangladesh Water Development Board
DEM	Digital Elevation Model
EGL	Existing Ground Level
EPA SWMM	The United States Environmental Protection Agency (EPA) Storm Water Management Model (SWMM)
EV I	The first asymptotic distribution of extreme values
GCP	Ground Control Point
GPS	Global Positioning System
HEC-HMS	The Hydrologic Modeling System is designed to simulate the precipitation-runoff processes of dendritic drainage basins.HEC-HMS is a product of the Hydrologic Engineering Center within the U.S. Army Corps of Engineers.
HEC-RAS	A computer program that models the hydraulics of water flow through natural rivers and other channels developed by the US Department of Defense, Army Corps of Engineers.
HFL	Highest Flood Level
IDF	Intensity Duration Frequency
L/B	Left bank
LFL	Lowest Flood Level
LGED	Local Government Engineering Department
mPWD	RL found against a PWD benchmark in meters
PWD	Public Works Department
R\B	Right Bank
RHD	Roads and Highway Department
RL	Reduced Level
TBM	Temporary Benchmark
UDD	Urban Development Directorate

Table of Contents

Page No.

Page No.

List of Tables:

Figures:

List of Maps:

List of Plates:

Annexures:

EXECUTIVE SUMMARY

This report presents the hydrological survey data obtained during the hydrological survey works conducted at Dohar Upazila under Dhaka district. The task is a part of the project, “Preparation of Development Plan for Fourteen Upazilas”, Package-1. Bathymetric survey of Ichamati River and other local tributaries at Dohar Upazila is done. During the survey works, information regarding any existing water control structure, river crossings, distributaries and tributaries were collected. It also presents the detailed survey data of the existing drains within the township. While collecting data for existing drainage systems, information about water logging zones or water logging points were collected. For the natural perennial channels, cross sections were surveyed at the locations of the existing structures on the rivers, at junctions with and of other channels or rivers. For drains, sizes were charted at starting locations, junctions and end points. The reduced levels of the existing ground at those locations were measured too. To measure the reduced levels on the field, dumpy levels were used. The levels were measured with respect to nearby benchmarks or temporary benchmarks of authorized organizations like Bangladesh Water Development Board, Public Works Department, Roads and Highways Department, Local Government Engineering Department, etc. GPS locations at each BM/TBM location, at the point of start of each cross section, at any structure location and at all the control points of the drains were recorded. Other collected data include flow directions, channel names, presence of tidal effects etc. The information will be incorporated with the DEM on GIS and if needed, adjusted according to the established GCPs. This will subsequently facilitate any sort of numerical watershed analysis and hence extrapolate a prediction for the future. This report also presents the analyzed data of water level gauge stations, the rainfall data analysis and the project site data deduced from them.

Engr. Md. Abdul Basher
Civil Engineer cum Hydrologist

CHAPTER 1
PROJECT OVERVIEW

1.0 Background and Objective

The project, “Preparation of Development Plan for Fourteen Upazilas” was initiated by Urban Development Directorate, Ministry of Housing and Public Works, Government of Bangladesh. The main objective of the project is upgrading the living standard of the local people. Ichamati River flows adjacent to the northern boundary of the Upazila but does not constitute the boundary. Most of the local canals fall into Ichamati River through Arial beel. Further north, Kaliganga River takes off from the Padma River in the west and falls into Dhaleswari near fulhar further south-east Ichamati falls into Kaliganga River. The southern boundary is bound by the Padma River. Dohar, being a beel area experiences heavy flooding. Arial beel is protected by flood protecting interventions to stop flood water coming in from Padma River. Thus the water shed of Arial beel is practically separated from the Padma River. During monsoon, the area mostly remain flooded. Only the built up areas remain over water. The urban areas lack proper drainage system. Flood modeling software should be used to understand flooding conditions, identify the water logging areas and establish the drainage requirements. Models should also be used to assess the efficiency of the existing and proposed drainage system.

One aspect of this Hydrological Survey is the bathymetric survey of the main rivers within the project area. The purpose of bathymetric survey is to provide bathymetric information of the Kaliganga River and its tributaries. The main drainage channels in this Upazila is Kaliganga River that eventually falls in to Dhaleseari River. The information obtained in the field will be incorporated in the DEM through a process called “Burning”. This will be necessary for analyzing the surface water flow to assess flood through flood modeling software. It is required to assess the flood conditions during different time period and season against different water levels and discharge *(Sample results shown in Fig: 1 & Fig: 2)*. If the actual cross-section of the river or channel is not obtained, the analysis will be faulty and will overstate the flood. This type of analysis will be helpful for preparation of effective and long lasting development plans for this Upazila. Hence, accuracy of the analysis is of prime importance.

To run a flood model of the area, water level, discharge and rainfall data of the vicinity have been collected from secondary source and analyzed. Water level data of BWDB gauge stations SW 70 at Kalatia and SW 93.4L at Bhagyakul have been collected. The rainfall data of the stations CL 402 at Bhagyakul has been collected to obtain rainfall data. The data are to be analyzed to obtain water level, discharge and rainfall data for different return period. The water level and discharge data are needed to set the boundary condition in flood models. The rainfall data will be used to obtain runoffs to calculate discharge at pour points of the sub-catchments.

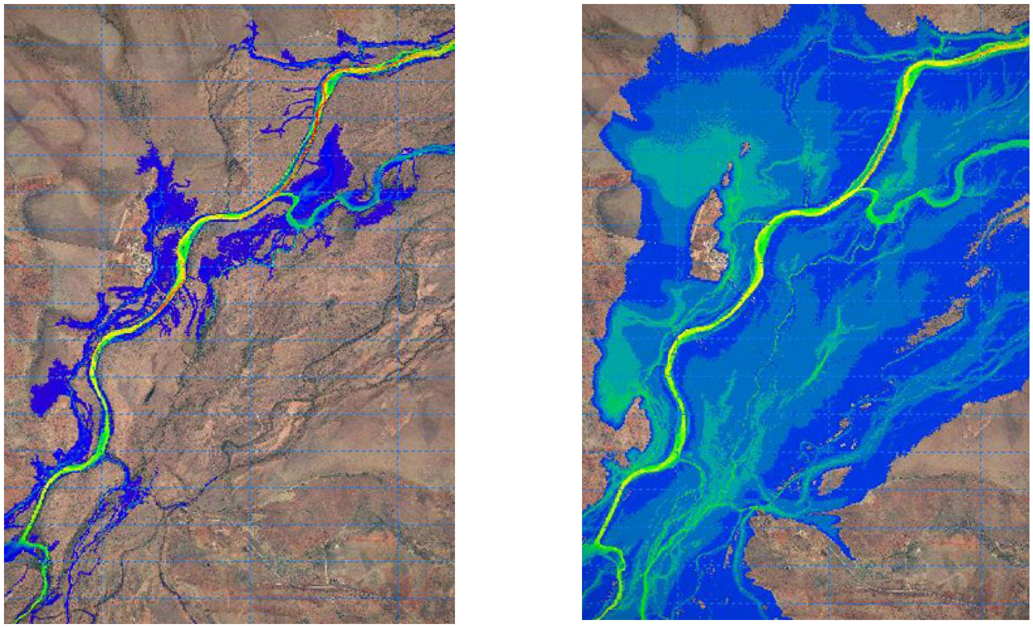


Fig-1: An integrated 1D-2D flood model on a flood plain showing flood conditions at different water level and flow time using Mike Flood (DHI)

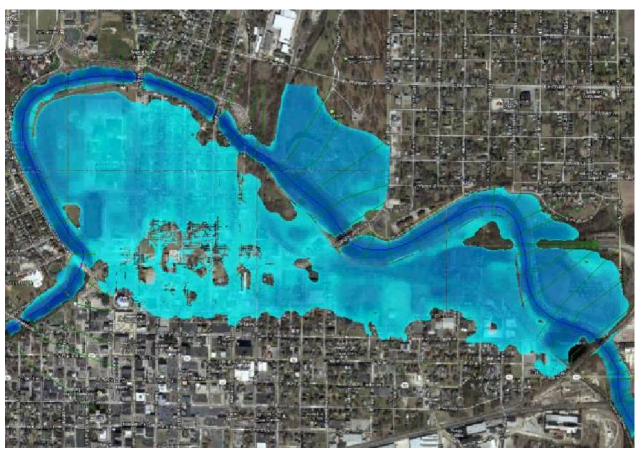


Fig-2: An integrated 1D-2D flood model showing flood conditions in a city area using HEC-RAS

Understanding the water logging problems within the town area and proposing a comprehensive drainage system is another aspect of the survey. Drainage system development is unavoidable when it comes to sustainable urbanization. It is necessary to plan ahead for an efficient drainage system. For this, assessment of capacity and utility of the existing drainage system is essential. Information of the existing drains in Dohar have been collected. The information includes depth, width and EGL at the junction points of the drains. 3-hourly rainfall data, collected from Goddard Earth Sciences Data and Information Service Center, will be used to prepare the hourly rainfall data or the intensity duration frequency (IDF) curve for designing storm sewer system. This will be used to assess the capacity of the existing drainage system and in designing the proposed drainage system. *(Fig: 3)*

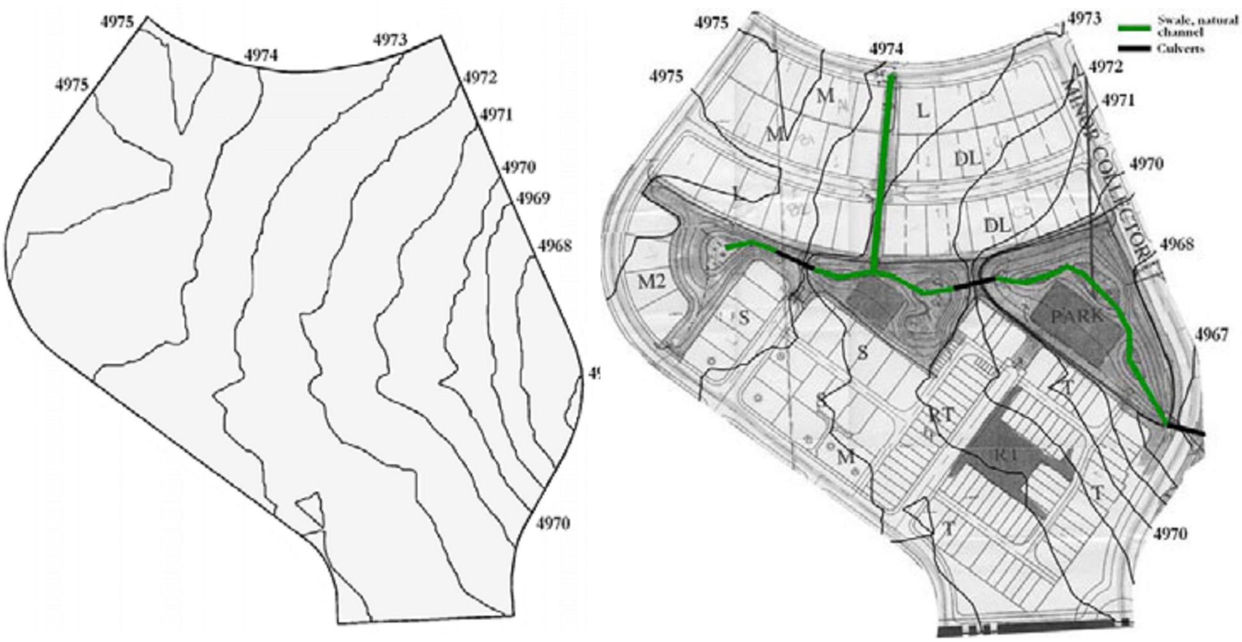


Fig-3: Model developed using EPA SWMM simulating undeveloped (left) and developed (right) conditions to calculate and compare the difference of discharge

With the above in view, the overall objectives of the survey are as listed below:

- Bathymetric survey of the major rivers.
- Identification of hydraulic structures and collecting information regarding capacity and sill levels of the structures.
- Identification of flood hazard locations.
- Identification of flow directions and tidal effects if any.
- Collection of observed flood levels in the field.
- Collecting information of any existing drainage system.
- Identification of water logging zones.
- Collecting information regarding encroachments of natural water bodies and drains.
- Collection of water level, discharge and rainfall data from secondary sources.

The analyses of the collected water level data done using EV I distribution are added in ANNEXURE - I(b). The Rest of the analysis using the Normal distribution, Log normal distribution and Log Pearson III distribution along with the goodness of fit analysis will be added in the final planning report of the project, “Preparation of Development Plan for Fourteen Upazilas”.

CHAPTER 2
METHODOLOGY

2.0 Survey Method

2.1 Measuring Reduced Levels

To measure the reduced levels, dumpy levels and 5m staffs were used. In case of rivers, the levels were measured with respect to the nearest known benchmarks of Bangladesh Water Development Board or temporary benchmarks of any authorized government organizations viz., Roads and Highways Department or Local Government Engineering Department etc. After establishing a horizontal line of collimation / line of sight with respect to a BM/TBM, staff readings are taken within the range of visibility of the dumpy level. For any reading beyond the visibility range, the dumpy level needs a change of station. A temporary benchmark is established and further measurements are made with respect to that. In case of a change of level of more than the height of the staff (5m generally), the levelling machine needs to be shifted and setup again. Subtracting the level of line of sight from the staff readings provides the reduced levels at the point concerned. In figure 4, a schematic diagram of survey method using Dumpy Levels is shown.

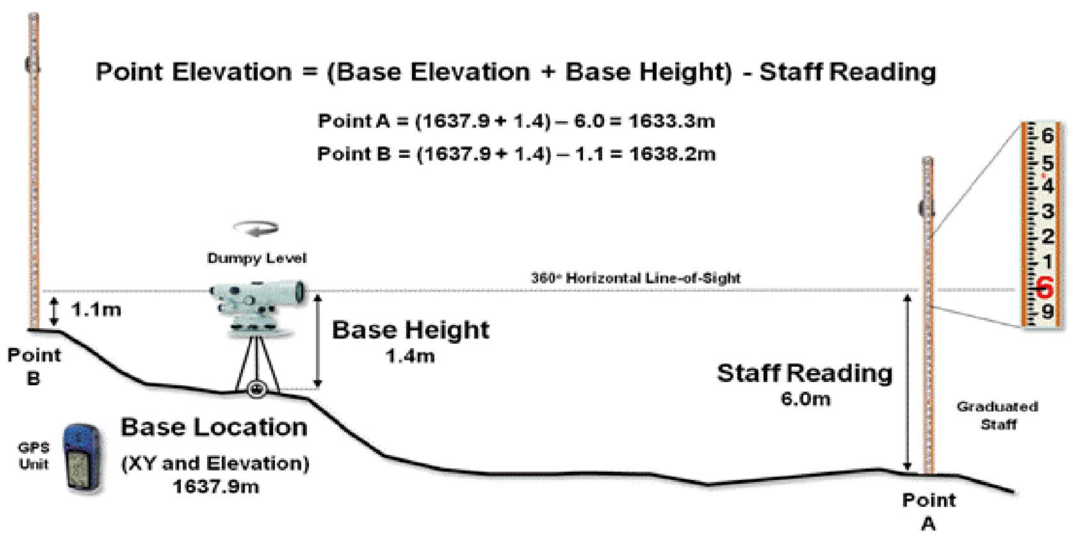


Fig-4: A Dumpy level establishes a horizontal plane to measure the relative elevation differences throughout a project area. A hand GPS is used to get the location of the base.

2.2 Identification of Location

A hand GPS was used to identify the location of the cross-sections, structures, drain control points etc.

2.3 Data Collection

To collect information regarding water control structures in the vicinity, the government organizations that are responsible for any development works regarding water resources development were contacted. The three government organizations that are active in the area are Bangladesh Water Development Board (BWDB), Local Government Engineering Department (LGED) and Bangladesh Agricultural Development Corporation (BADC). Key information of the structures about invert level, number and size of vents etc. were collected. *Plate-1 & 2* shows the Kaliganga River and Ichamati River respectively.

Plate-1: Ichamati Closure

Plate-2: Padma river

To identify locations that are prone to flood hazards or water logging problems, questionnaire was prepared and information was collected accordingly. The questionnaire is attached to ANNEXURE – II (a). During the engineering survey, information like highest and normal flood levels, highest tide levels and lowest tide levels were collected from the local farmers, fishermen or boatmen.

As for the secondary data, water level data of the gauge stations SW 70, SW 93.4L of Bangladesh water development is collected. Daily Rainfall data of BWDB gauge CL 402 has also been collected.

Plate-1: Arial Beel

Plate-2: Kartikpur Khal

CHAPTER 3
FINDINGS OF SURVEY WORKS

3.0 Survey Results

3.1 Survey of Main Rivers

The main rivers and channels as identified are shown in *Map – 1 & 2.* Cross-sections prepared using the reduced levels obtained in the field against Bangladesh Water Development Board benchmarks. Later, when the photogrammetric images will be processed, the cross-sections will be converted to MSL datum. During the physical feature survey, information about hydraulic structures on the rivers and along the banks of the rivers has already been collected.

3.2 Dependencies

The hydrological works are dependent upon the land use survey, topographic survey and physical feature survey for the respective outcomes of those survey works done under this project. During Physical feature survey, information regarding hydraulic structures has been collected. The local offices of Government Agencies like BWDB, BADC and LGED have been contacted to get data about any irrigation projects or drainage projects that are either currently being operated or being planned by them. The responses of the local populace have been inquired to understand their attitude towards those projects.

The land use survey will be required to prepare the rainfall runoff model for Dohar. Depending upon the use of land, the runoff over a certain segment of land will vary. On a surface exhibiting vegetation, the rainwater shall be impeded from reaching any natural or man-made drainage system. A portion of the precipitation will be intercepted by the canopy before the rain water can reach the ground, also the infiltration rate will be high. All these factors prevents the accumulation of rain water and thus reduces runoff. On the other hand, on a buildup area, much of the vegetation is gone and the land is more or less covered with impervious construction. Interception and infiltration hence reduces, resulting in an increase in net runoff.

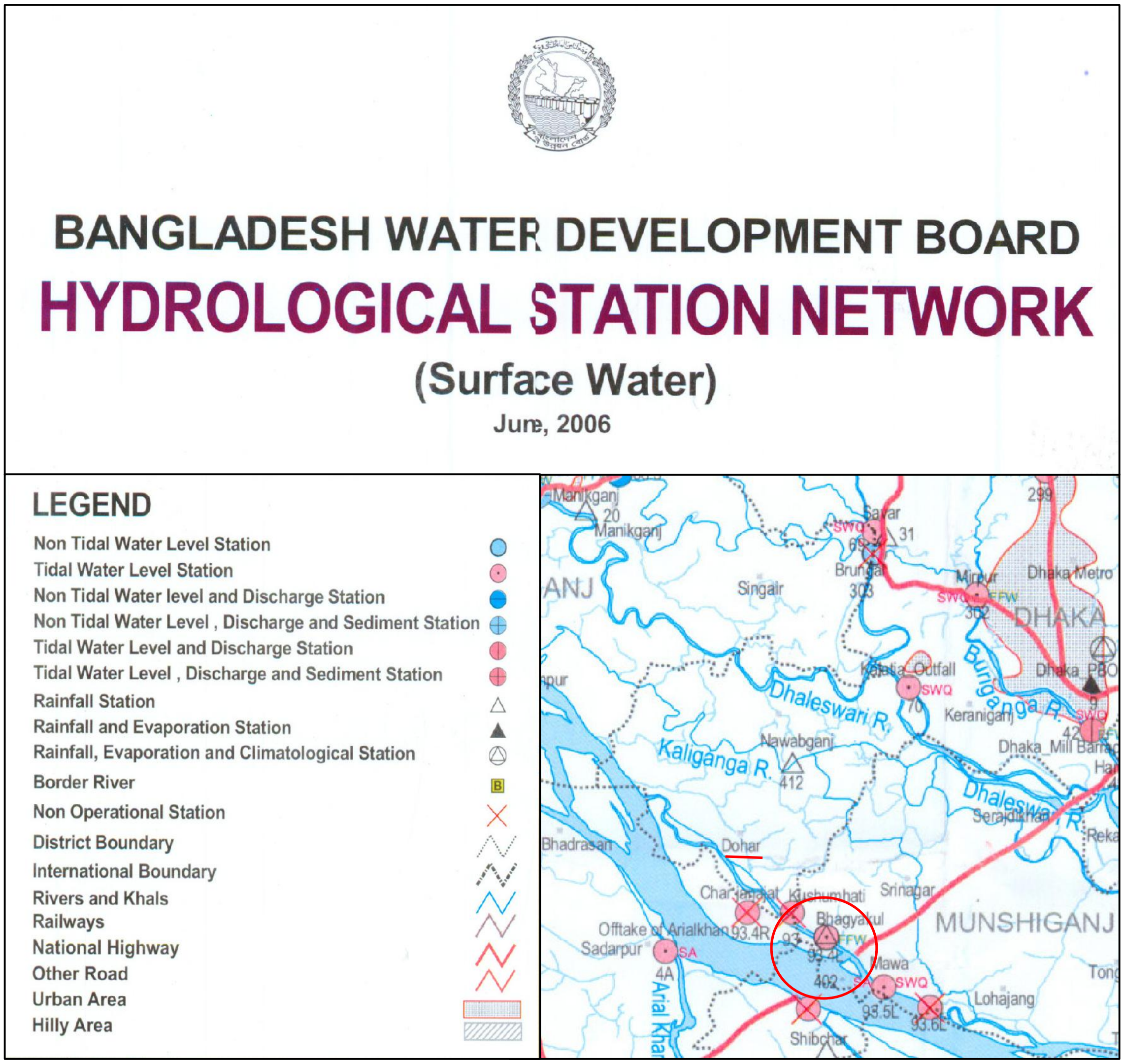
Topographic survey is required to understand the undulations on the ground surface. On a steep slope, the water flows quicker towards drainage bodies which are vice versa for a flat land. The digital 3D stereo imageries that have been collected as a measure of the survey works will be used to prepare a Digital Elevation Model (DEM) of the land.

3.3 Survey of the Existing Drainage Systems

Information of existing drains at Dohar regarding depth and width, RL and GPS locations at different junction points, starting points and ending points are obtained. Names of roads alongside the drains are also collected. Lining conditions (Lined or Unlined) of the existing drains have been identified during the survey. This information would be used to prepare a drainage inventory to assess the capacity of the existing drainage system and with a view to that; a drainage improvement plan will be prepared.

3.4 Samples of Collected Data

The BWDB Water Level and Rainfall gauge stations of which the data has been collected are shown on *Map-3.* The sample data are charted from **Table – 3.1 to 3.4**



Map-3: Locations of BWDB Water Level, Discharge and Rainfall gauge stations at and around Dohar, Dhaka, of which the data has been collected (SW 93.4L, CL 402)

Table 3.1: Sample of Collected Rainfall data of BWDB station CL402

District	Station	Station_ID	DATE	Rainfall(m)
Munshigar	Bhagyakul	CL402	01-feb-2003	0.00
Munshigar	Bhagyakul	CL402	02-feb-2003	0.00
Munshigar	Bhagyakul	CL402	03-feb-2003	0.00
Munshigar	Bhagyakul	CL402	04-feb-2003	0.00
Munshigar	Bhagyakul	CL402	05-feb-2003	0.00
Munshigar	Bhagyakul	CL402	06-feb-2003	0.00
Munshigar	Bhagyakul	CL402	07-feb-2003	0.00
Munshigar	Bhagyakul	CL402	08-feb-2003	0.00
Munshigar	Bhagyakul	CL402	09-feb-2003	0.00
Munshigar	Bhagyakul	CL402	10-feb-2003	0.00
Munshigar	Bhagyakul	CL402	11-feb-2003	0.00
Munshigar	Bhagyakul	CL402	12-feb-2003	0.00
Munshigar	Bhagyakul	CL402	13-feb-2003	10.50
Munshigar	Bhagyakul	CL402	14-feb-2003	14.00
Munshigar	Bhagyakul	CL402	15-feb-2003	0.00
Munshigar	Bhagyakul	CL402	16-feb-2003	0.00
Munshigar	Bhagyakul	CL402	17-feb-2003	0.00
Munshigar	Bhagyakul	CL402	18-feb-2003	0.00
Munshigar	Bhagyakul	CL402	19-feb-2003	0.00
Munshigar	Bhagyakul	CL402	20-feb-2003	0.00
Munshigar	Bhagyakul	CL402	21-feb-2003	0.00
Munshigar	Bhagyakul	CL402	22-feb-2003	0.00
Munshigar	Bhagyakul	CL402	23-feb-2003	0.00
Munshigar	Bhagyakul	CL402	24-feb-2003	0.00
Munshigar	Bhagyakul	CL402	25-feb-2003	0.00
Munshigar	Bhagyakul	CL402	26-feb-2003	0.00
Munshigar	Bhagyakul	CL402	27-feb-2003	0.00
Munshigar	Bhagyakul	CL402	28-feb-2003	0.00
Munshigar	Bhagyakul	CL402	01-mar-2003	0.00
Munshigar	Bhagyakul	CL402	02-mar-2003	0.00
Munshigar	Bhagyakul	CL402	03-mar-2003	0.00
Munshigar	Bhagyakul	CL402	04-mar-2003	0.00

Table 3.2: Sample of Collected Water level Data of BWDB Station SW93.4L

RiverName	StationName	StationID	DateTime	HighTide	LowTide
Ganges-Padma	Bhagyakul	SW93.4L	01-04-1981	1.77	1.46
Ganges-Padma	Bhagyakul	SW93.4L	02-04-1981	1.83	1.55
Ganges-Padma	Bhagyakul	SW93.4L	03-04-1981	1.95	1.62
Ganges-Padma	Bhagyakul	SW93.4L	04-04-1981	2.13	1.83
Ganges-Padma	Bhagyakul	SW93.4L	05-04-1981	2.44	1.98
Ganges-Padma	Bhagyakul	SW93.4L	06-04-1981	2.58	1.98
Ganges-Padma	Bhagyakul	SW93.4L	07-04-1981	2.41	1.98
Ganges-Padma	Bhagyakul	SW93.4L	08-04-1981	2.29	1.95
Ganges-Padma	Bhagyakul	SW93.4L	09-04-1981	2.16	1.86
Ganges-Padma	Bhagyakul	SW93.4L	10-04-1981	2.04	1.77
Ganges-Padma	Bhagyakul	SW93.4L	11-04-1981	2.01	1.80
Ganges-Padma	Bhagyakul	SW93.4L	12-04-1981	2.01	1.80
Ganges-Padma	Bhagyakul	SW93.4L	13-04-1981	2.04	1.83
Ganges-Padma	Bhagyakul	SW93.4L	14-04-1981	2.13	1.83
Ganges-Padma	Bhagyakul	SW93.4L	15-04-1981	2.18	1.98
Ganges-Padma	Bhagyakul	SW93.4L	16-04-1981	2.35	2.10
Ganges-Padma	Bhagyakul	SW93.4L	17-04-1981	2.56	2.29
Ganges-Padma	Bhagyakul	SW93.4L	18-04-1981	2.77	2.47
Ganges-Padma	Bhagyakul	SW93.4L	19-04-1981	2.77	2.44
Ganges-Padma	Bhagyakul	SW93.4L	20-04-1981	2.77	2.38
Ganges-Padma	Bhagyakul	SW93.4L	21-04-1981	2.74	2.32
Ganges-Padma	Bhagyakul	SW93.4L	22-04-1981	2.56	2.29
Ganges-Padma	Bhagyakul	SW93.4L	23-04-1981	2.50	2.26
Ganges-Padma	Bhagyakul	SW93.4L	24-04-1981	2.41	2.23
Ganges-Padma	Bhagyakul	SW93.4L	25-04-1981	2.35	2.13
Ganges-Padma	Bhagyakul	SW93.4L	26-04-1981	2.29	2.10
Ganges-Padma	Bhagyakul	SW93.4L	27-04-1981	2.26	2.10
Ganges-Padma	Bhagyakul	SW93.4L	28-04-1981	2.26	2.10
Ganges-Padma	Bhagyakul	SW93.4L	29-04-1981	2.30	2.10
Ganges-Padma	Bhagyakul	SW93.4L	30-04-1981	2.35	2.16
Ganges-Padma	Bhagyakul	SW93.4L	01-05-1981	2.44	2.26
Ganges-Padma	Bhagyakul	SW93.4L	02-05-1981	2.51	2.26
Ganges-Padma	Bhagyakul	SW93.4L	03-05-1981	2.51	2.26

CHAPTER 4
HYDROLOGIC DATA ANALYSIS

4.0 Analysis of Hydrological Data

4.1 Estimation of Design Discharge and Water Level

Estimation of both flood discharges and high water levels are necessary for bank protection design. Careful estimation of discharge and water level is important for all sites with erodible banks. This section describes the methods of assessing flood discharge and water level at the site under consideration. The design discharge and water level are determined for selected probability of exceedance or return period.

The design discharge and water level arising from floods should be selected after due consideration of the following:

- The maximum historical discharge as recorded at the site, or as calculated on the basis of recorded water level at the site, or as calculated on the basis of measured discharge at other points on the river from which corresponding site discharge can reasonably be inferred**.**
- The discharge derived from a frequency analysis using a probability of exceedance or return period which is appropriate to the importance and value of the protection work.
- The maximum historical water level as recorded at the site, or as inferred from observed or recorded water level at other points on the river from which level can reasonably be transferred to the site in question.
- The water level derived from a frequency analysis using a probability of exceedance or return period which is appropriate to the importance and value of the protection work.

In estimating high flows, primary reliance should be placed on careful field investigations, local enquiries and searches of historical records. Data so obtained should be compared with recorded data for hydrometric stations, and supplemented by analytical procedure using stage-discharge curves. At most hydrometric gauging stations reasonably stable relationship exists between water level and discharge. At some sites, however, the stage discharge curve may be quite unstable because of aggradation or degradation at channel bed or backwater effect from downstream, and may change drastically during major floods. A persistent trend of rising or lowering of curve indicates progressive channel aggradation or degradation. The stage corresponding to design flood which exceeds any recorded flow obtained by extrapolating the stage-discharge relationships.

The most commonly used method for estimating design discharge and water level examines the observed discharge and water level to arrive at suitable estimates. The method, known as frequency analysis, is founded on statistical analyses of discharge and water level records. For locations where records of stream flows are available, or where flows from another basin can be transported to the design location, design flood magnitude and water level can be estimated directly from those records by means of frequency analysis.

4.2 Frequency Analysis

Frequency of a hydrological event, such as the annual peak flow is the probability that a value will be equaled or exceeded in any year. This is more appropriately called the exceedance probability, P (F). The reciprocal of the exceedance probability is the return period T in years, that is, $T = {}^{1}\!/_{P(F)}$. The length of record should be sufficient to justify extrapolating the frequency relationship. For example, it might be reasonable to estimate a 50-year flood on the basis of a 30-year record, but to estimate a 100-year flood on the basis of a 10-year record would normally be absurd (Neill 1973) (1). Viessman and Lewis (1996) (2) noted that as a general rule, frequency analysis is cautioned when working with shorter records and estimating frequencies of hydrological events greater than twice the record length.

Frequency analysis can be conducted in two ways: one is the analytical approach and the other is the graphical technique in which flood magnitudes are usually plotted against probability of exceedance.

Here in the following sections, procedures are given mostly for discharge frequency analysis; the similar procedures can also be followed for water level frequency analysis.

4.3 Analytical Frequency Analysis

Analytical frequency analysis is based on fitting theoretical probability distributions to given data. Numerous distributions have been suggested on the basis of their ability to ‘fit’ the plotted data from streams (Linsley et al. 1982) (3). The Log-Pearson Type III (LP3) has been adopted for use in the United States Federal Agencies for flood analysis. The first asymptotic distribution of extreme values (EV1), commonly called Gumbel Distribution has been widely used and is recommended in the United Kingdom. For this project, all the collected data will be analyzed using Normal distribution, Log-Normal distribution, Log-Pearson III distribution and Extreme Variable Distribution and the best fit distribution will be adopted for analysis.

4.3.1 Extreme Value Distributions:

Distributions of the extreme values selected from sets of samples of any probability distribution converge to any one of three forms of Extreme Value Distributions, called Type I, II, and III, respectively, when the number of selected extreme values is large. The three limiting forms are special cases of a single distribution called Generalized Extreme Value (GEV) Distribution (Chow et al. 1988) (4). The cumulative distribution function for the GEV is:

$$F(x) = \exp\left[-\left(1 - \kappa\frac{x-u}{\alpha}\right)^{1/\kappa}\right] \qquad (1)$$

Here κ , u, and α are parameters to be determined. For EVI Distribution x is unbounded, while for EVII, x is bounded from below, and for EVIII, x is bounded from above. The EVI and EVII Distributions are also known as the Gumbel and Frechet Distributions, respectively.

The Extreme Value Type I (EVI) cumulative distribution function is:

$$F(x) = \exp\left[-\exp\left(-\frac{x-u}{\alpha}\right)\right] \qquad -\propto \le x \le \propto \qquad (2)$$

The parameters are estimated by

$$\alpha = \frac{\sqrt{6}}{\pi} s \quad \text{and} \quad u = \bar{x} - 0.5772\alpha \tag{3}$$

Eq (2) can be expressed as

$$F(x) = e^{-e^{-y}} \tag{4}$$

Where y is the reduced variate defined as

$$y = \frac{x - u}{\alpha} \tag{5}$$

Solving Eq (4) for y:

$$y = -\ln\left[\ln\left(\frac{1}{F(x)}\right)\right] \tag{6}$$

Noting that the probability of occurrence of an event $x \geq x_T$ is the inverse of its return period T, we can write

$$\frac{1}{T} = P(x \geq x_T) = 1 - P(x \leq x_T) = 1 - F(x_T)$$

So,

$$F(x_T) = 1 - \frac{1}{T}$$

Substituting for *F(*x_T*)* into Eq (6)

$$y_T = -\ln\left[\ln\left(\frac{T}{T-1}\right)\right] \tag{7}$$

For a given return period x_T is related to y_T by Eq (5), or

$$x_T = u + \alpha y_T \tag{8}$$

4.3.2 Frequency Analysis using Frequency Factors

Calculating the magnitudes of extreme events by the method outlined in the above example requires that the probability distribution function be invertible, that is, given a value of *T* or $F(x_T) = 1 - \frac{1}{T}$, the corresponding value of x_T can be determined. Some probability distribution functions are not readily invertible, like the Normal and Pearson Type III Distributions. Thus an alternative method based on frequency factor is used for calculating the magnitudes of extreme events. Chow (1951) [5] has shown that most frequency functions can be generalized to

$$x_T = \bar{x} + K_T s \tag{9}$$

where x_T is a flood of specified probability or return period *T*, $\bar{x}$ is the mean of the flood series, s is the standard deviation of the series; and K_T is the frequency factor and is a function of return period and type of probability distribution, as well as coefficient of skewness for skewed distributions, such as LP3.

In the event that the variable analyzed is $y = \log x$, for example as in Lognormal and LP3 Distributions, the same method is applied to the statistics for the logarithms of data using $y_T = \bar{y} + K_T s_y$, and the required value of x_T is found taking antilog of y_T.

Chow (1951) [5] proposed the frequency factor as in Eq (9), and it is applicable to many probability distributions used in hydrological frequency analysis. The K-T relationship can be expressed in mathematical terms or by a table.

Normal Distribution: From Eq (9) the frequency factor can be expressed as

$$K_T = \frac{x_T - \bar{x}}{s} = z \qquad (10)$$

Thus, for Normal Distribution K_T is the same as the standard normal variable z. The value of z and hence K_T can be obtained from Table 1 in ANNEXURE – I(a).

Lognormal Distribution: The recommended procedure for use of the Lognormal Distribution is to convert the data series to logarithms and compute:

1) $y_i = \log x_i$
2) Compute the mean, $\bar{y}$ and standard deviation s_y
3) Compute $y_T = \bar{y} + K_T s_y$

$$K_T = \frac{y_T - \bar{y}}{s_y} = z$$

So, K_T can be taken from Table 1 in ANNEXURE – I(a).

4) Finally compute $x_T = anti\log y_T$

Log-Pearson Type III (LP3) Distribution: The recommended procedure for use of the LP3 Distribution is to convert the data series to logarithms and compute:

1) $y_i = \log x_i$
2) Compute the mean, $\bar{y}$ and standard deviation s_y
3) Compute coefficient of skewness

$$C_s = \frac{n\sum (y_i - \bar{y})^3}{(n-1)(n-2){s_y}^3}$$

4) Compute $y_T = \bar{y} + K_T s_y$ (11)

Where K_T is taken from Table 2 in ANNEXURE – I(a)..

5) Finally compute $x_T = anti\log y_T$

Table 3 in ANNEXURE – I(a) gives values of the frequency factors for the LP3 Distribution for various values of return period and coefficient of skewness, C_s. When C_s =0, the frequency factor is equal to the standard normal variable z (Table 1 in ANNEXURE – I(a)).

Extreme Value I (EVI) Distribution: Chow (1951) [5] derived the following expression for frequency factor for the EVI Distribution

$$K_T = -\frac{\sqrt{6}}{\pi}\left[0.5772 + \ln\left\{\ln\left(\frac{T}{T-1}\right)\right\}\right] \qquad (12)$$

When $x_T = \mu$, Eq (9) (in population term) gives $K_T = 0$ and Eq (12) gives T=2.33 years. This is the return period of the mean of the EVI Distribution.

Table of frequency factors for the EVI Distribution, given in Table 3 in ANNEXURE – I(a), is taken from Haan (1977) (6). The values computed from the above equation are equivalent to an infinite sample size in Table 3.

4.3.3 Goodness of Fit Test

The goodness of fit of a probability distribution can be tested by comparing the theoretical and sample values of the relative frequency or the cumulative frequency function. In the case of the relative frequency function, the χ^2 – test is used and with cumulative frequency function the Kolmogorov-Smirnov test is used.

Chi-Square Test: The test statistic is given by

$$\chi^2 = \sum_{i=1}^{k} \frac{n[f_s(x_i) - p(x_i)]^2}{p(x_i)} \qquad (13)$$

Where, *k* is the number of intervals; the sample value of the relative frequency of interval *i* is, $f_s(x_i) = n_i/n$; the theoretical value of the relative frequency function (also called incremental probability function) is $p(x_i) = F(x_i) - F(x_{i-1})$. It may be noted that $nf_s(x_i) = n_i$, the observed number of occurrences in interval *i*, and $np(x_i)$ is the corresponding expected number of occurrences in interval *i*.

To describe the χ^2 test, the χ^2 probability distribution must be defined. A χ^2 distribution with $\upsilon = k-l-1$ degrees of freedom (*l* is the number of parameters used in fitting the proposed distribution) is the distribution for the sum of squares of υ independent standard normal random variables z_i. The critical χ^2 distribution function is tabulated (in Table 4 in ANNEXURE – I(a)) from Haan (1977) (6). A confidence level is chosen for the test; it is often expressed as 1-*α*, where *α* is termed the significance level.

Kolmogorov-Smirnov Test: The theoretical and sample values of the cumulative frequency are compared with the Kolmogorov-Smirnov (S-K) test. The test statistic *D*, which is based on deviations of the sample distribution function *P*(*x*) from the completely specified continuous hypothetical distribution function $P_o(x)$, such that:

$$D = \max\left|P(x) - P_o(x)\right|$$

Developed by Kolmogorov (Kite 1988) (7) in 1933, the test requires that the value of D computed from the sample distribution be less than the tabulated value of D (Table 5) at the required confidence level. Kolmogorov-Smirnov test for Gumbel's Extremal Distribution gives better result in Bangladesh.

4.4 Disaggregation of Daily Rainfall Data

4.4.1 Rainfall Cascade Disaggregation Model

Cascade level refers to the time series at a certain resolution. The transition from one cascade level to the higher one, corresponding to a doubling of resolution, is called *modulation*. A time interval at an arbitrary cascade level (i.e. time scale) is termed a *box*, which is characterized by an associated precipitation amount (0 if dry, >0 if wet). The break-up of a wet box into two equally sized sub-boxes is denoted *branching*. In one branching, the total amount is redistributed according to two multiplicative weights, $0 \le W_1 \le 1$ and $0 \le W_2 \le 1$ ($W_1 + W_2 = 1$). The model is a multiplicative random cascade of branching number 2 with exact conservation of mass (micro canonical property as opposed to canonical cascades where the volume is only approximately conserved). The model divides daily precipitation into non overlapping time intervals. If the precipitation in a day is P_d, $P_1 = P_d W_1$ is the precipitation amount assigned to the first half of the day, and $P_2 = P_d W_2$ the amount assigned to the second half. Similarly, each half is then branched to a doubled resolution, and so on. The implementation of cascade – based model allows the conversion of daily amount into 12-hourly (1 steps), 6-hourly (2 steps), and 3-hourly (3 steps) values. The short-time intensity disaggregation model (Connolly et al. 1998) [8], is used to have three fine-resolution time interval that are 1-hour, 1/2-hour and 10-minutes. A single Poisson distribution parameter represents the number of events, N, on a rainy day. The density function of the Poisson distribution (adjusted so that $N >= 1$) has the form:

$$f(N) = \frac{\eta^{N-1} \cdot e^{-\eta}}{(N-1)!} \qquad (14)$$

Where η is a fitted coefficient. Mean (μ_N) and variance (σ^2_N) are given as:

$$\mu_N = \eta + 1 \qquad (15)$$

$$\sigma^2{}_N = \eta \qquad (16)$$

The simulated number of event N is the lowest integer to satisfy:

$$\sum_{i=1}^{N} \frac{\eta^{i-1} \cdot e^{-\eta}}{(i-1)!} \ge U \quad N \ge 1 \qquad (17)$$

Where U is a uniform random number in the range 0–1.

The duration of each event, D, is represented with a gamma distribution. The scale parameter of the gamma distribution, α, has to be estimated and the shape parameter, β, is set held at 2. It results the following density function:

$$f(D) = \alpha^2 \cdot D \cdot e^{-\alpha \cdot D} \qquad (18)$$

A uniform random number in the range 0–1, U, is generated and the event duration is simulated by solving the cumulative density function of the gamma distribution using Newton's method:

$$1-(1+\alpha \cdot D) \cdot e^{-\alpha \cdot D} = U \qquad (19)$$

With these estimated point (10′-30′-1 h, 3 h, 6 h, 12 h and 24 h) following the procedures for the frequency distribution, it is possible to define the rainfall probability curves.

Using the above equations, daily and monthly basis analysis of water level data have been prepared which is shown in **ANNEXURE -I (b).**

CHAPTER 5
DESIGNING STORM SEWER

5.0 Capacity Estimate and Designing Drain Sections (Prismatic)

5.1 Manning's Formula

The Manning's formula is a widely used formula around the world to estimate capacity of an open channel or design required section. The formula is also known as Gauckler-Manning-Strickler formula. It is an empirical formula to estimate the average velocity of water flowing through an open channel. The Manning's equation is as follows:

$$V = \frac{K_n}{n} R^{\frac{2}{3}} s^{\frac{1}{2}} \qquad (20)$$

Where, V = average velocity of flow (SI unit: m/s; Imperial: ft/s)

K_n = Unit conversion factor (1.00 for SI unit and 1.49 for Imperial unit)

R = Hydraulic Radius = $\frac{P}{A}$ (SI unit: m, Imperial: ft)

Here, P = Wetted Perimeter (SI unit: m, Imperial: ft)

A = Cross-sectional area of flow (SI unit: m^2, Imperial: ft^2)

s = hydraulic gradient of flow (SI unit: m/m, Imperial: ft/ft)

n = Manning's dimensionless roughness coefficient

Manning's roughness coefficient may be selected using the following **Table-5.1.**

Table-5.1: Manning's n for Channels (Chow (1951)) [(5)].

Type of Channel and Description	Minimum	Normal	Maximum
Natural streams - minor streams (top width at floodstage < 100 ft)			
1. Main Channels			
a. clean, straight, full stage, no rifts or deep pools	0.025	0.03	0.033
b. same as above, but more stones and weeds	0.03	0.035	0.04
c. clean, winding, some pools and shoals	0.033	0.04	0.045
d. same as above, but some weeds and stones	0.035	0.045	0.05
e. same as above, lower stages, more ineffective slopes and sections	0.04	0.048	0.055
f. same as "d" with more stones	0.045	0.05	0.06
g. sluggish reaches, weedy, deep pools	0.05	0.07	0.08
h. very weedy reaches, deep pools, or floodways with heavy stand of timber and underbrush	0.075	0.1	0.15
2. Mountain streams, no vegetation in channel, banks usually steep, trees and brush along banks submerged at high stages			
a. bottom: gravels, cobbles, and few boulders	0.03	0.04	0.05

Table-5.1: Manning's n for Channels (Chow (1951)) [5].

Type of Channel and Description	Minimum	Normal	Maximum
b. bottom: cobbles with large boulders	0.04	0.05	0.07
3. Floodplains			
a. Pasture, no brush			
1.short grass	0.025	0.03	0.035
2. high grass	0.03	0.035	0.05
b. Cultivated areas			
1. no crop	0.02	0.03	0.04
2. mature row crops	0.025	0.035	0.045
3. mature field crops	0.03	0.04	0.05
c. Brush			
1. scattered brush, heavy weeds	0.035	0.05	0.07
2. light brush and trees, in winter	0.035	0.05	0.06
3. light brush and trees, in summer	0.04	0.06	0.08
4. medium to dense brush, in winter	0.045	0.07	0.11
5. medium to dense brush, in summer	0.07	0.1	0.16
d. Trees			
1. dense willows, summer, straight	0.11	0.15	0.2
2. cleared land with tree stumps, no sprouts	0.03	0.04	0.05
3. same as above, but with heavy growth of sprouts	0.05	0.06	0.08
4. heavy stand of timber, a few down trees, little undergrowth, flood stage below branches	0.08	0.1	0.12
5. Same as 4. with flood stage reaching branches	0.1	0.12	0.16
4. Excavated or Dredged Channels			
a. Earth, straight, and uniform			
1. clean, recently completed	0.016	0.018	0.02
2. clean, after weathering	0.018	0.022	0.025
3. gravel, uniform section, clean	0.022	0.025	0.03
4. with short grass, few weeds	0.022	0.027	0.033
b. Earth winding and sluggish			
1. no vegetation	0.023	0.025	0.03
2. grass, some weeds	0.025	0.03	0.033
3. dense weeds or aquatic plants in deep channels	0.03	0.035	0.04
4. earth bottom and rubble sides	0.028	0.03	0.035
5. stony bottom and weedy banks	0.025	0.035	0.04
6. cobble bottom and clean sides	0.03	0.04	0.05
c. Dragline-excavated or dredged			
1. no vegetation	0.025	0.028	0.033
2. light brush on banks	0.035	0.05	0.06
d. Rock cuts			

Table-5.1: Manning's n for Channels (Chow (1951)) [(5)].

Type of Channel and Description	Minimum	Normal	Maximum
1. smooth and uniform	0.025	0.035	0.04
2. jagged and irregular	0.035	0.04	0.05
e. Channels not maintained, weeds and brush uncut			
1. dense weeds, high as flow depth	0.05	0.08	0.12
2. clean bottom, brush on sides	0.04	0.05	0.08
3. same as above, highest stage of flow	0.045	0.07	0.11
4. dense brush, high stage	0.08	0.1	0.14
5. Lined or Constructed Channels			
a. Cement			
1. neat surface	0.01	0.011	0.013
2. mortar	0.011	0.013	0.015
b. Wood			
1. planed, untreated	0.01	0.012	0.014
2. planed, creosoted	0.011	0.012	0.015
3. un-planed	0.011	0.013	0.015
4. plank with battens	0.012	0.015	0.018
5. lined with roofing paper	0.01	0.014	0.017
c. Concrete			
1. trowel finish	0.011	0.013	0.015
2. float finish	0.013	0.015	0.016
3. finished, with gravel on bottom	0.015	0.017	0.02
4. unfinished	0.014	0.017	0.02
5. gunite, good section	0.016	0.019	0.023
6. gunite, wavy section	0.018	0.022	0.025
7. on good excavated rock	0.017	0.02	
8. on irregular excavated rock	0.022	0.027	
d. Concrete bottom float finish with sides of:			
1. dressed stone in mortar	0.015	0.017	0.02
2. random stone in mortar	0.017	0.02	0.024
3. cement rubble masonry, plastered	0.016	0.02	0.024
4. cement rubble masonry	0.02	0.025	0.03
5. dry rubble or riprap	0.02	0.03	0.035
e. Gravel bottom with sides of:			
1. formed concrete	0.017	0.02	0.025
2. random stone mortar	0.02	0.023	0.026
3. dry rubble or riprap	0.023	0.033	0.036
f. Brick			
1. glazed	0.011	0.013	0.015
2. in cement mortar	0.012	0.015	0.018
g. Masonry			

Table-5.1: Manning's n for Channels (Chow (1951)) (5).

Type of Channel and Description	Minimum	Normal	Maximum
1. cemented rubble	0.017	0.025	0.03
2. dry rubble	0.023	0.032	0.035
h. Dressed ashlar/stone paving	0.013	0.015	0.017
i. Asphalt			
1. smooth	0.013	0.013	
2. rough	0.016	0.016	
j. Vegetal lining	0.03		0.5

Estimation of capacity of the existing drains and drainage channels will be estimated using Manning's formula. Design sections of the proposed sections will also be calculated using this formula.

CHAPTER 6
CONCLUSION

6.0 Conclusion

The findings and the collected data during the survey works will be used in the subsequent planning stage of the project, “Preparation of Development Plan for Fourteen Upazilas”. The prepared DEM will be used for Delineation of Catchment area and preparing contours of the project area. The collected water level, rainfall and discharge data will be analyzed and tested for fitness with observed data and successively used to predict the respective data for different time periods. These are going to be incorporated in the final planning report. The results should assist in preparing a development plan that will be sustainable from the hydrologic point of view. The surveyed cross sections, drainage inventories and list of the road name along the drains will be updated after accumulation and processing of physical feature data.

References:

1. O'Neill ADJ and Gray DM; Proceedings of Banff Symposium on Role of snow and Ice in Hydrology; 1973.
2. Warren Viessman and Garry L. Lewis; Introduction to Hydrology$^{ed/4}$, Harper Collins (1996).
3. Linsley, R. K., M. A. Kohler and J. L. H. Paulhus; Hydrology for engineers$^{ed/3}$, McGraw-Hill (1982).
4. Ven Te Chow, David Maidment, and Larry Hays; Applied Hydrology$^{ed/1}$, McGraw-Hill (1988).
5. VT Chow; Open-Channel Hydraulics, McGraw-Hill, New York (1959)
6. Charles T Haan; Statistical Methods in Hydrology, The Iowa State University Press (1977).
7. Khaled Hamed, A. Ramachandro. Rao; Flood Frequency Analysis, CRC press.
8. Stephan Pauleit, Adrien Coly, Sandra Fohlmeister, Paolo Gasparini, Gertrud Jørgensen, Sigrun Kabisch, Wilbard J. Kombe, Sarah Lindley, Ingo Simonis, Kumelachew Yeshitela; Urban Vulnerability and Climate Change in Africa: A Multidisciplinary Approach, Springer.

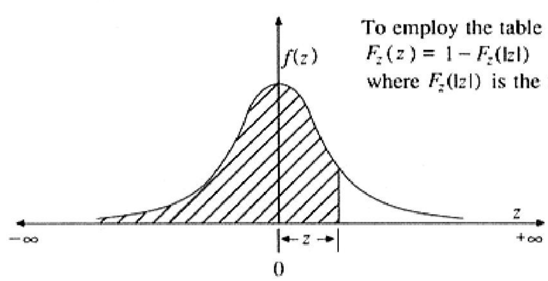
TABLES

Table 1: Cumulative probability of the Standard Normal Distribution

Cumulative probability of the standard normal distribution

z	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
0.0	0.5000	0.5040	0.5080	0.5120	0.5160	0.5199	0.5239	0.5279	0.5319	0.5359
0.1	0.5398	0.5438	0.5478	0.5517	0.5557	0.5596	0.5636	0.5675	0.5714	0.5753
0.2	0.5793	0.5832	0.5871	0.5910	0.5948	0.5987	0.6026	0.6064	0.6103	0.6141
0.3	0.6179	0.6217	0.6255	0.6293	0.6331	0.6368	0.6406	0.6443	0.6480	0.6517
0.4	0.6554	0.6591	0.6628	0.6664	0.6700	0.6736	0.6772	0.6808	0.6844	0.6879
0.5	0.6915	0.6950	0.6985	0.7019	0.7054	0.7088	0.7123	0.7157	0.7190	0.7224
0.6	0.7257	0.7291	0.7324	0.7357	0.7389	0.7422	0.7454	0.7486	0.7517	0.7549
0.7	0.7580	0.7611	0.7642	0.7673	0.7704	0.7734	0.7764	0.7794	0.7823	0.7852
0.8	0.7881	0.7910	0.7939	0.7967	0.7995	0.8023	0.8051	0.8078	0.8106	0.8133
0.9	0.8159	0.8186	0.8212	0.8238	0.8264	0.8289	0.8315	0.8340	0.8365	0.8389
1.0	0.8413	0.8438	0.8461	0.8485	0.8508	0.8531	0.8554	0.8577	0.8599	0.8621
1.1	0.8643	0.8665	0.8686	0.8708	0.8729	0.8749	0.8770	0.8790	0.8810	0.8830
1.2	0.8849	0.8869	0.8888	0.8907	0.8925	0.8944	0.8962	0.8980	0.8997	0.9015
1.3	0.9032	0.9049	0.9066	0.9082	0.9099	0.9115	0.9131	0.9147	0.9162	0.9177
1.4	0.9192	0.9207	0.9222	0.9236	0.9251	0.9265	0.9279	0.9292	0.9306	0.9319
1.5	0.9332	0.9345	0.9357	0.9370	0.9382	0.9394	0.9406	0.9418	0.9429	0.9441
1.6	0.9452	0.9463	0.9474	0.9484	0.9495	0.9505	0.9515	0.9525	0.9535	0.9545
1.7	0.9554	0.9564	0.9573	0.9582	0.9591	0.9599	0.9608	0.9616	0.9625	0.9633
1.8	0.9641	0.9649	0.9656	0.9664	0.9671	0.9678	0.9686	0.9693	0.9699	0.9706
1.9	0.9713	0.9719	0.9726	0.9732	0.9738	0.9744	0.9750	0.9756	0.9761	0.9767
2.0	0.9772	0.9778	0.9783	0.9788	0.9793	0.9798	0.9803	0.9808	0.9812	0.9817
2.1	0.9821	0.9826	0.9830	0.9834	0.9838	0.9842	0.9846	0.9850	0.9854	0.9857
2.2	0.9861	0.9864	0.9868	0.9871	0.9875	0.9878	0.9881	0.9884	0.9887	0.9890
2.3	0.9893	0.9896	0.9898	0.9901	0.9904	0.9906	0.9909	0.9911	0.9913	0.9916
2.4	0.9918	0.9920	0.9922	0.9925	0.9927	0.9929	0.9931	0.9932	0.9934	0.9936
2.5	0.9938	0.9940	0.9941	0.9943	0.9945	0.9946	0.9948	0.9949	0.9951	0.9952
2.6	0.9953	0.9955	0.9956	0.9957	0.9959	0.9960	0.9961	0.9962	0.9963	0.9964
2.7	0.9965	0.9966	0.9967	0.9968	0.9969	0.9970	0.9971	0.9972	0.9973	0.9974
2.8	0.9974	0.9975	0.9976	0.9977	0.9977	0.9978	0.9979	0.9979	0.9980	0.9981
2.9	0.9981	0.9982	0.9982	0.9983	0.9984	0.9984	0.9985	0.9985	0.9986	0.9986
3.0	0.9987	0.9987	0.9987	0.9988	0.9988	0.9989	0.9989	0.9989	0.9990	0.9990
3.1	0.9990	0.9991	0.9991	0.9991	0.9992	0.9992	0.9992	0.9992	0.9993	0.9993
3.2	0.9993	0.9993	0.9994	0.9994	0.9994	0.9994	0.9994	0.9995	0.9995	0.9995
3.3	0.9995	0.9995	0.9995	0.9996	0.9996	0.9996	0.9996	0.9996	0.9996	0.9997
3.4	0.9997	0.9997	0.9997	0.9997	0.9997	0.9997	0.9997	0.9997	0.9997	0.9998

Source: Grant, E. L., and R. S. Leavenworth, *Statistical Quality and Control*, Table A, p.643, McGraw-Hill, New York, 1972. Used with permission.



To employ the table for $z < 0$, use
$F_z(z) = 1 - F_z(|z|)$
where $F_z(|z|)$ is the tabulated value.

Table 2: Frequency factors for Pearson Type III Distribution

K_T values for Pearson Type III distribution (positive skew)

Skew coefficient C_s or C_w	Return period in years						
	2	5	10	25	50	100	200
	Exceedence probability						
	0.50	0.20	0.10	0.04	0.02	0.01	0.005
3.0	−0.396	0.420	1.180	2.278	3.152	4.051	4.970
2.9	−0.390	0.440	1.195	2.277	3.134	4.013	4.909
2.8	−0.384	0.460	1.210	2.275	3.114	3.973	4.847
2.7	−0.376	0.479	1.224	2.272	3.093	3.932	4.783
2.6	−0.368	0.499	1.238	2.267	3.071	3.889	4.718
2.5	−0.360	0.518	1.250	2.262	3.048	3.845	4.652
2.4	−0.351	0.537	1.262	2.256	3.023	3.800	4.584
2.3	−0.341	0.555	1.274	2.248	2.997	3.753	4.515
2.2	−0.330	0.574	1.284	2.240	2.970	3.705	4.444
2.1	−0.319	0.592	1.294	2.230	2.942	3.656	4.372
2.0	−0.307	0.609	1.302	2.219	2.912	3.605	4.298
1.9	−0.294	0.627	1.310	2.207	2.881	3.553	4.223
1.8	−0.282	0.643	1.318	2.193	2.848	3.499	4.147
1.7	−0.268	0.660	1.324	2.179	2.815	3.444	4.069
1.6	−0.254	0.675	1.329	2.163	2.780	3.388	3.990
1.5	−0.240	0.690	1.333	2.146	2.743	3.330	3.910
1.4	−0.225	0.705	1.337	2.128	2.706	3.271	3.828
1.3	−0.210	0.719	1.339	2.108	2.666	3.211	3.745
1.2	−0.195	0.732	1.340	2.087	2.626	3.149	3.661
1.1	−0.180	0.745	1.341	2.066	2.585	3.087	3.575
1.0	−0.164	0.758	1.340	2.043	2.542	3.022	3.489
0.9	−0.148	0.769	1.339	2.018	2.498	2.957	3.401
0.8	−0.132	0.780	1.336	1.993	2.453	2.891	3.312
0.7	−0.116	0.790	1.333	1.967	2.407	2.824	3.223
0.6	−0.099	0.800	1.328	1.939	2.359	2.755	3.132
0.5	−0.083	0.808	1.323	1.910	2.311	2.686	3.041
0.4	−0.066	0.816	1.317	1.880	2.261	2.615	2.949
0.3	−0.050	0.824	1.309	1.849	2.211	2.544	2.856
0.2	−0.033	0.830	1.301	1.818	2.159	2.472	2.763
0.1	−0.017	0.836	1.292	1.785	2.107	2.400	2.670
0.0	0	0.842	1.282	1.751	2.054	2.326	2.576

Cont….

Table 2 Continued

K_T values for Pearson Type III distribution (negative skew)

Skew coefficient C_s or C_w	Return period in years: 2	5	10	25	50	100	200
	Exceedence probability: 0.50	0.20	0.10	0.04	0.02	0.01	0.005
–0.1	0.017	0.846	1.270	1.716	2.000	2.252	2.482
–0.2	0.033	0.850	1.258	1.680	1.945	2.178	2.388
–0.3	0.050	0.853	1.245	1.643	1.890	2.104	2.294
–0.4	0.066	0.855	1.231	1.606	1.834	2.029	2.201
–0.5	0.083	0.856	1.216	1.567	1.777	1.955	2.108
–0.6	0.099	0.857	1.200	1.528	1.720	1.880	2.016
–0.7	0.116	0.857	1.183	1.488	1.663	1.806	1.926
–0.8	0.132	0.856	1.166	1.448	1.606	1.733	1.837
–0.9	0.148	0.854	1.147	1.407	1.549	1.660	1.749
–1.0	0.164	0.852	1.128	1.366	1.492	1.588	1.664
–1.1	0.180	0.848	1.107	1.324	1.435	1.518	1.581
–1.2	0.195	0.844	1.086	1.282	1.379	1.449	1.501
–1.3	0.210	0.838	1.064	1.240	1.324	1.383	1.424
–1.4	0.225	0.832	1.041	1.198	1.270	1.318	1.351
–1.5	0.240	0.825	1.018	1.157	1.217	1.256	1.282
–1.6	0.254	0.817	0.994	1.116	1.166	1.197	1.216
–1.7	0.268	0.808	0.970	1.075	1.116	1.140	1.155
–1.8	0.282	0.799	0.945	1.035	1.069	1.087	1.097
–1.9	0.294	0.788	0.920	0.996	1.023	1.037	1.044
–2.0	0.307	0.777	0.895	0.959	0.980	0.990	0.995
–2.1	0.319	0.765	0.869	0.923	0.939	0.946	0.949
–2.2	0.330	0.752	0.844	0.888	0.900	0.905	0.907
–2.3	0.341	0.739	0.819	0.855	0.864	0.867	0.869
–2.4	0.351	0.725	0.795	0.823	0.830	0.832	0.833
–2.5	0.360	0.711	0.771	0.793	0.798	0.799	0.800
–2.6	0.368	0.696	0.747	0.764	0.768	0.769	0.769
–2.7	0.376	0.681	0.724	0.738	0.740	0.740	0.741
–2.8	0.384	0.666	0.702	0.712	0.714	0.714	0.714
–2.9	0.390	0.651	0.681	0.683	0.689	0.690	0.690
–3.0	0.396	0.636	0.666	0.666	0.666	0.667	0.667

Source: U. S. Water Resources Council (1981).

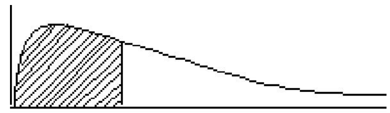
6.0

Table 3: Frequency factors for Pearson Type III Distribution

	Return Period								
Sample	5	10	15	20	25	50	75	100	1000
15	0.967	1.703	2.117	2.410	2.632	3.321	3.721	4.005	6.265
20	0.919	1.625	2.023	2.302	2.517	3.179	3.563	3.836	6.006
25	0.888	1.575	1.963	2.235	2.444	3.088	3.463	3.729	5.842
30	0.866	1.541	1.922	2.188	2.393	3.026	3.393	3.653	5.727
35	0.851	1.516	1.891	2.152	2.354	2.979	3.341	3.598	
40	0.838	1.495	1.866	2.126	2.326	2.943	3.301	3.554	5.576
45	0.829	1.478	1.847	2.104	2.303	2.913	3.268	3.520	
50	0.820	1.466	1.831	2.086	2.283	2.889	3.241	3.491	5.478
55	0.813	1.455	1.818	2.071	2.267	2.869	3.219	3.467	
60	0.807	1.446	1.806	2.059	2.253	2.852	3.200	3.446	
65	0.801	1.437	1.796	2.048	2.241	2.837	3.183	3.429	
70	0.797	1.430	1.788	2.038	2.230	2.824	3.169	3.413	5.359
75	0.972	1.423	1.780	2.029	2.220	2.812	3.155	3.400	
80	0.788	1.417	1.773	2.020	2.212	2.802	3.145	3.387	
85	0.785	1.413	1.767	2.013	2.205	2.793	3.135	3.376	
90	0.782	1.409	1.762	2.007	2.198	2.785	3.125	3.367	
95	0.780	1.405	1.757	2.002	2.193	2.777	3.116	3.357	
100	0.779	1.401	1.752	1.998	2.187	2.770	3.109	3.349	5.261
α	0.719	1.305	1.635	1.866	2.044	2.592	2.911	3.137	4.936

Source: Journal American Statistical Association 47:425-441, 1952.Z.W. Birnbaum.

Table 4: χ^2 Distribution



DOF v	$x^2_{.995}$	$x^2_{.99}$	$x^2_{.975}$	$x^2_{.95}$	$x^2_{.90}$	$x^2_{.75}$	$x^2_{.50}$	$x^2_{.25}$	$x^2_{.10}$	$x^2_{.05}$	$x^2_{.025}$	$x^2_{.01}$	$x^2_{.005}$
1	7.88	6.63	5.02	3.84	2.71	1.32	0.455	0.102	0.0158	0.0039	0.0010	0.0002	0.0000
2	10.6	9.21	7.38	5.99	4.61	2.77	1.39	0.575	.211	.103	.0506	.0201	.0100
3	12.8	11.3	9.35	7.81	6.25	4.11	2.37	1.21	.584	.352	.216	.115	.072
4	14.9	13.3	11.1	9.49	7.78	5.39	3.36	1.92	1.06	.711	.484	.297	.207
5	16.7	15.1	12.8	11.1	9.24	6.63	4.35	2.67	1.61	1.15	.831	.554	.412
6	18.5	16.8	14.4	12.6	10.6	7.84	5.35	3.45	2.20	1.64	1.24	.872	.676
7	20.3	18.5	16.0	14.1	12.0	9.04	6.35	4.25	2.83	2.17	1.69	1.24	.989
8	22.0	20.1	17.5	15.5	13.4	10.2	7.34	5.07	3.49	2.73	2.18	1.65	1.34
9	23.6	21.7	19.0	16.9	14.7	11.4	8.34	5.90	4.17	3.33	2.70	2.09	1.73
10	25.2	23.2	20.5	18.3	16.0	12.5	9.34	6.74	4.87	3.94	3.25	2.56	2.16
11	26.8	24.7	21.9	19.7	17.3	13.7	10.3	7.58	5.58	4.57	3.82	3.05	2.60
12	28.3	26.2	23.3	21.0	18.5	14.8	11.3	8.44	6.30	5.23	4.40	3.57	3.07
13	29.8	27.7	24.7	22.4	19.8	16.0	12.3	9.30	7.04	5.89	5.01	4.11	3.57
14	31.3	29.1	26.1	23.7	21.1	17.1	13.3	10.2	7.79	6.57	5.63	4.66	4.07
15	32.8	30.6	27.5	25.0	22.3	18.2	14.3	11.0	8.55	7.26	6.26	5.23	4.60
16	34.3	32.0	28.8	26.3	23.5	19.4	15.3	11.9	9.31	7.96	6.91	5.81	5.14
17	35.7	33.4	30.2	27.6	24.8	20.5	16.3	12.8	10.1	8.67	7.56	6.41	5.70
18	37.2	34.8	31.5	28.9	26.0	21.6	17.3	13.7	10.9	9.39	8.23	7.01	6.26
19	38.6	36.2	32.9	30.1	27.2	22.7	18.3	14.6	11.7	10.1	8.91	7.63	6.84
20	40.0	37.6	34.2	31.4	28.4	23.8	19.3	15.5	12.4	10.9	9.59	8.26	7.43

21	41.4	38.9	35.5	32.7	29.6	24.9	20.3	16.3	13.2	11.6	10.3	8.90	8.03
22	42.8	40.3	36.8	33.9	30.8	26.0	21.3	17.2	14.0	12.3	11.0	9.54	8.64
23	44.2	41.6	38.1	35.2	32.0	27.1	22.3	18.1	14.8	13.1	11.7	10.2	9.26
24	45.6	43.0	39.4	36.4	33.2	28.2	23.3	19.0	15.7	13.8	12.4	10.9	9.89
25	46.9	44.3	40.6	37.7	34.4	29.3	24.3	19.9	16.5	14.6	13.1	11.5	10.5
26	48.3	45.6	41.9	38.9	35.6	30.4	25.3	20.8	17.3	15.4	13.8	12.2	11.2
27	49.6	47.0	43.2	40.1	36.7	31.5	26.3	21.7	18.1	16.2	14.6	12.9	11.8
28	51.0	48.3	44.5	41.3	37.9	32.6	27.3	22.7	18.9	16.9	15.3	13.6	12.5
29	52.3	49.6	45.7	42.6	39.1	33.7	28.3	23.6	19.8	17.7	16.0	14.3	13.1
30	53.7	50.9	47.0	43.8	40.3	34.8	29.3	24.5	20.6	18.5	16.8	15.0	13.8
40	66.8	63.7	59.3	55.8	51.8	45.6	39.3	33.7	29.1	26.5	24.4	22.2	20.7
50	79.5	76.2	71.4	67.5	63.2	56.3	49.3	42.9	37.7	34.8	32.4	29.7	28.0
60	92.0	88.4	83.3	79.1	74.4	67.0	59.3	52.3	46.5	43.2	40.5	37.5	35.5
70	104.2	100.4	95.0	90.5	85.5	77.6	69.3	61.7	55.3	51.7	48.8	45.4	43.3
80	116.3	112.3	106.6	101.9	96.6	88.1	79.3	71.1	64.3	60.4	57.2	53.5	51.2
90	128.3	124.1	118.1	113.1	107.6	98.6	89.3	80.6	73.3	69.1	65.6	61.8	59.2
100	140.2	135.8	129.6	124.3	118.5	109.1	99.3	90.1	82.4	77.9	74.2	70.1	67.3

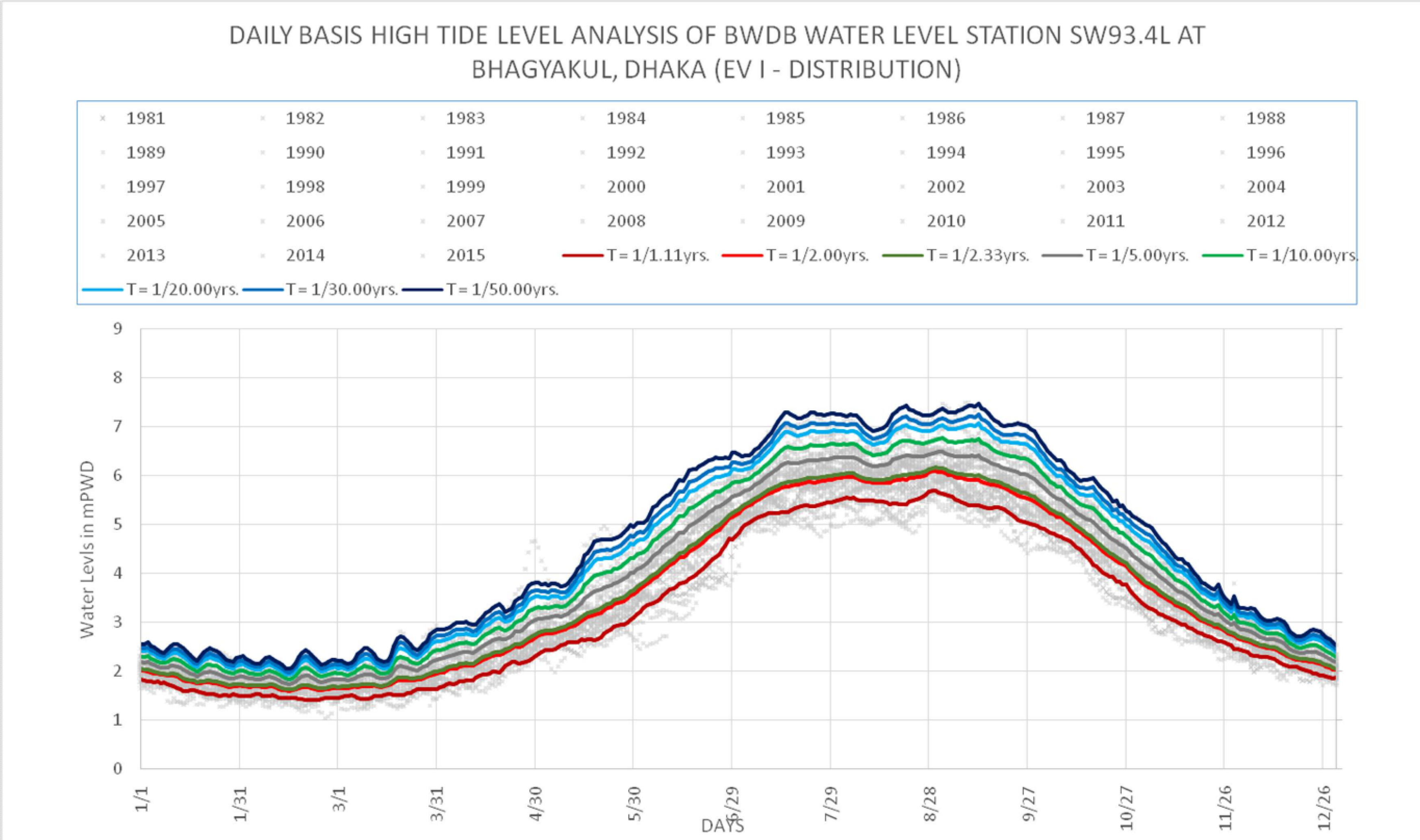
Source: Catherine M. Thompson, Table of percentage points of the χ^2 distribution, Biometrika, Vol. 32 (1941), by permission of the author and publisher.

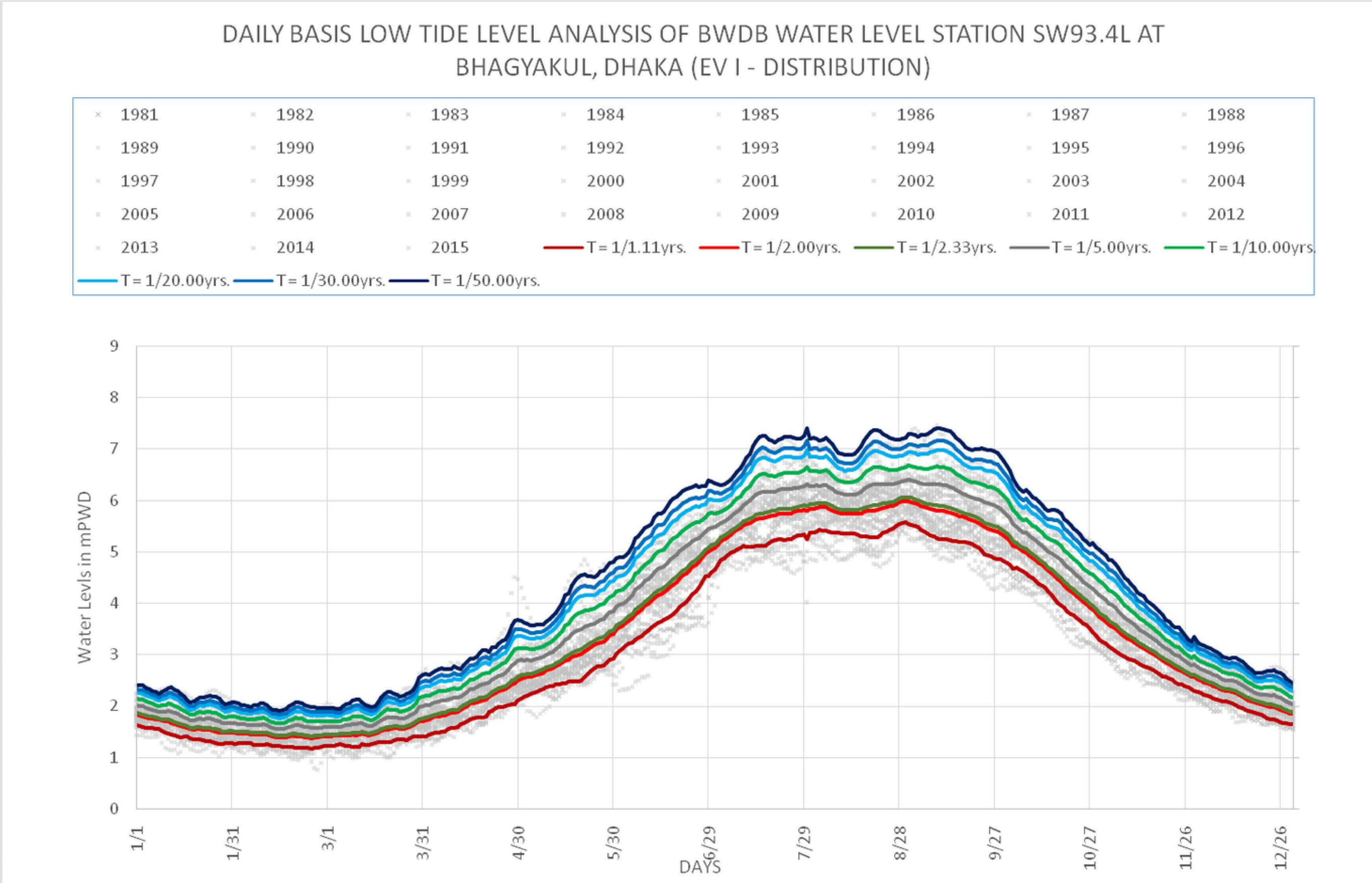
Table 5: Kolmogorov-Smirnov Distribution

Sample size (n)	Significance Level				
	.20	0.15	0.10	0.05	0.01
1	.900	.925	.950	.975	.995
2	.684	.726	.776	.842	.929
3	.565	.597	.642	.708	.829
4	.494	.725	.564	.624	.734
5	.446	.474	.510	.563	.669
6	.410	.436	.470	.521	.618
7	.381	.405	.438	.486	.577
8	.358	.381	.411	.457	.543
9	.339	.360	.388	.432	.514
10	.322	.342	.368	.409	.486
11	.307	.326	.352	.391	.468
12	.295	.313	.338	.375	.450
13	.284	.302	.325	.361	.433
14	.274	.292	.314	.349	.418
15	.266	.283	.304	.338	.404
16	.258	.274	.295	.328	.391
17	.250	.266	.286	.318	.380
18	.244	.259	.278	.309	.370
19	.237	.252	.272	.301	.361
20	.231	.246	.264	.294	.352
25	.21	.22	.24	.264	.32
30	.19	.20	.22	.242	.29
35	.18	.19	.21	.23	.27
40				.21	.25
50				.19	.23
60				.17	.21
70				.16	.19
80				.15	.18
90				.14	
100				.14	
Asymptotic Formula	$\frac{1.70}{\sqrt{n}}$	$\frac{1.14}{\sqrt{n}}$	$\frac{1.22}{\sqrt{n}}$	$\frac{1.36}{\sqrt{n}}$	$\frac{1.63}{\sqrt{n}}$

Source: Journal American Statistical Association 47:425-441, 1952.Z.W. Birnbaum.

A.1b.1 ANALYSED RESULTS OF BWDB WATER LEVEL GAUGE STATION SW 93.4L ON THE PADMA RIVER




DAILY BASIS LOW TIDE LEVEL ANALYSIS OF BWDB WATER LEVEL STATION SW93.4L AT BHAGYAKUL, DHAKA (EV I - DISTRIBUTION)
1981 1982 1983 1984 1985 1986 1987 1988
1989 1990 1991 1992 1993 1994 1995 1996
1997 1998 1999 2000 2001 2002 2003 2004
2005 2006 2007 2008 2009 2010 2011 2012
2013 2014 2015
T = 1/1.11yrs.
T = 1/2.00yrs.
T = 1/2.33yrs.
T = 1/5.00yrs.
T = 1/10.00yrs.
T = 1/20.00yrs.
T = 1/30.00yrs.
T = 1/50.00yrs.
Water Levls in mPWD
0 1 2 3 4 5 6 7 8 9
1/1 1/31 3/1 3/31 4/30 5/30 6/29 7/29 8/28 9/27 10/27 11/26 12/26
DAYS

MONTHLY BASIS ANALYSIS OF DATA OF WATER LEVEL GAUGE STATION SW 93.4L

Monthly Data

WL

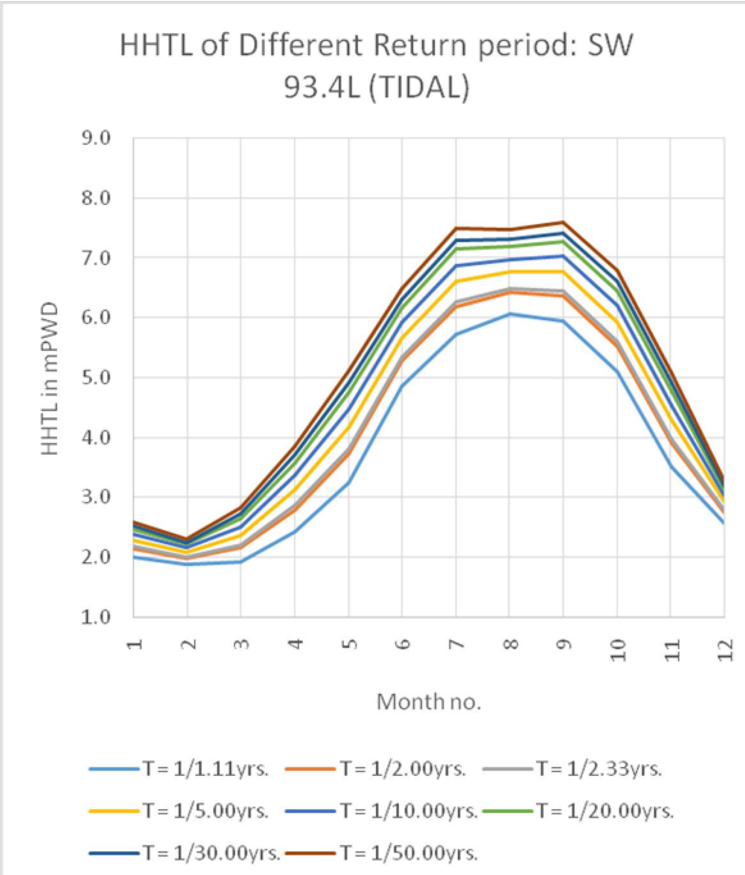
Monthly Maximum HTL (mPWD)

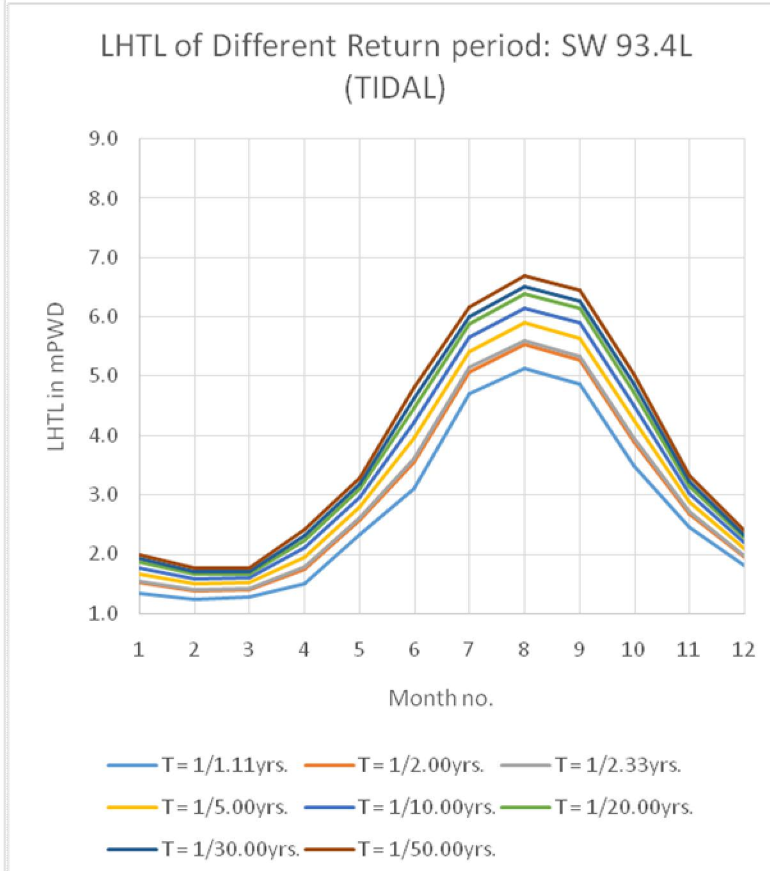
Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1981				02.77	03.29	04.74	06.04	06.28	06.07	04.92	03.30	02.68
1982	01.98	01.78	01.85									
1983				02.78	03.72	04.91	05.52	05.96	06.51	06.06	04.02	02.64
1984	02.25	01.92	02.25	02.87	04.41	05.43	06.60	06.73	06.82	05.78	03.94	02.38
1985	01.88	01.95	02.28	02.82	03.43	05.13	06.45	06.47	06.20	05.75	04.44	02.88
1986	02.15	01.82	02.07	03.15	03.12	05.01	05.88	06.35	06.09	05.42	04.22	03.07
1987	02.18	02.02	02.09	02.80	03.00	04.90	06.33	06.99	06.54	05.90	03.96	02.75
1988	02.12	02.14	02.28	02.87	04.70	04.90	06.19	07.28	07.47	05.17	03.79	02.87
1989	02.10	02.17	02.15	02.74	04.20	05.26	06.11	05.92	05.71	05.58	04.03	02.70
1990	01.97	02.10	02.28	03.47	03.97	05.51	06.32	06.27	05.85	06.09	04.30	02.95
1991	02.34	01.91	01.95	02.94	04.43	05.62	06.38	06.21	06.64	05.41	03.99	02.50
1992	01.98	02.09	01.98	02.90	03.53	04.91	05.33	05.74	05.76	04.57	03.94	02.65
1993	02.21	02.14	02.18	02.36	03.99	05.46	06.10	06.30	06.31	05.87	04.02	02.87
1994	02.25	02.01	02.85	02.93	03.44	05.38	05.58	06.35	05.95	04.95	03.46	02.66
1995	02.12	01.92	02.24	02.51	04.62	05.85	06.90	06.95	06.49	06.43	03.88	02.91
1996	02.04	02.05	02.26	02.72	04.78	05.41	06.83	06.47	06.56	05.37	04.20	02.84
1997	02.31	02.04	02.40	02.59	03.54	05.25	06.38	06.19	05.87	05.57	03.21	02.61
1998	02.28	01.98	01.82	02.62	04.09	05.58	06.84	07.15	07.50	05.26	04.74	03.11
1999	02.38	01.91	01.93	02.64	03.42	05.80	06.24	06.75	06.74	06.02	05.09	02.91
2000	02.47	01.94	02.09	03.03	03.84	05.97	06.05	06.76	06.66	05.96	03.79	02.73
2001	02.03	01.85	01.80	02.66	03.37	05.17	05.87	06.58	06.46	05.56	04.36	02.96
2002	02.15	01.85	01.96	02.70	03.62	05.52	06.86	06.87	05.94	05.44	03.64	02.78
2003	01.88	01.84	02.06	02.40	03.70	05.67	07.00	06.31	06.38	06.18	04.65	03.11
2004	02.09	01.98	02.07			05.99	07.26	06.58	06.19	05.92	03.85	02.80
2005	02.39	02.07	02.44	03.15	03.58	05.25	06.39	06.46	06.53	05.25	04.53	03.02
2006	02.15	02.06	02.21	03.09	03.05	05.57	05.87	05.82	05.98	05.32	03.36	02.40
2007	01.91	01.97	02.16	02.81	03.48	05.70	06.87	07.15	06.95	05.37	04.20	02.78
2008	02.25	02.15	02.23	02.67	03.62	05.56	06.52	06.77	07.00	05.42	04.17	02.80
2009	02.14	02.02	02.14	02.71	03.75	03.86	05.69	06.49	05.98	05.36	03.78	02.88
2010	02.05	02.02	02.64	04.64	04.96	05.92	06.30	06.57	06.72	06.07	04.01	02.81
2011	02.29	02.19	02.80	02.62	03.24	04.95	06.35	06.63	06.44	06.10	03.55	02.53
2012	02.25	02.12	02.27	02.77	03.69	05.99	06.38	06.06	06.75	06.62	03.80	02.72
2013	02.28	01.97	02.15	02.80	04.10	05.03	06.28	06.21	06.67	04.89	04.14	03.04
2014	02.44	02.15	02.23	02.80	03.98	05.26	05.66	06.58	06.57	05.50	03.56	02.68
2015	02.35	02.10	02.24	02.90	03.99	05.37	05.42	06.54	06.85	05.35	03.32	02.54
MAX	02.47	02.19	02.85	04.64	04.96	05.99	07.26	07.28	07.50	06.62	05.09	03.11
MIN	01.88	01.78	01.80	02.36	03.00	03.86	05.33	05.74	05.71	04.57	03.21	02.38
N	33	33	33	33	33	34	34	34	34	34	34	34
AVE.	02.17	02.01	02.19	02.86	03.81	05.35	06.26	06.49	06.45	05.60	03.98	02.78
σ	00.16	00.11	00.24	00.39	00.51	00.44	00.48	00.38	00.44	00.46	00.43	00.19
ANALYSED DATA:												
T = 1/1.11yrs. $K_{1.11}$ = -1.10	01.99	01.88	01.93	02.43	03.25	04.86	05.73	06.08	05.96	05.10	03.51	02.57
T = 1/2.00yrs. $K_{2.00}$ = -0.16	02.15	01.99	02.15	02.79	03.72	05.28	06.18	06.43	06.37	05.53	03.91	02.75
T = 1/2.33yrs. $K_{2.33}$ = 0.00	02.17	02.01	02.19	02.86	03.81	05.35	06.26	06.49	06.45	05.60	03.98	02.78
T = 1/5.00yrs. $K_{5.00}$ = 0.72	02.29	02.09	02.37	03.13	04.17	05.66	06.60	06.76	06.77	05.93	04.29	02.92
T = 1/10.00yrs. $K_{10.00}$ = 1.30	02.38	02.15	02.51	03.36	04.47	05.92	06.88	06.98	07.03	06.20	04.54	03.03
T = 1/20.00yrs. $K_{20.00}$ = 1.87	02.47	02.21	02.64	03.58	04.75	06.17	07.15	07.20	07.27	06.46	04.78	03.13
T = 1/30.00yrs. $K_{30.00}$ = 2.19	02.52	02.25	02.72	03.70	04.92	06.31	07.30	07.32	07.42	06.60	04.91	03.20
T = 1/50.00yrs. $K_{50.00}$ = 2.59	02.59	02.29	02.82	03.86	05.12	06.49	07.50	07.47	07.60	06.79	05.09	03.27

Monthly Minimum HTL (mPWD)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1981				01.77	02.35	03.35	04.54	05.73	04.98	03.29	02.42	01.78
1982	01.31	01.26	01.21									
1983				01.51	02.41	03.44	04.75	05.03	05.58	03.95	02.64	01.82
1984	01.50	01.03	01.32	01.65	02.66	04.29	05.19	05.07	05.85	04.03	02.31	01.70
1985	01.34	01.31	01.36	01.73	02.63	03.34	05.20	05.40	05.54	04.50	02.95	02.03
1986	01.46	01.16	01.23	01.56	02.54	02.45	05.15	05.15	05.33	04.15	03.03	01.83
1987	01.40	01.37	01.20	01.65	02.47	02.98	05.00	06.15	06.01	03.97	02.67	01.96
1988	01.34	01.44	01.46	01.92	02.52	04.28	04.77	05.72	05.17	03.65	02.74	01.85
1989	01.57	01.44	01.29	01.43	02.68	04.12	04.67	05.24	05.38	04.10	02.78	01.84
1990	01.46	01.30	01.44	01.71	03.09	03.98	05.04	05.63	05.20	03.89	02.64	01.97
1991	01.62	01.32	01.34	01.99	02.59	03.98	05.19	05.36	05.51	03.99	02.52	01.93
1992	01.41	01.32	01.38	01.88	02.62	03.08	04.85	04.82	04.80	03.99	02.74	01.97
1993	01.38	01.27	01.45	01.43	02.50	03.74	05.17	05.65	05.71	04.08	02.81	01.95
1994	01.42	01.36	01.44	02.32	02.65	03.30	04.92	05.54	05.06	03.33	02.22	01.70
1995	01.27	01.25	01.22	01.73	02.49	04.13	05.72	05.66	05.87	03.94	02.98	01.96
1996	01.53	01.45	01.39	02.02	03.11	04.00	05.61	06.06	05.30	04.19	02.87	02.15
1997	01.58	01.52	01.47	02.05	02.23	03.48	04.93	05.38	05.27	03.24	02.36	02.11
1998	01.62	01.40	01.39	01.56	02.38	04.00	05.62	06.54	05.17	04.41	03.14	02.06
1999	01.83	01.53	01.53	01.58	02.41	03.57	05.83	05.80	05.90	05.16	02.93	02.40
2000	01.71	01.66	01.72	01.86	03.08	03.90	05.55	06.02	06.07	03.69	02.76	02.05
2001	01.58	01.52	01.50	01.54	02.48	03.55	05.04	05.49	05.14	04.42	02.96	02.00
2002	01.57	01.46	01.45	01.76	02.52	03.30	05.19	06.02	05.10	03.47	02.66	01.83
2003	01.49	01.46	01.51	01.65	02.61	03.40	05.72	05.75	05.98	04.63	03.12	02.11
2004	01.80	01.63	01.55			04.05	05.46	05.63	04.72	03.97	02.81	02.33
2005	02.14	01.70	01.67	02.46	02.86	03.52	04.89	05.43	04.57	04.28	02.87	02.07
2006	01.43	01.46	01.70	01.68	02.50	02.63	04.96	04.96	05.35	03.42	02.24	01.75
2007	01.31	01.27	01.37	01.85	02.62	03.76	04.81	06.00	05.40	04.32	02.86	02.10
2008	01.65	01.55	01.47	01.82	02.75	03.40	05.62	06.16	05.18	03.96	02.82	02.07
2009	01.60	01.25	01.52	01.69	02.55	03.35	04.00	05.35	05.04	03.78	02.51	01.84
2010	01.47	01.27	01.26	02.30	03.32	04.43	05.65	05.53	06.18	04.06	02.79	02.07
2011	01.69	01.41	01.45	01.95	02.55	03.36	04.99	06.42	05.40	03.68	02.66	02.06
2012	01.52	01.45	01.52	01.58	02.80	03.40	05.47	05.50	05.27	03.86	02.70	01.93
2013	01.58	01.28	01.42	01.64	02.55	03.81	05.12	05.90	04.40	04.06	02.74	02.03
2014	01.60	01.52	01.33	01.64	01.97	03.48	05.21	05.27	05.06	03.54	02.52	01.89
2015	01.54	01.36	01.42	01.72	02.72	04.08	04.98	04.98	05.12	03.37	02.49	01.97
MAX	02.14	01.70	01.72	02.46	03.32	04.43	05.83	06.54	06.18	05.16	03.14	02.40
MIN	01.27	01.03	01.20	01.43	01.97	02.45	04.00	04.82	04.40	03.24	02.22	01.70
N	33	33	33	33	33	34	34	34	34	34	34	34
AVE.	01.54	01.39	01.42	01.78	02.61	03.62	05.14	05.60	05.34	03.95	02.71	01.97
σ	00.17	00.14	00.13	00.25	00.26	00.46	00.39	00.42	00.43	00.42	00.24	00.16
ANALYSED DATA:												
T = 1/1.11yrs. $K_{1.11}$ = -1.10	01.34	01.23	01.28	01.50	02.32	03.11	04.71	05.14	04.87	03.49	02.45	01.80
T = 1/2.00yrs. $K_{2.00}$ = -0.16	01.51	01.37	01.40	01.74	02.57	03.54	05.08	05.53	05.27	03.88	02.67	01.95
T = 1/2.33yrs. $K_{2.33}$ = 0.00	01.54	01.39	01.42	01.78	02.61	03.62	05.14	05.60	05.34	03.95	02.71	01.97
T = 1/5.00yrs. $K_{5.00}$ = 0.72	01.66	01.50	01.52	01.95	02.80	03.95	05.42	05.90	05.65	04.25	02.88	02.09
T = 1/10.00yrs. $K_{10.00}$ = 1.30	01.76	01.58	01.59	02.10	02.96	04.21	05.66	06.15	05.90	04.49	03.02	02.18
T = 1/20.00yrs. $K_{20.00}$ = 1.87	01.86	01.66	01.67	02.24	03.10	04.47	05.88	06.38	06.14	04.73	03.15	02.27
T = 1/30.00yrs. $K_{30.00}$ = 2.19	01.92	01.71	01.71	02.32	03.19	04.62	06.00	06.52	06.28	04.86	03.23	02.32
T = 1/50.00yrs. $K_{50.00}$ = 2.59	01.99	01.77	01.76	02.42	03.29	04.80	06.16	06.69	06.45	05.03	03.32	02.38

MONTHLY BASIS ANALYSIS OF DATA OF WATER LEVEL GAUGE STATION SW 93.4L





MONTHLY BASIS ANALYSIS OF DATA OF WATER LEVEL GAUGE STATION SW 93.4L

Monthly Data: WL

Monthly Maximum HTL (mPWD)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1981				02.47	03.05	04.48	05.97	06.22	05.94	04.65	03.05	02.33
1982	01.58	01.35	01.42									
1983				02.45	03.60	04.74	05.44	05.90	06.46	05.98	03.82	02.42
1984	01.77	01.45	01.68	02.43	04.21	05.35	06.52	06.69	06.75	05.67	03.80	02.15
1985	01.61	01.53	01.93	02.68	03.21	04.99	06.34	06.37	06.09	05.60	04.18	02.61
1986	01.79	01.51	01.72	02.73	02.85	04.74	05.79	06.20	05.91	05.32	03.90	02.87
1987	01.90	01.53	01.59	02.59	02.85	04.74	06.29	06.97	06.46	05.85	03.79	02.55
1988	01.82	01.59	01.89	02.52	04.53	04.80	06.09	07.22	07.40	04.98	03.54	02.73
1989	01.78	01.79	01.70	02.57	04.04	05.11	06.01	05.84	05.63	05.49	03.79	02.49
1990	01.67	01.65	01.86	03.18	03.81	05.34	06.27	06.23	05.81	05.89	03.69	02.59
1991	02.14	01.82	01.54	02.66	04.30	05.54	06.28	06.10	06.59	05.34	03.87	02.44
1992	01.86	01.92	01.87	02.80	03.40	04.80	05.11	05.51	05.62	04.47	03.83	02.59
1993	02.15	01.76	01.76	02.12	03.86	05.30	05.94	06.14	06.19	05.78	03.78	02.67
1994	01.97	01.69	02.63	02.72	03.32	05.22	05.48	06.29	05.86	04.88	03.19	02.28
1995	01.73	01.49	01.83	02.11	04.45	05.74	06.83	06.87	06.42	06.37	03.76	02.76
1996	01.82	01.75	02.00	02.51	04.59	05.25	06.80	06.39	06.48	05.27	04.11	02.78
1997	02.07	01.85	02.33	02.37	03.37	05.01	06.30	06.10	05.77	05.49	03.09	02.52
1998	02.18	01.83	01.67	02.46	03.97	05.46	06.78	07.10	07.46	05.17	04.67	03.05
1999	02.29	01.83	01.82	02.38	03.35	05.72	06.17	06.71	06.67	05.98	05.03	02.86
2000	02.40	01.87	01.99	02.95	03.79	05.88	05.95	06.71	06.57	05.89	03.73	02.66
2001	01.97	01.78	01.74	02.57	03.26	05.00	05.80	06.53	06.40	05.51	04.31	02.90
2002	02.09	01.79	01.91	02.62	03.57	05.44	06.79	06.80	05.87	05.36	03.46	02.73
2003	01.82	01.77	01.92	02.23	03.61	05.44	06.94	06.25	06.31	06.13	04.60	03.06
2004	02.01	01.92	02.01			05.94	07.20	06.50	06.10	05.84	03.81	02.71
2005	02.31	02.02	02.38	03.06	03.46	05.07	06.32	06.31	06.45	05.18	04.46	02.97
2006	02.11	01.96	02.13	02.96	02.97	05.52	05.82	05.72	05.86	05.23	03.21	02.22
2007	01.73	01.53	01.64	02.58	03.24	05.60	06.78	07.08	06.90	05.30	04.07	02.60
2008	01.91	01.70	01.75	02.49	03.28	05.38	06.47	06.68	06.95	05.30	04.01	02.59
2009	01.84	01.58	01.72	02.46	03.36	03.63	05.53	06.39	05.92	05.18	03.65	02.60
2010	01.77	01.57	02.06	04.50	04.84	05.82	06.21	06.47	06.66	06.01	03.87	02.63
2011	01.90	01.66	02.18	02.20	03.01	04.78	06.26	06.55	06.34	06.00	03.37	02.35
2012	01.90	01.62	01.70	02.58	03.52	05.84	06.27	05.92	06.70	06.49	03.50	02.44
2013	01.82	01.49	01.63	02.39	03.87	04.88	06.18	06.09	06.58	04.58	03.91	02.71
2014	02.02	01.71	01.71	02.39	03.80	05.09	05.49	06.53	06.52	05.39	03.22	02.34
2015	01.90	01.53	01.66	02.48	03.76	05.20	05.26	06.49	06.42	05.08	03.02	02.19
MAX	02.40	02.02	02.63	04.50	04.84	05.94	07.20	07.22	07.46	06.49	05.03	03.06
MIN	01.58	01.35	01.42	02.11	02.85	03.63	05.11	05.51	05.62	04.47	03.02	02.15
N	33	33	33	33	33	34	34	34	34	34	34	34
AVE.	01.93	01.69	01.86	02.61	03.64	05.20	06.17	06.41	06.35	05.49	03.80	02.60
σ	00.20	00.17	00.26	00.42	00.52	00.47	00.50	00.40	00.45	00.49	00.47	00.24

Monthly Minimum HTL (mPWD)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1981				01.46	02.13	03.14	04.36	05.61	04.71	03.08	02.13	01.55
1982	01.12	01.05	00.98									
1983				01.39	02.30	03.31	04.64	04.93	05.46	03.84	02.38	01.62
1984	01.31	00.76	01.06	01.39	02.37	04.04	05.02	04.98	05.66	03.89	02.20	01.63
1985	01.18	01.06	01.23	01.60	02.48	03.01	04.97	05.32	05.45	04.27	02.68	01.84
1986	01.25	00.95	01.02	01.25	02.36	02.30	05.02	05.05	05.24	03.94	02.85	01.66
1987	01.25	01.11	00.99	01.43	02.36	02.83	04.88	06.11	05.94	03.87	02.53	01.77
1988	01.21	01.23	01.29	01.69	02.30	04.02	04.50	05.66	04.92	03.65	02.54	01.75
1989	01.42	01.30	01.20	01.26	02.53	03.85	04.53	05.21	05.26	03.84	02.55	01.57
1990	01.29	01.19	01.27	01.58	02.96	03.82	04.95	05.58	05.03	03.58	02.54	01.81
1991	01.49	01.14	01.22	01.81	02.48	03.89	05.07	05.24	05.41	03.78	02.45	01.82
1992	01.33	01.26	01.31	01.74	02.53	02.96	04.66	04.71	04.63	03.89	02.69	01.93
1993	01.28	01.20	01.24	01.29	02.40	03.58	05.01	05.51	05.64	03.83	02.69	01.86
1994	01.30	01.26	01.30	02.19	02.53	03.16	04.76	05.46	04.98	03.22	02.11	01.54
1995	01.02	01.06	01.00	01.46	02.16	03.90	05.63	05.58	05.80	03.34	02.77	01.82
1996	01.35	01.23	01.22	01.77	02.95	03.85	05.44	05.99	05.17	03.99	02.82	02.00
1997	01.47	01.34	01.35	01.96	02.13	03.34	04.82	05.31	05.21	03.13	02.28	02.05
1998	01.52	01.31	01.32	01.48	02.31	03.93	05.50	06.46	05.11	04.34	03.07	02.02
1999	01.80	01.50	01.49	01.52	02.30	03.50	05.78	05.73	05.86	05.10	02.88	02.37
2000	01.67	01.60	01.65	01.78	03.00	03.84	05.48	05.95	05.98	03.63	02.69	02.00
2001	01.52	01.47	01.46	01.48	02.42	03.46	04.98	05.41	05.09	04.36	02.91	01.94
2002	01.53	01.40	01.38	01.68	02.44	03.24	05.12	05.96	05.03	03.40	02.61	01.78
2003	01.44	01.40	01.45	01.57	02.46	03.30	05.56	05.70	05.93	04.52	03.07	02.07
2004	01.73	01.58	01.48			03.94	05.41	05.50	04.66	03.91	02.75	02.27
2005	02.09	01.65	01.60	02.32	02.80	03.46	04.81	05.35	04.50	04.21	02.82	02.00
2006	01.36	01.40	01.64	01.62	02.39	02.57	04.89	04.90	05.19	03.30	02.14	01.57
2007	01.25	01.16	01.15	01.42	02.37	03.55	04.65	05.88	05.32	04.17	02.65	01.94
2008	01.52	01.31	01.28	01.58	02.52	03.14	05.47	06.09	05.07	03.70	02.60	01.87
2009	01.40	01.10	01.37	01.48	02.32	03.21	03.81	05.22	04.90	03.66	02.40	01.65
2010	01.27	01.05	01.07	02.15	03.18	04.26	05.57	05.42	06.09	03.90	02.67	01.90
2011	01.45	01.21	01.21	01.80	02.35	03.22	04.89	06.31	05.23	03.48	02.41	01.92
2012	01.41	01.27	01.22	01.33	02.58	03.14	05.35	05.34	05.16	03.54	02.47	01.76
2013	01.36	01.00	01.17	01.35	02.27	03.63	04.90	05.82	04.27	03.90	02.64	01.89
2014	01.37	01.31	01.14	01.35	01.78	03.35	05.05	05.10	04.89	03.27	02.36	01.70
2015	01.25	01.15	01.10	01.43	02.52	03.90	04.02	04.84	04.95	03.07	02.26	01.72
MAX	02.09	01.65	01.65	02.32	03.18	04.26	05.78	06.46	06.09	05.10	03.07	02.37
MIN	01.02	00.76	00.98	01.25	01.78	02.30	03.81	04.71	04.27	03.07	02.11	01.54
N	33	33	33	33	33	34	34	34	34	34	34	34
AVE.	01.40	01.24	01.27	01.59	02.45	03.46	04.99	05.51	05.23	03.78	02.58	01.84
σ	00.21	00.19	00.18	00.27	00.28	00.45	00.45	00.43	00.45	00.44	00.25	00.19

ANALYSED DATA:

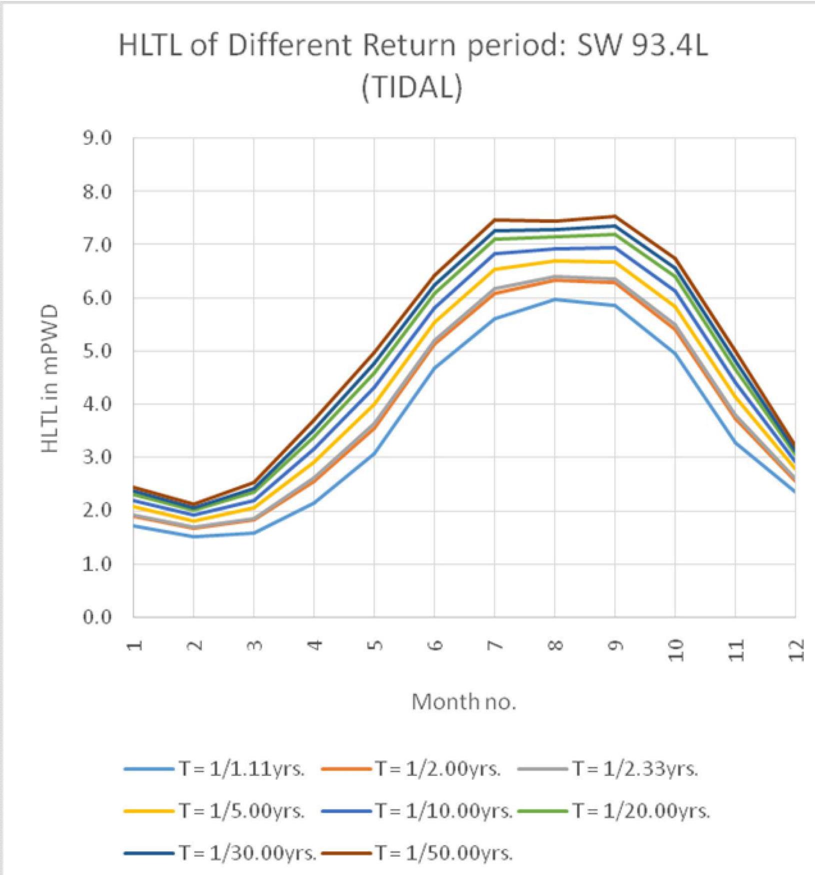
Monthly Maximum HTL (mPWD)

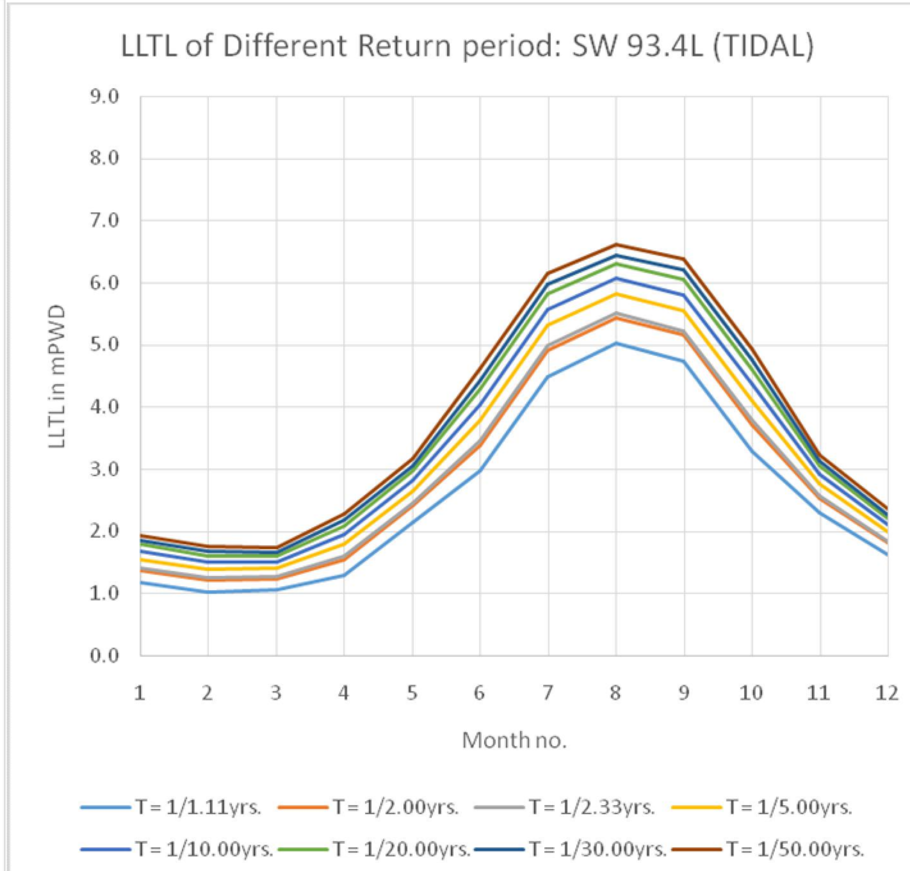
T	K		Value	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
T = 1/1.11yrs.	$K_{1.11}$	=	-1.10	01.71	01.51	01.58	02.15	03.07	04.68	05.61	05.97	05.85	04.95	03.28	02.34
T = 1/2.00yrs.	$K_{2.00}$	=	-0.16	01.90	01.66	01.82	02.54	03.55	05.12	06.08	06.34	06.28	05.41	03.72	02.56
T = 1/2.33yrs.	$K_{2.33}$	=	0.00	01.93	01.69	01.86	02.61	03.64	05.20	06.17	06.41	06.36	05.49	03.80	02.60
T = 1/5.00yrs.	$K_{5.00}$	=	0.72	02.07	01.81	02.04	02.91	04.01	05.54	06.53	06.70	06.68	05.84	04.13	02.77
T = 1/10.00yrs.	$K_{10.00}$	=	1.30	02.19	01.91	02.19	03.16	04.31	05.82	06.82	06.93	06.95	06.13	04.41	02.91
T = 1/20.00yrs.	$K_{20.00}$	=	1.87	02.30	02.00	02.34	03.39	04.60	06.08	07.11	07.16	07.20	06.40	04.67	03.04
T = 1/30.00yrs.	$K_{30.00}$	=	2.19	02.37	02.05	02.42	03.53	04.77	06.24	07.27	07.29	07.35	06.56	04.82	03.12
T = 1/50.00yrs.	$K_{50.00}$	=	2.59	02.45	02.12	02.52	03.70	04.98	06.43	07.47	07.45	07.53	06.75	05.01	03.21

Monthly Minimum HTL (mPWD)

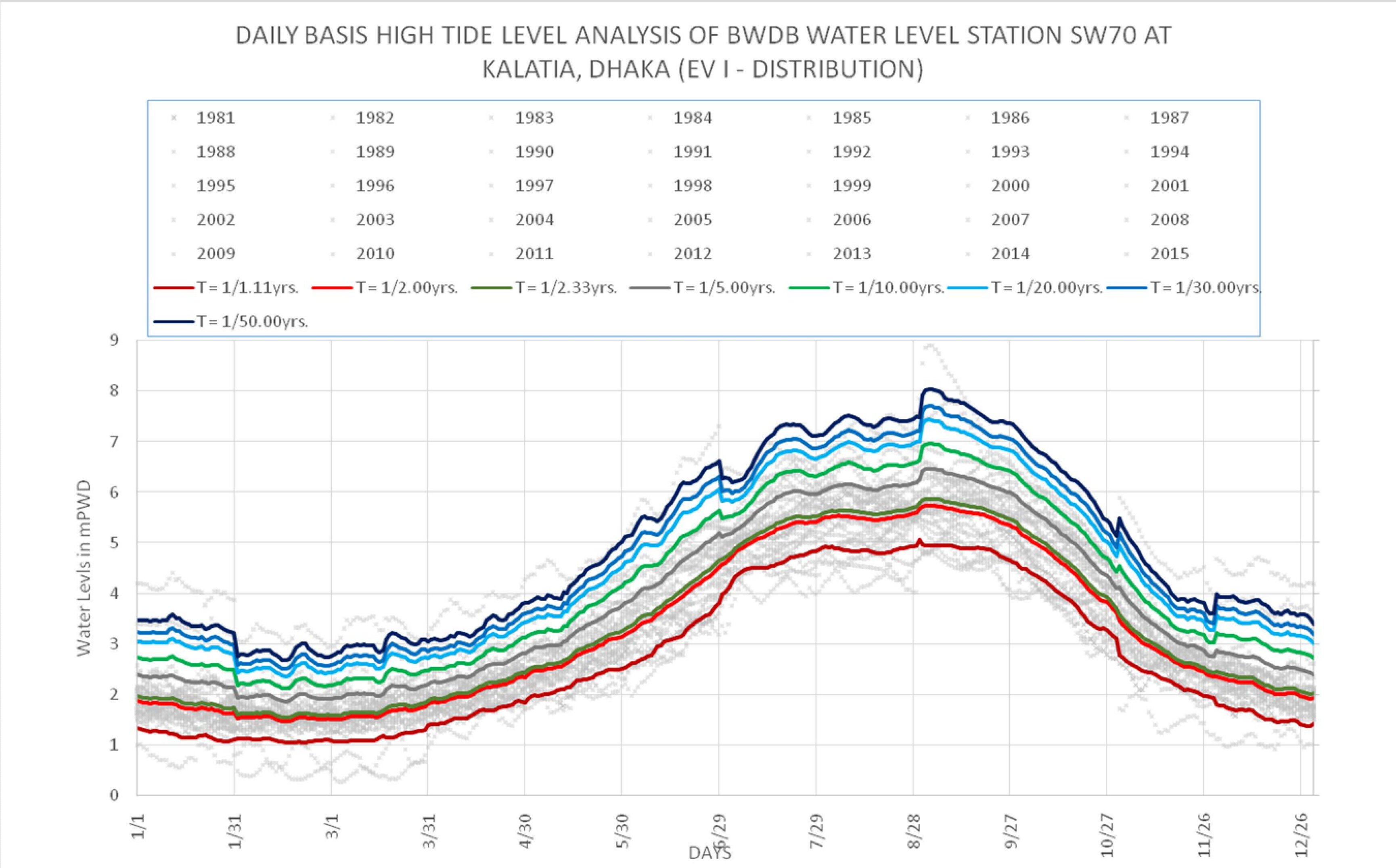
T	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
T = 1/1.11yrs.	01.17	01.03	01.07	01.30	02.15	02.97	04.49	05.03	04.74	03.29	02.30	01.63
T = 1/2.00yrs.	01.37	01.21	01.24	01.55	02.41	03.39	04.91	05.44	05.15	03.71	02.53	01.81
T = 1/2.33yrs.	01.40	01.24	01.27	01.59	02.45	03.46	04.99	05.51	05.23	03.78	02.58	01.84
T = 1/5.00yrs.	01.55	01.38	01.40	01.79	02.65	03.78	05.31	05.82	05.55	04.10	02.76	01.98
T = 1/10.00yrs.	01.67	01.50	01.51	01.94	02.81	04.04	05.57	06.07	05.81	04.36	02.91	02.10
T = 1/20.00yrs.	01.79	01.61	01.61	02.09	02.97	04.29	05.82	06.31	06.06	04.61	03.05	02.20
T = 1/30.00yrs.	01.85	01.67	01.67	02.18	03.06	04.44	05.97	06.45	06.20	04.75	03.13	02.27
T = 1/50.00yrs.	01.94	01.75	01.74	02.29	03.17	04.62	06.15	06.62	06.38	04.93	03.24	02.35

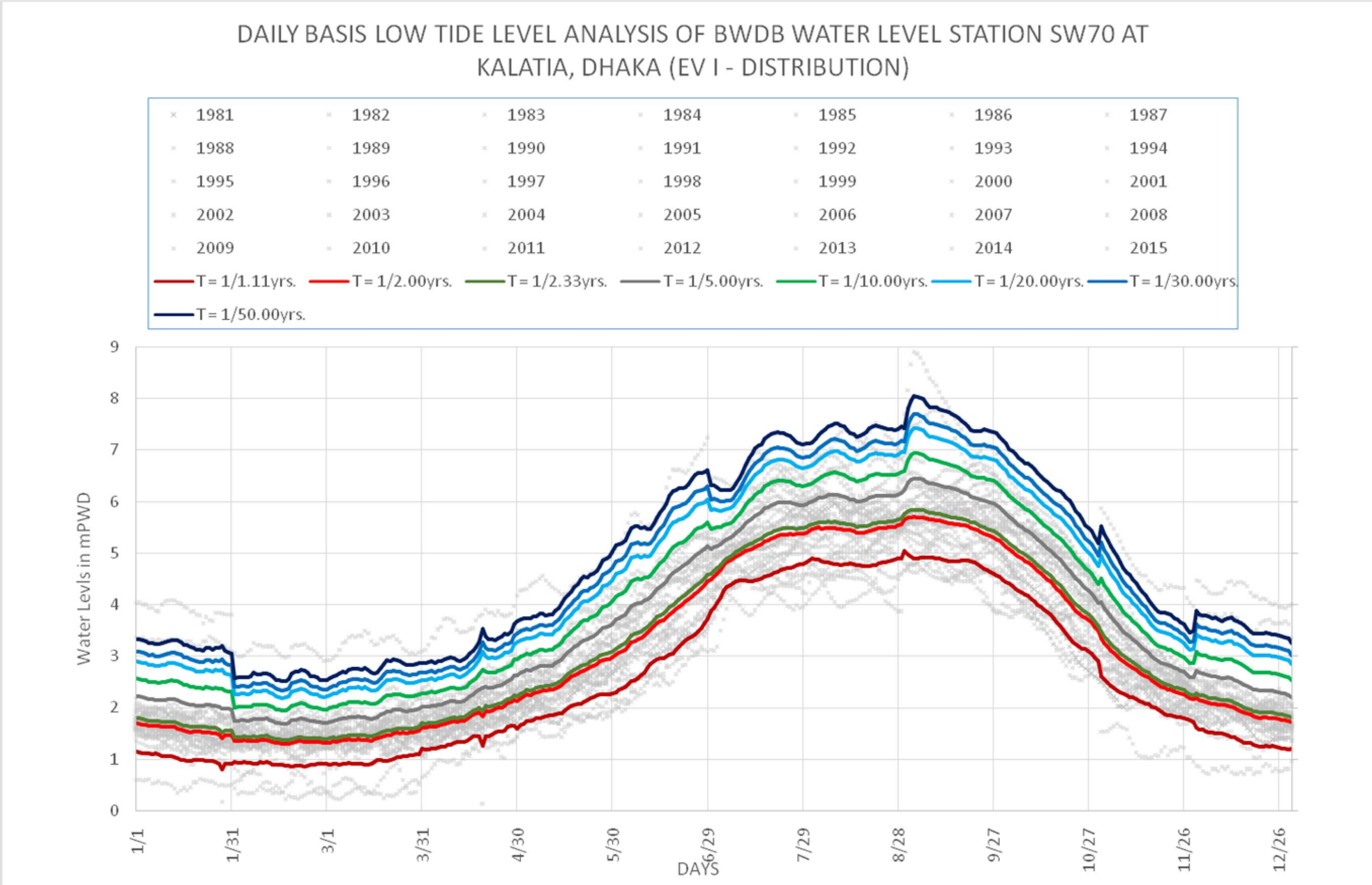
MONTHLY BASIS ANALYSIS OF DATA OF WATER LEVEL GAUGE STATION SW 93.4L





A.1b.2 ANALYSED RESULTS OF BWDB WATER LEVEL GAUGE STATION SW 70 ON DHALESWARI RIVER




DAILY BASIS LOW TIDE LEVEL ANALYSIS OF BWDB WATER LEVEL STATION SW70 AT KALATIA, DHAKA (EV I - DISTRIBUTION)
1981 1982 1983 1984 1985 1986 1987
1988 1989 1990 1991 1992 1993 1994
1995 1996 1997 1998 1999 2000 2001
2002 2003 2004 2005 2006 2007 2008
2009 2010 2011 2012 2013 2014 2015
T = 1/1.11yrs. T = 1/2.00yrs. T = 1/2.33yrs. T = 1/5.00yrs. T = 1/10.00yrs. T = 1/20.00yrs. T = 1/30.00yrs.
T = 1/50.00yrs.
Water Levls in mPWD
0 1 2 3 4 5 6 7 8 9
1/1 1/31 3/1 3/31 4/30 5/30 6/29 7/29 8/28 9/27 10/27 11/26 12/26
DAYS

MONTHLY BASIS ANALYSIS OF DATA OF WATER LEVEL GAUGE STATION SW 70 (HTL)

Monthly Data: WL

Monthly Maximum HTL (mPWD)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1981				02.41	02.77	03.75	05.52	05.96	05.84	04.98	02.70	02.58
1982	01.60	00.64	00.66									
1983				02.70	03.53	04.58	05.37	05.75	06.38	06.25	04.23	02.28
1984	01.90	01.66	01.97	02.75	04.37	05.30	06.59	06.94	07.11	06.77	04.22	02.20
1985	01.85	01.74	02.20	02.66	03.25	04.79	05.95	06.18	05.84	05.45	04.08	02.35
1986	01.82	01.58	01.82	02.80	02.82	04.70	05.75	06.10	06.20	06.06	04.36	02.58
1987	01.88	01.75	01.85	02.68	02.90	04.76	06.15	07.53	06.69	06.39	03.99	02.47
1988	01.98	01.93	01.96	02.42	04.28	04.76	06.36	07.85	08.91	05.80	04.23	03.12
1989	01.92	02.05	02.08	02.47	03.50	04.93	05.92	05.78	05.72	05.68	04.15	02.40
1990	01.96	01.80	02.10	02.95	03.44	05.09	06.02	06.12	05.62	06.00	04.10	02.44
1991	02.10	01.80	01.85	02.40	04.00	05.35	06.35	05.91	06.27	05.65	03.66	02.45
1992	02.20	02.36	02.32	02.65	03.30	04.10	04.78	04.69	04.82	04.54	03.43	02.20
1993	01.80	01.88	01.98	02.13	03.76	04.90	05.88	06.14	06.40	05.64	03.74	02.62
1994	02.25	01.80	02.70	02.51	02.95	04.70	04.75	05.80	05.45	04.52	02.91	02.16
1995	01.64	01.59	01.76	02.09	03.82	05.43	06.99	06.84	06.38	06.26	03.24	02.40
1996	01.70	01.63	01.86	02.14	03.75	04.19	06.65	06.36	06.29	04.85	03.82	02.30
1997	02.04	01.62	01.76	01.94	03.12	04.26	06.10	05.88	05.58	05.37	03.80	01.95
1998	01.79	01.66	01.97	02.53	02.97	04.52			07.78	05.03	04.10	02.59
1999	02.07	01.66	01.79	02.26	03.02		05.98	06.51	06.57	05.53	05.89	03.92
2000	03.50	03.39	03.54	04.12	05.01	07.30	06.48	07.41	06.98	06.35	03.54	02.33
2001	01.97	01.94	01.90	02.38	03.12	05.00	05.69	06.60	05.89	05.15	04.10	02.81
2002	02.13		02.39	03.20								
2003							06.67	05.90	05.93	05.87	03.78	02.32
2004	01.76	01.68	02.18			05.20		05.07	05.07	05.28	03.39	04.71
2005	04.40											
2006											02.01	01.56
2007	01.01	01.07	01.30	01.77	02.15	04.46	05.66	06.63	06.21	05.12	03.22	01.99
2008	01.89	01.70	01.82	01.99	02.58	03.88	05.37	05.91	06.23	04.41	03.26	02.53
2009	02.08	02.01	02.03	02.55	03.10	03.46	04.57	05.58		04.16	03.06	02.79
2010	02.12	02.22	02.72	03.70	04.26	05.10	05.57	05.58	06.01	05.70	03.52	03.02
2011	02.52	02.45	02.99	02.92	02.77	03.78	05.06	05.68	05.65	04.82	03.05	02.81
2012	02.57	02.51	02.59	02.59	02.96	04.56	05.29	05.20	05.40	05.48	03.08	02.49
2013	02.09	01.86	02.05	02.60	03.80	03.98	05.15	05.23	05.37	04.05	03.40	02.73
2014	02.21	02.06	02.11	02.64	03.21	04.29	04.89	05.99	06.04	05.16	03.36	02.71
2015	02.50	02.32	02.35	02.98	03.42		04.83	05.56	05.75	04.73	02.84	02.46
MAX	04.40	03.39	03.54	04.12	05.01	07.30	06.99	07.85	08.91	06.77	05.89	04.71
MIN	01.01	00.64	00.66	01.77	02.15	03.46	04.57	04.69	04.82	04.05	02.01	01.56
N	31	29	30	30	29	28	29	30	30	31	32	32
AVE.	02.10	01.87	02.09	02.60	03.38	04.68	05.74	06.09	06.15	05.39	03.63	02.57
σ	00.59	00.48	00.51	00.49	00.62	00.73	00.65	00.72	00.80	00.69	00.68	00.56

Monthly Minimum HTL (mPWD)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1981				01.19	01.77	02.93	03.98	05.56	05.03	02.70	01.97	01.42
1982	01.14	00.31	00.26									
1983				01.58	02.25	03.45	04.57	04.90	05.57	04.31	02.31	01.66
1984	01.45	01.21	01.23	01.43	02.49	04.31	05.14	05.66	05.70	04.34	02.20	01.73
1985	01.37	01.24	01.41	01.58	02.43	02.85	04.82	05.30	05.46	04.20	02.34	01.60
1986	01.23	00.96	01.13	01.25	02.24	01.97	04.88	05.50	05.69	04.42	02.50	01.66
1987	01.32	01.32	01.25	01.58	02.30	02.85	04.90	06.22	06.38	04.11	02.39	01.92
1988	01.31	01.35	01.30	01.55	02.10	04.09	04.67	05.93	05.88	04.38	02.85	01.62
1989	01.35	01.50	01.40	01.44	02.45	03.77	04.58	05.38	05.39	04.33	02.38	01.69
1990	01.50	01.22	01.26	01.63	02.74	03.52	05.04	05.65	05.13	04.22	02.37	01.70
1991	01.33	01.25	01.24	01.60	02.25	03.95	05.25	05.50	05.60	03.73	02.25	02.04
1992	01.80	01.72	01.73	02.00	02.32	02.59	04.26	04.26	04.46	03.51	02.24	01.70
1993	01.28	01.20	01.24	01.33	02.22	03.58	04.91	05.54	05.46	03.83	02.63	02.00
1994	02.00	01.40	01.47	01.96	02.05	02.75	04.42	04.75	04.57	02.89	01.76	01.48
1995	01.14	01.18	01.26	01.42	02.05	03.49	05.44	05.54	05.59	03.29	02.42	01.70
1996	01.37	01.30	01.24	01.72	02.12	03.36	04.37	05.78	04.91	03.80	02.34	01.92
1997	01.50	01.48	01.42	01.64	01.69	03.02	04.19	05.26	04.91	03.98	01.85	01.62
1998	01.42	01.28	01.32	01.65	02.04	02.87			05.12	03.76	02.50	01.79
1999	01.34	01.37	01.40	01.42	02.40		05.36	05.39	05.58	04.64	03.98	03.39
2000	03.12	03.00	02.92	03.17	04.25	05.13	06.11	06.37	06.10	03.34	02.34	01.91
2001	01.63	01.51	01.45	01.57	02.15	03.22	04.85	05.04	05.04	04.09	02.74	02.02
2002	01.77		01.58	01.81								
2003							05.96	05.25	05.60	03.91	02.36	01.74
2004	01.33	01.29	01.26			03.49		04.02	04.02	03.51	02.03	04.14
2005	03.76											
2006											01.19	00.91
2007	00.54	00.47	00.45	00.94	01.63	02.29	03.81	05.40	05.18	03.11	02.26	01.27
2008	01.26	01.07	01.09	01.40	01.78	02.32	04.09	05.33	04.47	03.00	02.26	01.92
2009	01.61	01.29	01.48	01.78	02.08	02.52	03.22	04.14		02.83	02.19	01.85
2010	01.63	01.54	01.62	02.19	02.81	03.92	05.10	04.88	05.61	03.51	02.66	02.32
2011	01.97	01.72	01.77	02.19	02.04	02.70	03.75	05.11	04.55	03.08	02.64	02.24
2012	01.97	01.77	01.65	01.57	02.41	02.83	04.54	04.57	04.47	03.05	02.35	01.74
2013	01.54	01.24	01.44	01.69	02.39	03.14	03.90	04.87	03.91	03.14	02.28	01.88
2014	01.53	01.53	01.28	01.69	01.91	02.83	04.36	04.51	04.83	03.06	02.50	02.06
2015	01.79	01.67	01.70	01.96	02.73		04.34	04.02	04.68	02.75	02.17	01.92
MAX	03.76	03.00	02.92	03.17	04.25	05.13	06.11	06.37	06.38	04.64	03.98	04.14
MIN	00.54	00.31	00.26	00.94	01.63	01.97	03.22	04.02	03.91	02.70	01.19	00.91
N	31	29	30	30	29	28	29	30	30	31	32	32
AVE.	01.59	01.36	01.38	01.66	02.28	03.20	04.65	05.19	05.16	03.64	02.35	01.89
σ	00.58	00.45	00.43	00.40	00.48	00.69	00.65	00.60	00.60	00.58	00.43	00.57

ANALYSED DATA:

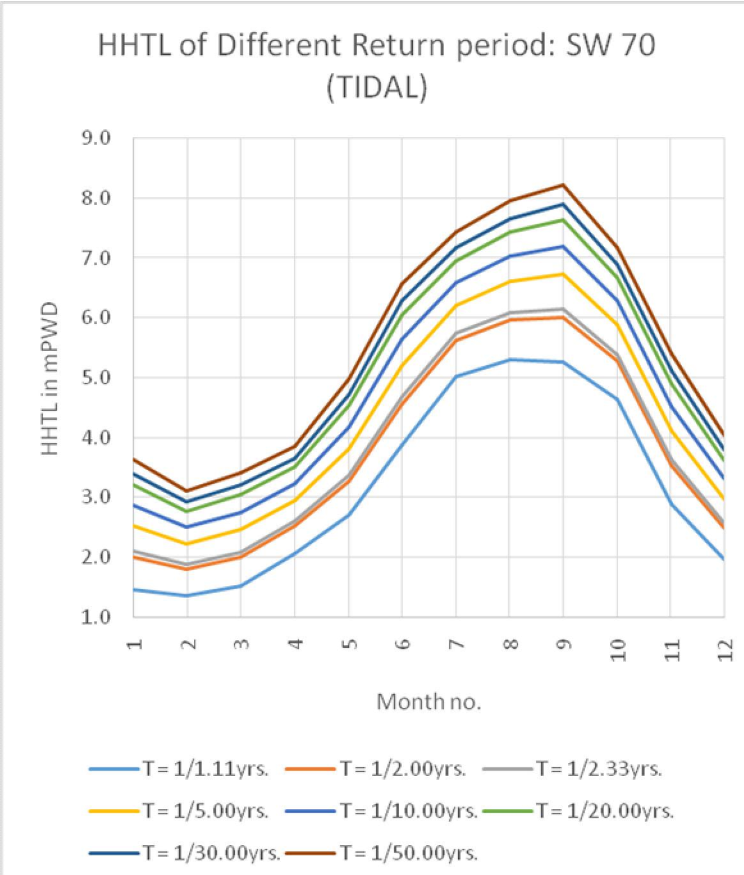
Monthly Maximum HTL (mPWD)

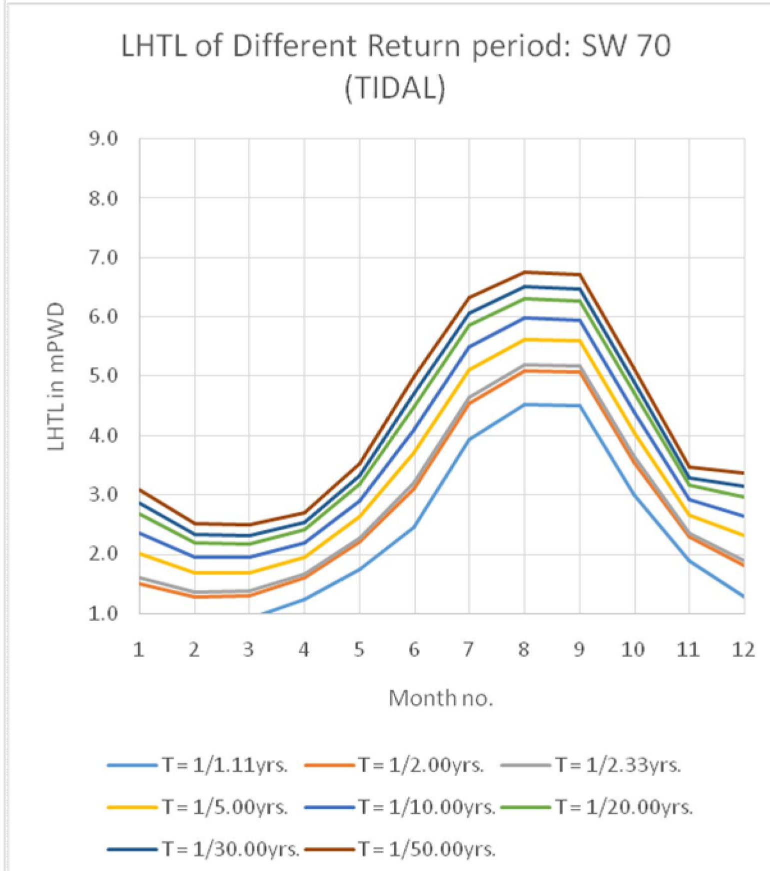
T	K			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
T = 1/1.11yrs.	$K_{1.11}$	=	-1.10	01.46	01.35	01.52	02.06	02.70	03.88	05.01	05.30	05.26	04.63	02.88	01.95
T = 1/2.00yrs.	$K_{2.00}$	=	-0.16	02.01	01.80	02.00	02.52	03.28	04.56	05.63	05.97	06.01	05.28	03.52	02.48
T = 1/2.33yrs.	$K_{2.33}$	=	0.00	02.11	01.88	02.09	02.60	03.38	04.68	05.74	06.09	06.15	05.39	03.63	02.57
T = 1/5.00yrs.	$K_{5.00}$	=	0.72	02.53	02.22	02.45	02.95	03.82	05.21	06.21	06.61	06.72	05.88	04.12	02.97
T = 1/10.00yrs.	$K_{10.00}$	=	1.30	02.87	02.50	02.75	03.23	04.18	05.64	06.59	07.03	07.19	06.29	04.52	03.30
T = 1/20.00yrs.	$K_{20.00}$	=	1.87	03.20	02.77	03.04	03.50	04.53	06.05	06.96	07.43	07.64	06.67	04.90	03.62
T = 1/30.00yrs.	$K_{30.00}$	=	2.19	03.39	02.92	03.20	03.66	04.73	06.28	07.17	07.66	07.90	06.89	05.12	03.80
T = 1/50.00yrs.	$K_{50.00}$	=	2.59	03.63	03.11	03.41	03.86	04.98	06.58	07.43	07.95	08.23	07.17	05.40	04.02

Monthly Minimum HTL (mPWD)

T	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
T = 1/1.11yrs.	00.95	00.86	00.90	01.23	01.75	02.45	03.93	04.52	04.50	03.00	01.88	01.27
T = 1/2.00yrs.	01.50	01.28	01.30	01.60	02.20	03.09	04.54	05.09	05.06	03.54	02.28	01.80
T = 1/2.33yrs.	01.59	01.36	01.38	01.66	02.28	03.21	04.65	05.19	05.16	03.64	02.35	01.89
T = 1/5.00yrs.	02.01	01.68	01.68	01.95	02.62	03.70	05.12	05.62	05.59	04.06	02.66	02.30
T = 1/10.00yrs.	02.35	01.94	01.94	02.18	02.91	04.10	05.49	05.98	05.94	04.39	02.91	02.63
T = 1/20.00yrs.	02.67	02.19	02.18	02.40	03.18	04.49	05.86	06.31	06.28	04.72	03.15	02.95
T = 1/30.00yrs.	02.86	02.34	02.32	02.53	03.33	04.71	06.07	06.51	06.47	04.90	03.29	03.14
T = 1/50.00yrs.	03.09	02.52	02.49	02.69	03.53	04.99	06.33	06.75	06.71	05.14	03.46	03.37

MONTHLY BASIS ANALYSIS OF DATA OF WATER LEVEL GAUGE STATION SW 70 (HTL)





ANNEXURE - 1

MONTHLY BASIS ANALYSIS OF DATA OF WATER LEVEL GAUGE STATION SW 70 (LTL)

Monthly Data: WL

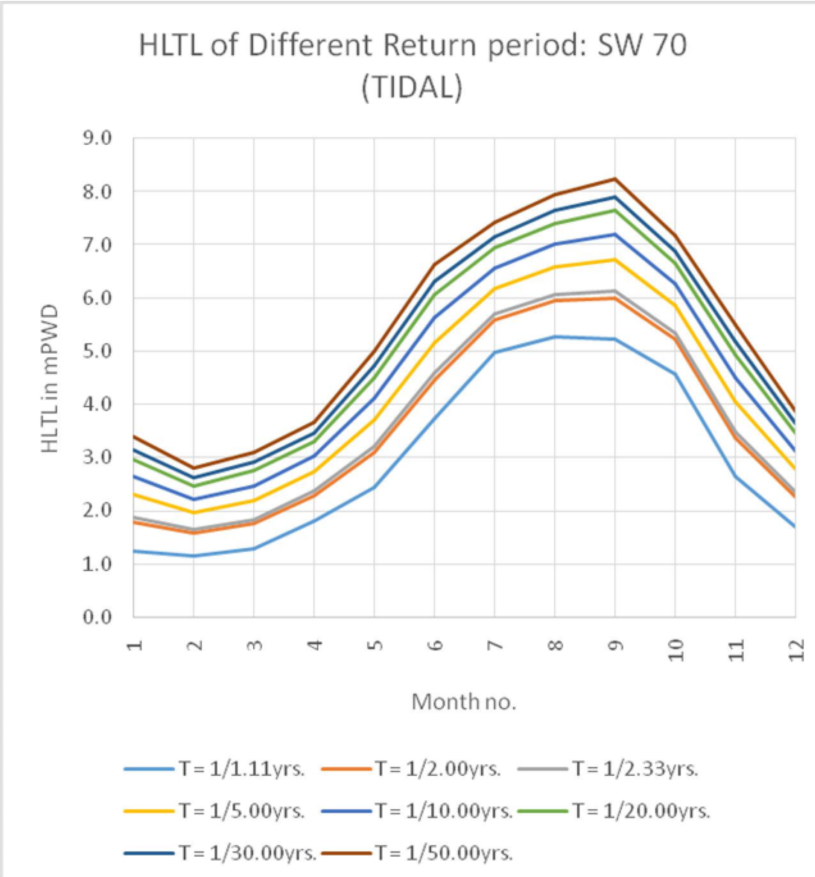
Monthly Maximum HTL (mPWD)

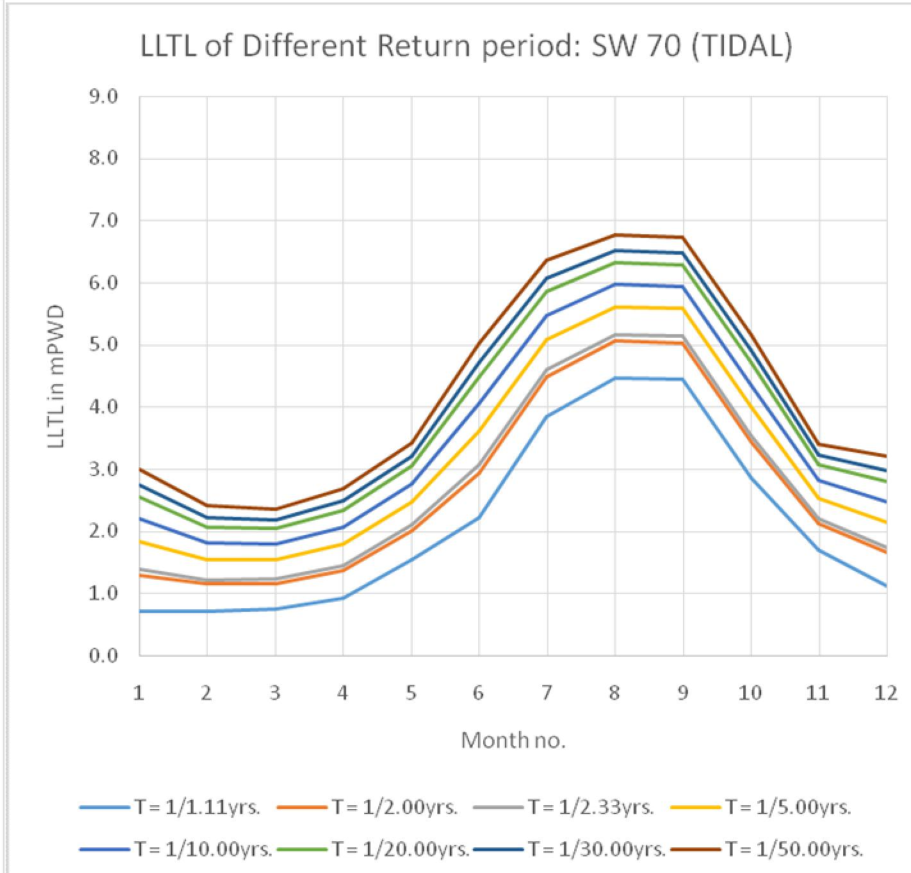
				Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
				1981				02.29	02.65	03.60	05.49	05.96	05.82	04.95	02.52	02.27
				1982	01.42	00.55	00.59									
				1983				02.56	03.43	04.56	05.34	05.75	06.37	06.19	04.20	02.22
				1984	01.74	01.58	01.77	02.60	04.33	05.30	06.58	06.93	07.10	06.70	04.15	02.13
				1985	01.70	01.61	02.03	02.53	03.05	04.76	05.91	06.18	05.84	05.45	04.00	02.29
				1986	01.66	01.54	01.68	02.64	02.68	04.30	05.70	06.10	06.20	06.00	04.33	02.57
				1987	01.80	01.62	01.66	02.49	02.70	04.69	06.04	07.53	06.64	06.37	03.95	02.38
				1988	01.80	01.70	01.83	02.22	04.20	04.74	06.36	07.70	08.90	05.77	04.18	02.94
				1989	01.78	01.86	01.92	02.30	03.45	04.93	05.91	05.77	05.71	05.66	04.12	02.33
				1990	01.85	01.64	01.97	02.82	03.27	05.08	06.01	06.12	05.61	05.97	04.05	02.29
				1991	01.93	01.70	01.70	02.20	03.91	05.35	06.35	05.90	06.26	05.60	03.60	02.36
				1992	02.08	02.12	02.20	02.59	03.20	03.90	04.75	04.65	04.82	04.51	03.38	02.00
				1993	01.65	01.76	01.80	02.02	03.76	04.89	05.88	06.14	06.38	05.63	03.70	02.55
				1994	02.00	01.45	02.30	02.33	02.75	04.68	04.75	05.78	05.42	04.47	02.80	01.96
				1995	01.50	01.48	01.54	01.92	03.79	05.41	06.96	06.84	06.38	06.21	03.14	02.29
				1996	01.64	01.56	01.74	02.04	03.65	04.04	06.63	06.34	06.29	04.83	03.76	02.24
				1997	01.92	01.56	01.63	01.82	02.96	04.16	06.10	05.88	05.58	05.34	03.60	01.83
				1998	01.72	01.53	01.85	02.35	02.87	04.51			07.78	04.99	04.06	02.50
				1999	01.90	01.55	01.64	02.08	02.88		05.88	06.48	06.57	05.52	05.87	03.84
				2000	03.38	03.26	03.49	03.97	04.99	07.24	06.47	07.40	06.94	06.32	03.50	02.24
				2001	01.93	01.82	01.80	02.30	03.04	04.96	05.65	06.58	05.85	05.13	04.06	02.73
				2002	02.08		02.18	03.03								
				2003							06.65	05.87	05.93	05.84	03.72	02.23
				2004	01.64	01.53	02.05			05.17		04.92	04.92	05.28	03.36	04.47
				2005	04.09											
				2006											01.69	00.96
				2007	00.62	00.76	00.92	01.44	01.94	04.44	05.57	06.62	06.21	05.05	02.85	01.76
				2008	01.29	01.17	01.29	01.45	02.10	03.83	05.35	05.89	06.22	04.36	03.12	02.23
				2009	01.65	01.55	01.59	02.18	02.65	03.12	04.51	05.57		04.02	02.74	02.39
				2010	01.77	01.77	02.22	03.41	04.16	05.04	05.51	05.54	06.00	05.68	03.38	02.60
				2011	02.05	01.94	02.40	02.41	02.44	03.53	05.02	05.68	05.63	04.75	02.64	02.29
				2012	02.19	01.96	02.11	02.12	02.53	04.48	05.28	05.16	05.36	05.47	02.80	02.04
				2013	01.69	01.50	01.64	02.19	03.39	03.77	05.12	05.20	05.36	03.87	03.01	02.19
				2014	01.88	01.65	01.61	02.19	02.93	04.19	04.79	05.96	06.03	05.14	02.94	02.26
				2015	02.00	01.85	01.84	02.57	03.12		04.74	05.52	05.73	04.63	02.49	01.85
				MAX	04.09	03.26	03.49	03.97	04.99	07.24	06.96	07.70	08.90	06.70	05.87	04.47
				MIN	00.62	00.55	00.59	01.44	01.94	03.12	04.51	04.65	04.82	03.87	01.69	00.96
				N	31	29	30	30	29	28	29	30	30	31	32	32
				AVE.	01.88	01.64	01.83	02.37	03.20	04.60	05.70	06.07	06.13	05.35	03.49	02.35
				σ	00.58	00.44	00.49	00.50	00.69	00.79	00.67	00.72	00.81	00.71	00.77	00.59
ANALYSED DATA:																
T = 1/1.11yrs.	$K_{1.11}$	=	-1.10		01.24	01.15	01.29	01.81	02.44	03.73	04.97	05.27	05.23	04.57	02.64	01.70
T = 1/2.00yrs.	$K_{2.00}$	=	-0.16		01.79	01.57	01.75	02.29	03.09	04.47	05.59	05.95	06.00	05.23	03.36	02.25
T = 1/2.33yrs.	$K_{2.33}$	=	0.00		01.88	01.64	01.83	02.37	03.20	04.60	05.70	06.07	06.13	05.35	03.49	02.35
T = 1/5.00yrs.	$K_{5.00}$	=	0.72		02.30	01.96	02.19	02.73	03.70	05.16	06.18	06.58	06.71	05.85	04.05	02.77
T = 1/10.00yrs.	$K_{10.00}$	=	1.30		02.64	02.22	02.47	03.02	04.11	05.62	06.57	07.01	07.19	06.27	04.50	03.12
T = 1/20.00yrs.	$K_{20.00}$	=	1.87		02.96	02.47	02.75	03.31	04.50	06.06	06.94	07.41	07.64	06.66	04.93	03.45
T = 1/30.00yrs.	$K_{30.00}$	=	2.19		03.15	02.61	02.90	03.47	04.72	06.32	07.16	07.64	07.90	06.89	05.18	03.64
T = 1/50.00yrs.	$K_{50.00}$	=	2.59		03.39	02.79	03.10	03.67	05.00	06.64	07.43	07.93	08.23	07.17	05.49	03.88

Monthly Minimum HTL (mPWD)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1981				01.07	01.69	02.74	03.87	05.56	05.00	02.58	01.75	01.33
1982	01.11	00.22	00.22									
1983				01.45	02.20	03.39	04.57	04.87	05.57	04.29	02.26	01.64
1984	01.42	01.20	01.20	01.40	02.37	04.28	05.14	05.64	05.70	04.28	02.16	01.68
1985	01.29	01.22	01.38	01.54	02.28	02.80	04.81	05.29	05.46	04.14	02.30	01.55
1986	01.18	00.95	01.06	01.22	02.20	01.92	04.80	05.50	05.68	04.38	02.49	01.60
1987	01.28	01.25	01.15	01.39	02.21	02.72	04.80	06.18	06.37	04.07	02.34	01.82
1988	01.24	01.21	01.19	01.45	01.95	04.03	04.67	05.93	05.83	04.30	02.62	01.52
1989	01.25	01.44	01.30	01.39	02.25	03.70	04.55	05.38	05.37	04.29	02.31	01.50
1990	01.38	01.14	01.12	00.13	02.70	03.41	05.02	05.64	05.13	04.16	02.32	01.67
1991	01.28	01.24	01.19	01.58	02.00	03.83	05.25	05.49	05.59	03.70	02.15	01.88
1992	00.17	01.68	01.68	01.92	02.27	02.57	04.14	04.22	04.45	03.49	02.10	01.70
1993	01.21	01.16	01.20	01.22	02.00	03.57	04.89	05.54	05.45	03.78	02.53	01.90
1994	01.62	01.15	01.22	01.76	01.85	02.53	04.42	04.72	04.54	02.84	01.67	01.40
1995	01.09	01.16	01.20	01.20	01.96	03.44	05.39	05.51	05.59	03.25	02.32	01.67
1996	01.32	01.26	01.20	01.61	01.94	03.30	04.29	05.78	04.88	03.68	02.29	01.84
1997	01.47	01.42	01.34	01.51	01.59	02.94	04.15	05.26	04.91	03.93	01.82	01.59
1998	01.39	01.22	01.27	01.58	01.94	02.84			05.08	03.71	02.40	01.72
1999	01.24	01.24	01.23	01.32	02.10		05.35	05.38	05.57	04.55	03.97	03.35
2000	03.10	02.97	02.91	03.09	04.17	05.08	06.10	06.32	06.09	03.33	02.27	01.89
2001	01.62	01.48	01.41	01.55	02.10	03.08	04.81	05.03	05.02	04.08	02.70	02.00
2002	01.75		01.56	01.78								
2003							05.93	05.24	05.59	03.82	02.34	01.69
2004	01.27	01.25	01.20			03.44		03.87	03.87	03.46	01.84	03.93
2005	03.64											
2006											00.95	00.71
2007	00.34	00.32	00.33	00.65	01.43	02.04	03.79	05.39	05.17	02.94	01.87	01.02
2008	00.89	00.67	00.72	01.05	01.42	01.97	03.95	05.32	04.43	02.77	02.07	01.56
2009	01.28	00.98	01.11	01.41	01.83	02.12	03.10	04.10		02.70	01.97	01.52
2010	01.34	01.17	01.14	01.92	02.68	03.85	05.07	04.84	05.56	03.30	02.37	01.90
2011	01.47	01.37	01.30	01.82	01.62	02.31	03.65	05.06	04.50	02.87	02.34	01.91
2012	01.59	01.44	01.36	01.11	02.01	02.41	04.51	04.52	04.40	02.78	02.01	01.42
2013	01.24	00.96	01.14	01.34	02.02	02.92	03.73	04.80	03.83	02.99	01.95	01.58
2014	01.24	01.24	01.00	01.24	01.68	02.56	04.23	04.49	04.81	02.88	02.24	01.77
2015	01.47	01.40	01.42	01.59	02.38		04.22	03.95	04.61	02.53	01.80	01.52
MAX	03.64	02.97	02.91	03.09	04.17	05.08	06.10	06.32	06.37	04.55	03.97	03.93
MIN	00.17	00.22	00.22	00.13	01.42	01.92	03.10	03.87	03.83	02.53	00.95	00.71
N	31	29	30	30	29	28	29	30	30	31	32	32
AVE.	01.39	01.22	01.23	01.44	02.10	03.06	04.59	05.16	05.13	03.54	02.20	01.74
σ	00.62	00.46	00.43	00.48	00.51	00.76	00.68	00.62	00.62	00.62	00.47	00.57
T = 1/1.11yrs.	00.71	00.72	00.75	00.92	01.54	02.23	03.84	04.47	04.45	02.85	01.69	01.12
T = 1/2.00yrs.	01.29	01.15	01.15	01.36	02.01	02.94	04.48	05.06	05.03	03.44	02.13	01.65
T = 1/2.33yrs.	01.39	01.22	01.23	01.44	02.10	03.06	04.59	05.16	05.14	03.54	02.20	01.74
T = 1/5.00yrs.	01.84	01.55	01.54	01.79	02.46	03.61	05.08	05.61	05.58	03.99	02.54	02.15
T = 1/10.00yrs.	02.20	01.82	01.79	02.07	02.76	04.05	05.48	05.97	05.94	04.36	02.81	02.48
T = 1/20.00yrs.	02.55	02.07	02.04	02.34	03.05	04.48	05.86	06.32	06.29	04.71	03.07	02.80
T = 1/30.00yrs.	02.75	02.22	02.18	02.49	03.21	04.72	06.08	06.52	06.49	04.91	03.22	02.98
T = 1/50.00yrs.	03.00	02.41	02.35	02.68	03.42	05.03	06.35	06.77	06.74	05.16	03.41	03.21

MONTHLY BASIS ANALYSIS OF DATA OF WATER LEVEL GAUGE STATION SW 70 (LTL)





INSTRUCTIONS TO SURVEYORS:
INFORMATION TO BE COLLECTED DURING BATHYMETRIC SURVEY AND PHYSICAL FEATURE SURVEY:

1. During survey works, information regarding water levels should be collected. Information should include: a. Notable highest flood level (HFL) and lowest flood level (LFL) in the past. (ASK LOCALS) b. Notable Highest tide level (HTL) and lowest tide level (LTL) in the past. (ASK LOCALS) c. Present water level (PWL) during survey at the point of surveyed section should be measured.
2. Cross-sections should be collected at entry and exit of a bends of rivers, at centers of riffles of rivers at junctions with tributaries and distributaries and mouths of rivers, near locations of water level gauges and at locations of hydraulic structures.
3. GPS location of the surveyed section should be collected.
4. Local names of the rivers being surveyed and their tributaries (If any) should be collected. (ASK LOCALS)
5. Information regarding hydraulic structures have to be collected consulting with the government agencies like BWDB, BADC, LGED and RHD. Information should include: a. Sill level of regulators, rubber dams, weirs and culverts. b. Opening of the structures. c. Storage level of water retention structures and dams. d. Information of the projects that funded the construction of the structures if possible to collect.
6. Consulting with the local people, information regarding flash flood have to be collected. Information should include: a. Number of incident(s) of flash flood in a year. b. Probable time(s) of flash flood(s) to occur. c. Duration(s) of flash flood(s). d. Areas that are more prone to damage inflicted by flash flood.
7. Information regarding water logging should be collected. Local people should be consulted in this regard. Information should include: a. Name of the areas experiencing frequent water logging problems. b. Duration of water logging. c. Local idea about cause of water logging.
8. Information regarding drains should include: a. Size of drains: (Depth X Width) b. RL of drains at different locations.
    1. c. Construction type of drains: i. Lined / Unlined ii. Man-made / Natural d. Method of connection of households to the drains. e. Location of different point of the drains: i. Starting points ii. Junction points iii. End points f. Name of roads alongside the drains, ward no. / name of village. g. Use of drains: i. Sewer ii. Storm-sewer iii. Mixed
9. Information regarding encroachment of drains and natural channels should be collected.

Table A2.1: Dumpy level reading sheet

Ch.	Distance (m)		Staff reading			Height of instrument	RL	Remarks
(m)	(m)	(m)	BR (m)	IS (m)	FR (m)	(m)	(m)	

Table A2.2: Drainage Inventory

Upazila	Ward no.	By road	Reach	GPS location		RL (mPWD)		Reach Length	Depth	Width	Type
				Start	End	Start	End	(m)	(mm)	(mm)	

CROSS-SECTIONS OF RIVERS AND CHANNELS AS SURVEYED