# Flood Risk Assessment of the Proposed Nuclear Power-Plant in Bangladesh

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**Abstract:**

To satisfy the increasing energy demand, Bangladesh has started building a nuclear power-plant. Before building a power-plant, environmental impact assessment of the location is very crucial. In a country like Bangladesh, which has numerous big rivers, a flood risk assessment of the study area is essential for precautious measurements. The objective of this project is to conduct a flood risk assessment of the proposed nuclear power-plant which is located at the bank of River Ganges in Pabna district of Bangladesh. In this project, the hydrological assessment was done by using Gumbel Distribution- Extreme Value type I (EV1) to estimate the 100 years return period flood. Consequently, a hydraulic assessment was done by using the Hydrologic Engineering Center's River Analysis System (HEC-RAS) modeling for estimating the area under risk during extreme flood. Required data was collected from the nearest hydrological station from the Water Development Board Bangladesh, and some other physical parameters were taken by interpolating data from Google maps. The output of the HEC-RAS model was used to show whether the proposed nuclear power-plant is within the risk zone. Further studies with reliable data, can improve the result into a more accurate model, and depending on the severity of the risk, necessary measures can be taken.

**Key words:** Flood Risk Assessment, HEC-RAS, Nuclear Power-plant, Hydrologic Assessment, Hydraulic Assessment, Ruppur-Bangladesh, Ganges River

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## 1. Introduction:

The first nuclear power-plant in Bangladesh is under construction in Ruppur union of Pabna district, the north of capital. To meet the increasing demand of energy, this is a significant step for this developing country. The non-renewable energy production is nevertheless a quicker way to produce more energy. Therefore, nuclear energy is a necessity at this moment, and necessary steps should be taken for the safety measurements. The fact that the power plant is built at a flood plain of Ganges is an issue to be concerned about the flood risk of the power plant. The power plant might be vulnerable to floods, which may result in nuclear power plant accidents besides the usual damages caused by flood. Even though the other factors may have been taken into consideration, the issue about flood is still not conducted. Therefore, to ensure the safety of the power plant and the people living around it, a flood risk assessment is important.

Since Bangladesh is exposed to annual floods and most importantly vulnerable to severe damages caused by the extreme floods (see more details in section 2), a flood risk assessment is a prerequisite before building any important infrastructure. The severity of a nuclear Power Plant accident and its vulnerability due to flood is a foremost concern for doing the flood risk assessment. This study will explore the risk of inundation due to extreme floods in the River Ganges.

This study will explore various stages of a flood risk assessment process and conduct a flood risk assessment of River Ganges at the specific point in Pabna, which is very close to the nuclear power plant. This study is specifically focused on the hydrologic modeling for estimating the magnitude of 100 years return period flood using mean daily discharge from the past years. Also, the most significant part of this study is to build a hydraulic model using HEC-RAS software to estimate the inundation depth of the nuclear power plant for 100 years return period flood. In brief, assessment of the risk of the nuclear power plant being inundated by extreme flood is the main objective of this study.

## 2. Literature Review:

### 2.1.Flood scenario in Bangladesh:

Flood is a common natural disaster in Bangladesh and it has huge impact on the country's economy, social welfare, and the environment. Despite of flood damaging a large amount of properties including crops, houses, livestock, and human lives, the damage caused by the extreme floods are very severe. Table 1 includes a brief overview of some of the extreme floods and the consequences in past few decades (MoEF 2005).

**Table 1: Severe flood in last 25 years (MoEF, 2005)**

| Event | Impact |
|---|---|
| 1984 | • Inundated over 50,000 sq. km<br>• Estimated damage $378 million |
| 1987 | • Inundated over 50,000 sq. km,<br>• estimated damage $1 billion<br>• 2055 deaths |
| 1988 | • Inundated over 90,000 sq. km<br>• Estimated damage $1.2 billion<br>• 2000-6500 deaths<br>• 45million homeless |
| 1998 | • Inundated 100,000 sq. km<br>• Estimated damage $2.8 billion<br>• 1100 deaths<br>• 30 million homeless<br>• Heavy loss of infrastructure |
| 2004 | • Inundated 56,000 sq. km<br>• Estimated damage $6.6 billion<br>• 700 deaths |
| 2007 | • Inundated 32,000 sq. km<br>• Estimated damage $1 billion<br>• 649 deaths |

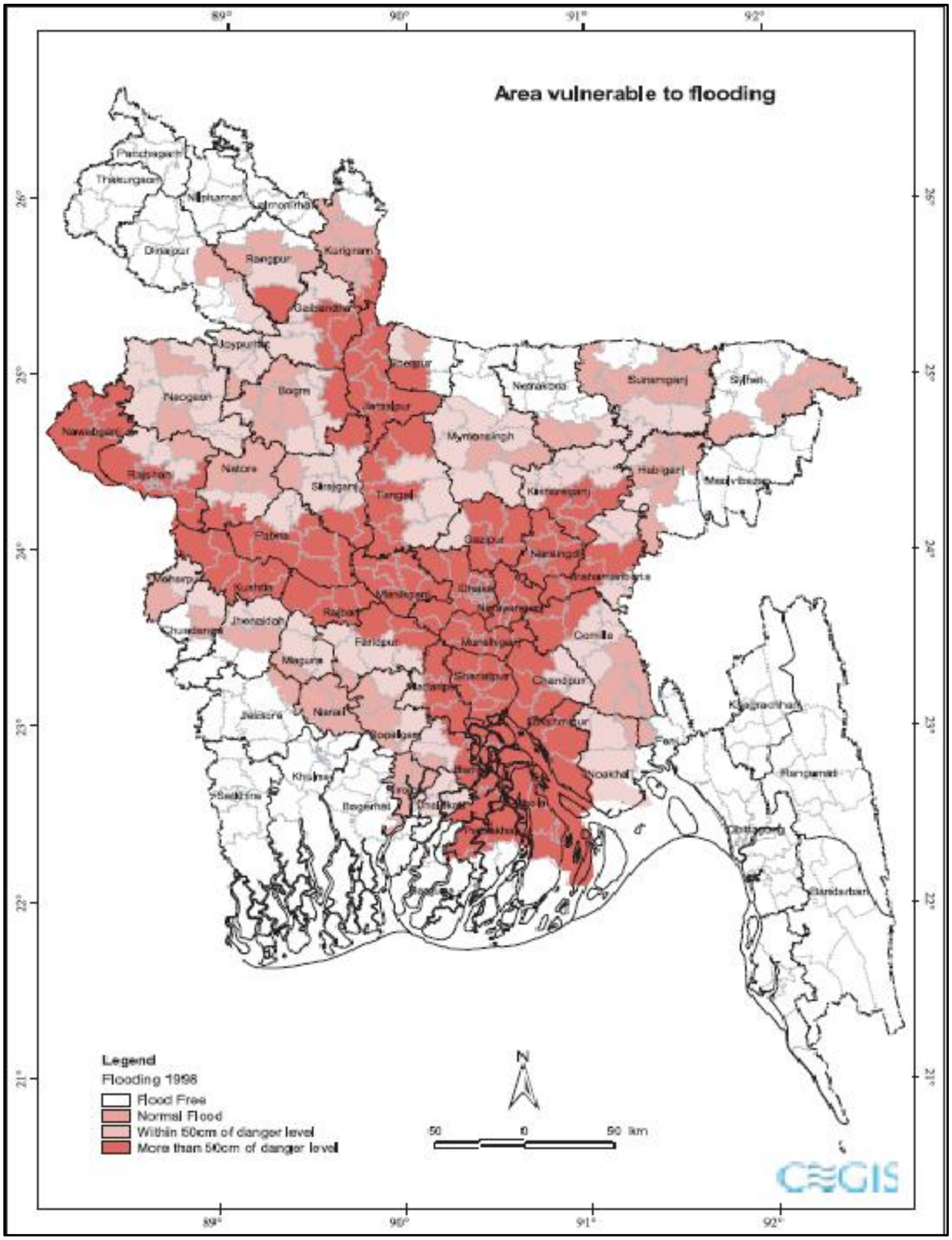



**Figure 1**: Area vulnerable to flood (MoEF, Bangladesh)

In addition to the flood history, figure 1 gives a clear idea about how much area is vulnerable to flooding. The Ganges basin and its flood plain are the most susceptible area for disaster like flood. Most important and alarmingly, the study area, the location of the proposed nuclear power plant is within the most vulnerable area of Bangladesh in terms of flood. Therefore, before the power plant starts operation, a flood risk assessment will aid in determining the safety measurements.

## 2.1.Flood risk assessment:

Flood risk assessment is the crucial part of the flood management of a specific region or flood plain. Assessment is obligatory before building any bridge, damn, and other significant infrastructure at a flood plain or close to any big river basin. The assessment of flood risk includes prediction of floods, nature of floods, magnitude of flood, probability of reoccurrence of extreme floods, and most importantly degree of flood risk. For conducting a flood risk assessment, past history of mean discharge and precipitation of a specific region is required. Sometimes, the assessment is done using the pattern of flood in other streams or rivers at the corresponding region (Han 2011).

## 2.2.Flood risk assessment in Bangladesh:

Risk assessment of flood in Bangladesh has changed with time and has adapted to risk-oriented approach. A typical flood risk assessment includes three different aspects: estimation of the intensity of flood, estimation of the flood inundation and duration, and estimation of damages caused by the flood (Gain and Hoque 2012). Among many different approaches for flood frequency analysis, the most common methods in Bangladesh are Log Normal Distribution, Gumbel Distribution or Extreme Value Type- 1, Log-Pearson Type- 3 (Ferdows et al 2005). For the hydraulic analysis HEC-RAS software is commonly used along with data representation using GIS tools (Baky, Zaman, and Khan 2012).

### 2.3.Gumbel Distribution:

For conducting flood frequency analysis, one the most commonly used method is Gumbel Distribution. This study will focus on Extreme Value Type -1 (EV1) distribution which is a special case of Gumble distribution. EV1 method is usually used for calculating the maximum or minimum cases of any distribution (Rao and Hamed 2000). In this study, estimation of the 100 return period flood magnitude was the objective; therefore, the maximum discharge for the past years were taken to conduct the flood frequency analysis.

### 2.4.HEC-RAS:

Hydrologic Engineering Center's River Analysis System (HEC-RAS) was developed by the US military, and it was first released in 1995. HEC-RAS can be used in various kinds of analysis such as steady flow, unsteady flow, and sediment transportation calculations of a river (Brunner 2002). This software is a very useful tool for hydraulic modeling such as estimating the water depth and area of inundation for a specific amount of discharge. In this study, the hydraulic model was done by using this HEC-RAS software.

## 3. Study Area:

The proposed nuclear power plant is located at the bank of river Ganges. It is located at Ruppur Union in Pabna district of Bangladesh, which is 200km north-west from the capital Dhaka. Flood risk assessment determines the risk of the site selected for building the nuclear power plant. To do the frequency analysis, data was taken from the nearest hydrological station to the nuclear power plant. The coordinates of the site of interest and the hydrological station are included in table 2.

**Table 2: Location of the hydrological station and the proposed nuclear power plant at Ruppur, Pabna, Bangladesh.**

| Location and coordinates | Latitude | Longitude |
|---|---|---|
| Nuclear Power Plant | 24° 06'6 0" N | 89° 04' 70" E |
| Hydrological Station<br>(SW90: Ganges-Padma) | 24°06'58" N | 89°02'64" E |

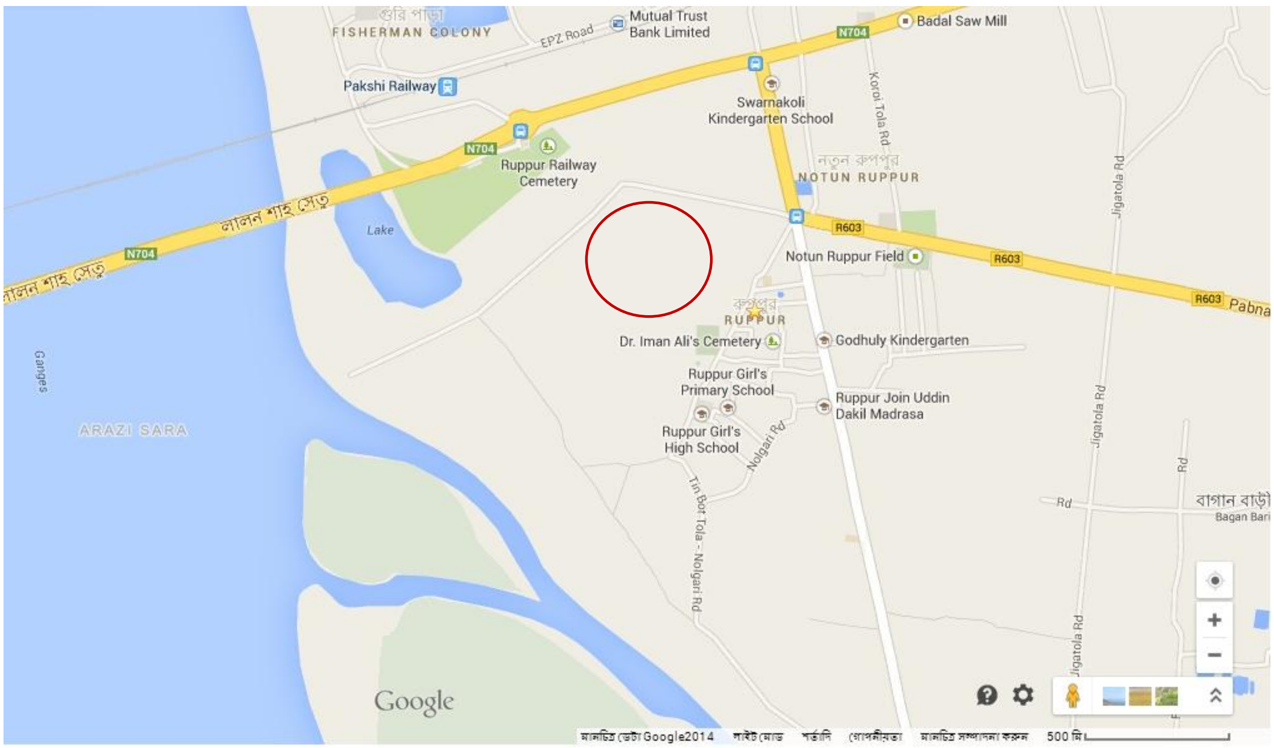



**Figure 2: Location of the nuclear power-plant next to Ganges River (Google map)**

## 4. Methodologies:

Flood risk assessment of the river requires two different types of analysis. The frequency analysis was done to estimate the magnitude of the flood for 100 return period followed by a hydrological assessment of the area under risk. Both these analysis will help in assessing the flood risk of the proposed nuclear power-plant.

**4.1. Hydrological modeling:**

The frequency analysis was based the mean daily flow for 36 years. The maximum discharge per year was taken to construct a cumulative probability curve. Using the Gumbel distribution of Extreme Value Type 1 (EV1) method, the magnitude of 100 return period floods was measured. Using the probability plot and the following formula, magnitude of 100 return period floods was measured. These data for assessment was taken from the closest hydrological stations.

$X_{100} = u + \alpha [ - \ln \{ - \ln ( 1- 1 / 100) \} ]$

$u = \mu - 0.5772 * \alpha$

$\alpha = ( \sqrt{6} * \sigma )/\pi$

Here,

$X_{100}$ = magnitude of 100 years return period flood

$\mu$ = mean discharge

$\sigma$ = standard deviation

$\alpha$ and $u$ = parameters

Also, an EV1 probability plot was constructed by plotting F against y to verify the fitness of using Gumbel distribution.

$y = - \ln (-\ln F)$

$F= ( i - 0.44) / (N + 0.12)$

Here,

y = EV1 parameter

N = number of extreme values

i = rank based on descending order

F = flood magnitude (Subramanya, 2013)

### 4.2.Hydraulic modeling:

Using the data from frequency analysis, a model was built representing the elevation of water level at various cross sections of the Ganges River. The model was designed to estimate the area that is under risk of extreme flood. The model was built using the HEC-RAS software, and the Manning's coefficient was considered as 0.045 for the River Ganges (Baky, Zaman, and Khan 2012). For this project, the version 4.1.0 was used to do one dimensional steady flow analysis. Using the 100 return period floods from the hydrological analysis as an input, the water surface elevation was calculated after using the model.

## 5. Results and Discussion:

### 5.1. Hydrological modeling:

The mean daily discharge for 36 years was collected from the closest hydrological station. Then the annual maximum discharge data was used for frequency analysis. Figure 3 shows the distribution of the maximum discharge for 36 years flood.

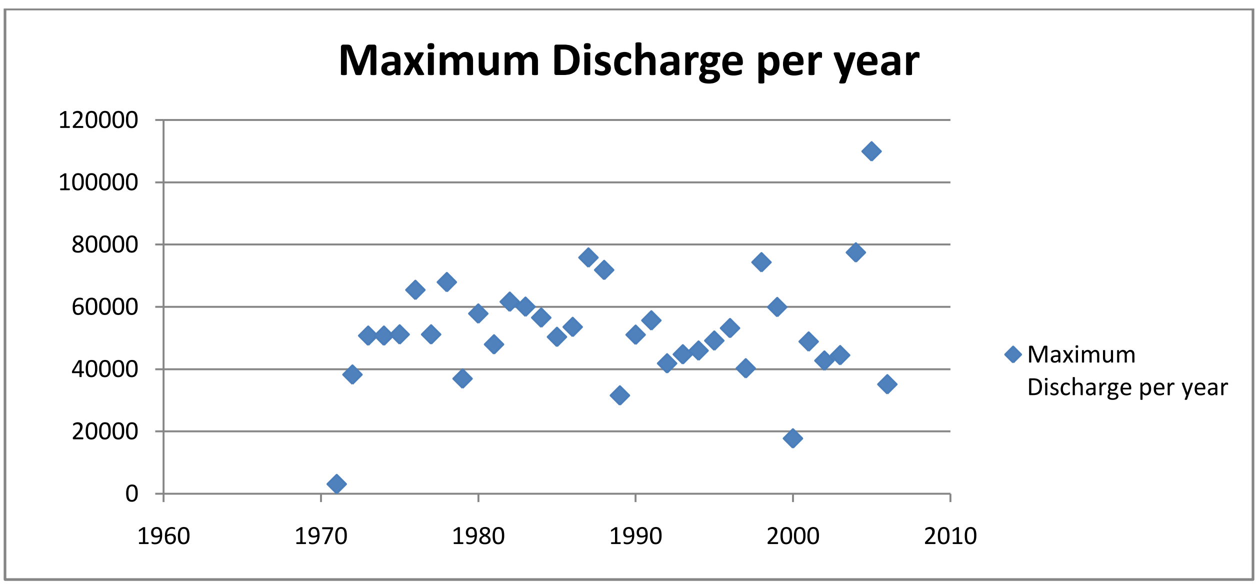



**Figure 3: Maximum discharge (1971-2006)**

By utilizing the past years discharge data and the probability distribution, the magnitude of floods with various return periods was estimated. Table 3 includes the result of the hydrologic analysis. The methodology described in section 4.1 was used to calculate the magnitude of the various return period floods.

**Table 3: Various return period floods**

| T | Magnitude |
|---|---|
| 100 | 108644.2208 |
| 50 | 98819.79283 |
| 25 | 88922.28321 |
| 10 | 75580.7525 |
| 5 | 65021.58929 |

The cumulative probability curve by using the data from last 36 years is shown in figure 4. This probability plot can also provide the estimation of magnitude of the flood with various return periods.

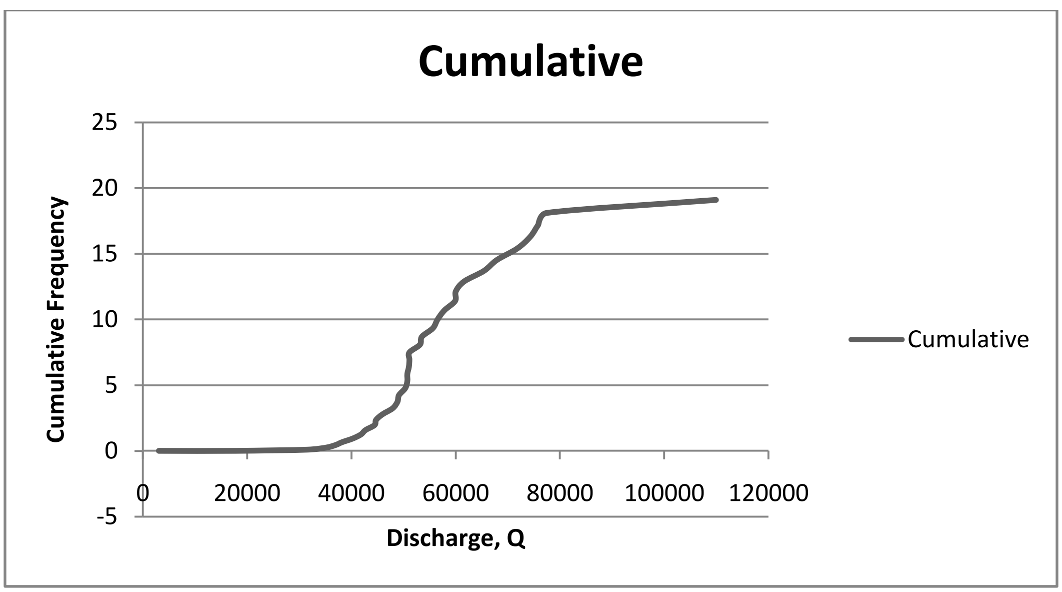



**Figure 4: Cumulative probability plot**

To ensure the validity of the cumulative probability curve and the use of Gumbel distribution, a EV1 distribution curve was plotted. Figure 5 shows that data described by the EV1 distribution produce quite a straight line, which justifies the validity of the cumulative probability curve or frequency analysis.

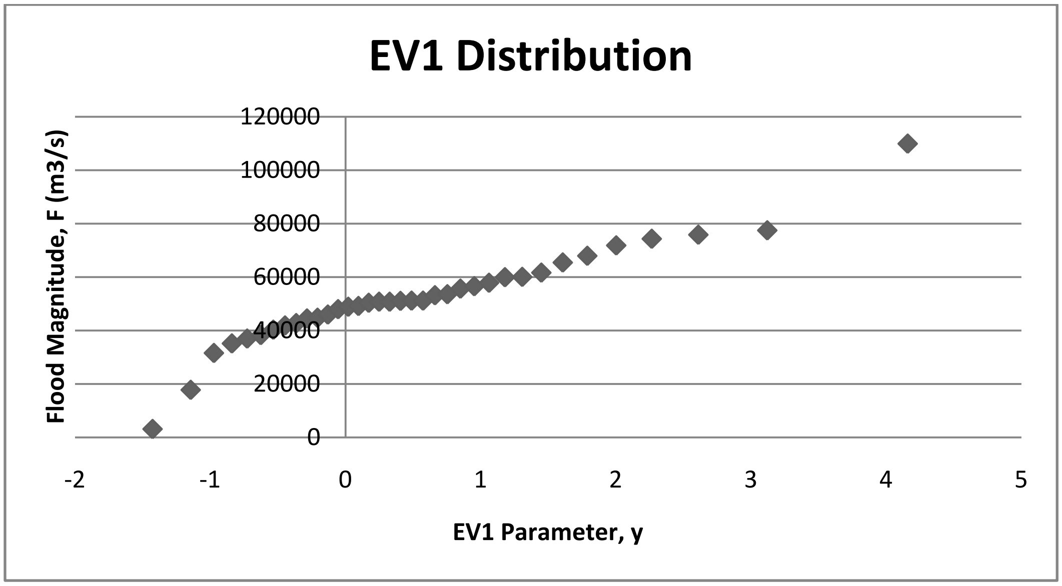



**Figure 5: EV1 distribution verification**

## 5.2. Hydraulic modeling:

Using HEC-RAS and the 100 return period floods from hydrological analysis, a model was built. The cross-section used in the model includes the flood plain besides the main channel as shown in figure 6.

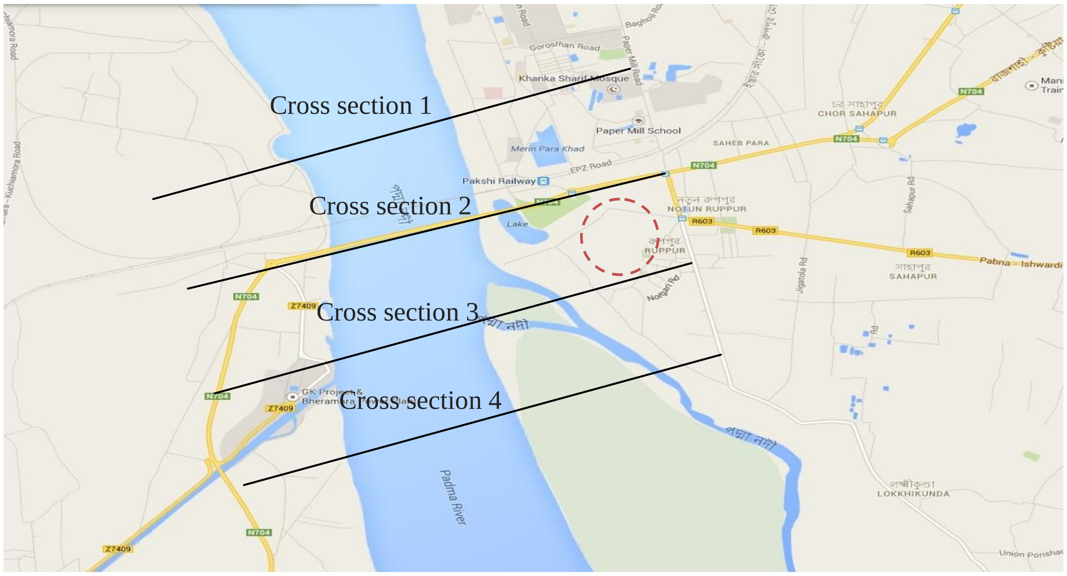
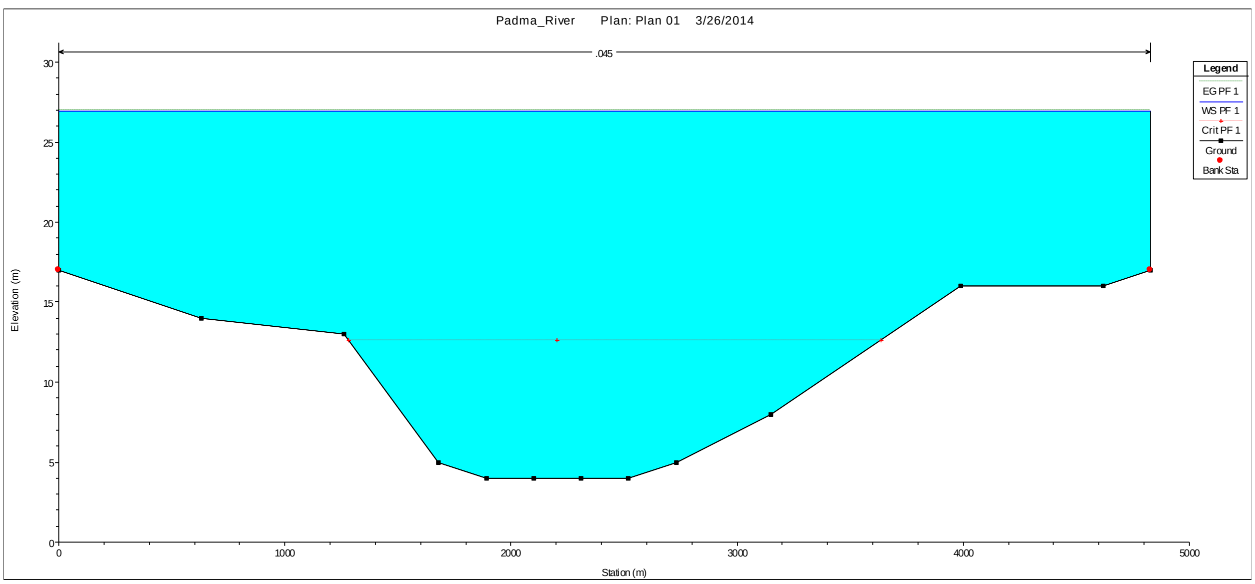
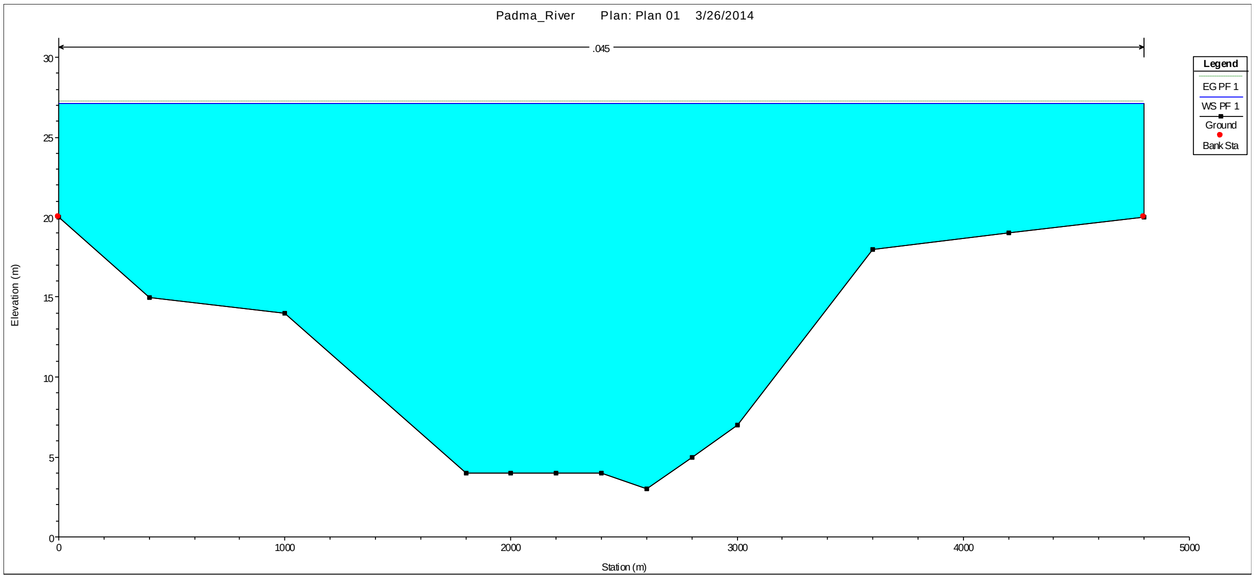



**Figure 6: Cross sections used for hydraulic modeling close to the nuclear power plant**

After running the model, the water surface elevation is as shown in the figure 7.

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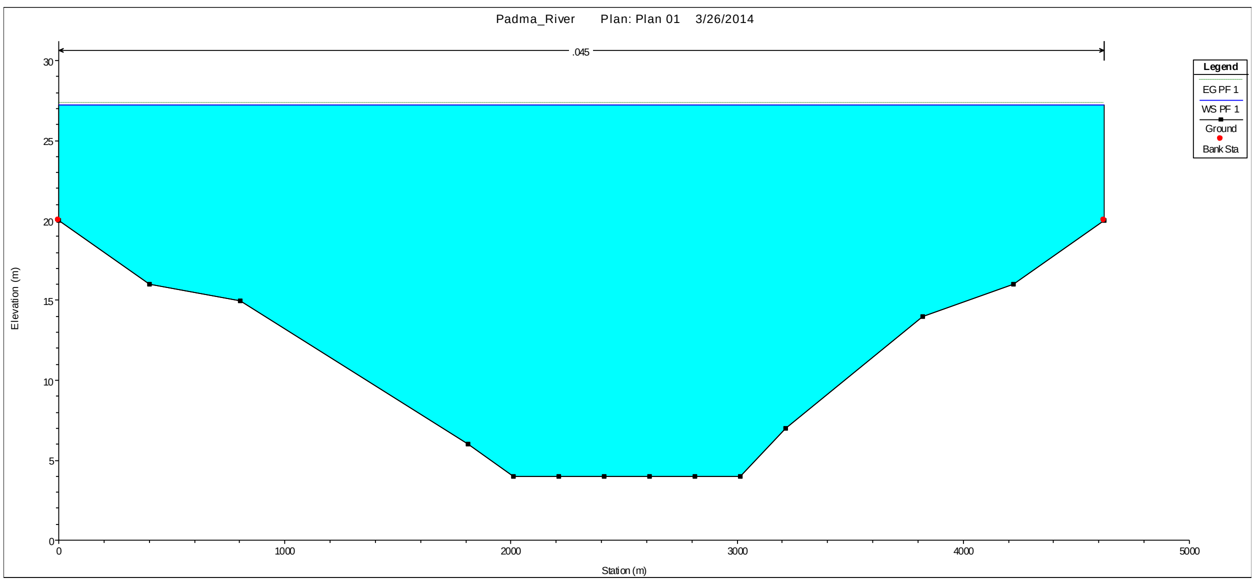
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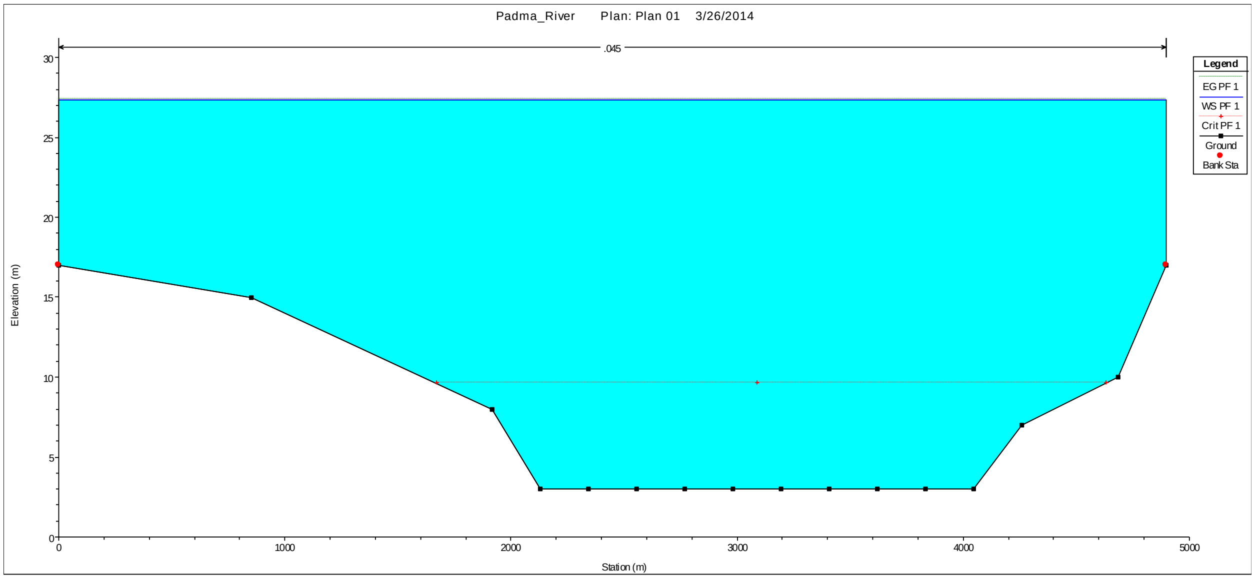


**Figure 7: Water surface elevation during 100 return period floods at 4 stations close to the proposed nuclear power-plant**

In each cross-sections of the river Ganges close to the proposed nuclear power plant, the water surface elevation is approximately 10 meters. This huge amount of water is considered to inundate the flood plain including the power plant. The result might improve if actual data regarding the river cross-section and flood plain is used in the hydraulic model.

## 6. Conclusion:

This study was an attempt to estimate the magnitude of the 100 return period flood and possible inundation area resulting from these floods. Despite of some limitations like lack of data and technological error, the model predicts that the nuclear power-plant is at risk of inundation during extreme floods. The nuclear energy is a promising source of energy for Bangladesh in near future; therefore, the operation of nuclear power-plant is inevitable. However, the risk benefit ratio should be considered carefully before the operation of the nuclear power plant starts.

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