Civil and Environmental Research www.iiste.org
ISSN 2224-5790 (Paper) ISSN 2225-0514 (Online)
Vol.7, No.7, 2015

Hydraulic Relationships of the Ikpoba River for Flood Studies

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1.0 Introduction

Flooding is a temporary condition of partial or complete inundation of normally dry areas of overflow of inland or tidal waters or from extreme and rapid accumulation of runoff. Flooding phenomenon is considered the world worst global hazard in terms of magnitude, occurrence and geographical spread, loss of life and property, displacement of people and socio-economic activities. In the tropical and sub-tropical regions, severe flooding hazards resulting from heavy thunderstorms, torrential downpours, hurricanes and tidal waves are yearly occurrences. Flood disasters are said to account for one-third of all natural catastrophes throughout the world by number and economic losses and are responsible for more than half of the facility damage (Askew, 1999).

In Nigeria, many urban floods occur because of excessive extreme rainfalls improper land use and poor drainages. It has been estimated that more than seven hundred thousand hectares of useful land for agricultural and residential purposes are either lost or rendered useless due to annual floods (David and Aggrawal 2008). The Niger Delta region of Nigeria is mostly flat low lying swampy basin resulting in severe regular flooding which has led to a limited land area for residence. Benin City experiences flash Flood and Flood pondages. Areas are inundated for more than two hours during flood episodes with an average water height of one meter (Ogbonna, et al 2011). As a result of flood events, every year government spends huge sums of money on compensation for flood victims, yet, the problems are unabated. Decision makers need supporting tools such as knowledge of extreme flood magnitudes and probability of re-occurrence, flood stages and river discharge relationships to enable decisions on a particular line of action which would be most adequate in mitigating against flood

This study seeks to derive hydraulic relationships for the Ikpoba River which can serve as decision support tools that can be used in evaluating flood damages in suburban-areas of Benin-city metropolis.

The specific objectives are to:

i. Determine the exceedance frequency discharge relationship for the Ikpoba River.

ii. Establish depths for longitudinal and cross sectional profiles of the Ikpoba River

iii. Derive the stage discharge relationship of the Ikpoba River

2.0 MATERIALS AND METHODS

2.1 Location of Study

The study was conducted in the Ikpoba basins, Benin City, Edo State, Nigeria. The Ikpoba basin a sub basin of the Osse Ossiomo basin, drains approximately 520.3km^2 area (Aziegbe, 2003). It is on a latitude $6^0 21'$N and longitude $5^0 39'$E. The study area/catchment for which this flood frequency analysis is carried out is situated within the Western Littoral hydrological area (HA-6) of Nigeria (Akintola, 1986). The Western Littoral hydrological area (HA-6) is one of the eight hydrological area into which Nigeria is subdivided. The gauging station from which the data for this study was collected is located along Ikpoba River at Benin City which is some 160km East of Lagos. The catchment area is underlain by deeply weathered sedimentary rock that is often referred to as the Benin formation, (Ogunkunle, 1980). The topography is undulating with a relative relief of 12 meters (Odemerho, 1992). Tropical rainforest, which has now been removed by farming and urbanization, is the natural vegetation of the watersheds (Odemerho, 1992. Ever since, the built up area of the city has increased some 15 folds (Ozo and Ikhuoria, 1983). However, rapid urbanization has been going on without commensurate basic runoff disposal facilities (Omuta, 1985). During storms, large quantities of runoffs flow freely into this river.

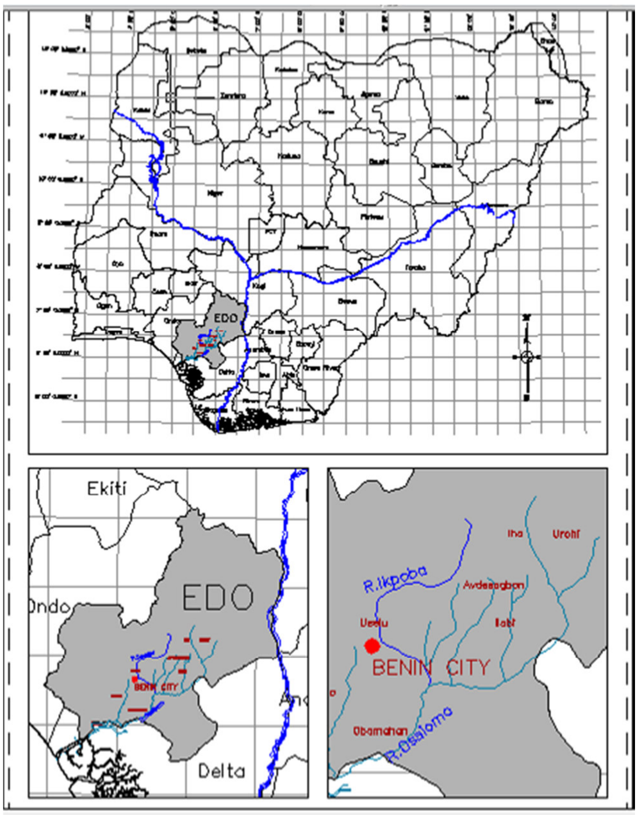


Fig. 1.0 Map of Nigeria Showing Edo State and Ikpoba Basin.

2.2 Data Collection and Field Study

Streamflow records for the Ikpoba River were obtained from the Benin Owena River Basin Development Authority. Daily discharge and corresponding stages from the year 1988 to 2000 were collected**.** An annual maximum series was extracted from the data to be used for the analysis. The logarithmic mean, standard deviation and coefficient of skew for the annual maximum series were determined. The Log Pearson type III distribution was fitted to the data and exceedance frequencies of 99%, 50% 20%,10%,5%,2% and 1% were obtained.

A hydrographic survey was also carried out at the Ikpoba River using the following instruments

- Richotum analogue Echo sounder fitted with Transducer
- Gavin 6.0 handheld G.P.S
- Survey vessel.

The Echo sounder was connected to the dry cell battery and transferred into the survey vessel (Canoe). The handheld G.P.S was set after searching for available satellite. The starting point was the abutment of the Ikpoba Bridge and depths at cross sections from both right and left bank stations were recorded. The procedure began at the downstream section beginning at the foot of the bridge and proceeded upstream at intervals of fifty meters for corresponding cross sections for a length of three hundred and fifty meters. At the end of noting the cross sections the longitudinal profile (depths along the centre line) were taken corresponding to the cross sections initially taken. An aerial survey was obtained using Google earth to determine datum elevations of the water surface of the river and adjoining banks up to lengths of one hundred meters along the line of cross sections initially taken. The depths obtained from the hydrographic survey were subtracted from the datum heights of the water surface to obtain a datum elevation for the water levels measured. Manning's roughness coefficients were estimated for the vegetation type and coefficients of contraction and expansion were also obtained in accordance to the HEC-RAS hydraulic reference manual. These values were inputed into the HEC software under the geometric data editor. Discharge value of 75m^3/s were imputed into the Flow data editor of the software. Known water stages for discharges were obtained from the rating curve and inputed into the flow editor. A uniform gradually varied flow analysis was performed and cross sections depicting water stages for each discharge imputed were obtained.

3.0 Results and Discussion of results

3.1 Monthly Maximum Series.

The results for the monthly maximum series of discharge for Ikpoba River are as shown in Figure 3.1 Monthly maximum series for the Ikpoba River from 1989-2000

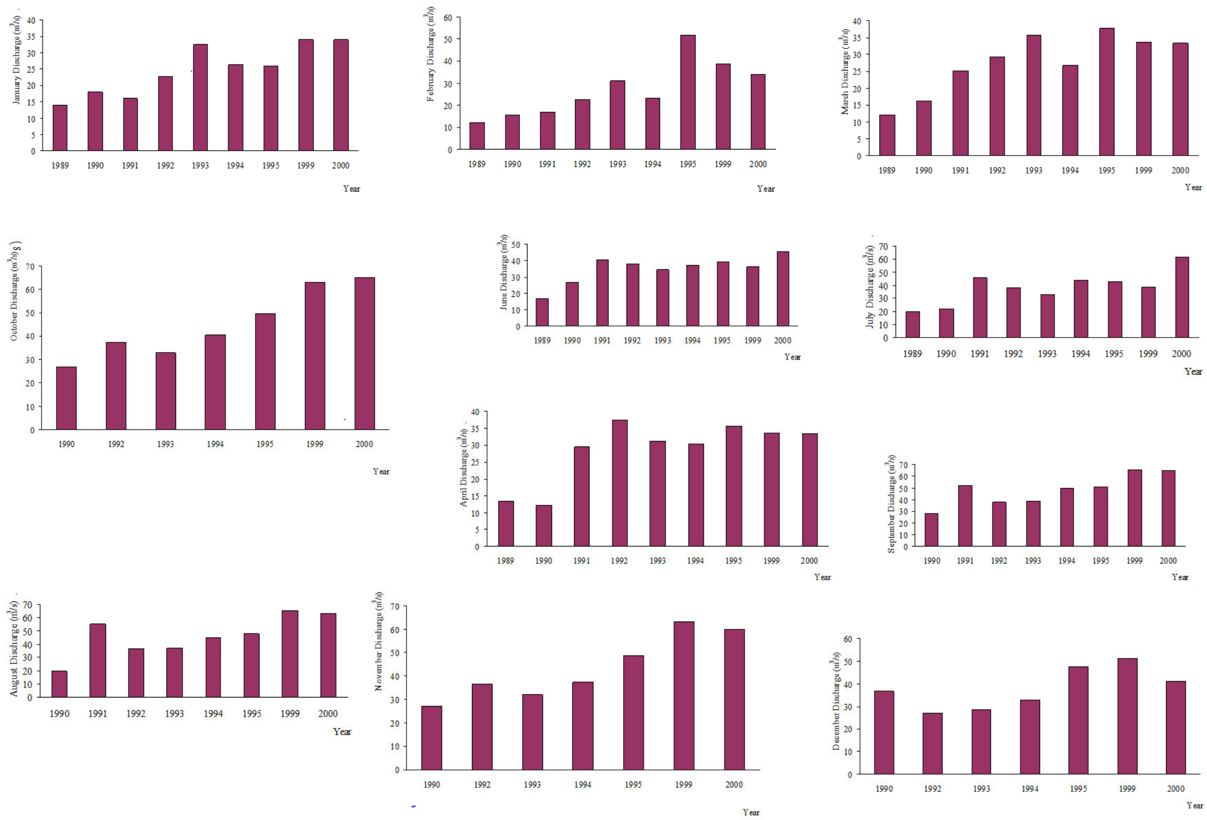


Figure 3.1 Monthly maximum series for the Ikpoba River from 1989-2000

3.2 Annual Maximum series.

The annual maximum series extracted from the daily discharge data of the Ikpoba River is presented in figure 3.3.

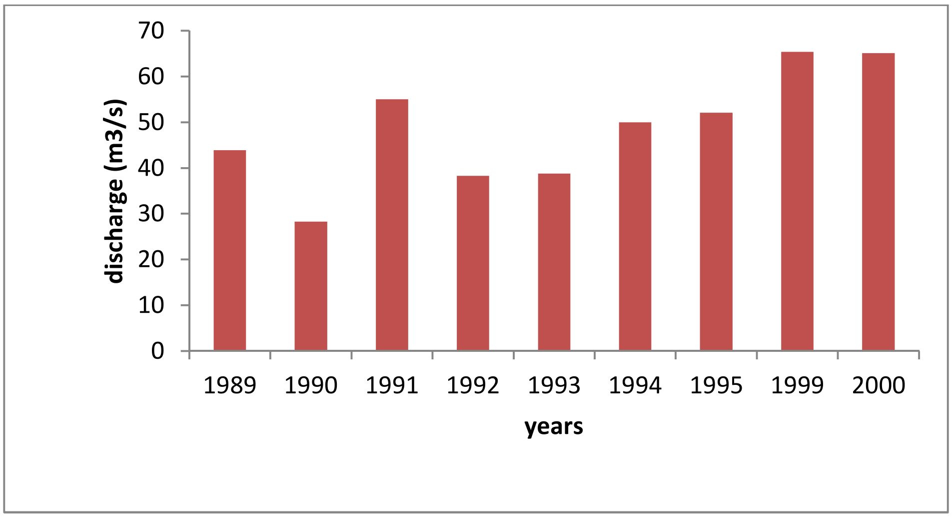


Figure 3.3. Annual Maximum series from 1989-2000

TABLE 3.1 Exceedance Discharge Function

Return Period Years	Probability (%)	Frequency Factor	Log Q	Q (m^3/s)
2	50	0.059	1.666	46.34
5	20	0.854	1.747	55.84
10	10	1.237	1.786	61.09
25	4	1.622	1.825	66.89
50	2	1.859	1.849	70.73
100	1	2.062	1.870	74.18
200	0.5	2.242	1.888	77.38

3.3 Existing River Profile

The map extracted from the Google map editor was used to show the datum elevations of the water surface at each cross section and is shown in Figure 4.2 below

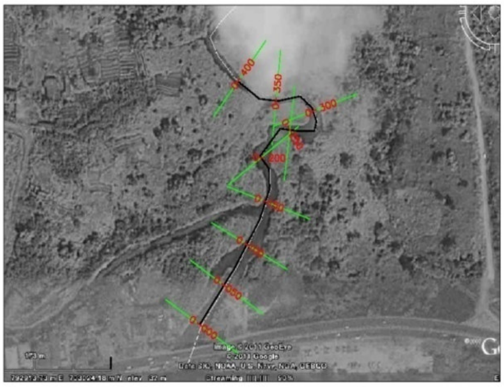


Plate 3: Map of the Ikpoba River showing cross sections for each station
Source: Google earth maps December 2011

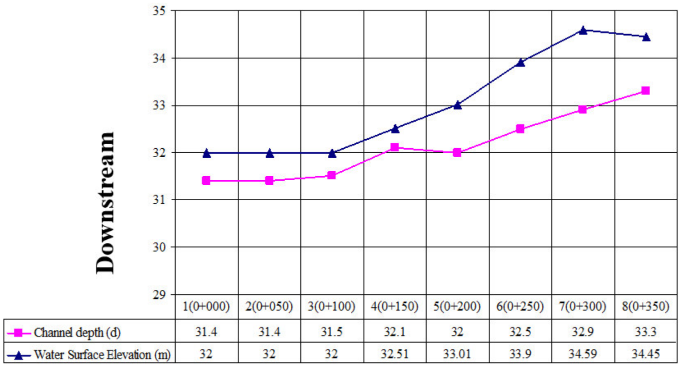


Figure 3.3 Longitudinal Profile of the Ikpoba River Channel.(December 2011)

plots of the cross sections depicted in plate 3 are shown in figure 3.4

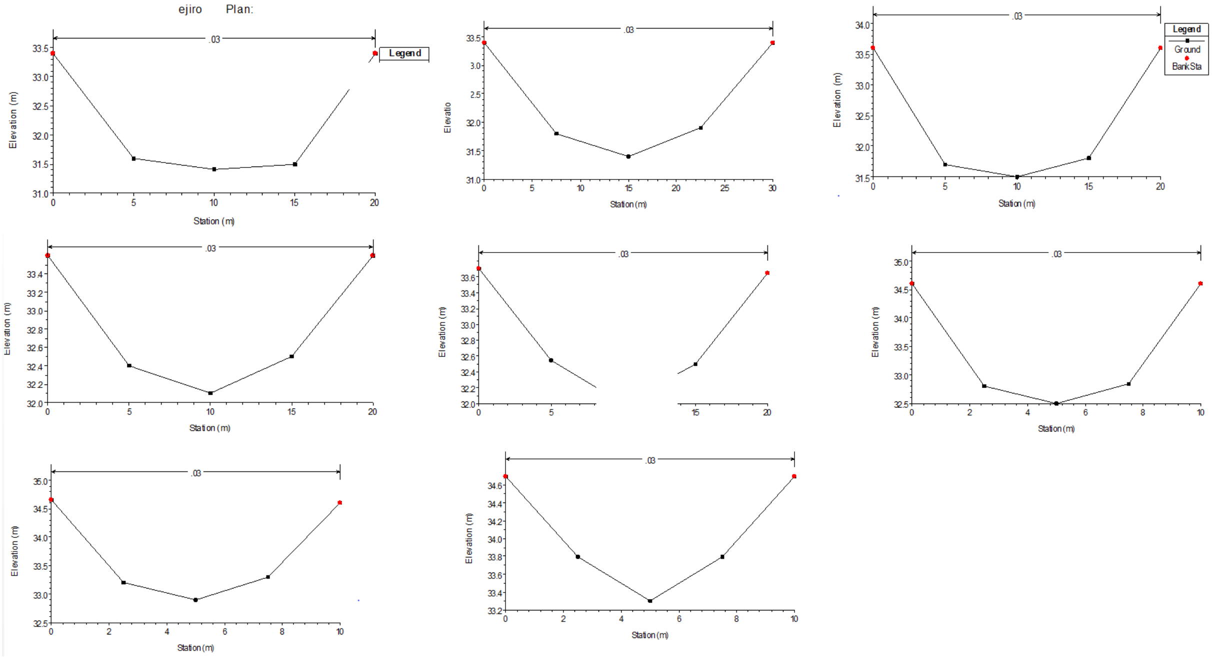


Figure 3.4 Plots of cross sections 1-8 for the Ikpoba River

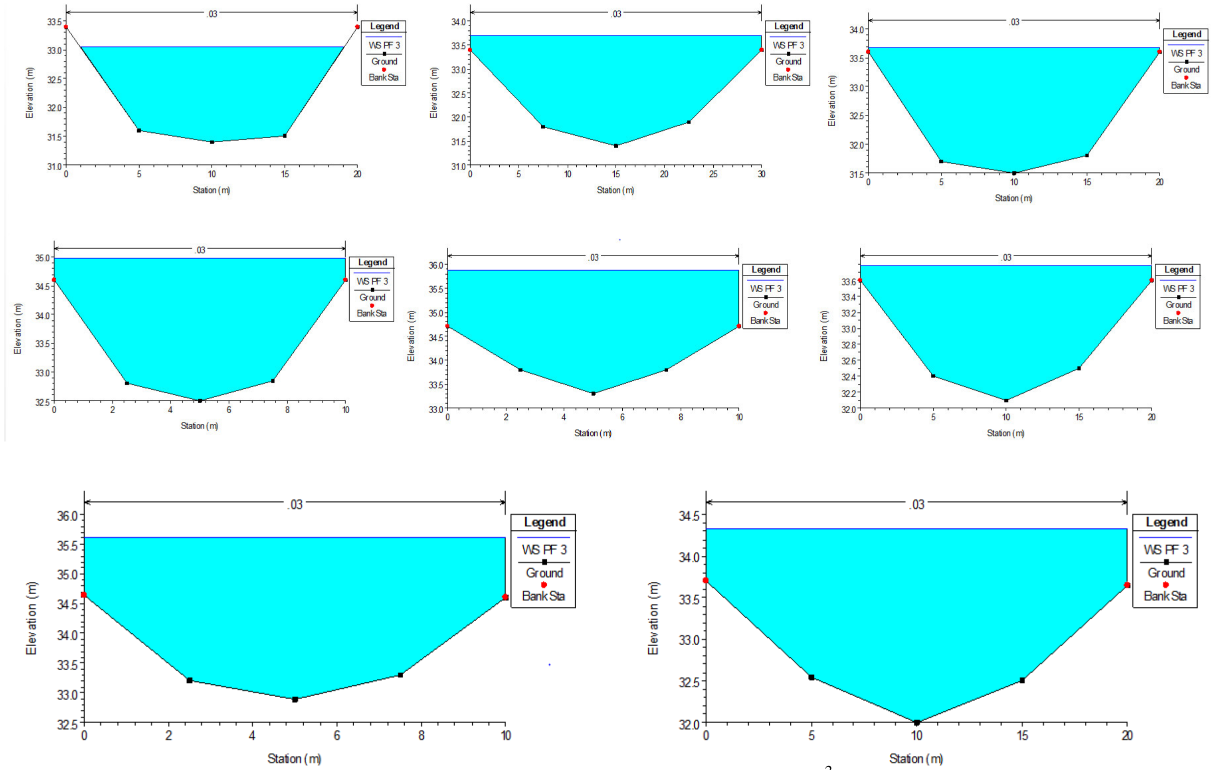
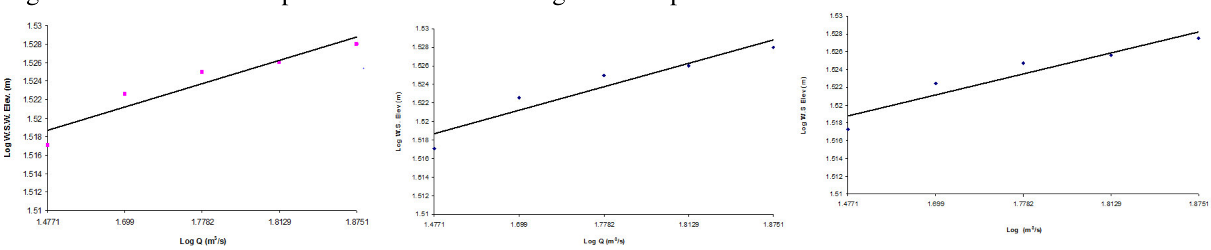
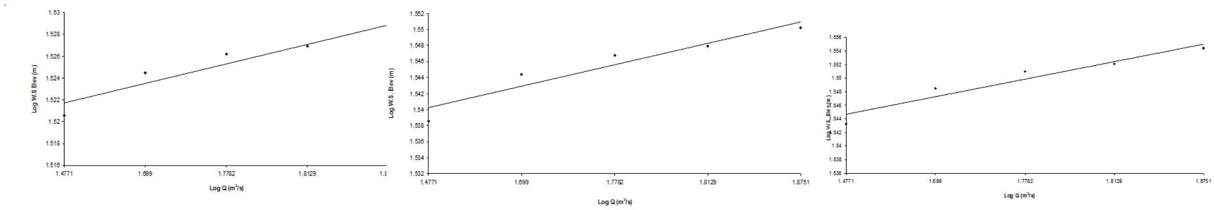


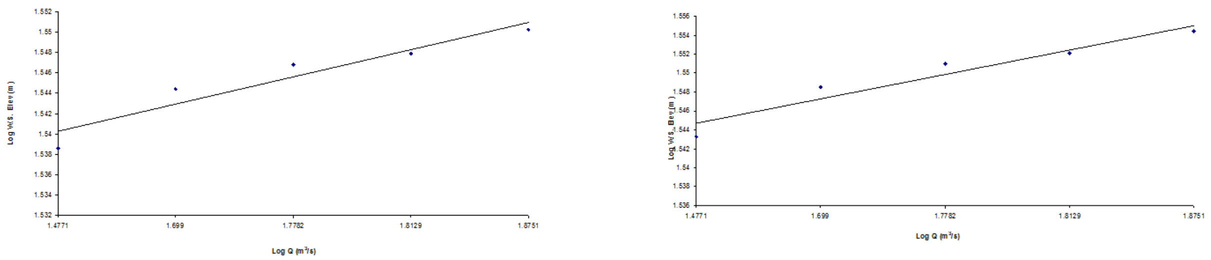
Figure 3.7: cross sections plots for section one to eight for the profile of 75m^3



Station 1 station 2 station 3



Station 4 station 5 station 6



Plots of rating curves for stations 1-8 Ikpoba River.

4.0 Discussion of Results

The mean monthly discharge over the period from 1989 to 2000 is 33.82m^3 /s while the modal discharge is 65.4m^3/s recorded in September 1999.The lowest discharge observed is 12.15m^3/s which was recorded in February 1989.September is the month with the highest recurring monthly discharge having maximum discharge records in 1991,1992, 1993,1994,1999 and 2000.January has the lowest monthly average discharge at 24.78m^3/s.

The logarithmic mean of the annual maximum series is 1.66, standard deviation determined as 0.102 while the coefficient of skew is -0.356.

From the exceedance frequency relationship it can be seen that a discharge of 46.34m^3/s can be observed or exceeded once in two years. For five ten and twenty five years return period the discharge values which could be observed or exceeded are 55.84m^3/s, 61.09m^3/s and 66.89m^3/s respectively. The one hundred year return period gives a discharge of 74.18m^3/s.

At a return period of 100years the water surface at sections, 1 ,2 ,3 and 4 are 33.05m, 33.7m, 33.7m and 33.8m respectively while at sections 5, 6, 7 and 8, the water surface elevation above sea level are 34.3m, 35m, 35.1m and 35.8m respectively. The ground level adjoining the sections are 33.1m, 33.4m 33.6m and 33.8m for sections 1, 2, 3, 4 and 33.7m, 34.6m, 34.6m and 34.7m for sections 5, 6, 7 and 8 respectively.

At 75m^3/s station three and four have overflows of 0.1m and 0.2m respectively while station 5 has an overflow of 0.6m. Station six has an overflow of 0.4m, station seven an overflow of 1.00m while station eight has an overflow of 1.25m figure 4.8. The difference in shapes and intercepts of the rating curves can be attributed to the difference in the geometry of each cross section.

4.1 Conclusion

The discharge value for return period of one hundred years cannot be accommodated by the existing river channel as depicted by the cross sections shown in figure 4.8 indicating the need for channel modifications (i.e. expansion and dredging for the river) determining right of way restrictions evaluate impacts of obstructions and restrictions etc.

The water surface profile is typical of a subcritical gradually varied flow where the depth of flow changes gradually with channel distance. These water levels are indicators of inundation levels that can be experienced within relative areas of the flood plain and can be used in predicting flood discharge in unguaged catchments Anupam (2010).

Areas within the area of survey have known elevations above sea level of 34 – 35m. Infrastructure constructed in this areas with foundation depths less than 1m would be inundated by 100 year return flood for up to 1 – 1.8m.

4.2 Recommendation

i. Provision should be made for data collection from rivers and updated to enable accuracy in estimation and frequency analysis for enhanced watershed modelling. The use of automated gauge and discharge recording instrument should be encouraged.

ii. More field surveys should be carried out to determine cross sectional data for rivers where dredging may be an alternative for accommodating excessive flows and as it gives information on inundations levels that can be obtained in peak flows

iii. Building regulations and restriction should be made on areas that are downstream of rivers, which are flood prone as to foundation depth and structural types [light weight structures should be encouraged to reduce damage sustained]

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