Implication of Tidal Motion and Heavy Rainfall towards Drainage in Estuary.

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ABSTRACT

Estuary is a semi-enclosed coastal body of water which has free connection with the sea, thus is strongly affected by the tidal action. Also in these areas, the level of the receiving water body is directly or indirectly affected by tidal or wave effects, including different rainfall conditions in varying intensity and duration. Estuaries as a low-lying area will be facing a direct effect from the conditions of huge tidal and heavy rainfall occurrences. This paper investigates the behaviour of the drainage in estuaries with occurrences of tidal wave and heavy rainfall. Study of the tidal affect and rainfall towards drainage system is carried out in Sungai Dinding Kiri area in Sitiawan, Perak and which the drainage of study area is located in Kampung Baru, Sitiawan which is very near to the estuary. The 100 years ARI rainfall is analysed, as stated in MASMA. Collections of data, consisting of water level and flow of water were conducted for four consecutive months. HEC-RAS Software was then used to simulate and analyse the data. To determine the effective water discharge of channel in the study area, Min and Mean Section Method were used. The peak water discharge from Sungai Dinding is 851.66m^3/s.

1.0 INTRODUCTION

1.1 Background Study

This project is dealing with the hydraulics and physical characteristics of drainage and the morphology that will be affected by the tidal wave and heavy rainfall or storm surge.

Nowadays, the global climate change may increase the frequency and severity of storms. A very wide area of coastal wetlands and other lowlands could be inundated. Flooding would threaten the surroundings in term of their lives, agriculture, livestock, buildings and infrastructures. The salt water would advance landward into aquifers and up estuaries, and acts as a threat to the water supplies, ecosystems and agriculture in some areas.

In addition of present population growth and development, coastal areas worldwide are under increasing stress. Along with that, an increased exploitation of non-renewable resources is degrading the functions and values of coastal zones in many parts of the world. Consequently, the populated coastal areas are becoming more and more vulnerable to sea level rise and other impacts of climate change. Worst, even a small rise in sea level could have serious adverse effects. Following the rainfall and storms which are not constant throughout the year, it is much afraid that it would affect the estuaries drainage physically and change a whole lot of the dynamic and coastal processes along the area. The flow and the volume are to be determined to find out at which point of the flow would affect the system. Also other physical changes would be observed accordingly.

1.2 Problem Statement

Sungai Dinding, Manjung has been a major resource of income for most of the villagers. Activity as such fishing is done daily as to support their lives. Almost all of the villagers own their own boat, and having the Sungai Dinding as path of their transportation. The activities as such are mainly affected by the tidal fluctuation occurs daily. On the other hand, the inland area is occupied by a large number of villagers and three chalets commonly used to accommodate students coming for survey and other school or college activities. Meanwhile, during heavy rainfall, it is observed that a certain area will be flooded and could not be accessed. It may affect the surrounding area, such as the structures nearby and people's activities.

Villager's belonging also might be jeopardized from the direct or indirect effect of the drainage system inefficiency during peak conditions. Therefore, hydraulic and hydrology model analysis will be carried out in order to measure the effectiveness of current system in the area within three conditions, which are the 1) tidal wave motion; 2) heavy rainfall, 3) combination of high tide and heavy rainfall.

During the peak condition of high tide and heavy rainfall, it is much afraid that the drainage might not be adequate to store the runoff and overflow, which causing flood in the area.

1.3 Objectives and Scope of Study

The objective of this study is to evaluate the effectiveness of the drainage system used in the site area of estuary during the conditions of high tide and heavy rainfall occurrence. A water surface profile will be developed as well using software of HEC-RAS.

Data collection conducted to collect the data of water depth, currents and to draw cross sectional of the channel. Data of rainfall is obtained from the JPS Manjung.

1.4 Relevancy of the Project

The study is undertaken in the area with a very wide opening of estuary and much prone to flooding event. While, the area is developing by each year, any occurrence of flooding may put many lives and belongings at stake. To take a prevention measure, a study on how the major cause of flooding should be undertaken. Therefore, the behaviour of drainage during peak condition of high tide and heavy rainfall should be observed to actually see the efficiency of the system and how to improve.

2.0 THEORY

2.1 Tidal Wave

Tidal affected are characterized by both river flow and tidal fluctuations. The degree to which tidal fluctuations influence the discharge at the river crossing depends on such factors as the relative distance from the ocean to the crossing, riverbed slope, cross-sectional area, storage volume, and hydraulic resistance [1].

River crossings located closer to the ocean have two directional flows, because of the storage of the river flow at high tide; the ebb tide will have a larger discharge and velocities than the flood tide. The amount of daily tidal flow often far exceeds upland flows [2].

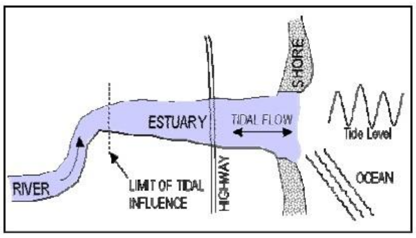

Figure 1: Estuary

2.2 Rainfall

Malaysia faces two monsoon winds seasons, which are the Southwest Monsoon occurrences from late May to September, and the Northeast Monsoon lasting from November to March. The Northeast Monsoon usually brings in much more rainfall compared to the Southwest Monsoon, originating from China and the North Pacific. The average rainfall is 250 cm (98 in.) in a year [3].

Drainage system in which most of the outflow has drained through the soil profile is referred to as the subsurface drainage systems. While systems where surface runoff is the primary drainage mechanisms are called surface drainage systems [4].

2.3 Drainage System

Diking of estuarine wetlands and tidal channels which are intends to reduce or eliminate tidal influence has been extensively practice throughout the United States [5].

In the discharge ends of the culverts, tide gates or flap gates are attached to control water flow. Tide gates are closed during incoming tides to prevent from the tidal waters to move upland. Meanwhile, they are open during outgoing tides to allow the upland water to flow through the culvert and thus into the receiving body of water. Tide gates are effective at maintaining low water levels[6].

2.4 Calculations

The calculations of the total discharge, Q of a channel can be done in two methods which are:

1) Mean Section Method
2) Mid Section Method

The difference of these two methods is in the average depth used in the equations.

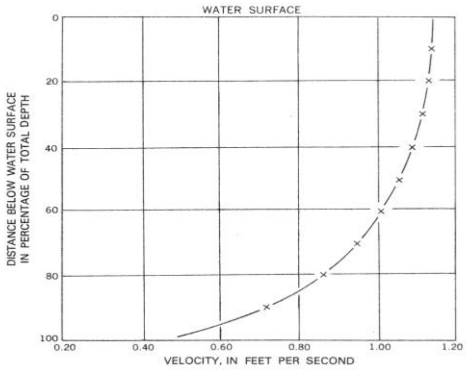

Figure 2: Vertical velocity distribution

Discharge - The amount of water passing at any point in a given time

$$\mathbf{Q = \Sigma(V \times A)}$$

Where Q = Discharge (m^3/sec); A = Cross-sectional Area (m^2); V = Average Velocity (m/sec)

<u>Mean Section method</u>

$$q_x = \left(\frac{\overline{V}_x + \overline{V}_{x+1}}{2}\right)\left(\frac{d_x + d_{x+1}}{2}\right)W_x$$

<u>Mid Section method</u>

The product of this area and the mean velocity at the vertical gives the discharge for the partial section between the two halfway points. A summation of the partial discharges gives the total discharge.

$$q_x = \overline{V}_x \left(\frac{W_{x-1} + W_{x+1}}{2}\right) d_x$$

<u>Rational Method</u>

The rational method is used around the world for peak flow estimation of small rural drainage basins and is the most widely used method for urban drainage design. The rational method equation is

$$Q = kCiA$$

C: runoff coefficient

A: Catchment area (m^2)

i: rainfall intensity (mm/hr)

k: 1.008

2.5 HEC-RAS Study Limit Determination

During the process of performing the study, it is necessary to gather data from both upstream and downstream of study reach. Gathering of additional data in the upstream is necessary to evaluate the difference level of water for both during the respective condition of tidal ebbing and tidal flooding. A constraint of data causes the data Input of HEC-RAS was done in Steady Flow rather than Unsteady Flow, which is much more compatible to the condition of the flow in the study area [7].

3.0 METHODOLOGY

3.1 Data Collection and Observation

Equipment	**Purpose**
SONDE	To measure water depth
Electromagnetic Current Meter (ECM)	Determine water velocity
Distometer	Measure width of the river
Softwares	**Purpose**
HEC-RAS	Simulates flow and cross-section

Data collection conducted once in a month starting from March until June. It is done in the area of Sungai Dinding in Manjung, Perak. Data such as water depth and current velocity is measured using the equipments of SONDE and Electromagnetic Current Meter respectively.

Table `1: Tools and Equipments used

Data of rainfall is obtained from the Department of Drainage and Irrigation (JPS) in Manjung.

Tide motions	Time
High tide	0600 and 1800 hours
Low tide	1000 and 2200 hours
Intermediate	1400 hours

Table 2: Tidal motion in Sungai Dinding daily

Data is taken during these hours to obtain the water depth during these conditions.

A continuous observation was done towards the behaviour of drainage system in the area, especially under the conditions of high tide and heavy rainfall.

3.2 Anaysis

An analysis of the data gained from the field trips is done to understand the surface runoff and water depth according to its conditions of ebbing and flooding tide, as well as the current velocity. The data were compared to the conditions of the occurrence and none occurrence of rainfall.

3.3 HEC-RAS Simulation

1. Enter geometric data and draw the schematic of the river system.

2. Enter cross-sectional data of the two points of data collection. Data as total discharge (Q), Energy Gradeline elevation (E.G), velocity head and area must be calculated using the equations before inserted.

3. Enter the unsteady flow data.

4. Enter boundary condition to establish the starting water surface at the ends of the river system. The four types of boundary conditions are the water surface elevations, critical depth, normal depth, and rating curve.

5. Perform the hydraulic calculations to calculate the unsteady water profiles.

6. Compute the simulation.

4.0 RESULTS AND DISCUSSIONS

4.1 Analysis

<u>Rainfall</u>

Rainfall data gained from the JPS is analysed into average monthly rainfall volume for the past 20 years in Pejabat JPS Sitiawan station.

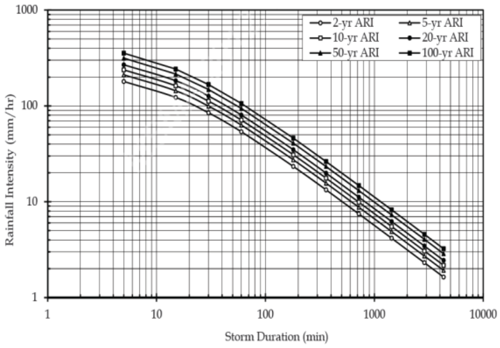

Figure 3: Average Recurrence Interval (ARI) of the rainfall intensity at JPS Sitiawan Rainfall Station – 4207048

By having the data of actual rainfall, the data collection of surface runoff can be compared with. Any increase in surface runoff is usually related to the rainfall occurrence. The graph shows the Average Recurrence Interval (ARI) of the rainfall intensity at JPS Sitiawan Rainfall Station – 4207048.

The prediction of rainfall conditions were done up until 100 years of return period. It is predicted that the global warming as an added factor of higher rainfall intensity could cause a massive flooding in the area.

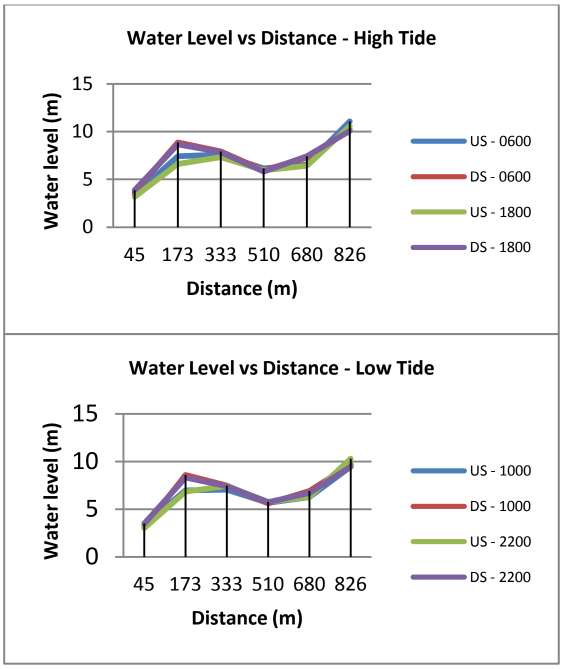

Figure 4: Graph of Water Level vs. Distance for Upstream and Downstream

As data of water level taken during high and low tide conditions, the average and maximum value of water level is analysed. The crititcal condition of water level is taken during the high tide of 0600 hours, to be analysed in the HEC-RAS simulation.

As for the total discharge of the stream, few calculations has been made using the Mean and Mid Section Method. The calculations done for both Upstream and downstream sides and during the high and low tide conditions.

	High		Low	
	US	**DS**	**US**	**DS**
Mean	682.34	722.17	806.44	792.95
Mid	712.34	756.79	851.66	829.72

*US: Upstream DS: Downstream

Using both the equations for the calculations, the differences of value are not much high. These values are compared with the HEC-RAS simulation results.

the critical profile for both Profile 3 in the upstream and downstream. While in the upstream, the condition of water surface profile might be exceeding the river banks of the channel during the peak condition of the occurrences of both heavy rainfall and a very high tide.

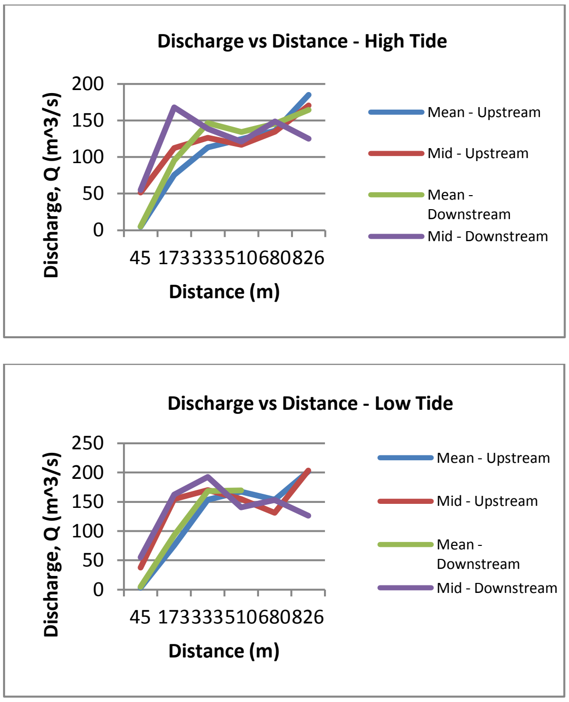

Figure 5: Graph of Discharge vs. Distance for High Tide and Low Tide conditions

4.3 HEC-RAS Analysis

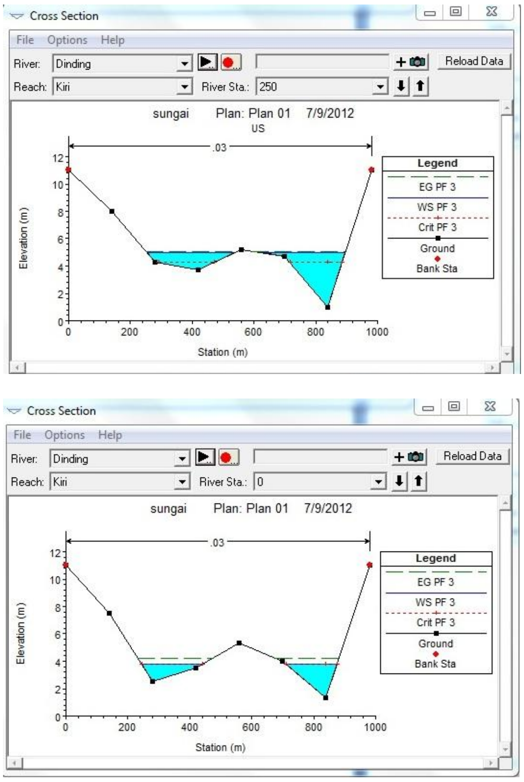

Figure 6: Cross-sections in Upstream and Downstream

As shown in the figures above, the cross section of river output were above

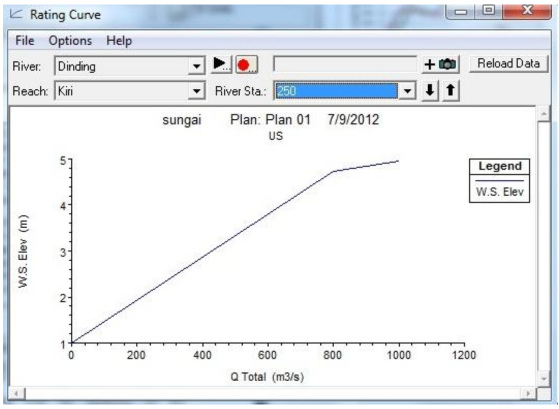

Figure 7: Rating Curve of Upstream Boundary

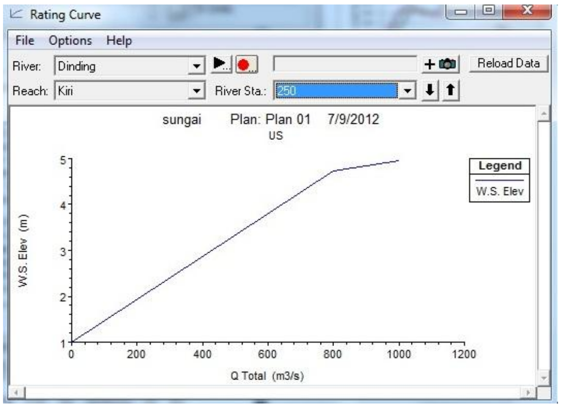

Figure 8: Rating Curve for Downstream Boundary

The rating curves show the total discharge, Q of both upstream and downstream boundaries of the stream. The resulted simulation shows a deviant of value from the total discharge calculated. This might occurred because of the steady flow condition used in the software rather than using the unsteady flow condition of the actual stream.

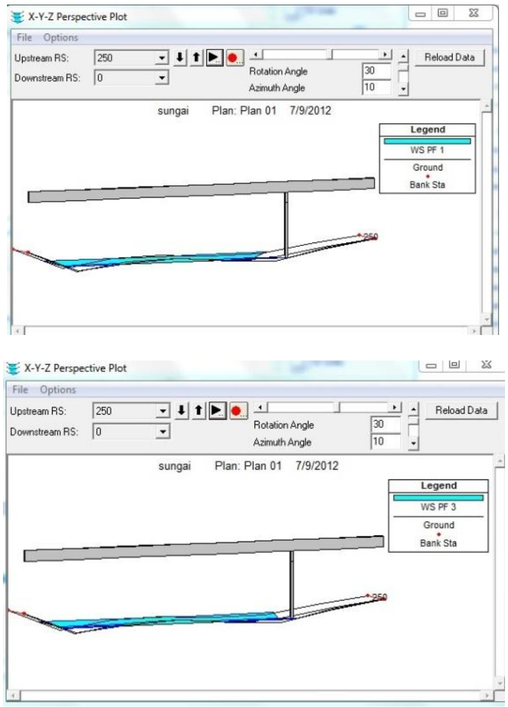

Figure 9: XYZ Perspective Plot

Figure shows the condition of the stream channels before and after the tidal reconnections. The upstream boundary is predicted to be having an overflow of runoff into the low land during high tidal or critical condition.

5.0 CONCLUSION

Based from the analysis made using HEC-RAS, the flow of surface runoff might be overflow from the river into the river banks following the critical condition, which is in a high tide including the increased surface runoff produced by the rainfall occurrences.

There are points where runoff generated enters the network, but also the points where, in case of surcharge, water level may exceed ground elevation, and flow out of the network (flooding).

As a conclusion, the resulting surface runoff and the total discharge condition which are highly influencing the stream movement are very much high in the study area. Including the peak condition where the high tidal and heavy rainfall combined will be causing flood to the area of estuaries.

Although the condition used in flow characteristic is the steady flow, rather than using the unsteady flow which is much suitable for the stream flow, the result is still reliable and much further research and simulations can be done to make sure the actual result gained.

Besides improving their drainage systems to prevent flooding, communities might choose to implement a combination of planning and structural measures to adapt to increase flooding. Buildings in low areas can be made flood proof, construction of basement can be avoided, and new buildings and streets to be constructed at higher elevations. The rural drainage has not been designed to manage an ARI of 100 and there will therefore need to be careful consideration of the increased risk imposed by the rural drainage overtopping.

As for any further research and work to be done in future, it is best to do the continuation of data collection and comparison with the existing data from other sources. The method can be extended and applied to similar drainage systems in coastal areas, and may turn useful during both the design and the operation and management phase. This will make the result to be much more reliable and can be used for further research and improvement.

6.0 REFERENCES

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