Assessment of the Effect of High Tide and Low Tide Condition on Stream Flow Velocity at Sungai Rompin’s Mouth

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Abstract. The variation in stream flow velocities depends on the riverbed slopes. In upstream areas, where slope is steep, the magnitude of velocity is high, whereas in downstream areas, where slope is gentle, the magnitude of velocity is slow. The focus of this study is in the downstream area, where variations in the magnitude of velocities are due to high tide and low tide situations. Due to sea level rise, flooding occurs with high tides in several coastal regions which causes road closures due to submerged in water and public inconveniences. Velocities in high tide conditions need to be examine for safety and health risk of people. Therefore, the main objective of this study to assess the variation in velocity values of stream flow at both high tide and low tide condition near river mouth. One dimensional Hydrological Engineering Centre-River Analysis System (HEC RAS) simulation was conducted 9.4 km along reach of Sungai Rompin. A total of 188 river cross sections were used at an interval of 50 m. Other river geometries such as river central line, riverbanks and flow paths were constructed in RAS mapper of HEC RAS. The unsteady flow was run in both high tide and low tide conditions. The outputs of the simulation were compared and analysed. The results revealed that the stream flow velocities reduced up to 60% in high tide condition when compared to the low tide condition near the river mouth.

1. Introduction
The rise and fall of sea level, which is also called as tides, is a natural phenomenon. The rising and lowering down of sea level is called high tide and low tide conditions respectively. The stream flow velocity reduces its power when it encounters with gentle slope areas. The river mouth lies in gentle slope area of any watershed but here, variation in velocities are due to high and low tide conditions. The high tide and low tide condition are also controlled by the monsoon and temperature variation of a region [1]. In high tide condition, water from sea starts moving backward towards upstream side which causes flooding near the river mouth [2].

With the advancement of computation technology, several hydrological models were developed to simulate a real stream flow and runoff situation. These models have been used for accurate flood
vulnerability assessment either at upstream or at downstream [3-5]. HEC RAS hydrological model is publicly available software generally use for the assessment of flood vulnerability. However, several ground-based or surveyed data also need to run HEC RAS model [6].

The focus of this study was to conduct one dimensional HEC RAS simulation at river mouth of Sungai Rompin to analyse the effect of stream flow velocity variation in downstream area. Therefore, the objectives of this study were (i) to conduct 1D HEC RAS simulation at 9.5km reach of Sungai Rompin near the river mouth and (ii) to assess the stream flow velocity variation due to high tide and low tide condition in the study area. The information and assessment from study will be helpful for policy makers to mitigate coastal flood risk and vulnerability.

2. Materials and methods

2.1. Study area

The study area is located in Pahang State, eastern part of Peninsular Malaysia that lies between Latitudes 2° 48’N and 2°49’ N, longitudes 103° 27’E and 103° 29’E. The coastal area is bounded by South China Sea as shown in Figure 1. The elevation ranges from 0 to 25m above mean sea level with gentle slope in the study area. The climate is tropical, humid with average temperature ranges from 20 °C to 30 °C. The period from November to January receives maximum rainfall, while between June and July, the season remains dry. The average annual rainfall of the area is approximately 3000 mm, while the average daily wind speed is 1.50 m/s.

2.2. Data

The bathymetry data was obtained from the field survey in study area using ODOM MKIII Echo Sounder mounted on a boat along with other sensors such as Trimble SPS 461 Receiver Differential Global Positioning System (DGPS), HydroPRO 2.4v Nav Software for Data Acquisition and TOPCON GNSS RTK Systems GR-5 Receiver. DGPS was used to navigate and positioning for survey vessel and sensors with great data accuracy, HydroPRO was used for navigation of integrated survey vessel and survey sensor to data recording & tide processing and TOPCON GNSS RTK was used to Measure ground level for topographic XYZ data using GPS base station reference. The data obtained from different sensors were processed through the aforementioned software. The Digital Elevation Model (DEM) of 25 m resolution was developed by using the surveyed data in the GIS environment. The DEM was used as a reference terrain during hydrological simulation. Because of unavailability of stream flow data for the study area, the data of Kelantan was used. Stream flow data of December 2010 were used in this study.

2.3. Methodology

For stream flow simulation, HEC RAS 5.0.7 was used. The project was defined, and the projection of the project was set as WGS_1984_UTM_zone_48N in RAS Mapper. The terrain was created by using the DEM in RAS Mapper. A geometry file was created for the project and river central line, bank line, flow path, river cross sections were digitized in the RAS Mapper. The digitized cross sections read automatically the elevation points and saved it in the geometric file. The spacing of the cross sections were at 50 m interval. A total of 188 river cross sections were digitized along the 9.4 km reach. The Manning’s $n$ value for the left and right riverbanks and for central line were set as 0.5 and 0.025 respectively. For unsteady flow, the upstream boundary condition was used as hydrological flow in which the streamflow data was input, while for downstream boundary condition, stage option was chosen. The slope for normal depth was used as 0.0003195 which was calculated from DEM. In high tide condition, the average height of sea level was 4.49 m while the average height of sea level at low tide was 1.32 m [7].
3. Results and discussions
The width of in situ river cross sections ranges from 720 m to 1310 m. The maximum depth of -7.7332 (at downstream boundary of the reach) while minimum depth of -2.4322 (upstream boundary of the
reach) were reported from in situ cross sections. The streamflow values range from 29.4 m$^3$/s to 1113.4 m$^3$/s with an average of 87.4 m$^3$/s.

The average velocity in the study area during high tide was observed as 0.3 m/s while during low tide it was 0.7 m/s. During high tide, minimum velocity which is almost zero was found at the mouth of the river while maximum velocity (0.9 m/s) was found at upstream boundary of the reach. During low tide, minimum velocity (0.44 m/s) was found at the mouth of the river while maximum velocity (1.22 m/s) was found at midstream of the reach. The average minimum velocity, during high tide in the month of December was found to be 0.04 m/s at the mouth of the reach, while the average minimum velocity in case of low tide was 0.6 m/s. Average maximum velocity during high tide in the month of December was found to be 0.42 m/s at the mouth of the reach, while the average maximum velocity in case of low tide was 0.8 m/s at the river mouth of the reach as shown in Table 1. The results indicate that due to low velocity during high tide makes the water stagnant which increases water level towards upstream side and hence, flooding occurs. However, due to high velocity during low tide makes the way of river water to flow frequently and does not make it stagnant at the upstream side. The extent and depth of flooding depends on the magnitude of velocities during high tides. This type of information can be used to demarcate flooding area during high tide, restrict any settlement around the demarcated area and avoid any construction in this area.

| Places | Min | Max | Average |
|--------|-----|-----|---------|
| High tide | Low tide | High tide | Low tide | High tide | Low tide | Average |
| 1 | 0.00 | 0.44 | 0.26 | 0.89 | 0.04 | 0.58 |
| 2 | 0.06 | 0.64 | 0.61 | 1.22 | 0.22 | 0.84 |
| 3 | 0.11 | 0.55 | 0.73 | 1.08 | 0.29 | 0.73 |
| 4 | 0.17 | 0.51 | 0.81 | 1.04 | 0.35 | 0.70 |
| 5 | 0.23 | 0.44 | 0.89 | 0.99 | 0.42 | 0.63 |

Table 1. Velocity values (m/s) at 5 different places along the reach

The maximum difference of stream flow velocities during high tide and low tide condition was observed at the river mouth which indicates the maximum daily fluctuation occurring at river mouth. On the other hand, minimum difference of stream flow velocities during high tide and low tide condition was observed at the upstream boundary which indicates the minimum daily fluctuation occurring at the upstream boundary of the reach (Table 2).

| Difference between the tides | % decrease |
|-----------------------------|------------|
| 0.535 m/s                  | 92.6       |
| 0.622 m/s                  | 74.1       |
| 0.440 m/s                  | 60.0       |
| 0.344 m/s                  | 49.2       |
| 0.209 m/s                  | 33.1       |

These results indicate that the fluctuation in the stream flow velocity decreases towards the upstream side of the river from the river mouth. The results also indicate that the effect of high tide and low tide was observed up to 9.4 km towards upstream boundary from the river mouth. The fluctuation at the
downstream reflects the social and economic impact as number of fishermen lives and do their daily businesses and such environmental impacts can destroy coastal habitats. It also effects natural and man-made barriers due to swell condition during high tide. Moreover, waves generated from the fluctuation can be vulnerable to jetties situated in nearby area. Therefore, this information can be used by policy makers for engineered and natural defences for the safety of people and coastal infrastructure.

4. Conclusions
The study was conducted to know the effect of high tide and low tide conditions on stream flow velocities at downstream areas. The results showed that stream flow velocity becomes zero at the river mouth during high tide condition while it becomes normal during low tide condition which causes rise and fall in water level due to high and low tide conditions. The fluctuation in the stream flow velocity was found maximum at river mouth while minimum at the upstream boundary of the reach. The fluctuation can generate waves which will be vulnerable to the people and coastal infrastructure. Overall, almost 60% of the stream flow velocity decreased during the high tide condition. It can be concluded that due to 60% reduction in velocity near river mouth can cause increment in water level and hence coastal flooding. In addition to this, with respect to future work perspective, a deep learning model of the proposed study can also be developed, whereby parallel image processing using map-reduce [8] algorithm can be used to correlate the experimental results.

5. References
[1] Akhir M, Fadzil M, Zakaria N Z, and Tangang F 2014 Intermonsoon variation of physical characteristics and current circulation along the east coast of Peninsular Malaysia International Journal of Oceanography 2014 1-9 doi: 10.1155/2014/527587
[2] Hinkel J, Lincke D, Vafeidis A T, Perrette M, Nicholls R J, Tol R S and Levermann A 2014 Coastal flood damage and adaptation costs under 21st century sea-level rise Proc. of the National Academy of Sciences 111(9) 3292-3297 doi: 10.1073/pnas.1222469111
[3] Masood M, and Takeuchi K 2012 Assessment of flood hazard, vulnerability and risk of mid-eastern Dhaka using DEM and 1D hydrodynamic model Natural hazards 61(2) 757-770 doi: 10.1007/s11069-011-0060-x
[4] Ouma Y, and Tateishi R 2014 Urban flood vulnerability and risk mapping using integrated multi-parametric AHP and GIS: methodological overview and case study assessment Water 6(6) 1515-1545 doi: 10.3390/w6061515
[5] Khattak M S, Anwar F, Saeed T U, Sharif M, Sheraz K, and Ahmed A 2016 Floodplain mapping using HEC-RAS and ArcGIS: a case study of Kabul River Arabian Journal for Science and Engineering 41(4) 1375-1390 doi: 10.1007/s13369-015-1915-3
[6] Anees M T, Abdullah K, Nawawi M N M, Ab Rahman N N N, Piah A R M, Zakaria N A and Omar A M 2016 Numerical modeling techniques for flood analysis Journal of African Earth Sciences 124 478-486 doi: 10.1016/j.jafrearsci.2016.10.001
[7] Zakariya, R., Ahmad, Z., Saad, S., & Yaakop, R 2013 Modelling Suspended Sediment Transport in Monsoon Season: A Case Study of Pahang River Estuary, Pahang, Malaysia. In EGU General Assembly Conference Abstracts (Vol. 15) https://ui.adsabs.harvard.edu/abs/2013EUGA...15.2592Z
[8] Akhtar M N, Saleh JM, Awais H and Bakar E A 2020 Map-Reduce based tipping point scheduler for parallel image processing Expert Systems With Applications 139 112848 doi:10.1016/j.eswa2019.112848
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