FLOOD SUSCEPTIBLE ANALYSIS AND INUNDATION RISK MAPPING FOR A REGULATED RIVER, CASE STUDY: SG. TAJAR

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ABSTRACT

Flood is a natural disaster that is frequently affecting our country. Flood happen because of overspill excess river flow, sudden storm flow, bund break, dam damage and others. Furthermore, illegal flood plain encroachment further worsens the existing problem. Therefore, prediction and pre-control of flood must be determined. To visualize this, hydrologic and hydraulic modelling software like HEC-HMS and HEC-RAS are used. This software enables predictions of changes in water level. Based on this, the flood mitigation measures can be identified. The study area that this research covers is Sungai Tajar. It flooded frequently as it has a gentle slope river and low bund along the river. Sungai Tajar has a total length of 6.5 km and has a catchment area of 8.5 km^2. Along the river has paddy field that are much likely to be in a very low-lying condition prone to inundated and damaging the farmers crops. Hence current research predicts its future and current flood level based on data collected from site observations. The predicted flood level later transformed into flood inundation maps which clearly indicates the flood risk zones. By doing this research, cultivating paddy can be planned accordingly and lessen the impact of flood in the Sungai Tajar catchment.

Keywords: flood analysis, flood risk mapping, regulated river, Sungai Tajar

1. INTRODUCTION

Peninsular Malaysia is considered facing uncertain condition of hydrological event throughout each year. Hydrological cycle of the area is unique which results from the fact that there is on average above land surface more precipitation than evaporation depending on spatial or location, major monsoons occurrences and wind intrusion. This uniqueness of hydrological events making forecasting and mapping flood is quite challenging. This resulting probability various hydrological conditions has to be taken into account.

There are many analyses of flood that have been done in Malaysia and it is spatial dependence. Each analysis tailored to certain rivers. Precipitation in Malaysia influenced by the intensity, depth, duration, area and frequency of event. With intense and isolated rainfall causing extreme flows and flooding happening in single river will differ with not so intense but extreme rainfalls throughout the catchment area (Quinn et. al., 2019).

Flood risk mapping plays a pivotal role in future planning of the location or to assist the stakeholders to making decisions in making good of the location. It also reducing the casualties in damages or losses to the people living at the location (Minh Duc, 2013). As a consequence, flood risk mapping is getting better and growing considering factored mentioned above.

In any such cases on analyzing or mapping of a river catchment it is seldom to taking account of a regulated river in Malaysia. This is caused by major rivers in Malaysia is not morphologically circulate or regulate for irrigation or flooding purposes.

Regulated rivers are water sources from rainfall or uncontrolled flow upstream conveying in river been extracted thru pumps or control structures and irrigates nearby area and drained out to the same river.

This research concentrating the flood analysis and mapping with several conditions in relating to a river that is regulated for irrigation and water excessive purposes.

2. RESEARCH BACKGROUND

The Muda Area of 100,685 hectares is the largest granary contributing 40% of national paddy production. The average annual rainfall in Muda Area is 2,107 mm (1971-2018). Hence, sources for irrigation in this area is depend heavily on direct rainfall and uncontrolled flow (Loh & Cho, 2008). The rainfall trend in Muda Area has two separate wet seasons that is April to June and from September to November. Main rivers flowing through the Muda Area are Sungai Padang Terap, Sungai Bata, Sungai Arau, Sungai Pendang and Sungai Gurun. Therefore, during paddy growth stage, standing water in paddy fields can be a cause of flood occurrence.

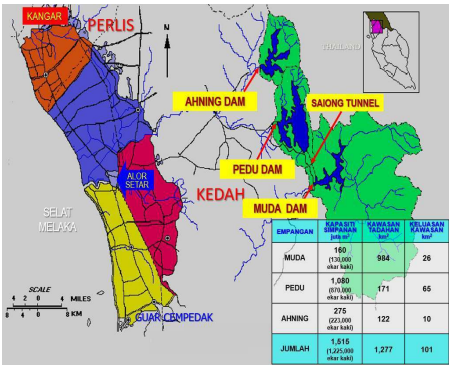

Figure 1 Location plan of Muda Area

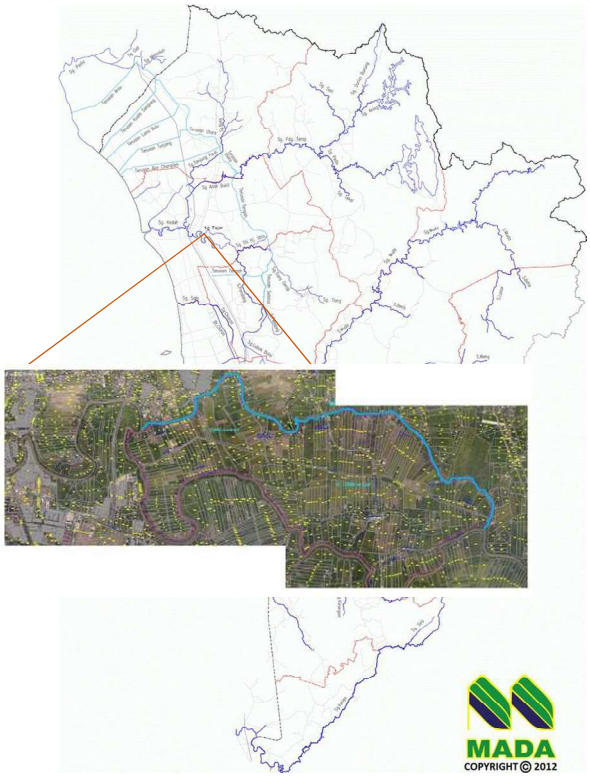

Figure 2 Sungai Tajar

The Muda Area is frequently hit by floods especially in monsoon season when the monsoon transition or during the northeast monsoon where extraordinary rain is obtained either outside the area or downstream of the dam. Exceptional rain-borne conditions in riverside catchments resulted in high flow rates in major rivers causing water levels to rise to the level of danger and expose agricultural areas to flood occurrences.

Among the main factors of frequent flood problems in the Muda Area are due to the inability of rivers to flow high into the sea due to heavy rain in the river catchment area. In November 2010 flood incident, the recorded inundated area is 25,404 hectares that is a quarter of Muda Area. Usually around that month the paddy growth stage is vegetative stage that is 60 days to 90 days needed standing water in fields between 50 mm to 100 mm (Teoh & Chua, 1989) and it brings monsoonal rain where it rains a lot at dam catchment. The operational of water management became conflicted between distributing water for irrigation and conveying flood to the sea.

The flood events in the Muda Area are due to heavy rainfall (100 - 200mm) within 1 - 3 days or more in river catchment areas. Continuously increasing the flow of water will cause overflows on the lower banks along the river. Most of the morphological rivers have a low slope level of 1: 15,000 and a relatively narrow cross section and shallow that filled with sediment.

In addition, the tributaries that are still in a state of nature and the absence of a control structure at the end cause water from the main stream flowing back into the affected area. This surplus stream will cause an increase in the water level in the affected area and will make it difficult to drain the water from the field due to heavy rain.

3. MOTIVATION

Studies about regulated rivers in Malaysia seldom focusing on the rivers itself rather more on hydropower plant and usually in depth about its effects on ecological. Adjustments or manipulating increase or decrease water levels in river is known as hydropeaking (Hauer, 2016). In Muda Area, most of the rivers flow within the area are regulated from flowing as drainage water to an irrigated source to paddy fields that majorly covers in the area. Paddy are cultivated twice a year. Therefore, the water demand for the area is very high and critically has to be managed wisely and optimum. If there is flood occurrence, the flood routing has to be done and in the same time does not jeopardizing the crop establishment.

This study is about flood analysis and mapping but taking considerations of regulated river in some portion of the river system in the Muda Area.

4. PROBLEM STATEMENT

The research area is situated 15 km south of Alor Setar as indicated in Figure 1.2 below. The existing paddy area covers about 1,800 acres and adjacent to North South Expressway. The catchment area is approximately 8.45km^2. The total number of farmers involved in this area is estimated to be 85 peoples.

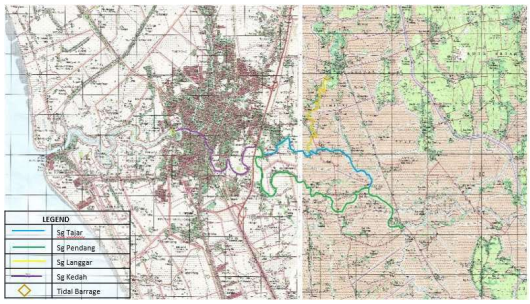

Figure 3 Topography Map of Sg Tajar

Due to the undulating plain and occurrence of many local depressions of this area, irrigation and drainage are major problem. Furthermore, occasional occurrence of flood has further reduced the paddy yield in this area. In 2005 flood event, the yield reduced approximately 43% that impacted about 10,575 farmers in Muda Area.

The catchment also covers a tributary called Sg Langgar and has recycling pump stations of capacity of 20 cusecs of 5 pumps supplying nearby irrigation canals. The pumps can convey recycling water for irrigation purposes for an irrigation blocks that is about 2,100 acres. It also received uncontrolled flow upstream from Sg Pendang and converged to Sg Pendang. The uncontrolled flow may achieve the highest recorded in 2010 that is 3,200 cusecs. Sungai Pendang has steep catchment at upstream area (from Bukit Perak to PondokChegar); therefore, it has low water retention property and high peak discharge. This factor brings flooding to Sungai Tajar that is located at the middle stretch of Sungai Pendang.

When planting seasons usually starts between September to January the following year, the recycling pump will operate and depend on Sungai Pendang has high water stage, may reduce the inundation to the paddy area but the flooding problem still remains since the river converges and diverges at the same river Sungai Pendang. The average pumping discharge to the irrigation blocks are 4,000 cusecs. The length between the verges are short and low gradient approximately 6.46km.

The Sg Tajar regulates water that convey from upstream catchment and surface runoff of the catchment and differs in water activities relating to paddy growth stages. This is the problem where conflict of water activities in conveying excess water and irrigates the paddy fields.

Furthermore, tidal effect happens in Sg Tajar because of the downstream of the river is Sg Kedah that will flow out to the sea via a tidal barrage downstream. For the planting seasons the downstream level must be kept 3 to 3.3 feet mean sea level for the pump stations can be operated.

This research will study several conditions in analyzing flood, effects of installing water control structures at the verges and inundated area that can be mapped. There is no flood modelling been done in this area therefore is best to investigate and to benchmark to other rivers that has same characteristics as Sg Tajar.

5. OBJECTIVES

There are several objectives for this research as listed below:

5.1 to derive flood hydrograph for various river water regulations condition using HEC- HMS.

5.2 to analyse flood level using HEC-RAS model for regulated river during planting season and monsoonal season.

5.3 to produce digital flood inundation maps for Sungai Tajar by using Geographical Information System (GIS).

6. SIGNIFICANCE OF STUDY

The Sg Tajar regulates water that convey from Sg Pendang length about 53 km at upstream catchment about 237.28km^2 of upstream river and also at mid length of the river conveys from Sg Langgar catchment about 188km^2 with its length 8.8 km and this differs in water activities relating to paddy growth stages. This is the problem where conflict of water activities in conveying excess water and irrigates the paddy fields. When managing water in the paddy field it has to be according to the paddy growth stages.

The research will proof flood analysis and mapping for regulated river is possible with taken considerations several conditions that is happening in this area. It will set benchmark or guidance in analyzing a regulated river and assists stake holder in making future planning in flood mitigation measures in any river that has same characteristics as Sg Tajar.

This research also can reduce in damages to the crops if the planting activities is adherence the planting schedule and suits the hydrological pattern in the area. Agencies like MADA, JPS and SADA can benefitted from this research by planning the operational task each year. The paddy yield also can increase that will benefit the farmers in terms of their household income is secured.

7. CASE STUDIES: FLOOD PROBLEMS IN SUNGAI TAJAR CATCHMENT

The Sungai Tajar is a tributary of Sg Kedah. It is one of the rivers that is important source of water supply for irrigation and as flood routing channels. The remaining reach of the river is predominantly surrounded by paddy field with scattered rural settlements. The river is a midstream where the upper and lower catchment is fully and partially developed with housing and city administration area.

Flooding issues in Sg Tajar extensively because of large volume of excess water upstream that it cannot withstand the volume hence it overtops the river bund and inundated nearby low-lying area that is mostly paddy fields.

Plate 1: Pictures of flood at Sg Tajar Catchment

Inability to carry large volumes of floods to downstream based on this several factors that is flat topography of flood plain with ground level ranging between +1.0 m to +3.0 m along it stretch of 8.5 km this means shallow, narrow waterways and very gentle gradients. It also happens to be at downstream high tide level around +2.0 m compared to ground level at the area ranging +1.0 m to + 1.5 m. There is also cause of the constricting effects of debris, tree branches and aquatic growth in the river.

Flood occurrences worst recorded is on November 2010. It was said to be generated from the inter – catchment transfer of water at the boundary Thailand and Kedah through Ahning and Pedu catchment. The flood is widespread due to partly from high tide effect combined with intense rainfall and runoff from the hilly area and also happen to be on the monsoonal northeast where heavy downpour is throughout the country.

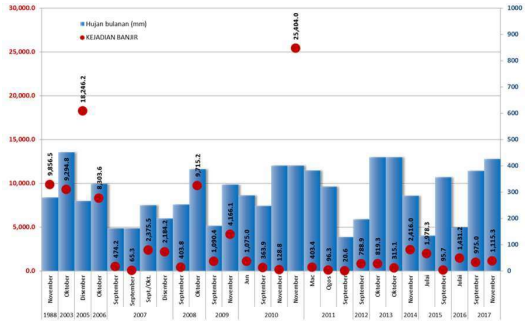

Figure 4 Major Flood Occurrences in Muda Area (1988 – 2017)

8. METHODOLOGY

The entire study structure has been developed below:

8.1 Hydrology study including hydrologic modeling using HEC-HMS for existing and future condition

8.2 Hydraulic study including river modeling using HEC-RAS.

8.3 Flood Mapping by integrating Arc GIS and HEC-RAS.

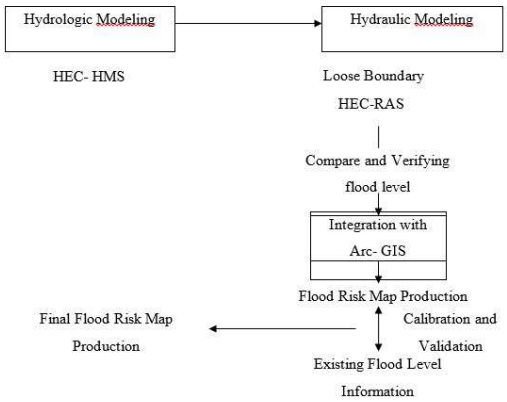

Figure 5 Research Methodology Plan

To meet the objectives of flood study, characteristically peak flow, total runoff volume, hydrograph timing, peak stage, and floodplain delineations are required. These values are calculated for current development and future development conditions. In general, the procedures to develop a watershed model and calculate values include steps such as:

a. Select appropriate methods to represent watershed
b. Get and use various maps representing Sungai Tajar catchment like topography map, landuse map and cadastral map.
c. Collect watershed data and characteristics
d. Data collected using previous drainage and channel studies or reports from agencies related like soil types, infiltration rates, land use characteristics and the percent of impervious area due to development, physical characteristics of the watershed including lengths and slopes, local precipitation patterns, drainage patterns and drainage channel geometry and conditions.
e. Utilize regional studies and equations to estimate parameter values by calculating the discharge or in other word process rainfall runoff analysis.

f. Calibrate the model if historical data are available.
g. Exercise the model with various precipitation events, using either historical or hypothetical frequency-based events as needed.
h. Analyze results to determine required values such as the peak flow or total runoff volume.
i. Modify the watershed model to reflect changes in the watershed.
j. Re-exercise the model with the same precipitation events.
k. Compare the results to quantify the impact of the watershed changes.
l. Develop tight-coupling integration procedure to take computed water surface profiles generated from the river models.
m. Tabulate in GIS the stored cross section parameter and determine cross section elevation and flood extent will know for floodplain at each cross section.
n. Transfer the information above to 2D and 3D flood risk maps by using One to One relation in GIS.

9. DATA COLLECTION

Data required for the study includes topographical data from topographical map, landuse data for hydrological modeling such as river geometry and river sediment characteristic for determination of Manning's Roughness, river survey for hydraulic modeling, hydrological data for hydrological modeling and flood estimation, geotechnical information for stability and scour analysis and tidal levels observations for setting the downstream boundary condition in river modeling.

9.1 Landuse Data

The data will be obtained from the Rancangan Tempatan by Majlis Bandaraya Alor Setar and Majlis Daerah Pendang the local plan was proposed until 2025. Generally, the proposed land use varies from fully industrial in the upstream catchment and mixed commercial, institutional and residential in the downstream reach near Sungai Tajar.

9.2 Engineering Survey

Survey data will be obtained from MADA that consists of survey of Sungai Tajar from JKR Bridge Jalan Datuk Kumbar to Highway bridge at downstream covering a distance of approximately 6.5 km. Field survey will be conducted to set extra elevation information on floodplain elevations.

9.3 Hydrological Data

The rainfall data will be obtained from Hydrology Section, MADA. The records of data include several rainfall stations in the catchment. The rainfall stations identified are at Alor Binjal and Hutan Gelam whereas for water level stations are located at PN15 Tajar Flume and downstream Sg Tajar.

9.4 Tidal Level Observations

As the downstream reach of the river is under influence of tidal fluctuation so tidal observations readings is a must in Land Survey Datum. This data is important for river modeling where the varying tailwater condition can be simulated set based on the observation results. For tidal recorded data can been retrieve from MADA station at Ampang Jajar Barrage

Table 1 Checkpoint for sampling data and validation at Sg Tajar

No. Check Point	Nama Sungai	Struktur / Cabang Sungai	Koordinat		Gambar
			Latitude	Longitude	
1	Sungai Kedah	Tandop Ampang Jajar	6.117268	100.349047	
2	Sungai kedah / Sungai Anak Bukit	Cabang sungai Kedah & Anak Bukit	6.116789	100.361718	
3	Sungai Kedah	Jambatan JKR, jalan Sultan Muhammad Jiwa (Pekan Melayu / Cina)	6.115528	100.363476	
4	Sungai Kedah / Sungai Raja	Jambatan JKR, jalan Raja (Balai Bomba lama)	6.114588	100.364834	

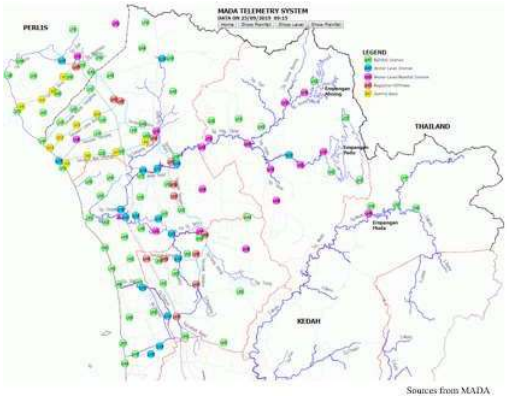

Figure 6 Telemetry Station in Muda Area

10. CONCLUSIONS

10.1 Expected Outcomes on the Sungai Tajar Flood Analysis and Mapping

Table 2 Summary of expected outcomes

NOS	PROBLEM STATEMENTS	RESEARCH OBJECTIVES	OUTPUTS	OUTCOMES
1	Flood susceptible analysis for a regulated river is not analysed	To produce hydrologic and hydraulic analysis for a regulated river (HEC-HMS and HEC-RAS)	Result simulation of rainfall – runoff and river analysis on HEC HMS and HEC RAS	Reference or benchmark in analysis of hydrological and hydraulic for a regulated river
2	There has been a little discussion about inundation risk mapping on a regulated river	To produce flood risk mapping on a regulated river	GIS Flood map for Sg Tajar	Benefits in future modelling on regulated rivers
3	Relationships between paddy planting activities with flood occurrences should be addressed	To produce the analogy on paddy growth with flood forecast	Forecast planting schedule for Muda Area	As a reference on time best to start paddy cultivating

10.2 Scope and Limitation of the Study

10.2.1The study covers only Sg Tajar but still consider discharges from Sg Pendang and Sg Langgar as inflow.

10.2.2Assumptions of discharges from Sg Pendang and Sg Langgar are not regulated rivers.

10.2.3Tidal effect is constants whether the barrages fully close or fully open.

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