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Modeling of Flood Mitigation Structures for Sarawak River Sub-basin Using InfoWorks River Simulation (RS)

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***Abstract*—**The distressing flood scenarios that occur in recent years at the surrounding areas of Sarawak River have left damages of properties and indirectly caused disruptions of productive activities. This study is meant to reconstruct a 100-year flood event that took place in this river basin. Sarawak River Sub-basin was chosen and modeled using the one-dimensional hydrodynamic modeling approach using InfoWorks River Simulation (RS), in combination with Geographical Information System (GIS). This produces the hydraulic response of the river and its floodplains in extreme flooding conditions. With different parameters introduced to the model, correlations of observed and simulated data are between 79% – 87%. Using the best calibrated model, flood mitigation structures are imposed along the sub-basin. Analysis is done based on the model simulation results. Result shows that the proposed retention ponds constructed along the sub-basin provide the most efficient reduction of flood by 34.18%.

***Keywords*—**Flood, Flood mitigation structure, InfoWorks RS, Retention pond, Sarawak River sub-basin.

I. INTRODUCTION

SARAWAK River's left tributary basin springs from the mountainous area in the remote jungle adjacent to the southern border to Kalimantan, Indonesia. Then, the river flows through Kpg. Bengoh, Kpg. Danu, Kpg. Git, Buso, Kpg. Sekunyit and Bt. Kitang, where it confluences with Sarawak River's right tributary and passes Kuching City to the South China Sea [1]. For this study, data is taken from the stretch of Kpg. Git to Bt. Kitang. Bt. Kitang has a catchment area of 657km^2 and is situated approximately 35km from Kuching City; while for Kpg. Git, its catchment area is 440.1km^2 and is roughly located 51km from Kuching City [2]. Fig. 1 shows the Sg Sarawak System that indicates the location of Kuching City, Bt. Kitang and Sarawak River Barrage.

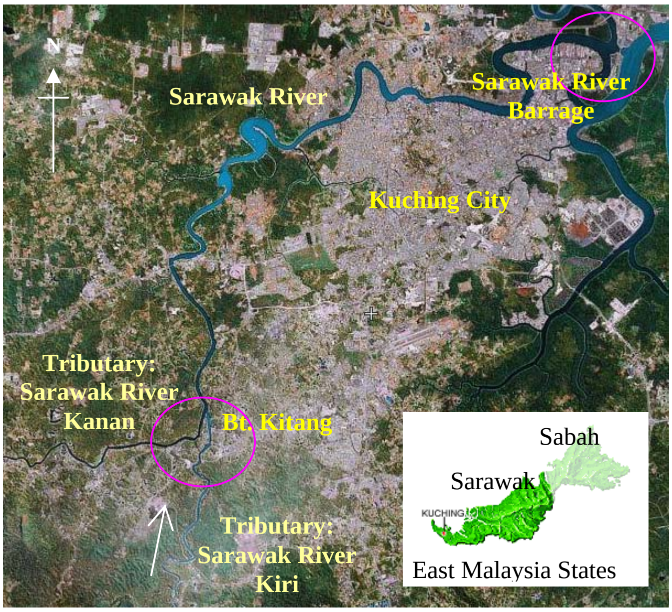

Fig. 1 Sarawak River Basin (http://www.wikimapia.org)

It was reported that before the construction of Sarawak River Barrage in 1998, the most significant flood events in the history of Sarawak occurred in January and February 1963. During this period, the state experienced an abnormal heavy rainfall, recorded as 2500mm for the two months. Spring tides from the sea coincided with heavy precipitation from the upstream catchments. Therefore the excess of runoff had given rise to the water levels and causing the low-lying areas to be flooded, as high as 7 meters. Even after the barrage is in operation, hitherto major flood events still occur although in a smaller magnitude. Examples are the flood events in February 2003 and January 2004 which saw a rise in the water levels, up to 3 meters.

InfoWorks River Simulation (RS) software developed by the Wallingford Software [3] is used in this study to model 100-year flood in Sarawak River sub-basin. This software is

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preferred as it has been widely used for flood analysis and modeling in Malaysia, such as in Juru River [4], Kerian River [5], Selangor River [6], Bang Pakong River [7], and Sarawak River Kanan [8].

II. METHODOLOGY

The cross section profiles of Sarawak River sub-basin are collected from the Department of Irrigation and Drainage, Sarawak resulted from a survey done in May 2000. There are 14 river cross section profiles (see Fig. 2) available in AutoCAD format, which is later processed through ESRI ArcView that enables the shapefiles (SHP) data to be converted directly into InfoWorks RS model database.

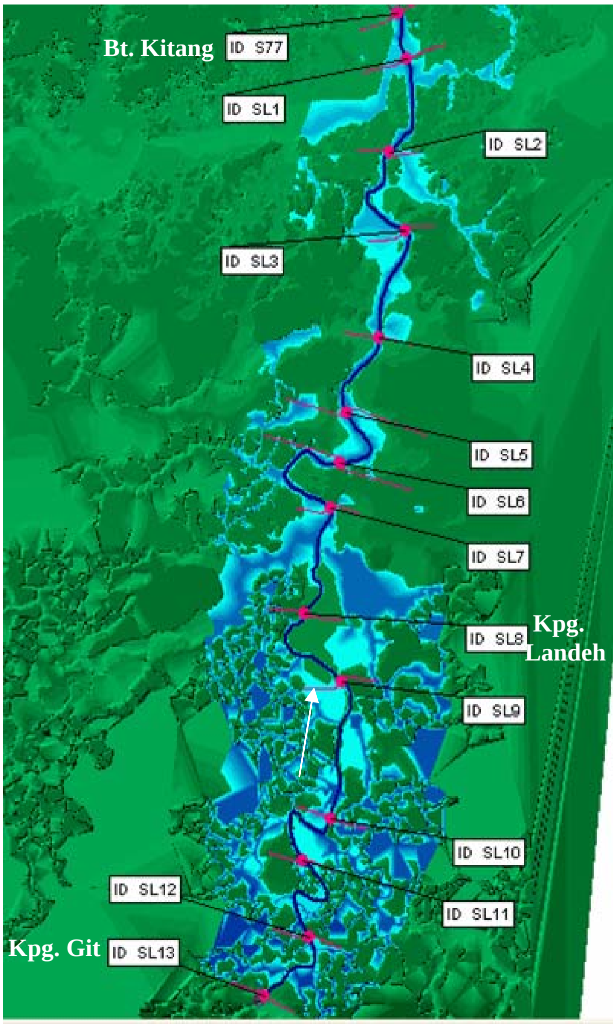

Fig. 2 Location of the 14 Cross Sections along Sarawak River Sub-basin Model without Flood Mitigation Structure

Hydrological data inclusive of cross section and water level data is imported into InfoWorks RS. From these data, a model is created and later simulated for the process of calibration and verification. The results can be either obtained from InfoWorks RS or directly displayed through ArcView.

The multiple steps involved in modeling the river by using InfoWorks RS is as summarized in Fig. 3.

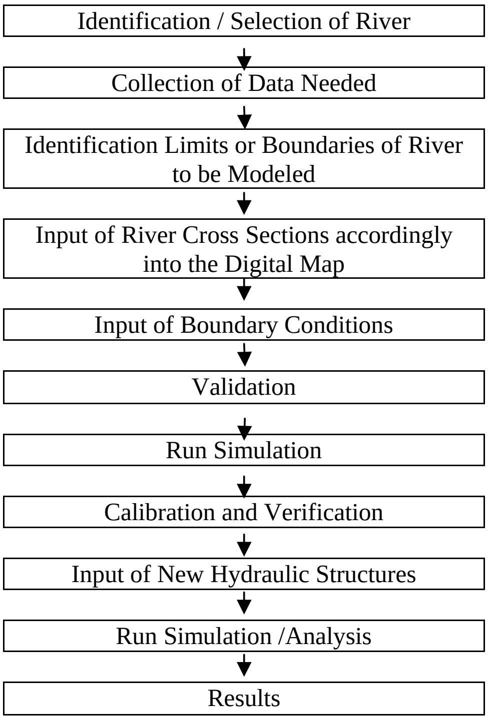

Fig. 3 Summaries of Steps in River Modeling

In any hydrodynamic river simulation, the most important input would be the shape of the river which is represented by the cross section, hydraulic structure, river flow, and water level. Boundary conditions are the input data that are applied either at the upstream or downstream end points, to present the river flow on each end or junction of the network. Flow-Time Boundary is applied on Kpg. Git as the upstream inflow hydrographs. The Flow-Time Boundary specifies a set of pairs of data consisting of flows and times. Stage Time Boundary is used on Bt. Kitang as the downstream end of the network. A Stage Time Boundary specifies a set of pairs of data that comprises of water levels above datum and times.

Simulation is the last process involving river modeling. This procedure is carried out to view the behavior of the river network under particular conditions and the effects of the input or given boundary conditions to the modeled river over a period of time. Simulations are grouped into runs, with each run applying to a single network but utilizing one or more event data sets. The time span given for simulations is depending on the model. For this study, time span used for simulations is 24 hours.

The data required for calibration was the Manning's roughness coefficient, *n* for river and floodplains. Manning's *n* roughness coefficient depends on channel material, surface irregularities, variation in shape and size of cross section, vegetation and flow condition, channel obstruction, and degree of meandering [9]. The calibration session involves a trial and error method where different sets of model options and parameters were used until an acceptable match between the observed and modeled water level is achieved.

Three 24-hour events are taken, where two for calibration and one for verification of the model. Calibration events are carried out on 1st and 9th April 2007, while event on 3rd April 2007 is chosen for verification. Correlations of observed and simulated data are between 79% – 87%. The analysis indicates that for Sarawak River sub-basin, a Manning's *n* of 0.095 and 0.12 are appropriate for its waterway and floodplain respectively. A time step of 15 s is appropriate for the conversion of model.

Hydraulic structures are added after the errors in the network have been checked and corrected. For this project, the added structures are used for the purpose of mitigating the flood conditions in Sarawak River sub-basin. The flood mitigation structures that are considered in this study are levees and retention ponds. There were two scenarios used for design; using retention ponds and combination of the levees and retention ponds.

Retention ponds are chosen because they are generally used to siphon off excess discharge during high flows, thus reducing the flood probabilities. The low lying areas of the river basin also can be easily converted into retention ponds.

Levees are chosen for this study because it is an effective solution to reduce flood damage and have been used throughout the world. Levees are probably the most often used flood control structure because it is normally the easiest to build and the least expensive to construct and maintain.

The selected flood mitigation structures are positioned at appropriate locations along the stretch of Kpg. Git to Bt. Kitang. After the input of these structures, simulations of the model are re-run, so that further analysis can be made.

III. RESULTS

Results of mapping flooded areas of Sarawak River sub-basin are based on the highest water level data obtained from KTA Consulting Engineers [10]. Due to the fact that the hourly hydrographs data of Sarawak River sub-basin are not available, which includes the 100-year flood hydrographs data, readings from the water level are used as an alternative. The highest water levels are based on the 1963 flood event, which was reported as the most severe flood in the recorded history of Sarawak and generally perceived as the 100-year flood.

Flood mitigation structures are designed along Sarawak River sub-basin after the modeling of river network and simulating the flood conditions. Then, analysis is conducted based on the results obtained from running the model, which includes flood depth, flow, and velocity of the simulated river dynamic before and after the input of the mitigation structures.

Table I shows the comparison of flood depths for each of the river cross sections of the calibrated model using the scenario inclusive of retention ponds, the difference of 100-years flood levels with retention ponds and of the existing ones; without structures and the percentage of difference of flood depths. Presented in the table, the river section SL4

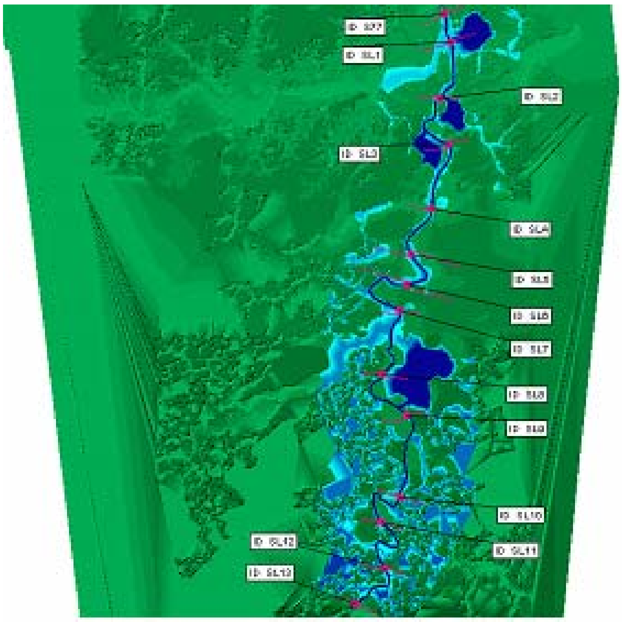

Fig. 4 Flood Map for 100-Years Flood
(with Retention Ponds)

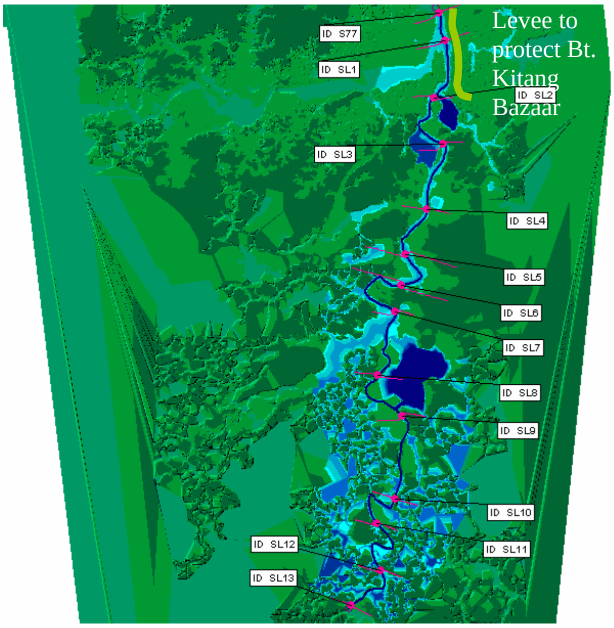

Fig. 5 Flood Map for 100-Year Flood
(with Retention Ponds and Levees)

TABLE I
COMPARISON OF SIMULATED FLOOD DEPTHS AT STAGE LEVEL FOR FLOOD SCENARIO WITH RETENTION PONDS

ID Section	Flood Scenarios without Mitigation Structures (m)	Flood Scenario with Retention Ponds (m)	Difference of Flood Depths (m)	Percentage of Difference of Flood Depths (%)
S77	4.04	4.04	0	Neutral
SL1	4.312	4.117	-0.195	-4.52
SL2	4.975	4.153	-0.822	-16.52
SL3	5.843	4.205	-1.638	-28.03
SL4	7.2	4.739	-2.461	-34.18
SL5	7.721	6.221	-1.5	-19.43
SL6	7.874	6.758	-1.116	-14.17
SL7	8.653	8.591	-0.062	-0.72
SL8	9.912	8.769	-1.143	-11.53
SL9	10.688	8.924	-1.764	-16.50
SL10	10.895	9.391	-1.504	-13.80
SL11	11.11	9.858	-1.252	-11.27
SL12	12.372	12.036	-0.336	-2.72
SL13	12.638	12.349	-0.289	-2.29

TABLE II
COMPARISON OF SIMULATED FLOOD DEPTHS AT STAGE LEVEL FOR FLOOD SCENARIO WITH COMBINATION OF RETENTION PONDS AND LEVEES

ID Section	Flood Scenarios without Mitigation Structures (m)	Flood Scenario with Levees & Retention Ponds (m)	Difference of Flood Depths (m)	Percentage of Difference of Flood Depths (%)
S77	4.04	4.04	0	Neutral
SL1	4.312	4.312	0	Neutral
SL2	4.975	4.504	-0.471	-9.47
SL3	5.843	4.549	-1.294	-22.15
SL4	7.2	5.093	-2.107	-29.26
SL5	7.721	6.393	-1.328	-17.20
SL6	7.874	6.88	-0.994	-12.62
SL7	8.653	8.621	-0.032	-0.37
SL8	9.912	8.796	-1.116	-11.26
SL9	10.688	8.949	-1.739	-16.27
SL10	10.895	9.411	-1.484	-13.62
SL11	11.11	9.815	-1.295	-11.66
SL12	12.372	11.871	-0.501	-4.05
SL13	12.638	12.21	-0.428	-3.39

has the most prominent difference in water level; with difference of -2.461m and maximum difference in percentage of -34.18 %.

Fig. 4 features the flood depth map for the 100-year flood with retention ponds as its flood mitigation structures.

Table II shows the comparison of flood depths for each of the river cross sections of the calibrated model using the scenario of combined levees and retention ponds, the difference of 100-years flood levels with combination of levees and retention ponds, and of the existing ones; without structures and the percentage of difference of flood depths. Presented in the table, river section SL4 has the most prominent difference in water level; with difference of -2.107m and difference in percentage of maximum -29.26 %.

Fig. 5 features the flood depth map for the 100-year flood with combination of retention ponds and levees as its flood mitigation structures.

From the results obtained, the effect of using only retention ponds is more significant with a maximum reduction of 34.18 % of flood depths in river section SL4.

For the combination of levee and Sarawak River sub-basin, the levees were located at the lower stream of the river, and retention ponds located at the upper stream. The effects of these combined structures also cause reduction of flood depths, which is 29.26%.

Thus, the suggested structures that are appropriate in mitigating the flood condition of Sarawak River sub-basin is the retention ponds only.

When taking environmental aspect into account, retention ponds are beneficial to protect watercourses downstream from both point and diffuse pollution by means of sedimentation. Not only does the flood volume held in the retention ponds able to reduce the impact on downstream storm water system, it could also remove pollutants through settling and biological uptake.

The ponds are capable of removing 30-80% of pollutants such as sediments, bacteria, greases, oils, metals, total suspended solids, phosphorous, nitrogen and trash [11]. The benefit of retention ponds in water treatment is an additional, as the river basin is water supply catchments for Kuching City. In terms of economic aspect, the construction of retention ponds may not cost as much than the construction of levees that were using concrete embankments and it also has the esthetic value benefits that can be used for commercial purposes.

Retention ponds are one of the most cost-effective and widely used storm water treatment practices. The construction costs itself depend on the size and landscaping requirements, thus the initial investment of the cost may be spread over a relatively long time.

IV. CONCLUSION

The appropriate flood mitigation structures in reducing the flood scenarios along Sarawak River sub-basin are suggested, modeled and tested. The effects of the suggested structures are retention ponds and combination of levees and retention ponds, in which these measures are analysed and evaluated in terms of their projected 100-year flood depths.

The most appropriate structure from this study to tackle flood problems along Sarawak River sub-basin is to construct retention ponds. With these retention ponds, water level of the

100-year flood is shown capable of a reduction significantly by 34.18%.

Future studies on the effects of the mitigation structures in water quality and environmental aspects can be duly carried out.

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