Flood Water Level Mapping and Prediction Due to Dam Failures

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Abstract. Sembrong dam has undergone overflow failure. Flooding has been reported to hit the town, covering an area of up to Parit Raja, located in the district of Batu Pahat. This study aims to identify the areas that will be affected by flood in the event of a dam failure in Sembrong Dam, Kluang, Johor at a maximum level. To grasp the extent, the flood inundation maps have been generated by using the InfoWorks ICM and GIS software. By using these maps, information such as the depth and extent of floods can be identified the main areas flooded. The flood map was created starting with the collection of relevant data such as measuring the depth of the river and a maximum flow rate for Sembrong Dam. The data were obtained from the Drainage and Irrigation Department Malaysia and the Department of Survey and Mapping and HLA Associates Sdn. Bhd. Then, the data were analyzed according to the established Info Works ICM method. The results found that the flooded area were listed at Sri Lalang, Parit Sagil, Parit Sonto, Sri Paya, Parit Raja, Parit Sempadan, Talang Bunut, Asam Bubok, Tanjung Sembrong, Sungai Rambut and Parit Haji Talib. Flood depth obtained for the related area started from 0.5 m up to 1.2 m. As a conclusion, the flood emanating from this study include the area around the town of Ayer Hitam up to Parit Raja approximately of more than 20 km distance. This may give bad implication to residents around these areas. In future studies, other rivers such as Sungai Batu Pahat should be considered for this study to predict and reduce the yearly flood victims for this area.

Keywords: Semberong dam, flood map, dam failure.

1. Introduction
According to DBP [1], dam is a structure used to hold the current or water flow. Water retained in dams usually have specific functions according to the type of dams built. Among the functions available in Malaysia is to supply water to generate hydro power, mitigating floods, irrigation and also as recreation, for example Kenyir dam in Terrengganu was built to generate hydropower and Bekok dam in Johor as a flood insulator.

Sembrong dam is located about 10 km from the town of Ayer Hitam. It was a rainy mitigation dam, but was used by Syarikat Air Johor as a source of water supply. The Sembrong dam has a catchment area of about 130 km². Sources of water supplied to the dam are from Sembrong’s river and Merpo’s river which flows from the north-west and east. The outflow from the reservoir is released into river of Sembrong which is a tributary of Simpang Kanan’s river which then flows into Batu...
Pahat’s river before flowing into the Strait of Malacca. The dam was built in 1981, began operations in 1984 and is still functioning until now. The construction cost RM 24 million [2] and [3].

Normally, dam failure will be analyzed based on two conditions, namely, the flow of the dam failure during good weather or sunny day with the situation at the level of an ordinary reservoir and receiving normal inflows or the flow of dam failures in the rain or flooding. Dam failure in good weather is generally considered to have the greatest potential for loss of life events, due to the element of surprise while failure during rainy conditions are deemed to have a low potential for loss of human life for residents of the area would potentially be more alert.

Sembrong River Basin located in Kluang district covers an area of almost 200 km$^2$ in the catchment area of Sungai Batu Pahat. The catchment area is the largest in the state of Johor. Sungai Batu Pahat formed from two rivers namely Sungai Simpang Kanan and Sungai Simpang Kiri. Sungai Simpang Kiri’s length is 57 km from north near Sungai Simpang Kanan, Chaah while starting from the junction of the Sembrong and Bekok river. Bekok river flows as far as 55 km to meet Sembrong and Simpang Kanan river [4].

The outflow from the reservoir is released into Sungai Sembrong, which is a tributary of Sungai Simpang Kanan which later went into Sungai Batu Pahat before flowing into the Strait of Malacca. Sembrong dam has a catchment area of about 130 km$^2$. These dams provide flood protection in the area downstream of up to 100 years return period. The dam consists of three main dam embankment and four saddle dam embankment, fence for flood control and an un-gated spillway. The water flows out of the dam through the un-gated spillway. Figure 1 shows the un-gated spillway at Sembrong’s dam.

1.1 Dam failures
According to [5], dam failure is the failure of a major disaster. Features of dam failure is a case of the release of water held back by the sudden, rapid and uncontrolled current. Dam failure is usually the secondary effects of large-scale rain and flooding, it occurs when too much water flows into the spillway system. These events may occur along with a warning or not. In addition, poor maintenance can cause failure of the dam.

Dam failure generally can be associated with one or more of the following reasons, overflow caused by floods that exceed the capacity of the dam; the act of intentionally; the failure of structural materials used in the construction of the dam; cracks in concrete ponds or dams; soil erosion in the dam embankment; and inadequate care or maintenance.

Flood maps is one of the most effective approaches to describe the pattern of flooding, especially in the approach to reduce the incidence of flooding. The last study was done by [5]. Sembrong River flood map was generated to get contour maps so the lowlands can be determined. The data collection work were carried out including the position, topography height, time and details of a study observation. SURFER 9 software was used to generate a map of the flooding catchment area at Sembrong’s river. Figure 2 shows the mapping results.
A map that has been produced is a map of failure of the dam at the reservoir level PMF (Probable Maximum Flood). PMF can be defined as the expected flood of combination meteorology worst conditions and critical depending on hydrological conditions that are reasonable in the drainage basin under study [6].

2. Materials and methods
This study was conducted and analyzed based on the drainage system, hydrological data and mapping sources.

2.1 Data collection
This section describes the data collection and inspection of the work that was involved in the process of preparing this analysis. Effectiveness of analysis conducted is highly dependent on the quality of data for the creation of flood maps. Topographic map is one of the necessary data for this study. This map is available from the Department of Survey and Mapping (JUPEM) in digital form and hardcopy with the scale of 1:50,000 and 20 m contour interval. This map serves as the main base map outlining the boundaries of the study and catchment. While maps from Geographical Information System software was used as a reference and as a guide to its original position for Sungai Sembrong sheet and Sembrong dam. The map was taken from GIS software into the Infoworks ICM software as the basis to start development work on the river model. Figure 3 showed that the information from GIS software indicated Sembrong's river and Sembrong's dam in a scale of 1:125 000.
For hydrological data, there are two important data required for this study which were cross-sectional river engineering survey and the maximum flood discharge from the Sembrong dam. River engineering study data are required to determine the depth of the cross section of the Sembrong River while the data of Probable Maximum Flood conditions was taken as maximum water discharge for this study.

2.2 Data analysis

The process of data analysis were the development model of the river, entering data into Infoworks ICM software and generate maps using ArcGIS. The river model development was done entirely through Infoworks ICM software. Using this software, the model was developed by taking data from GIS software. Map from GIS software layer was used as the basis for the model development work.

River model with establishment continued by inserting the river reach line data and data for the right and left bank. Once all the data is entered, the model was built using ICM Infoworks in full. At this stage all nodes will be linked in order to form the surface of the river that flows from the Sembrong dam as a starting point and end at the end point which is at the junction of the Bekok’s and Simpang Kanan’s river. Figure 4 shows the river cross sectional data that was added in InfoWorks ICM software and Figure 5 shows the completed Sembrong’s river streams.

![Figure 4. River cross-sectional data was added to InfoWorks ICM software.](image)

![Figure 5. Completed Sembrong’s river stream in InfoWorks ICM software.](image)

The analyzed data continued by the data in the software development Infoworks ICM made based on information taken from HLA Associates Sdn. Bhd. The data entered was to identify areas affected by flooding in the event of a dam failure which is the Sembrong Dam. The data at issue is the
flow rate data against time for the Probable Maximum Flood case scenario. Figure 6 shows the example of data that were inserted in the software.

![Figure 6. Example of inserting flow rate data against time data in the software.](image)

3. Results and discussion

Results for the extent of river overflow can be viewed in detail through the cross section for each node that was constructed in the early stages of development of the river. There are 11 nodes that represent a cross section that has been selected for Sembrong River, where, node structural bench, SB-1 (point downstream) and node structural bench, SB 107 (point upstream). Results for the cross river section was shown in Figure 7, where the graph shows the increase and decrease rate by time and water flow rates that have been entered into the software.

![Figure 7. Result for each cross section shows the rate of increase and decrease of water flow.](image)

Apart from cross-river view, the results of the analysis can also be seen from the map that has been built. The results of the maps that have been built showed that there are 11 villages or regions that were expected to be flooded as Sri Lalang, Parit Sagil, Parit Sonto, Sri Paya, Parit Raja, Parit Sempadan, Talang Bunut, Asam Bubok, Tanjung Semberong, Sungai Rambut and Parit Haji Talib. Table 1 shows the details of the affected areas for flowrate of 587.34m³/s while Figure 8 shows the flood map of the study.
### Table 1. The flooded area information based on studies.

| Areas            | Maximum flood depth (m) | Type | Number of population |
|------------------|-------------------------|------|----------------------|
| Sri Lalang       | 1 – 1.2                 | Main | 4690                 |
| Parit Sagil      | 1 – 1.2                 | Main | 1006                 |
| Parit Sonto      | < 0.5                   | Main | 2505                 |
| Sri Paya         | 1 – 1.2                 | Main | 1397                 |
| Parit Raja       | 1 – 1.2                 | Main | 2052                 |
| Parit Sempadan   | < 0.5                   | Main | 2851                 |
| Talang Bunut     | 1 – 1.2                 | Main | 1025                 |
| Asam Bubok       | < 0.5                   | Main | 468                  |
| Tj. Semberong    | < 0.5                   | Main | 182                  |
| Sungai Rambut    | 1 – 1.2                 | Main | 463                  |
| Parit Haji Talib | 1 – 1.2                 | Main | 1488                 |

#### Figure 8. Flood map of the studies area.
4. Conclusion
In general, this study aims to investigate or determine the areas that will be affected by flood in the event of a dam failure. The areas chosen for this study are the area that includes Sembrong Dam catchment area. However, only Sembrong river that serve to map flooded area of Sungai Sembrong. Flood areal are maps that has been produced 587.34 m$^3$/s flow rates PMF (Probable Maximum Flood) conditions for 100 years return period as shown in Figure 9.

The study has shown where it can be seen between the main areas to be inundated by flood water at the maximum flow rate was released as Sri Lalang 1 to 1.2 m, Parit Sagil 1 to 1.2 m, Parit Sonto less than 0.5 m, Sri Paya 1 to 1.2 m, Parit Raja of 1 to 1.2 m, Parit Sempadan less than 0.5 m, Talang Bunut 1 to 1.2 m, Asam Bubok less than 0.5 m, Tanjung Semberong less than 0.5 m, Sungai Rambuth of 1 to 1.2 m and Parit Haji Talib also 1 to 1.2 m. However, the study also found that the probability of the region have begun to flood at a flow rate 216 143 m$^3$/s, especially near the banks of the river based on the results of the analysis obtained by cross-view Sembrong river. The flood that might occurred may caused bad effects to the residents of certain area that were affected.

Figure 9. Flood arial mapping at Q = 587.34m$^3$/s.

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