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Flood Mitigation Measures and Suggested Improvements in UiTM Pahang

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ABSTRACT

This paper discusses the critical issue of managing flood problems in Universiti Teknologi MARA (UiTM) Pahang with particular insight to its capabilities to mitigate the flood prone inundation area, the farm area located at the furthest downstream end of the campus where the main UiTM runoff drainage conveyance channel meets the incoming flow from the Jengka river. All aspects of flood parameters are highlighted especially the critical design storm discharge 15 years return period (Q_{15}), and its steps to derive the discharge volume incorporating the Drainage and Irrigation Department (DID) hydrological procedures namely HP5 and HP1, the tidal backwater effect and lastly the detention storage concept to alleviate the seriousness of inundation area and its depth. In conclusion, mitigation measures are presented to alleviate flood problems in UiTM Pahang.

KEYWORDS: Flood Mitigation, Storm Discharge, Backwater Effect, Drainage Conveyance and Detention Storage.

INTRODUCTION

Floods are more frequently reported nowadays, and the damage caused by floods has increased tremendously. The flooding may differ from one area to another, depending on physiographic and hydrologic conditions of the areas in question. The main causes to flooding are believed to be the change in land use (especially of flood prone regions), from agricultural to developed area and also due to climate change [1]. Urbanization, uncontrolled deforestation and reduction of natural hydrological storage sites are also marked reasons for flooding. Like other natural disasters, the aftermath of floods include loss of lives, significant economic damage, pollution on the environment, community disorder and health issues.

Lately, floods have become the most significant natural hazard in Malaysia especially in Kelantan, Terengganu and Pahang. Even states that were previously unaffected by the seasonal floods were hard hit. More recently the heavy rains on December 17th 2014 resulted in flooding throughout the states of Kelantan, Terengganu, Pahang, partially in Perak and Sabah. Losses were estimated to be approximately RM4.12 billion. This is exclusive of deaths, pollution to the environment, community disorder, health issues and other 'intangible' socio-economic impacts.

However, the flood problem in the UiTM campus is not a yearly problem basis. But based on past record, it is going to be critical and serious every 15 years return period. The concerned area is the farm area located at the furthest downstream side of the main UiTM runoff drainage conveyance channel, and close to the incoming flow from the Jengka river. It is critical whenever there is a heavy rainfall or any severe storm events of 1.5-2 hours duration, since this is going to cause much inundation on the farm areas and its surrounding as shown in Figure 1.

CAUSES OF FLOODING

The occurrence of flooding in UiTM on the farm area is going to be of much concerned whenever there is a severe storm event. Although there are 2 basic types of rainfall that contribute and cause flooding namely (i) moderate intensity-long duration rainfall which covering a catchment area of 323 acres that generates runoff to the main-drainage channel A→B and (ii) high intensity-short duration (≈ 2 hours) localized rainfall, the main and common cause is the second factor.

The heavy rainfall intensity with its incremental volume of runoff is going to intensify downstream flooding problems. Since farm area is located at this end, it is therefore going to be the most affected area. In normal circumstances, the inundation is going to last for almost 3 days. In addition, the farm area that adjacent to the fence line 2-3-4 is topographically a low laying area which called as area M. The result indicates an intrusion of water from the surrounding area M into the farm area. The area M is an area where the conveyance runoff volume from UiTM drainage channel B and incoming flow from Jengka river meets. Due to this enormous volume capacity of runoff but a small and limited conveyance and storage impoundment capacity of Jengka river drainage way for exit flow at N to handle, it is going to result huge significant backwater effects. In turn upstream flooding problems are also intensified, especially the area around valley C and its surrounding. Practically, the UiTM main conveyance drainage channel A→B is capable of handling the runoff capacity from the catchment area within 323 acres, whereas the remaining part (776 acres) is handled by the Jengka river which suggesting that the design is still sound and adequate.

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For a list, the main causes of flooding and in sequence of its effect (i.e. for the first three) in UiTM Pahang are; (i) localized continuous heavy rainfall, (ii) tidal backwater effect, (iii) intrusion of water from outside boundary area, M and (iv) inadequate Jengka river conveyance capacity at exit N. Whilst the minor factors are; (i) inadequate drainage system conveyance capacity, i.e. channel B at its downstream side, (ii) siltation in the main conveyance channel, i.e. channel B and (iii) increased runoff rates due to impervious areas (i.e. new buildings). For these minor factors, improvement can be made through channelization works to include widening and deepening.

It is also to be stated that flooding is intensified by the existing floodway constriction at the bridge and inadequate Jengka river capacity to accommodate for the high incoming runoff volume and its disability to discharge this inflow through exit N. Therefore, any prolonged heavy rainfall from any storm event of duration 2-3 hours is going to result in a large runoff volume which is very much in excess capacity of Jengka river to impound at exit N. This accumulated runoff in turn causes inundation of area M, which is then going to cause tidal backwater effect that resulting in the intrusion of water to the downstream side of farm D. The inundated area is quite extensive, and normally going to last for at least 3 days before it recedes. Figure 2 shows the photo of channel (A and B) and farm (D).

THE HYDROLOGIC DESIGN FLOOD PARAMETER ESTIMATION METHOD

A common problem encountered in the design of water control structure is the determination of design flood. This is straight forward when records of stream flow and rainfall are available for the catchment. Except for the catchment area contributing to the surface runoff in the main UiTM drainage channel A→B which is about 323.7 acres (1.3104km^2) out of total 1000 acres, the stream flow and rainfall records are unavailable. Realizing this unavailability, data collected and procedures that produced by Drainage and Irrigation Department (DID) in form of Intensity-Duration-Frequency (IDF) curves and hydrological procedures (HPs) are going to be referred to in the estimation for the catchment design flow. The only relevant hydrological procedures applicable for the estimation of the design flood are hydrological procedure such as HP 5, 4, 16 and 11 as tabulated and recommended by the DID Malaysia for the design flood estimation.

From Table 1 in [2], the only HP that is going to fit the area of catchment is HP5 [3]. However, HP5 needs to be used in conjunction with HP1 [4] for the calculation of storm intensity (mm/hr) since Isopleth maps need to be referred to. However, it must be stated that the procedures of HP are by no means the best or the only method to go about estimating the hydrological parameters, instead hydrological design parameters should preferably be estimated directly by analysing data collection on the site [5]. If the data are inadequate or not available for analysis, then other methods of estimating the parameters are to be resorted to. Apart from HPs which adopted to estimate Q_{peak}, the data collected on site particularly the flood prone area with its inundated depth. It is going to be the main design criteria in alleviating flood discharge at the outlet point.

Since Jengka river is not a 'gauged site' for any hydrological parameters, the most that can be done is to refer to the IDF curve from the nearest gauging site at the Temerloh station. Hence, any parameters-calculation in the determination of rainfall intensity, duration, return period, runoff and Q_{peak} flow are estimations based on the data collected from this station. These are the commonly required parameters which may have considerable influence on the design. Average runoff describes the amount of water available in the catchment, peak flow determines the drain size to provide for whereas rainfall intensity dictates the flash flood problems in an area.

The calculated storm intensity (i) is then compared with the value interpolated from the DID IDF curves at the nearest station available that is the Temerloh station. From these 2 values of i (mm/hr), conclusion can then be made whether to make used of i (mm/hr) from the nearest station (Temerloh) by using IDF curves as to the calculated value at the Jengka catchment area by using the available Isopleth and the related HPs, HP1 and HP5.

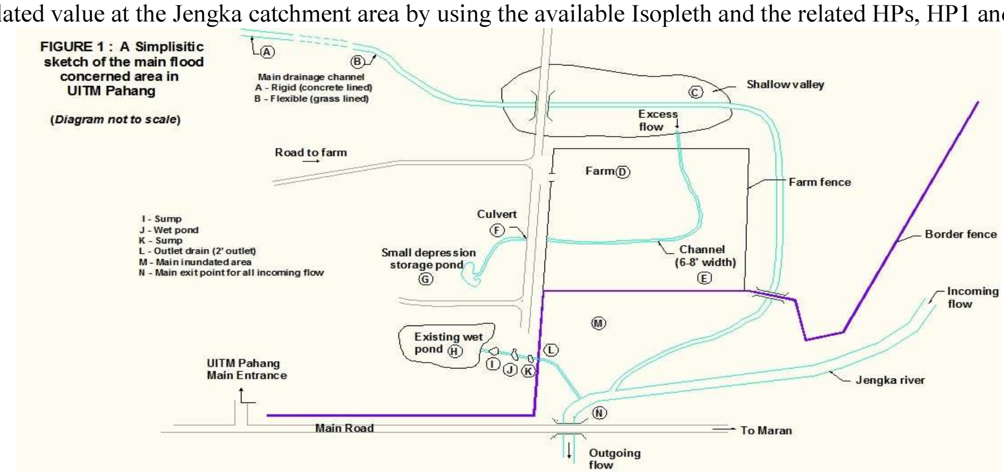

Figure 1: A simplistic sketch of main flood concerned area in UiTM Pahang

A: Main drainage channel (concrete lined)

B: Main drainage channel (grass lined)

D: Farm entrance, the inundated area

D: Farm downstream side bordering site M

Figure 2: Photo of channel (A and B) and farm (D)

(i). Calculation of rainfall/storm intensity i (mm/hr) for a storm with a return period of 15 years for Jengka at a location point with latitude of 3° 45' and longitude of 102° 35' E for storm duration of 2 hours over a catchment area of 1.310 km^2 (323.7 acres) using DID HP1. X (T, t) refers to rainstorm depth (mm) with a return period (T) years and duration (t) hours.

1. Read values of X (T, t) for T = 2, 20 and t = 0.5, 3, 24 from Figures 1-6 of DID HP1 (i.e. the Isopleths).

X (2, 0.5) = 37, X (20, 0.5) = 63, X (2, 3) = 77, X (20, 3) = 140
X (2, 24) = 115, X (20, 24) = 177

2. Plot these values and straight lines drawn between points (Figure 3).
3. Read off the depth values on Figure 3, corresponding to a return period of 15 years.

X (15, 0.5) = 61, X (15, 3) = 134

4. Plot these 2 values on Figure 4, and straight line drawn between them.
5. The required 15 years storm depth can now be read off the plot for the 2 hours duration required.

$$X\,(15, 2) = 124\text{mm}$$

6. Storm intensity i, (mm/hr) is found by dividing the total depth estimate by storm duration.

$$i\,(15, 2) = X\,(15, 2)/2 = 124/2 = 62\text{mm/hr}$$

7. The estimated i to be used for catchment average is found by multiplying by the factor for an area of 1.3104km^2 and the particular storm duration from Table 6 (refer HP1 in page 12). By interpolation, factor is about 0.98. Therefore, catchment average i (15, 2) = 62 x 0.98 = 60.70mm/hr = 61mm/hr.

(ii). For a comparison, IDF curves for Temerloh (Figure 5) is used to estimate the value of i for X (15, 2) depth. From Figure 4, i = 60mm/hr (i.e. is almost equal to the i = 61mm/hr, which previously calculated by using HP1 for Jengka).

(iii). A flood estimate of Q_{15} is then calculated which utilizing HP5 for the UiTM catchment that possessing the following characteristics.

Area = 1.3104km^2
Slope = 2%
Length of mainstream = 2.0km
Development from jungle = 60%

Step 1: T = 15 years

Step 2: From $T_c = \dfrac{1.286 \times L}{A^{0.223} \times S^{0.263}} = \dfrac{1.286 \times 2.0}{1.3104^{0.223} \times 2^{0.263}} = 2.02$ (assume 2 hours)

Step 3: From DID HP1, X (2, 2) = 51.3mm, X (15, 2) = 124 mm, X (20, 2) = 93.3mm

Step 4: Confidence interval = 0.43D (refer HP1 in Table 1), D = X (20) - X (2) = 93.3 - 51.3 = 42mm

$$0.43D = 0.43(42) = 18.06\text{mm}$$

Step 5: $i_{15} = X(15) = \dfrac{124 \pm 18.06}{2} = 62.0 \pm 9.03$mm/hr

Step 6: From curve frequency factor CT/C_{10} to find for region 4. (refer HP5 in page 8 and 9)

$$C_{10} = 0.38 \text{ (and } C_{15}/C_{10} = 1.055)$$
$$C_{15} = 1.055 \times 0.38 = 0.40$$

Step 7: $Q_{15} = 0.278 \times C_{15} \times i_{15} \times A = 0.278 \times 0.40 \times (62 \pm 9.03) \times 1.3104 = 9.03 \pm 1.32\text{m}^3/\text{s}$

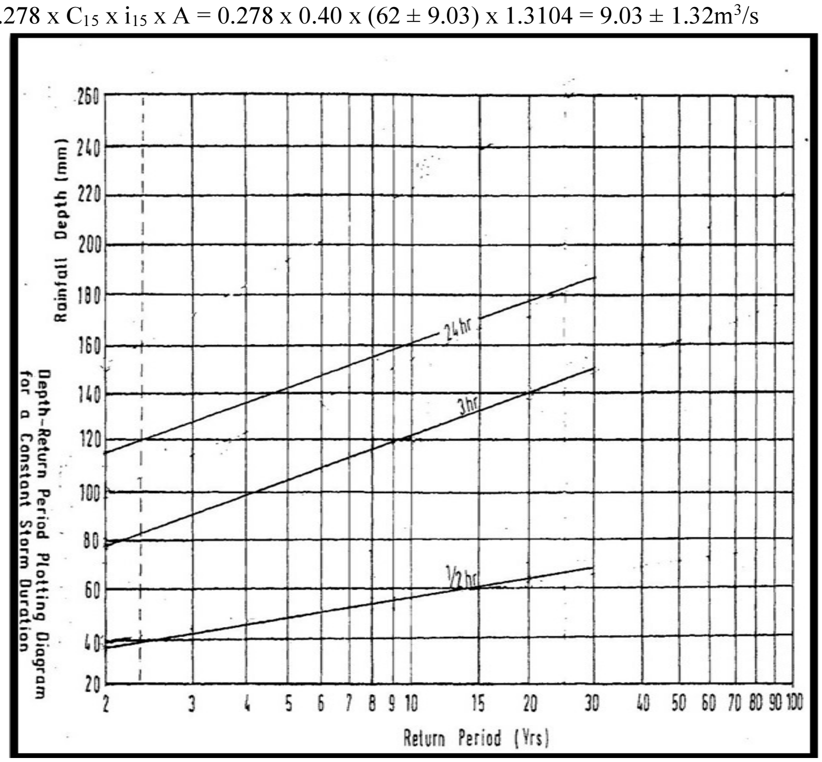

Figure 3: Plotting of return period-rainfall depth

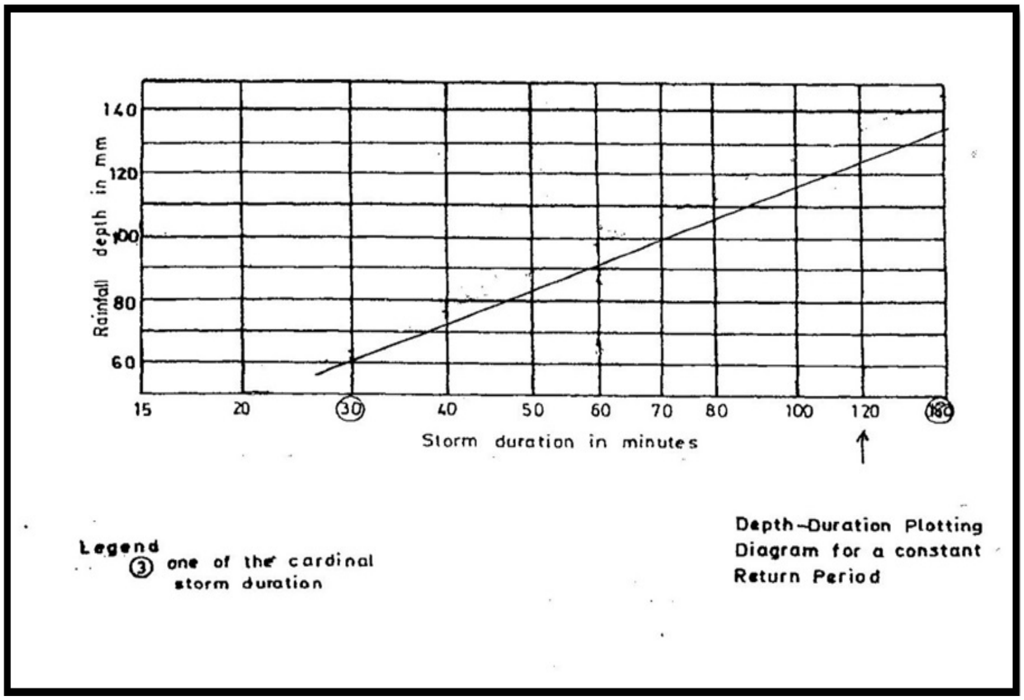

Figure 4: Plotting of rainfall depth-storm duration

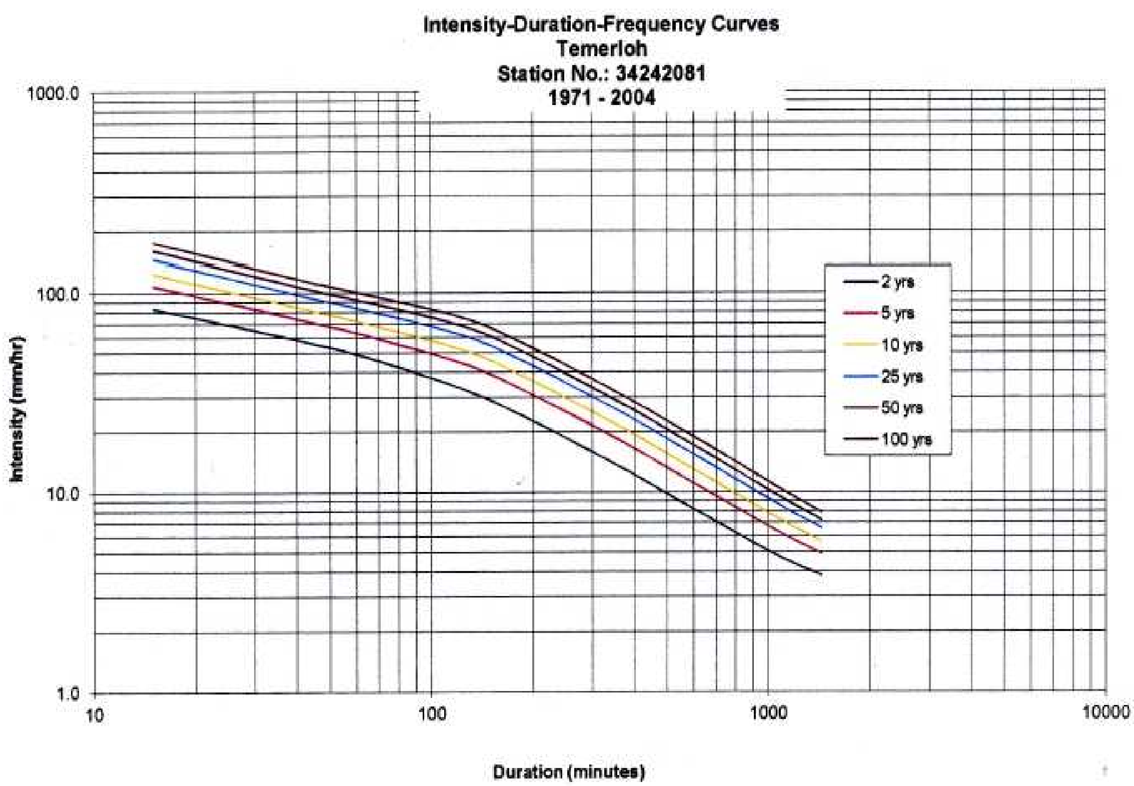

Figure 5: IDF curves for Temerloh

Despite the limitations of HP5 to estimate flood discharge for rural catchments, the Q_{15} calculated is going to be a valid value as far as conformity is concerned. This is due to the Rational Method (HP5) is widely used, and suited when the catchment area is less than 5km^2 [6].

Hence, the design rainstorm for the catchment, $Q_{15} = 9.03 \pm 1.32$ is an instantaneous peak discharge for the suggested design of a water control structure to alleviate flood problems in UiTM Pahang. However, it is to be noted as previously mentioned that the main UiTM drainage channel A→B is capable to discharge the current design storm without any overflowing. It is still adequate to provide both conveyance mechanism and temporary storage for excess water. The problem is only critical on the exit downstream part of channel B where there is an overflowing but it is not due to its under capacity, rather due to the water intrusion from the backwater effect at the main exit point N. This is the main cause of flood problems in UiTM Pahang.

FLOOD MITIGATION MEASURES AND SUGESSTED IMPROVEMENTS

Figure 6 shows the flood prone area on the farm and its vicinity at the downstream side of drainage channel together with water intrusion due to the backwater effect. The result is to cause inundation to most part of the area with an average water depth of 3.5 feet. Studies that have been carried out various structural (engineering methods) measures have been proposed to alleviate flood problems [7]. These measures are to include (i) increasing the river capacity to accommodate the surplus runoff through channel improvement, (ii) construction of embankment to exclude water intrusion, (iii) flood bypass, (iv) river diversion and (v) flood attenuation ponds. Looking at these proposals together with the topographical condition at the site and its inundation condition during the occurrence of flood, the options that are feasible are:

(i). increasing the Jengka river capacity. However, it is well outside UiTM boundary area and under the authority of Maran District Council for its supervision and maintenance-ship. The most that can be done is to do a canalization related works which include widening and deepening of main drainage channel (part B) specifically alongside the farm area. It needs to be mentioned that the main drainage channel A→B is in fact a storm water channel (or flood-control channel).

(ii). the construction of embankment bordering the flood prone area along the border and farm fence.

(iii). flood attenuation pond (i.e. storm water detention basin). It is to function as flood storage. The objective is to divert the flood water from valley C (during overflow) through the pond, and then regulate the outflow so as to attenuate the flood peak. The storage water will be released slowly back through the exit outlet L after the flood water has receded.

For a summary, the suggested options recommended to alleviate flood are as follows refer to Figure7):

a) to excavate new storm water detention basin at site G, as pond 1 discarding the depression storage pond G and pond 2 on the downstream side of farm if the calculated detention storage volume is still in excess. The storage volume requirement is to be calculated in the next section.
b) to convert the existing wet-pond H to a dry-pond (or partially dry-pond). Again, its capacity to contain water is given in the next section.
c) to make improvement to the flow passage for channel E. It needs widening and deepening as well as cleaning from marsh plants to improve conveyance velocity to either pond 1 and 2. For a conveyance to pond 2, a diverting channel is needed.
d) to construct an embankment wall along the perimeter fence stretching the length of water intrusion. The excavated earth-material from pond 1 and 2 can be utilized for this purpose.
e) Exit L needs a proper open-close gating system to regulate flow from inside to the outside. The same goes for a new exit Q.

The main criteria for alleviating flood problems in UiTM Pahang is not going to be a conveyance system (i.e. sewer system), but rather an impounding system (i.e. ponding system) to contain and impound the excess water as a storage volume. As such the design discharge Q_{15} that previously calculated is not a main design perimeter, but the flood-volume. This is going to be dealt with in the next section.

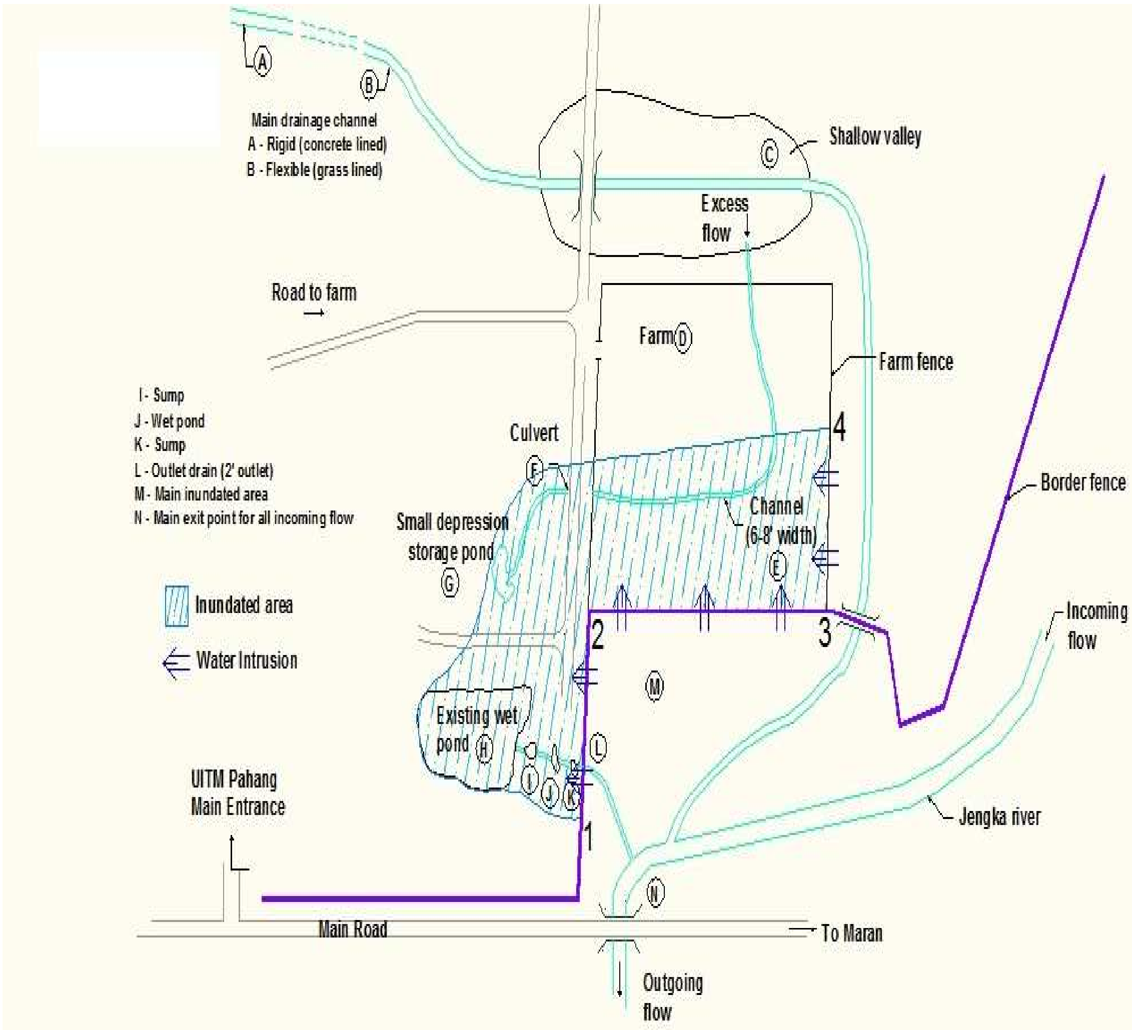

Figure 6: Inundated area with water intrusion

CONCEPT OF DETENTION STORAGE

The detention storage refers to the storage of excess runoff on the site prior to its discharge into the downstream drainage systems, and gradual release after the peak of the runoff inflow has passed. The major benefit offered is the reduction in the downstream flooding problems on the farm site D as well as area M. Its basic purpose is to reduce the rate of runoff that from the contributory catchment or accumulated backwater runoff by providing a temporary storage. The detention storage will not reduce the total volume of runoff but instead redistribute the rate of runoff over a certain time period. Therefore, in these circumstances, the major design consideration is the volume of storage-requirement [8].

Although the storage volume required can be determined in a number of ways, the most practical and validable value is to calculate based on the current inundated volume on the farm D and its surrounding. Standard engineering design methods that have not been developed which are universally accepted by designers of facilities [8] is not be focused in this research. The main part that need to be highlighted are the required basic parameters of the pond namely its area, water depth and its impounded volume.

STORAGE VOLUME OF POND

Inundated area (farm + surrounding) = 8.39ac

Average water depth = 3.5ft

Total inundated volume (IV) = 29.36ac.ft

This volume is to be impounded by 3 ponds, the existing pond H and 2 new ponds, pond 1 and pond 2.

(i). Pond H

$$A_H = 2.39ac$$
$$d_H = 8ft$$
$$\text{Volume of storage, } V = 19.2ac.ft$$

Converting it to a partially dry-pond with available space of 2/3V. The storage available is:

$$V_H = 2/3\ (19.12) = 12.75ac.ft$$

(ii). Pond 1

$$\text{Approximate space available, } A_1 = 50 \times 60m = 0.74ac$$
$$d_1 = 8ft$$
$$V_1 = 5.92ac.ft$$

(iii). Pond 2

$$\text{The storage volume required, } V_2 = 29.36 - 12.75 - 5.92 = 10.69ac.ft$$

For a depth, d_2 = 7 ft, the area required, A_2 = 1.527ac (this is equivalent to 125m x 50m size pond)

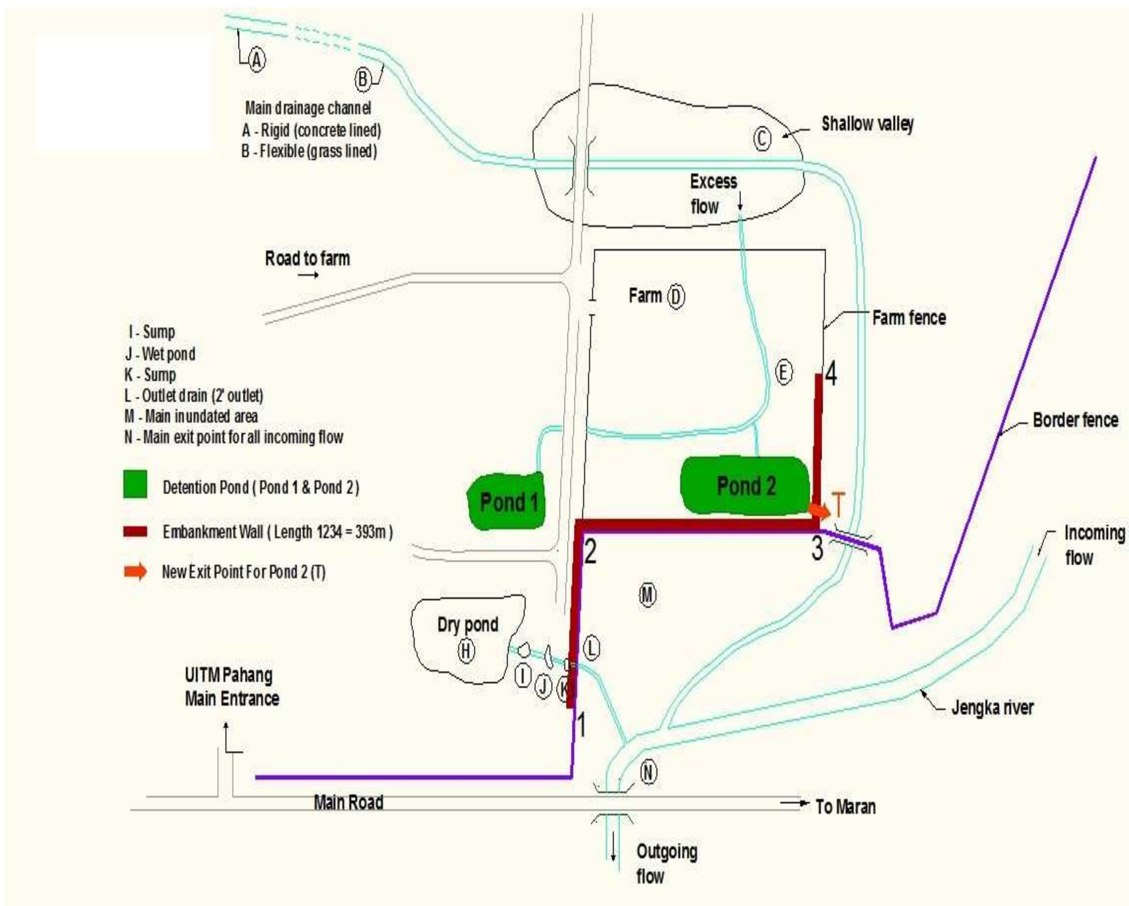

Figure 7: A recommendation measures

CONCLUSION

There are 5 conclusions that can be made such as:

a) The critical design storm ($Q_{15} = 9.03 \pm 1.32m^3/s$) is of 15 years return period with 2 hours duration.
b) The main drainage channel A→B is still capable of conveying the runoff within UiTM under normal circumstances.
c) The main causes of flooding in UiTM are:

(i). tidal backwater effect at the downstream end of channel B which in turn causing much water intrusion to farm D.
(ii). inadequate conveyance and disposal capacity of Jengka river at exit N.

d) The inundated depth on farm D (covering > 50% of its total area) and its surrounding is about 3.5 feet which is normally going to last for at least 3 days.
e) The mitigation measures to alleviate flood problems are:
(i). Channel B (downstream end) needs widening and deepening of its depth.
(ii). Channel E needs a cleaning up of its marsh plants to improve conveyance to both pond 1 and 2.
(iii). Converting wet-pond H to a partially dry-pond.
(iv). To excavate 2 new detention ponds, pond 1 and 2.
(v). Embankments 1-2-3-4 to be constructed to exclude flood water (6.5 feet) height.
(vi). Exit L and T need a proper gate-system structure facility to regulate flow.

Finally, all these are suggestions and efforts to alleviate flood problem in UiTM for the capacity of Jengka river at exit N to discharge the accumulated runoff at M and N.

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