JABATAN PENGAIRAN DAN SALIRAN MALAYSIA

DETENTION POND DESIGN

Kursus Saliran Mesra Alam

15 Mac 2023

By

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Bahagian Saliran Mesra Alam

Content

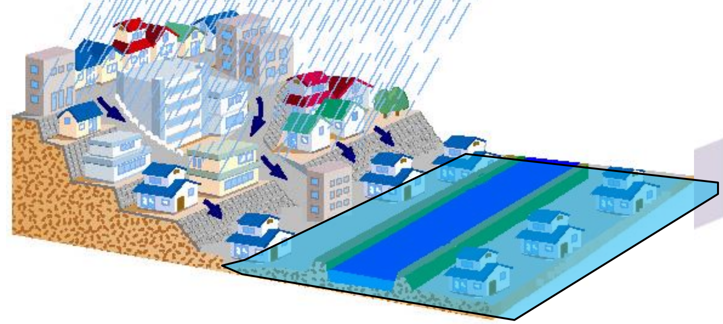
1. Detention/retention pond design (theory)
2. Hands on
   a. Rational hydrograph method (morning session)
   b. Pond routing (afternoon session)

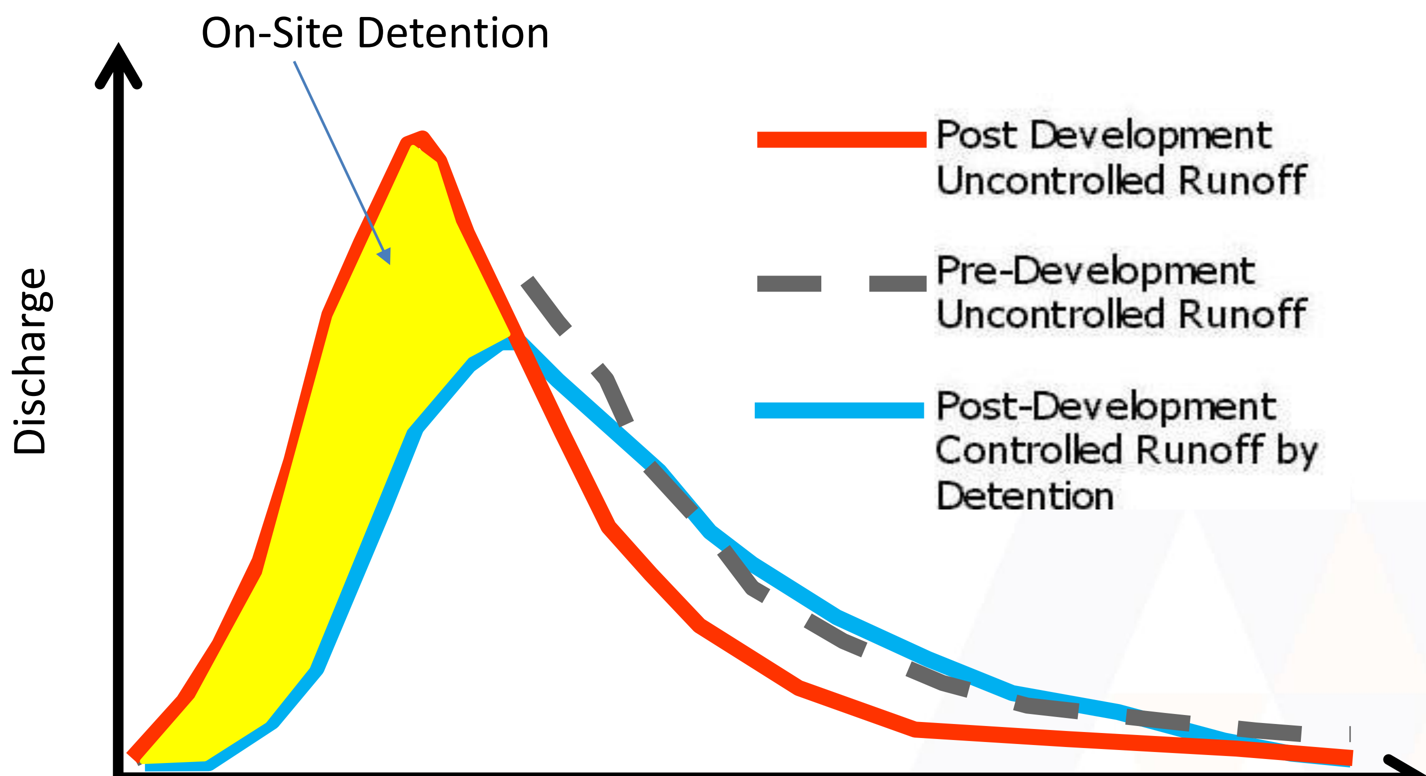
STORMWATER QUANTITY DESIGN CRITERIA

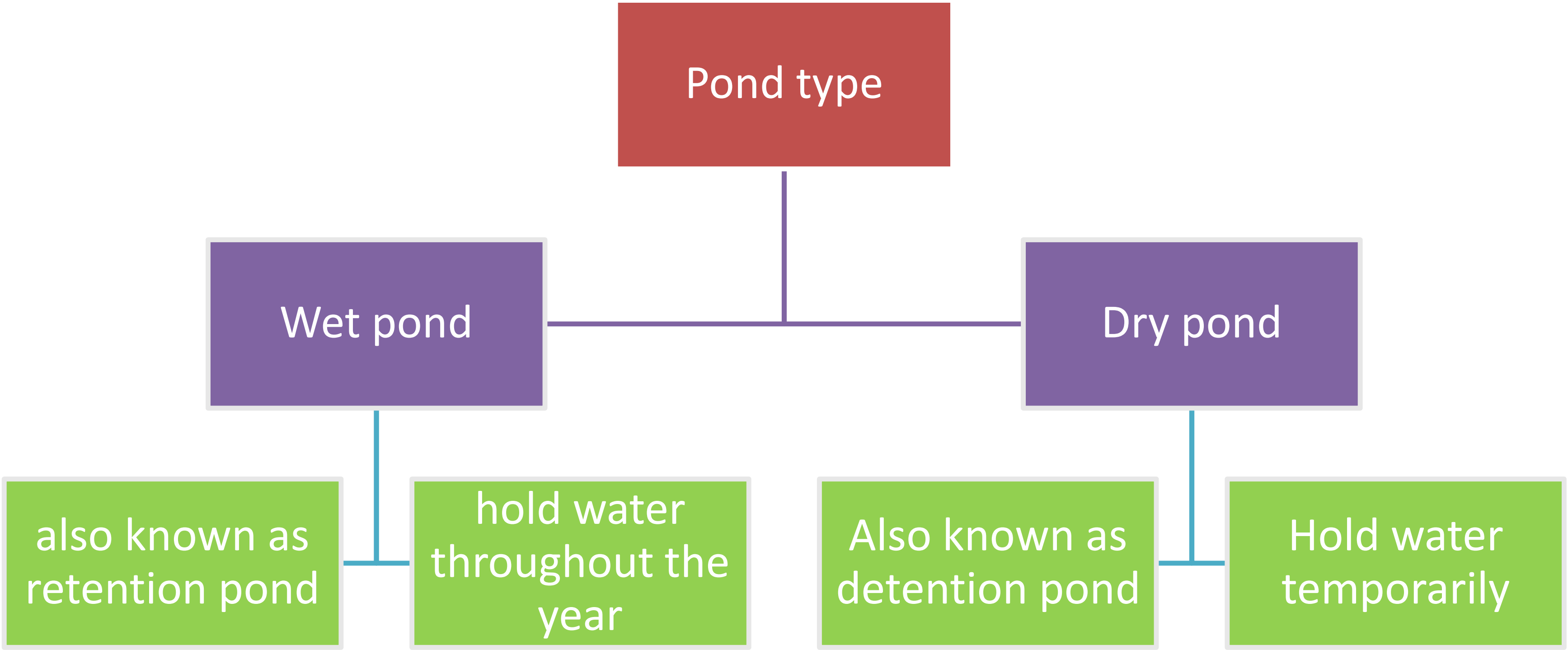
- MSMA 2nd Edition (2012)
  - ***Runoff quantity*** *control requirements for any size of development or re-development project is*

$$“(Q_{post} \leq Q_{pre})”.$$

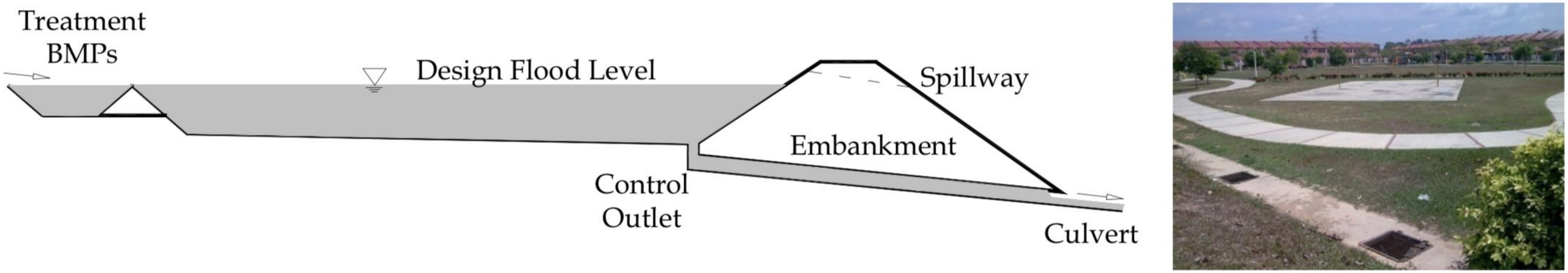
rategies




On-Site Detention
Discharge
Post Development Uncontrolled Runoff
Pre-Development Uncontrolled Runoff
Post-Development Controlled Runoff by Detention

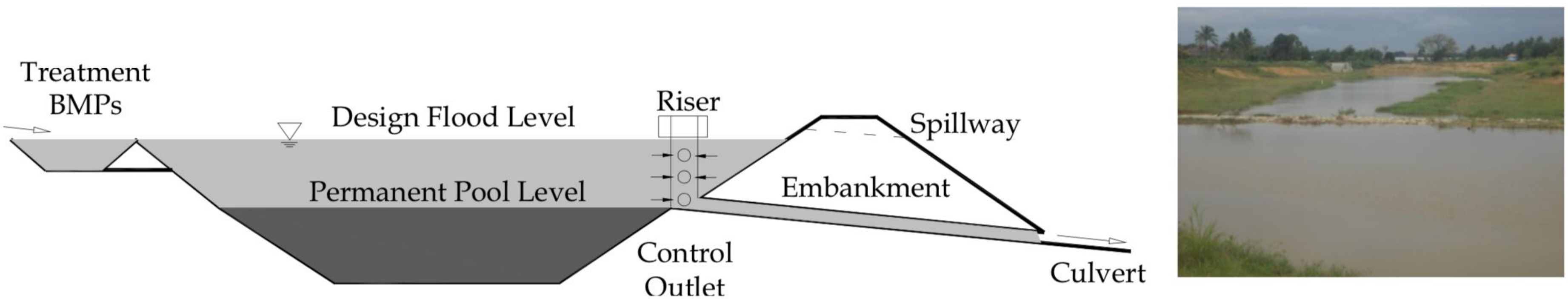


Catchment area >10ha



Concept Completion

(a) Dry Type - Kemaman



Concept Completion

(b) Wet Type - Malacca

DESIGN CONSIDERATIONS

1. Design and Analysis
    - Primary outlet
    - Secondary outlet
2. Release Timing
3. Public Safety
4. Multiple design storms and extreme flood
5. Inlet structure
6. Water quality pond (wetland)

Water Quality Control

SECTION A-A

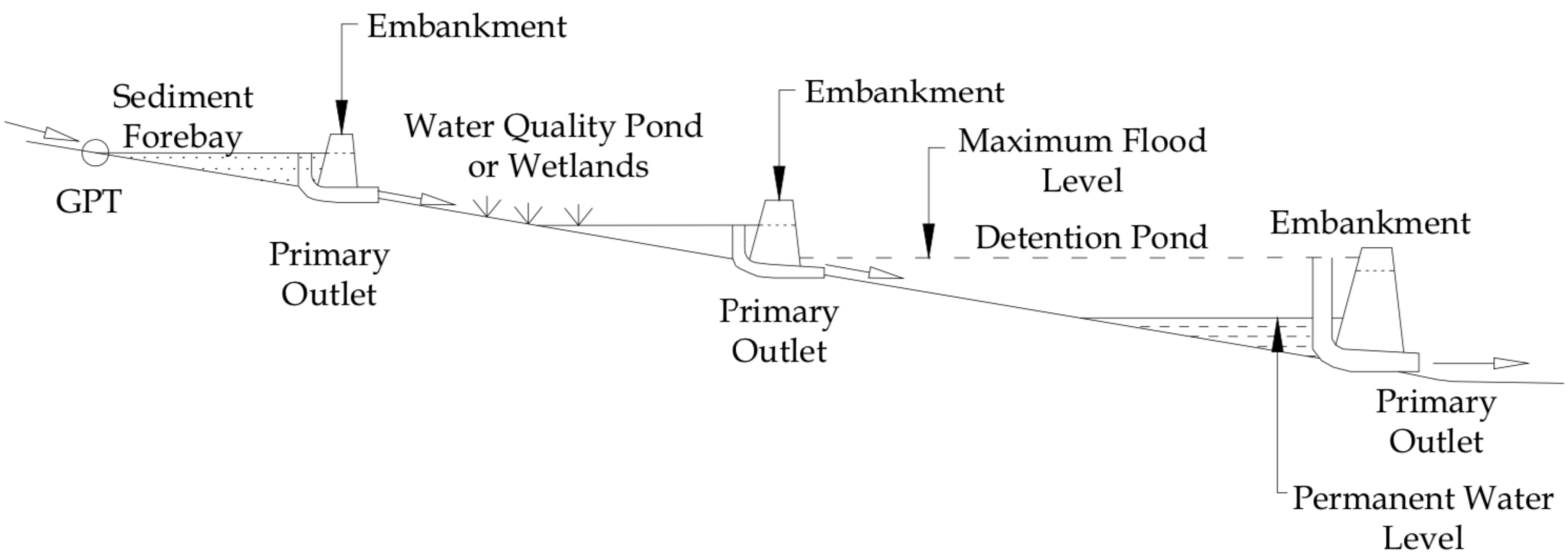


Figure 7.2: Typical Detention Pond Components

THEORY OF POOL ROUTING

What is flow routing ?

Flow routing is a procedure to determine the time and magnitude of flow at a point on a watercourse from known or assumed hydrographs at one or more points upstream.

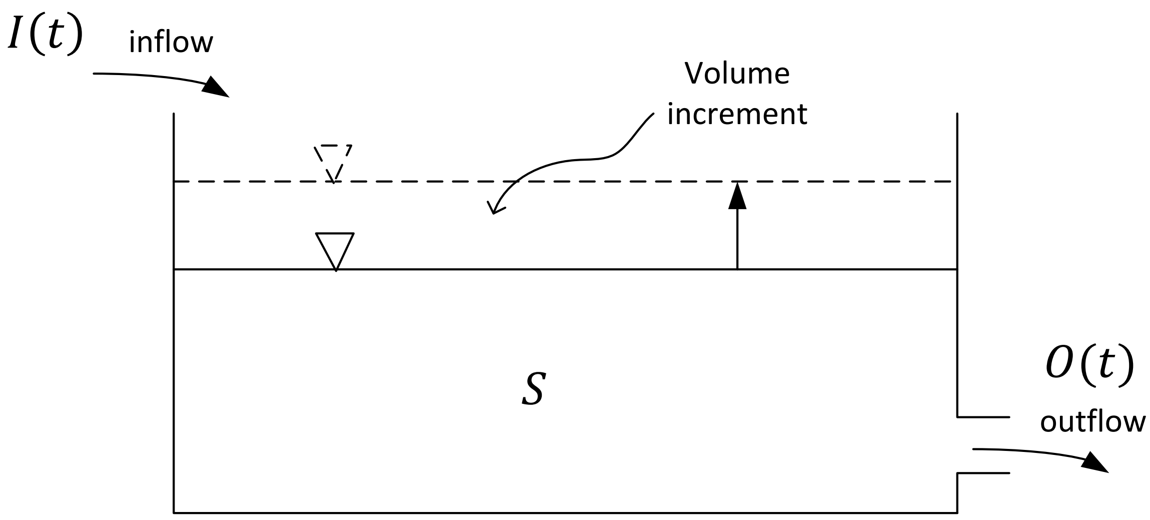
It is a technique to trace the flow (its characteristic) through a hydrologic system.

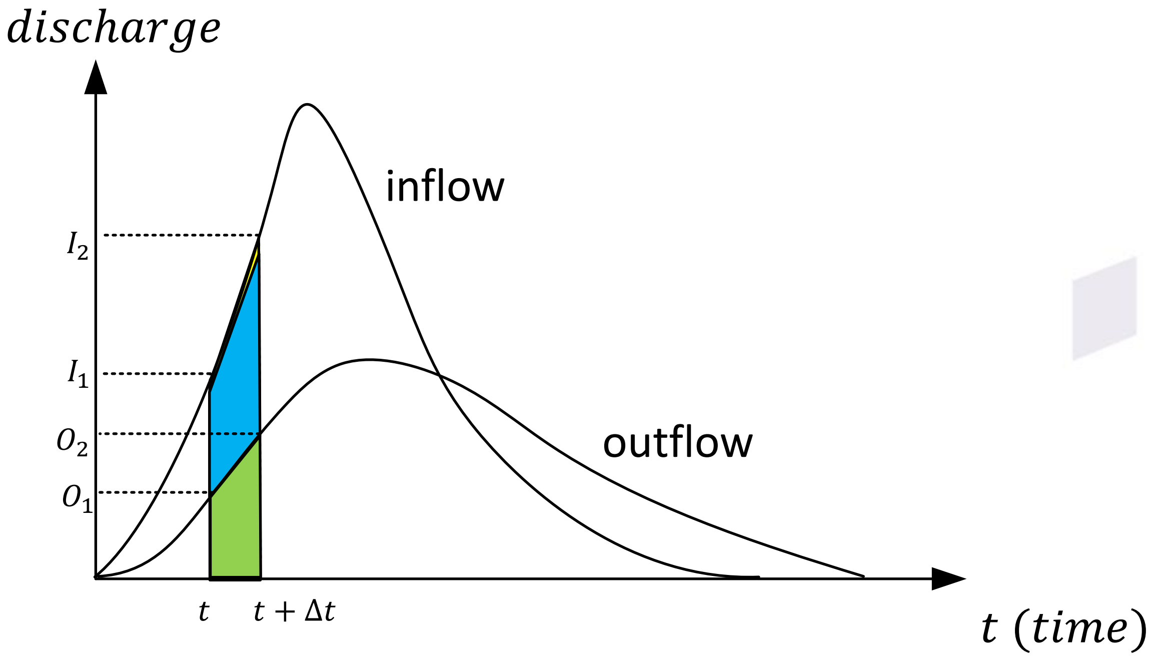
Concept of "pond routing"

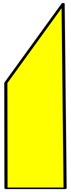
Pond routing conforms to the Continuity Equation

$$\frac{dS}{dt} = I(t) - O(t)$$

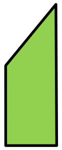
$I(t)$ = inflow discharge
$O(t)$ = outflow discharge
S = storage volume



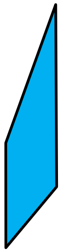




$$A1 = \frac{1}{2}\Delta t(I_2 + I_1)$$



$$A2 = \frac{1}{2}\Delta t(O_2 + O_1)$$



Excess volume to store, ΔS,

$= A1 - A2$

$$= \frac{1}{2}\Delta t(I_2 + I_1) - \frac{1}{2}\Delta t(O_2 + O_1)$$

$$\Delta S = \frac{1}{2}\Delta t(I_2 + I_1) - \frac{1}{2}\Delta t(O_2 + O_1)$$

$$S_2 - S_1 = \frac{1}{2}\Delta t(I_2 + I_1) - \frac{1}{2}\Delta t(O_2 + O_1)$$

Continuity Equation

$$S_2 - S_1 = \frac{1}{2}\Delta t(I_2 + I_1) - \frac{1}{2}\Delta t(O_2 + O_1) \rightarrow \frac{dS}{dt} = I(t) - O(t)$$

S_2: unknown; S_1: known; $\frac{1}{2}\Delta t(I_2 + I_1)$: known; O_2: unknown; O_1: known

$$\frac{S_2}{\Delta t} + \frac{O_2}{2} = \frac{1}{2}(I_2 + I_1) + \left(\frac{S_1}{\Delta t} + \frac{O_1}{2}\right) - O_1$$

Left side: unknown. Right side: known.

$\frac{S_2}{\Delta t} + \frac{O_2}{2}$: Storage indicator number

$\left(\frac{S_1}{\Delta t} + \frac{O_1}{2}\right)$: Storage indicator number

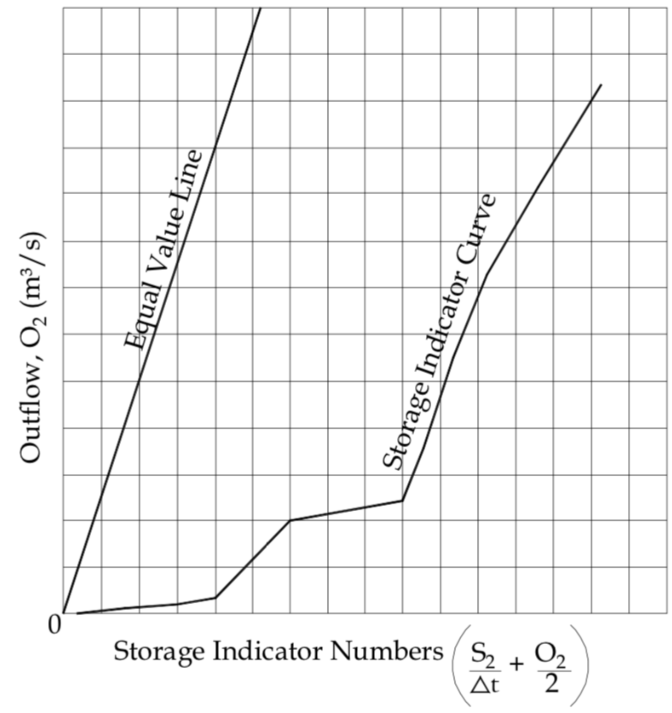


Figure 2.12: Storage Indicator Curve

DESIGN PROCEDURE

STEP 1

Determine design storm

a. Minor or Major infrastructure → ARI

b. Time of concentration → duration of rainfall, $d >= t_c$

c. Design rainfall intensity I → IDF curve, or IDF constant

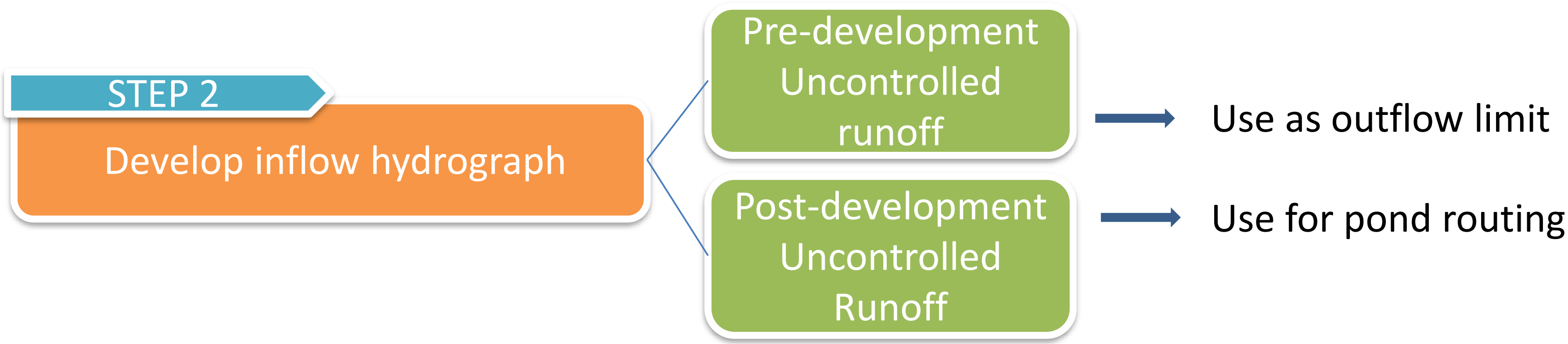
$$i = \frac{\lambda T^{\kappa}}{(d+\theta)^{\eta}}$$

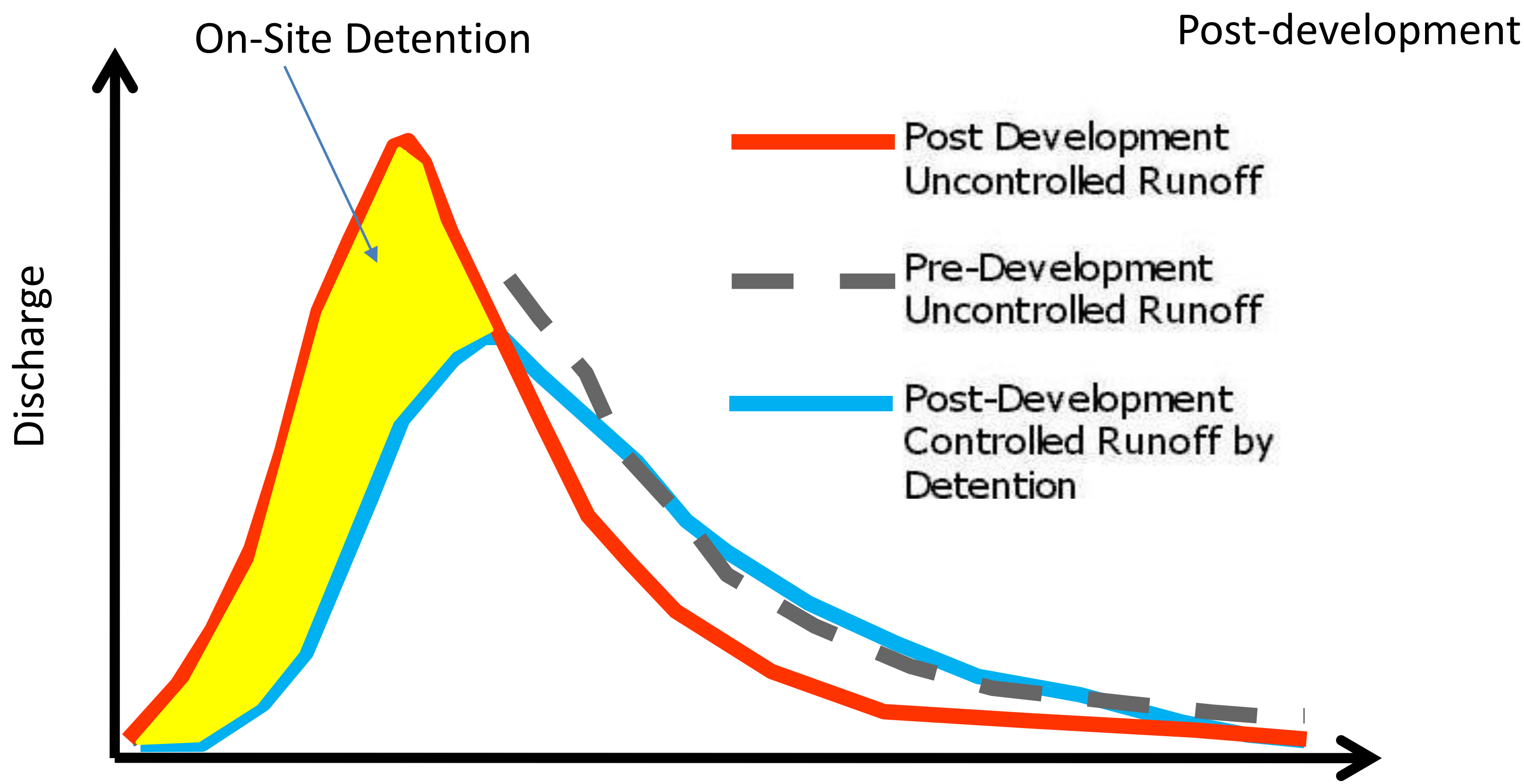
i = Average rainfall intensity (mm/hr);

T = Average recurrence interval - ARI ($0.5 \le T \le 12$ month and $2 \le T \le 100$ year);

d = Storm duration (hours), $0.0833 \le d \le 72$; and

λ, κ, θ and η = Fitting constants dependent on the raingauge location (Table 2.B1 in Appendix 2.B).


STEP 2
Develop inflow hydrograph
Pre-development Uncontrolled runoff
Use as outflow limit
Post-development Uncontrolled Runoff
Use for pond routing

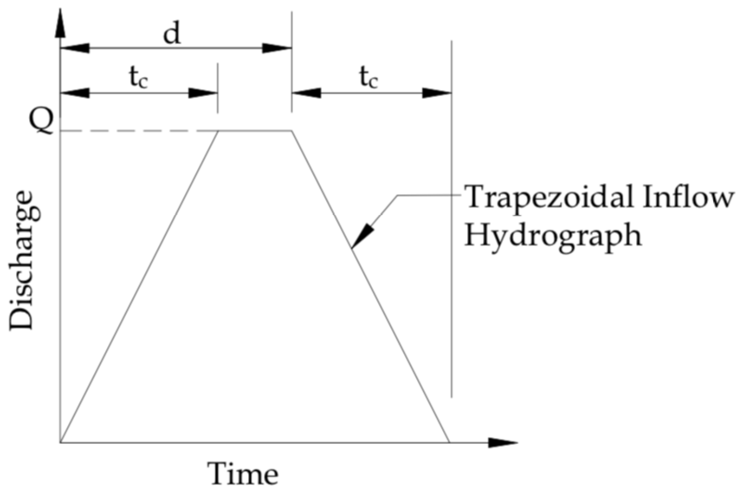

On-Site Detention
Post-development
Discharge
Post Development Uncontrolled Runoff
Pre-Development Uncontrolled Runoff
Post-Development Controlled Runoff by Detention

STEP 3

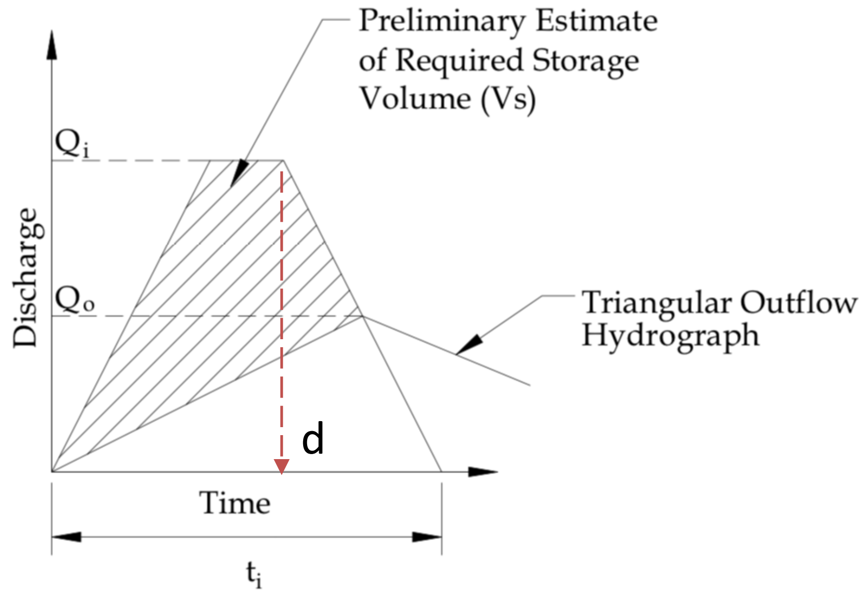
Design pond (volume capacity)

TYPE 1 HYDROGRAPH

$$V_s = Q_i\, d - 0.5 t_i Q_o$$



a) Inflow Hydrograph



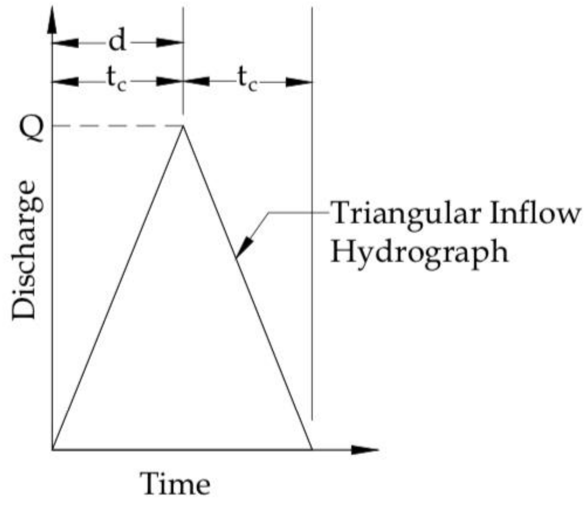
b) Storage Volume Estimate

Figure 7.6: Estimating Detention Pond Storage by RHM for Type 1 Hydrograph

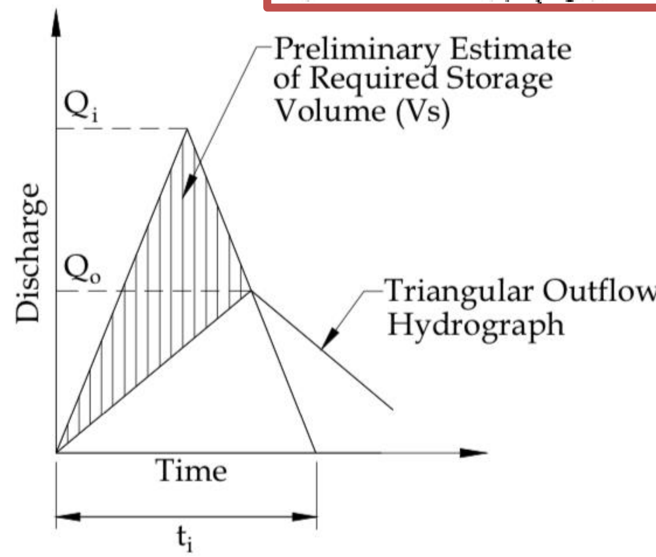
Pond volume estimate

TYPE 2 HYDROGRAPH

$$V_s = 0.5\,t_i, (Q_i - Q_o)$$



a) Inflow Hydrograph



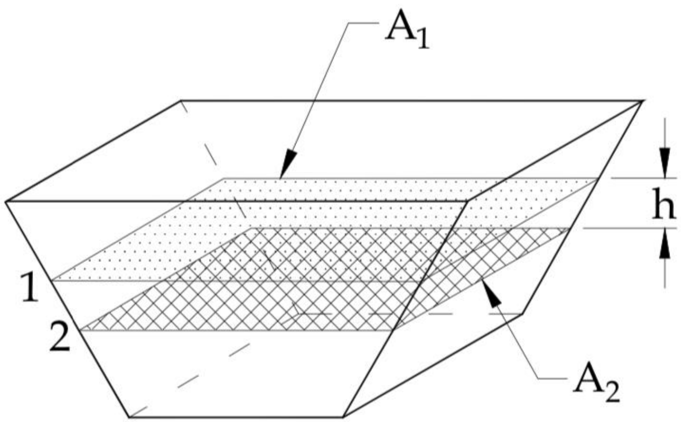
b) Storage Volume Estimate

STEP 3

Design pond (volume capacity)

Stage- Storage relationship

Calculation of volume increment when pond depth increase by h



Volume increment $$V_{1,2} = \left[\frac{A_1 + A_2}{2}\right] h$$

$V_{1,2}$ = Storage volume between elevations 1 and 2 (m^3);
A_1 = Surface area at elevation 1 (m^2);
A_2 = Surface area at elevation 2 (m^2); and
h = Change in elevation between points 1 and 2 (m).

STEP 3

Design pond (volume capacity)

Stage- Storage relationship

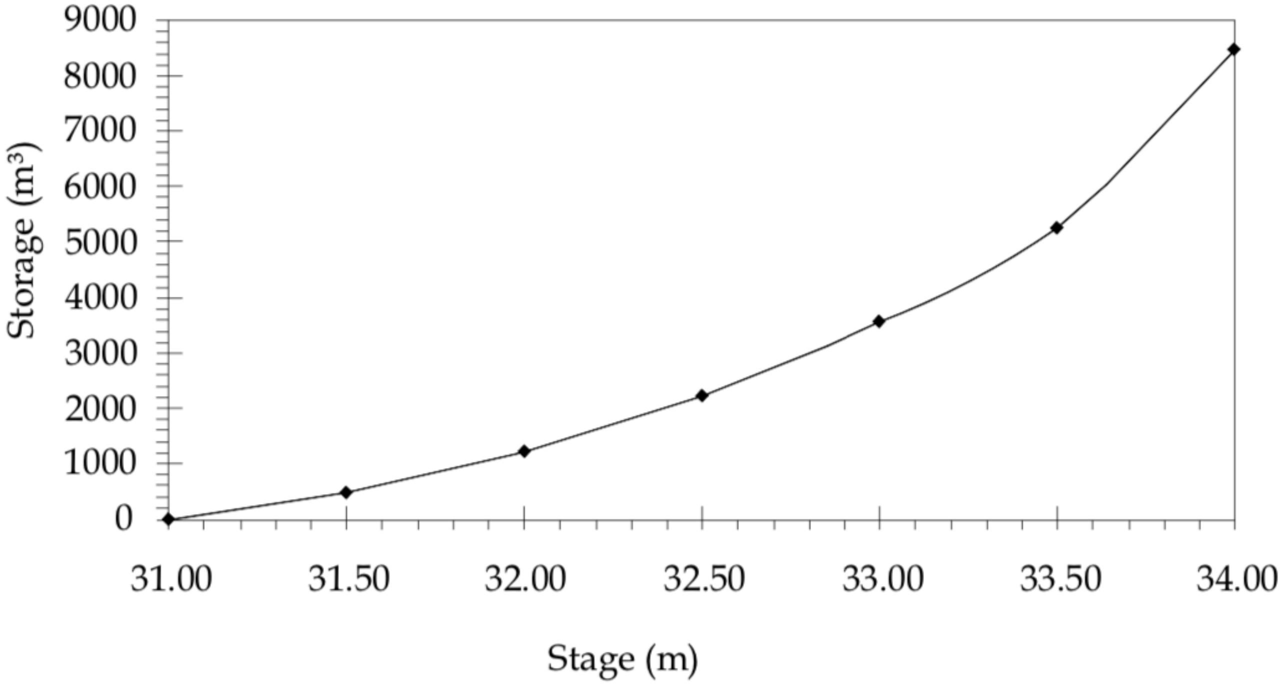


Figure 2.G2: Stage-storage Curve

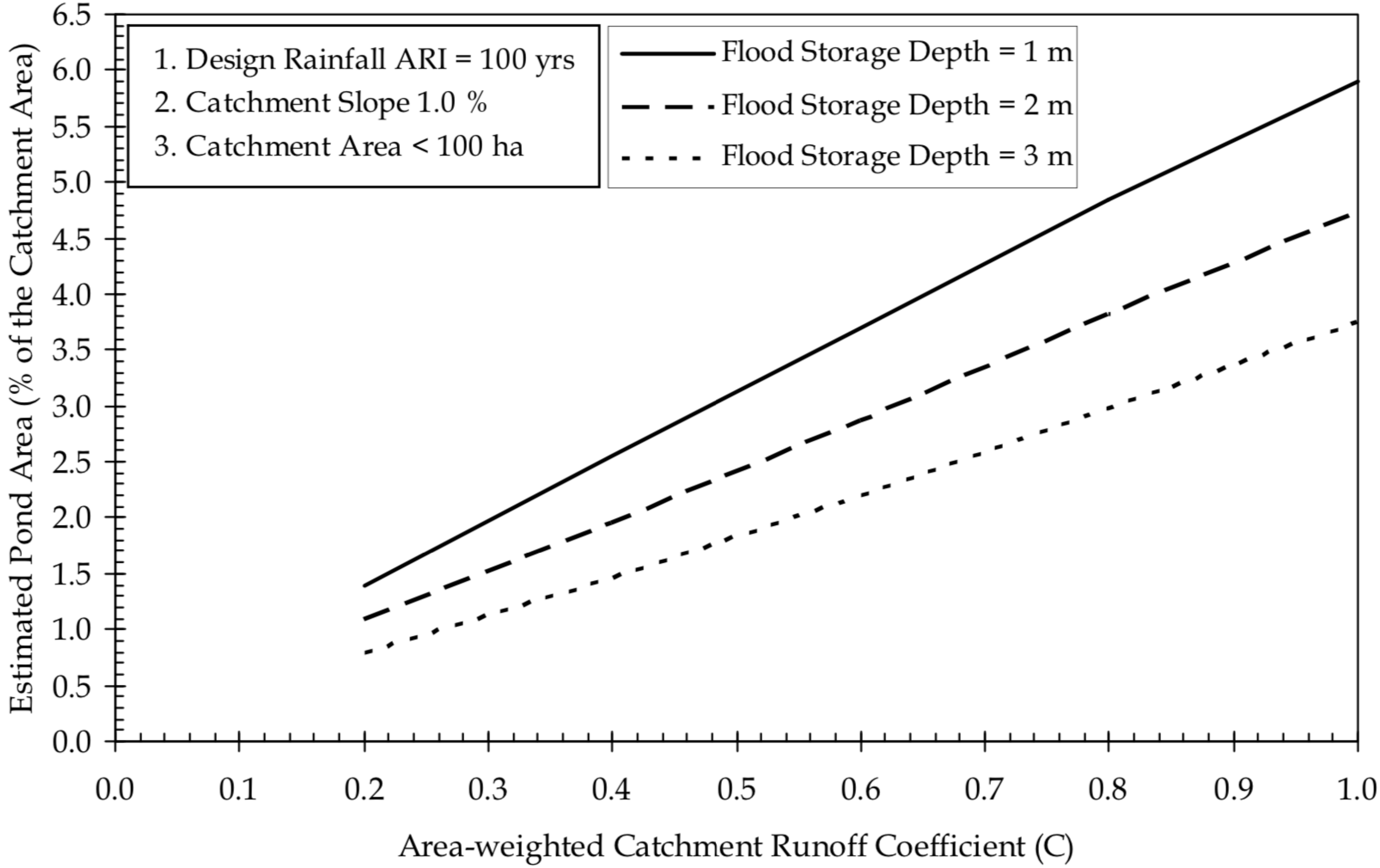
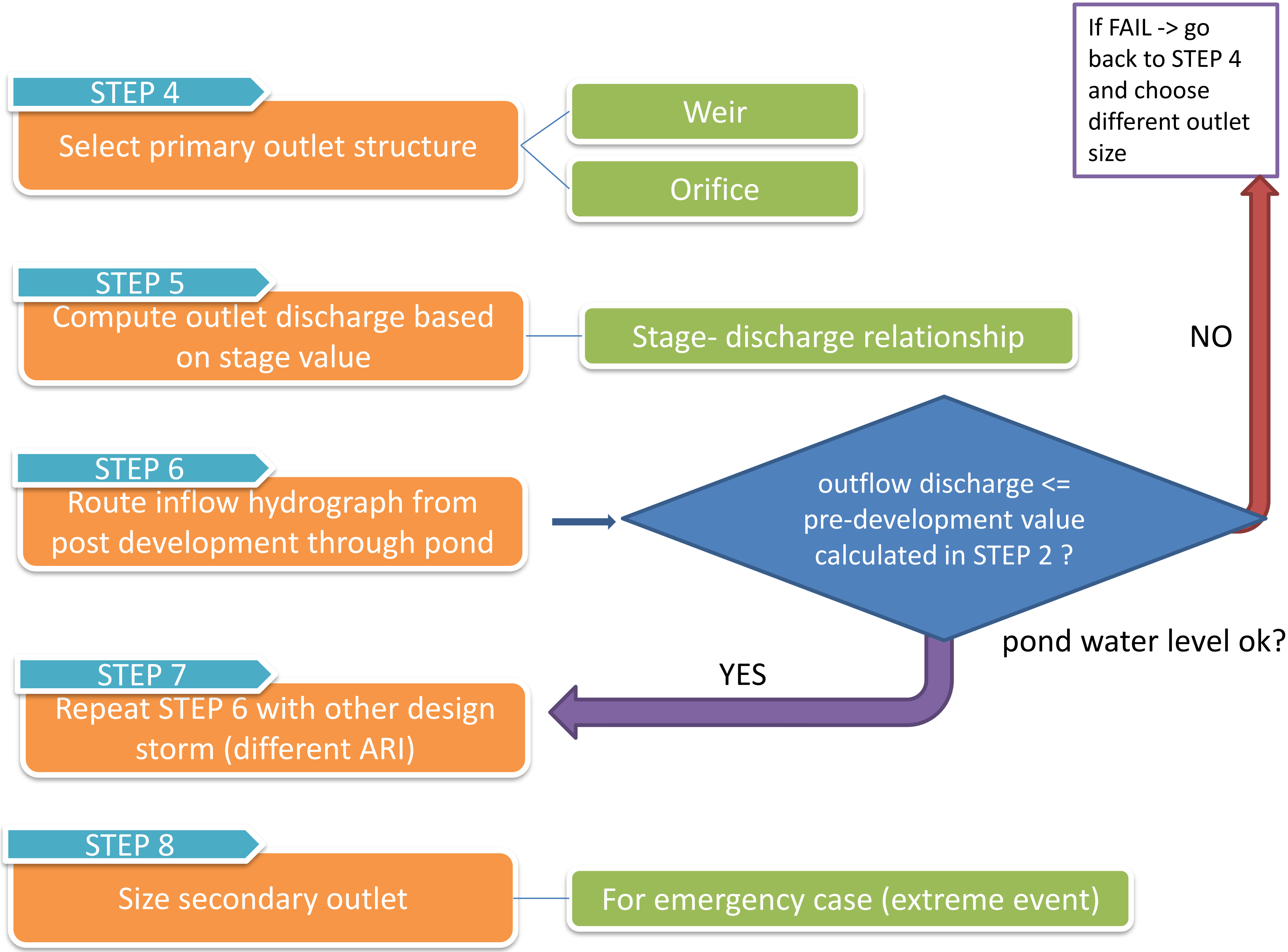


Figure 7.5: Pond area estimation (planning purpose)



STEP 4
Select primary outlet structure
Weir
Orifice
STEP 5
Compute outlet discharge based on stage value
Stage- discharge relationship
STEP 6
Route inflow hydrograph from post development through pond
outflow discharge <= pre-development value calculated in STEP 2 ?
pond water level ok?
NO
If FAIL -> go back to STEP 4 and choose different outlet size
YES
STEP 7
Repeat STEP 6 with other design storm (different ARI)
STEP 8
Size secondary outlet
For emergency case (extreme event)

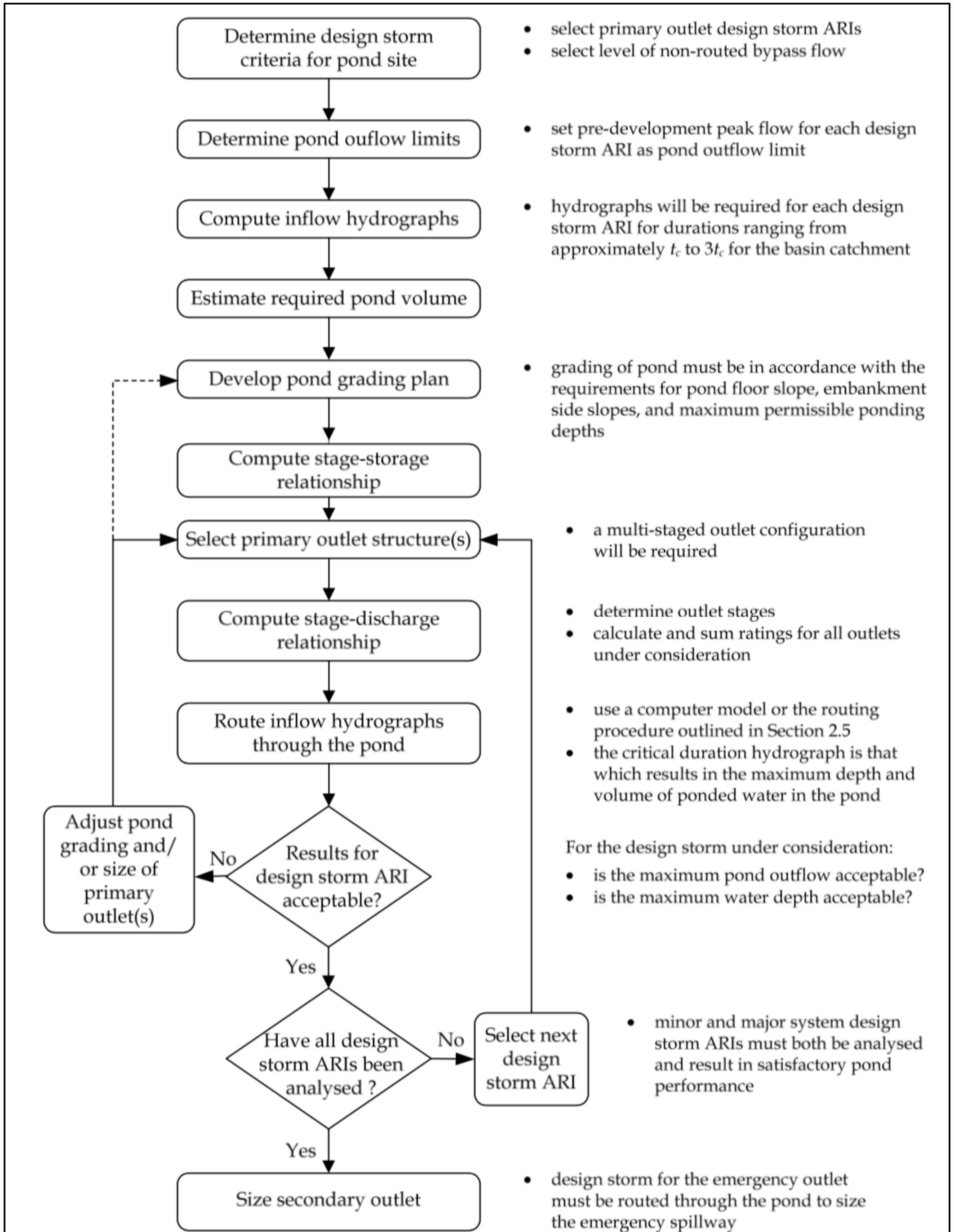


Figure 7.8: Detention Pond Sizing For Volume and Primary Outlets (DID, 2000)
MSMA Pg 7-13

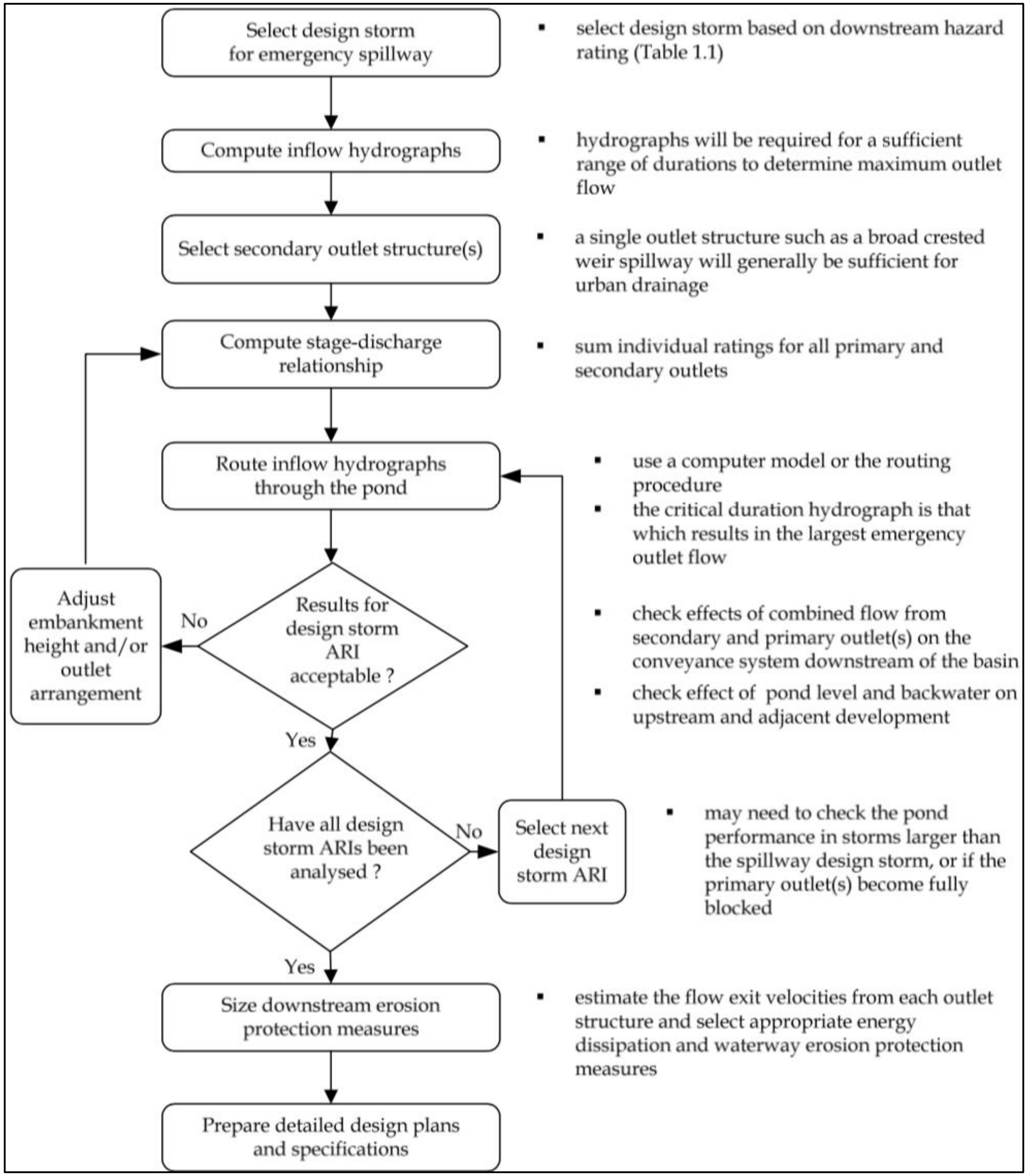


Figure 7.9: Detention Pond Sizing For Volume and Secondary Outlets (DID, 2000)
MSMA Pg 7-13

Hands-on

Problem:

A catchment located in upstream of Sungai Buloh, Selangor, with area of 38.761 ha, is proposed to be developed for residentials consisting Bungalow dwellings. A wet detention pond is to be incorporated to control the increased runoff resulting from the development. Flows will be directed to the pond via grassed channels built on existing streams. The existing and proposed triangular channel with slope = 1:1. From the site visit the depth of the channel is 0.3 m and width = 0.6 m, while the depth of the proposed channel is 0.42 m and width = 0.84 m. Design the pond and its outlet facilities with initial water level set at 31.00 m LSD and initial water depth of at least 1.0 m. The catchment is as shown in Figure 7.A1. The pond is required to be designed for 50 year ARI with primary outlets in the riser to control 5 and 50 year ARIs. The secondary outlet, a broad crested weir spillway, is to be provided to cater for the 100 year ARI event. The followings are data for the catchment and the streams/channels:

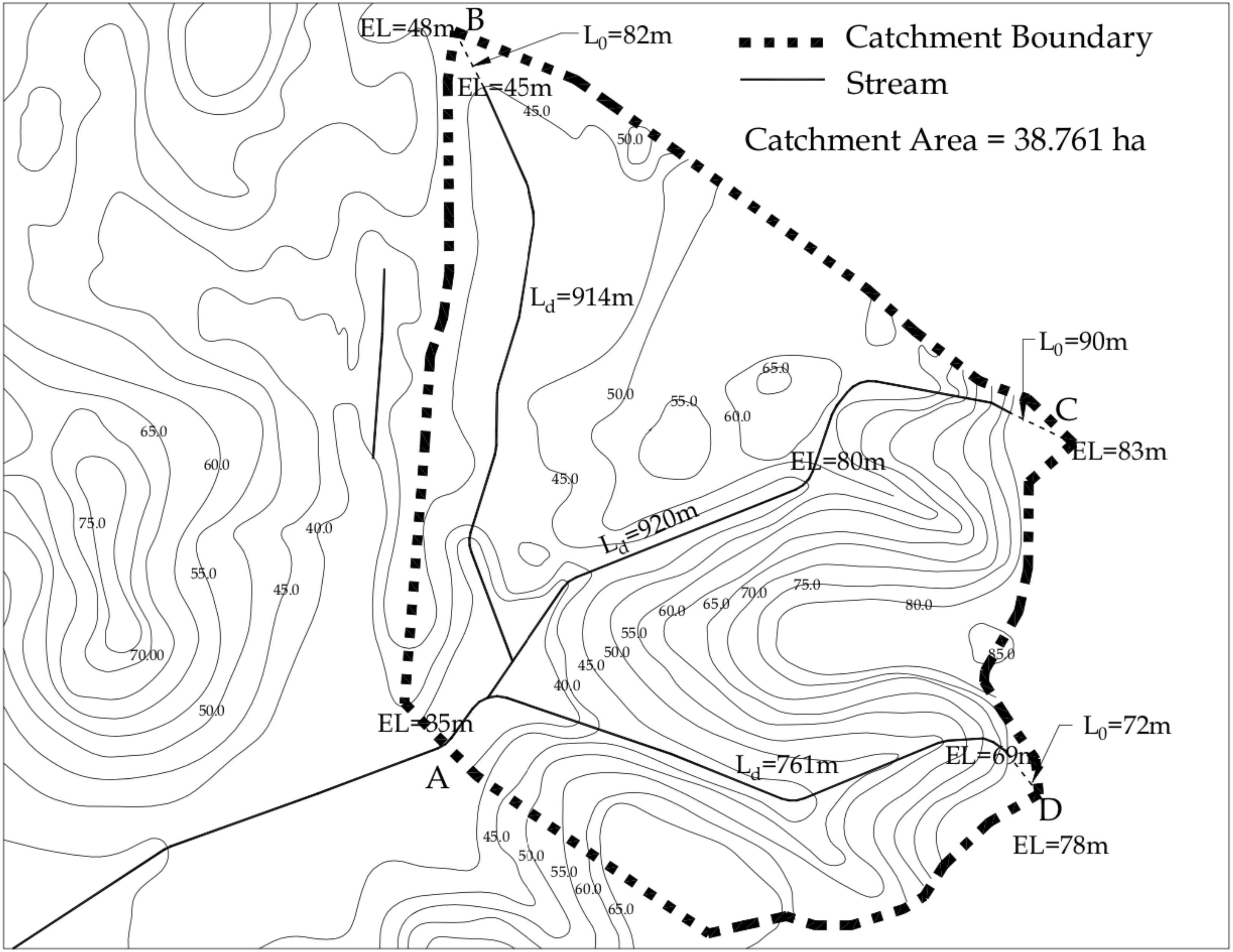


Figure 7.A1: Catchment Area

Given data :

Pre-development catchment and stream properties

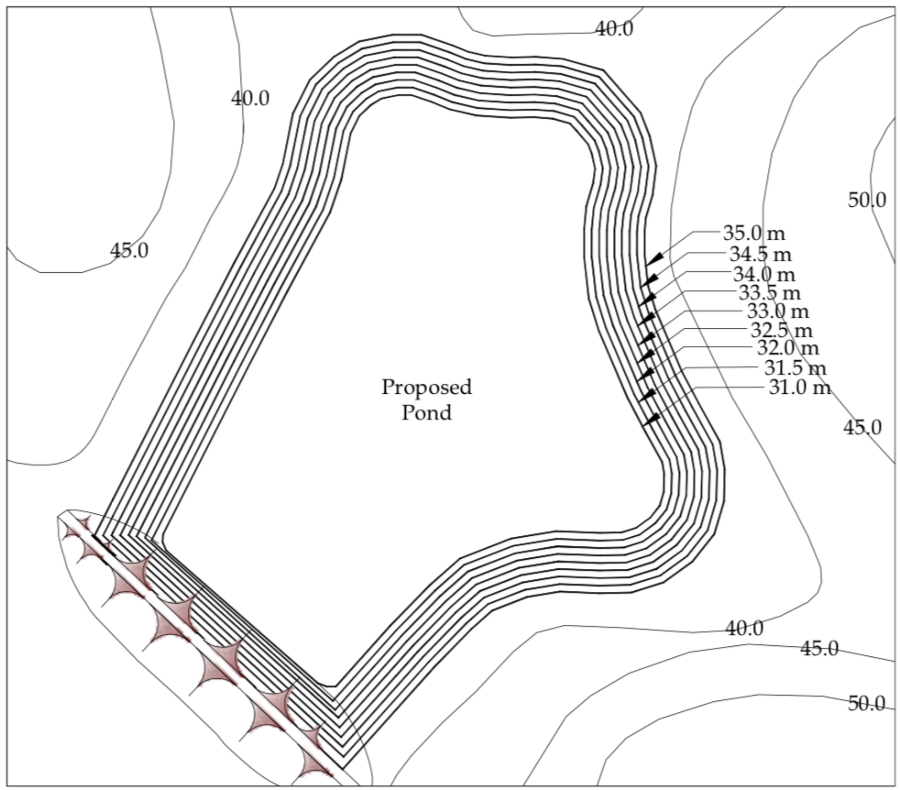
Reach	Overland			Natural Stream			
	L_o (m)	n^*	S_o (%)	L_d (m)	n	S_d (m/m)	R (m)
AB	82.0	0.045	3.66	914.0	0.05	0.011	0.11
AC	90.0	0.045	3.33	920.0	0.05	0.049	0.11
AD	72.0	0.045	4.17	761.0	0.05	0.053	0.11

Post-development catchment and channel properties

Reach	Overland			Grass Channel			
	L_o (m)	n^*	S_o (%)	L_d (m)	n	S_d (m/m)	R_r (m)
AB	82.0	0.035	3.66	914.0	0.035	0.009	0.15
AC	90.0	0.035	16.67	920.0	0.035	0.024	0.15
AD	72.0	0.035	13.89	761.0	0.035	0.026	0.15

Determine stage-volume relationship

The location and grading of the pond embankment and storage area is selected by trial and error so that at least the preliminary estimated volume of 14630 m^3 is available in the pond to cater for the critical 50 year ARI design storm event.



(iv) Route the inflow hydrographs through the pond

Route the inflow hydrographs through the pond, using a suitable computer model or the procedures presented in Chapter 2, to determine the maximum pond outflow and water level. The routing time step adopted should be a uniform integer value and should be small enough so that the change in inflow and outflow between time steps is relatively linear. A value of $2t_i$ / 300 may be used as a rough guide. However, for manual calculations, a minimum value of five (5) minute is recommended.

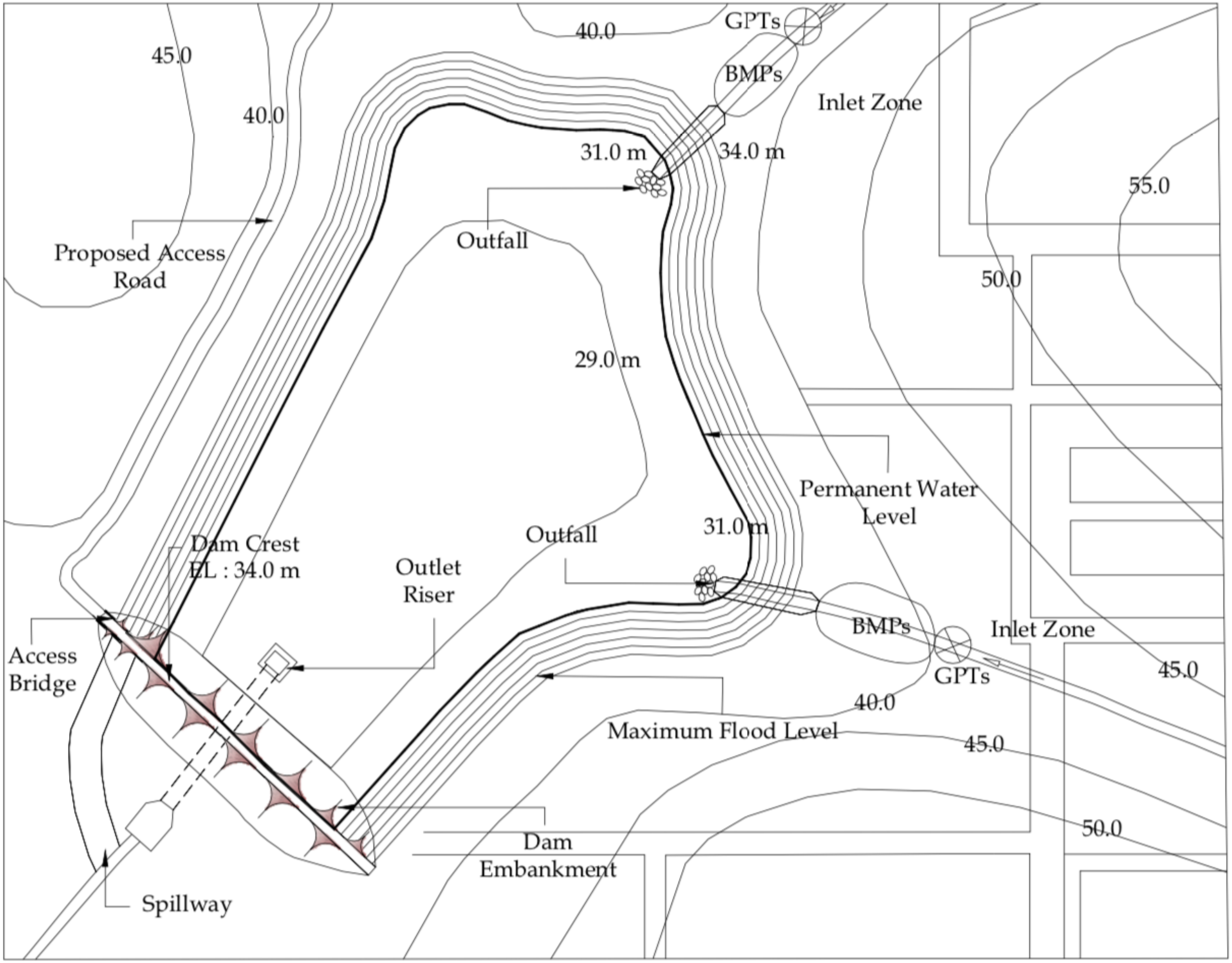


Figure 7.A10: Layout Plan of the Designed Detention Pond

Thank You