DETENTION POND

chapter 7

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DEFINITION

DETENTION POND

A stormwater BMP designed to protect against flooding and, in some cases downstream erosion by storing water for a limited period of time.

Detention Pond is used for controlling stormwater quantity impacts resulting from larger urbanising catchment - (MSMA 2nd Edition)

DEFINITION

- DETENTION POND vs RETENTION POND?
- WET POND vs DRY POND?
- ONLINE POND vs OFFLINE POND?

Structure of pond, condition of pond and route / diversion

DEFINITION

DETENTION POND VS RETENTION POND

DETENTION	RETENTION
• Provide only flood control measures and are known as dry ponds **(Can be wet:if water table high and dry)** Control the rate of flow by using a control device that maintains the pre-development rate of flow • Volume of the detention pond is calculated by comparing the pre- and post- development runoff volumes • The pond is intended to drain the stormwater within a period of time to make the volume available for the next storm event. • The outlet pipe (or control device) is placed at the bottom elevation of the detention volume to allow the pond to drain dry (for dry pond)	• Hold a permanent pool of water and are referred to as wet ponds **(Can be wet and dry:if water table low)** • Usually a retention pond is constructed because of a high groundwater table • The bottom of the pond is excavated below the water table elevation to establish a permanent pool. • The outlet of the pond is placed at or above the desired pool elevation • In general, retention ponds require more area than a detention pond

Source : Google

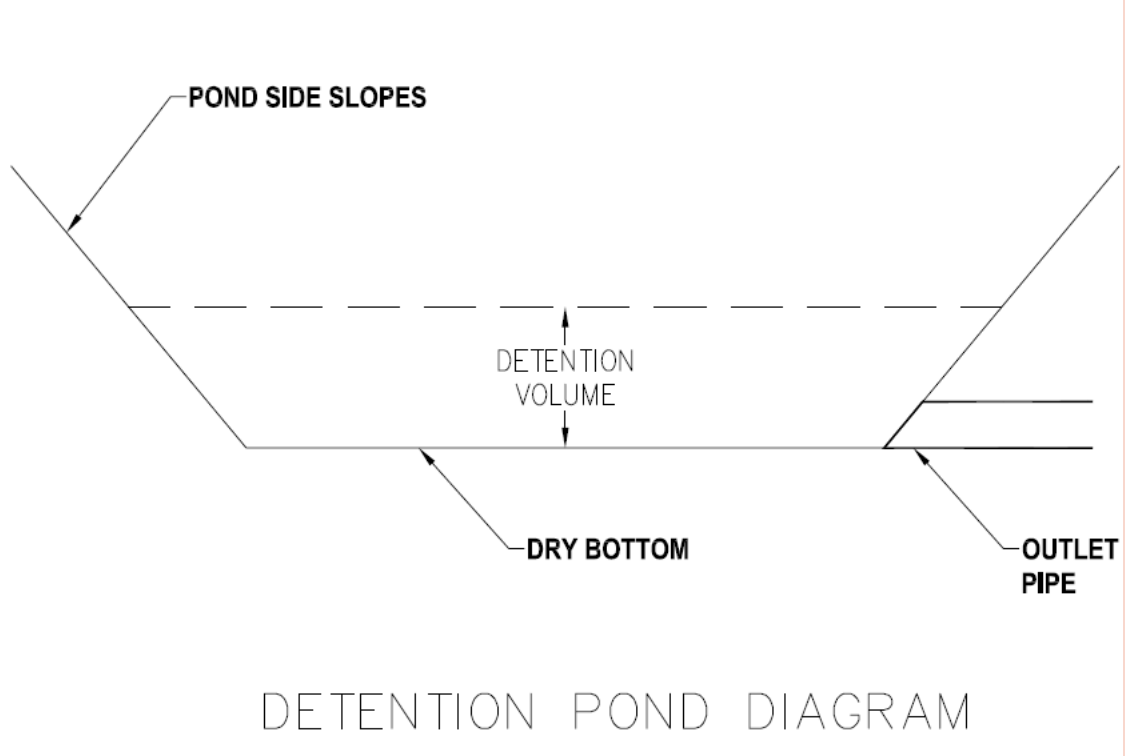
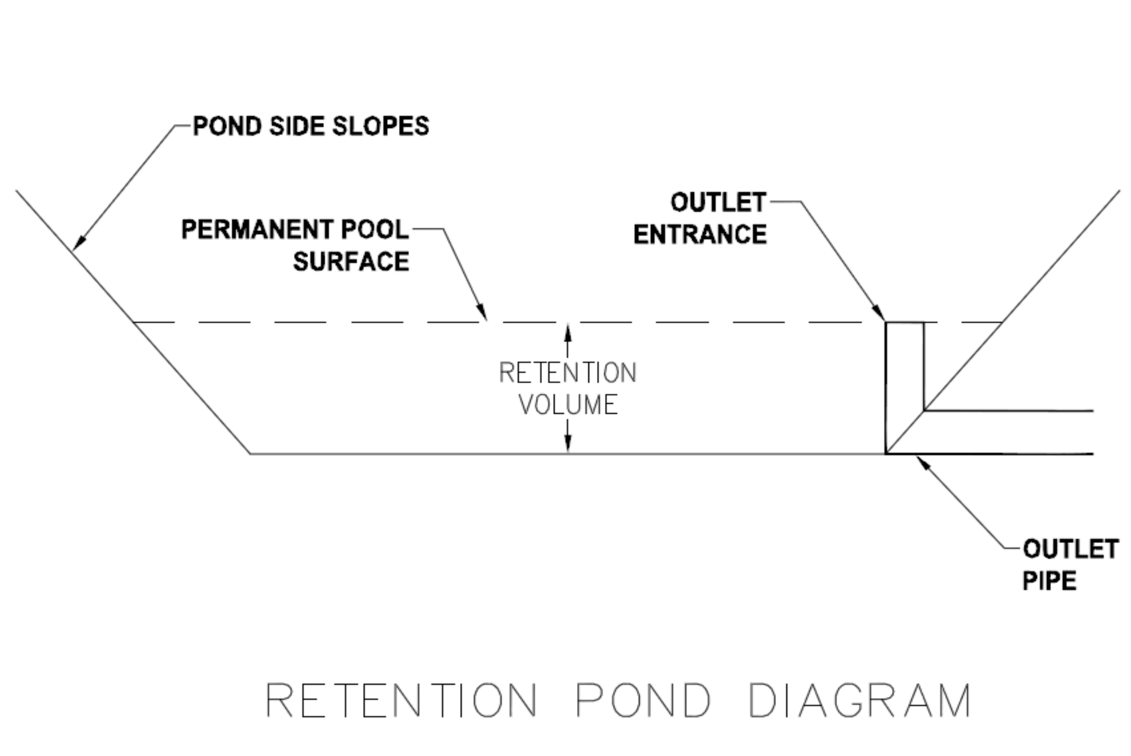
Table 2.5: Recommended Runoff Coefficients for Various Landuses (DID, 1980; Chow et al., 1988; QUDM, 2007 and Darwin Harbour, 2009)

Landuse	Runoff Coefficient (C)	
	For Minor System (≤10 year ARI)	For Major System (> 10 year ARI)
Residential		
Bungalow	0.65	0.70
Semi-detached Bungalow	0.70	0.75
Link and Terrace House	0.80	0.90
Flat and Apartment	0.80	0.85
Condominium	0.75	0.80
Commercial and Business Centres	0.90	0.95
Industrial	0.90	0.95
Sport Fields, Park and Agriculture	0.30	0.40
Open Spaces		
Bare Soil (No Cover)	0.50	0.60
Grass Cover	0.40	0.50
Bush Cover	0.35	0.45
Forest Cover	0.30	0.40
Roads and Highways	0.95	0.95
Water Body (Pond)		
Detention Pond (with outlet)	0.95	0.95
Retention Pond (no outlet)	0.00	0.00

Note: The runoff coefficients in this table are given as a guide for designers. The near-field runoff coefficient for any single or mixed landuse should be determined based on the imperviousness of the area.

DEFINITION

DETENTION POND VS RETENTION POND

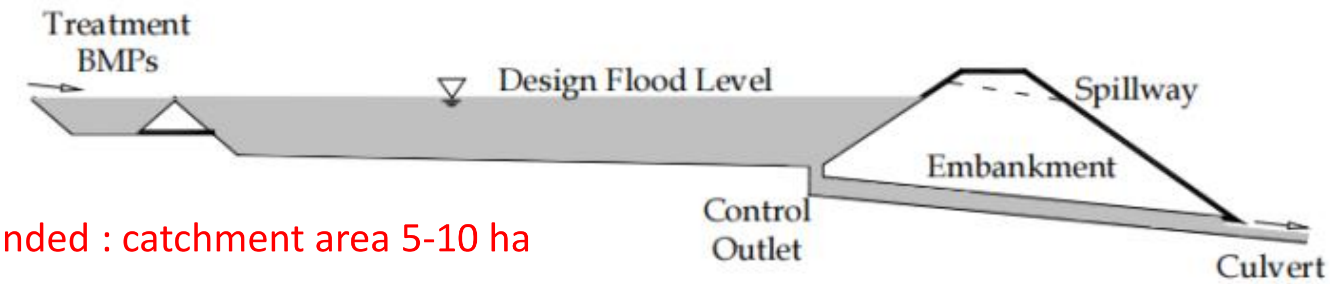
DETENTION	RETENTION
	

DEFINITION

WET POND VS DRY POND

a) Dry Pond

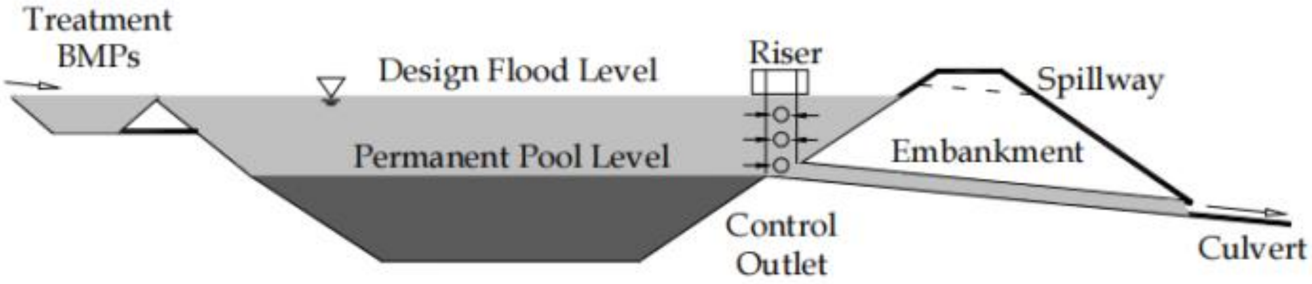
→ Recommended : catchment area 5-10 ha



Concept

Completion

(a) Dry Type - Kemaman



b) Wet Pond

→ Recommended : catchment area >10ha

Concept

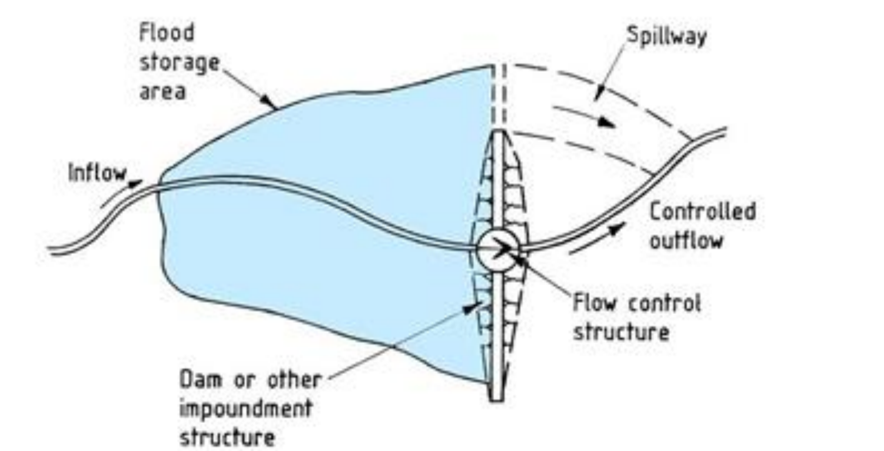
Completion

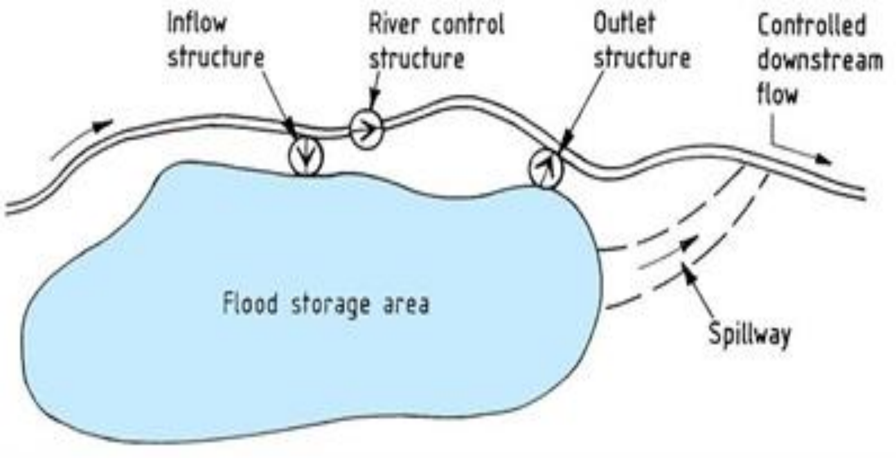
(b) Wet Type - Malacca

DEFINITION

ONLINE POND VS OFFLINE POND

ONLINE	OFFLINE
• An impounding structure – generally comprises an earth or concrete structure across the river and floodplain, behind which the water is stored; • A **flow control structure – normally located within the impounding structure to** control the outflow from the storage area; • A spillway – to pass floods that are more extreme than those that the reservoir is designed to attenuate.	• an intake structure to divert water to the storage area when the river flow or level exceeds a pre-determined value; • a **storage area that comprises a reservoir separated from the river,** formed either by low ground levels (natural or excavated) or by retaining structures (embankments, walls, or a combination of the two); • an outlet structure that returns water from the storage area to the river after the flood peak has passed; • a spillway to pass floods that are more extreme than those that the reservoir is designed to attenuate.

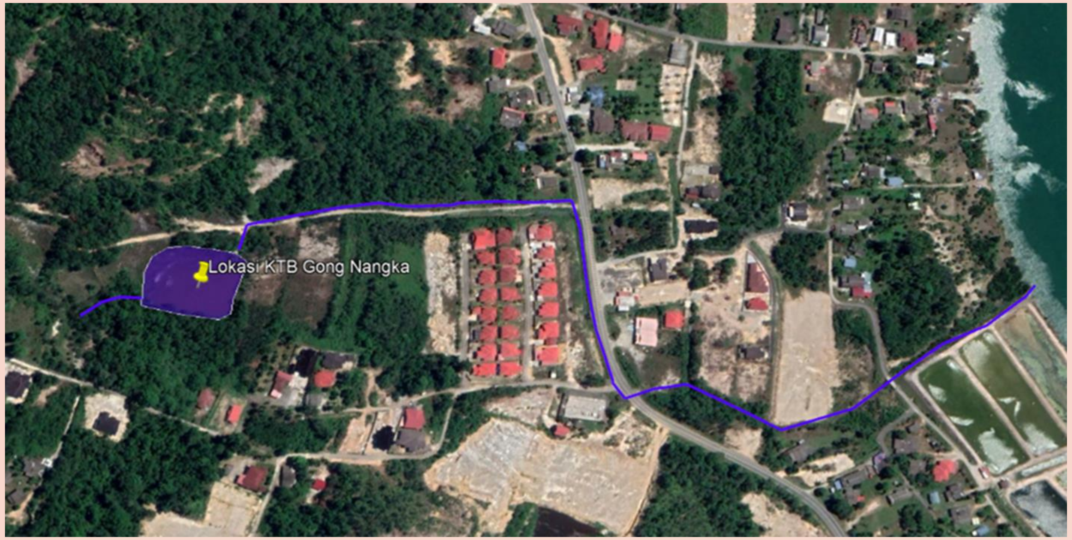




DEFINITION

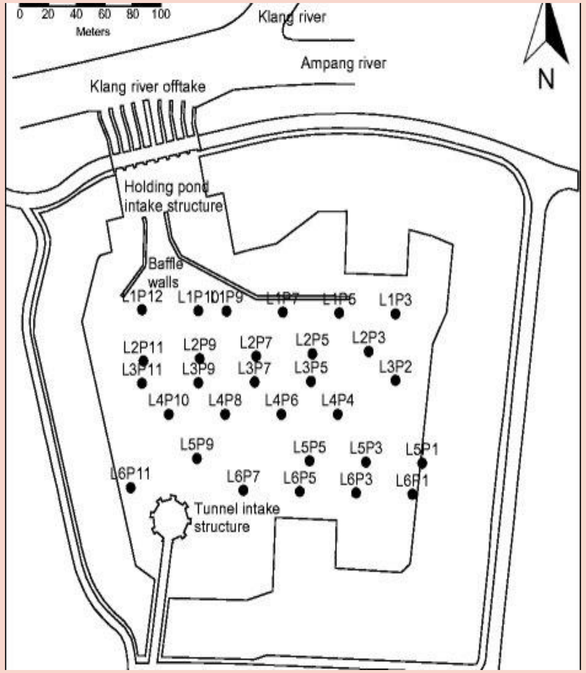
ONLINE POND VS OFFLINE POND

ONLINE



Kolam Takungan Banjir SMK Gong Nangka,
Marang, Terengganu

OFFLINE



Berembang Pond, JPS SMART, Ampang

INTRODUCTION

1. Detention Pond - used for controlling stormwater quantity impacts resulting from larger urbanising catchment

2. Location of Detention Pond:

Location

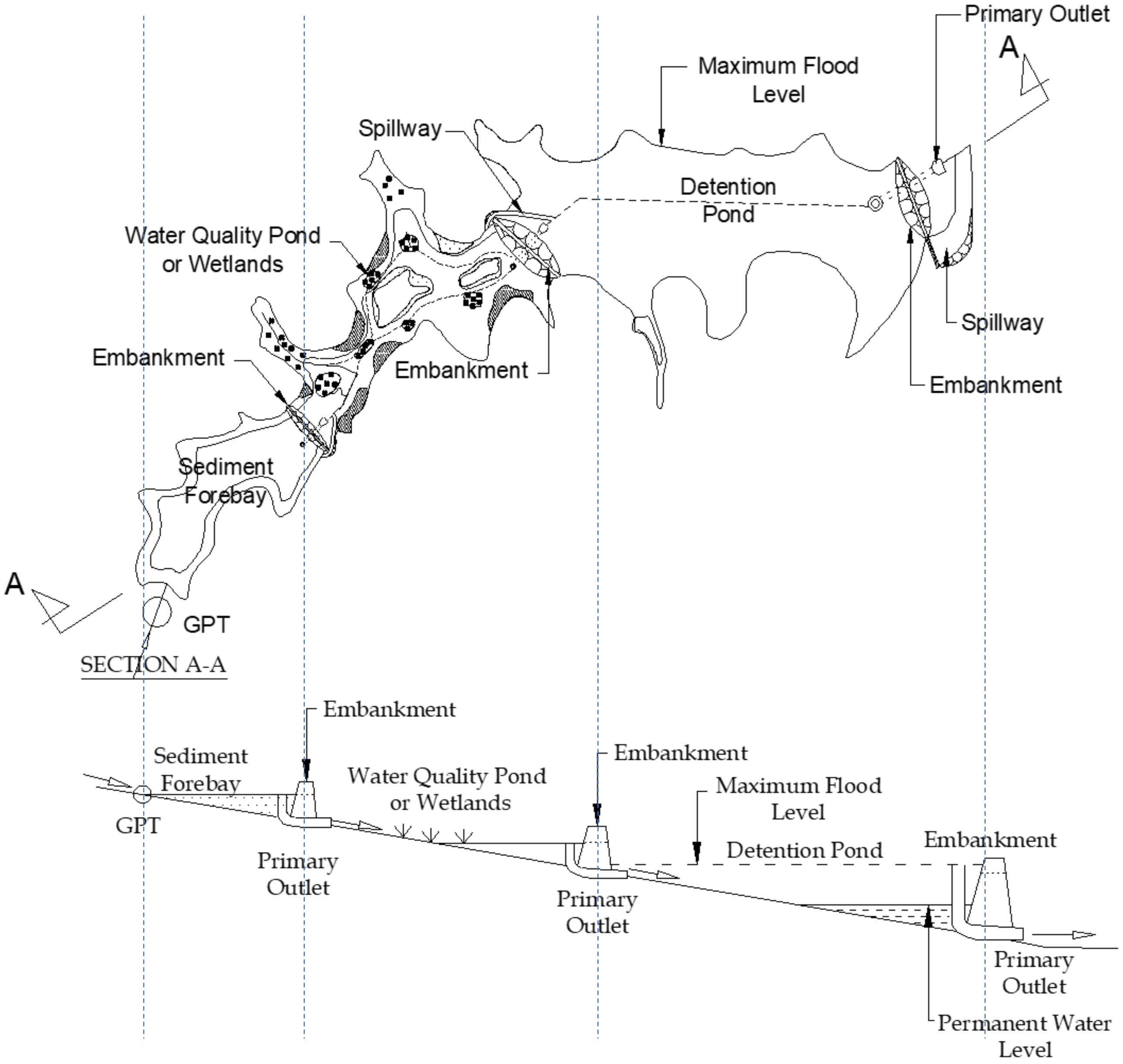
- Public areas by the construction of embankment across stream
- Channel or by the excavation of a potential storage area

Garis Panduan Perancangan Kawasan Kolam Takungan Sebagai Tanah Lapang JPBD 4/1997

Setiap pembangunan →

- **>10 hektar (25 ekar), kolam takungan perlu disediakan.**
- **3-5% kawasan kolam takungan**

SYSTEM COMPONENTS AND CONFIGURATION



SYSTEM COMPONENTS AND CONFIGURATION

- **Inlet zone** – inlet structure, GPT, sediment forebay, water quality pond or wetlands, maintenance ramp and rock weir;

Sediment Forebay

Water Quality Pond

SYSTEM COMPONENTS AND CONFIGURATION

- **Storage zone** – low flow channel/drain, maintenance ramp and pond body; and

Pond body

SYSTEM COMPONENTS AND CONFIGURATION

- **Outlet zone** – primary outlet (usually a multi-level riser with culvert), secondary outlet (usually a spillway), embankment, outfall/energy dissipater.

Primary & Secondary outlet

Secondary outlet – riser / spillway

WATER QUALITY CONTROL REQUIREMENTS

- All detention ponds require pre-treatment facilities (BMPs)

Location
- Inlet zone
- Upstream of the ponds

To ensure
- Ponds are not polluted
- Water quality levels →regulatory standards

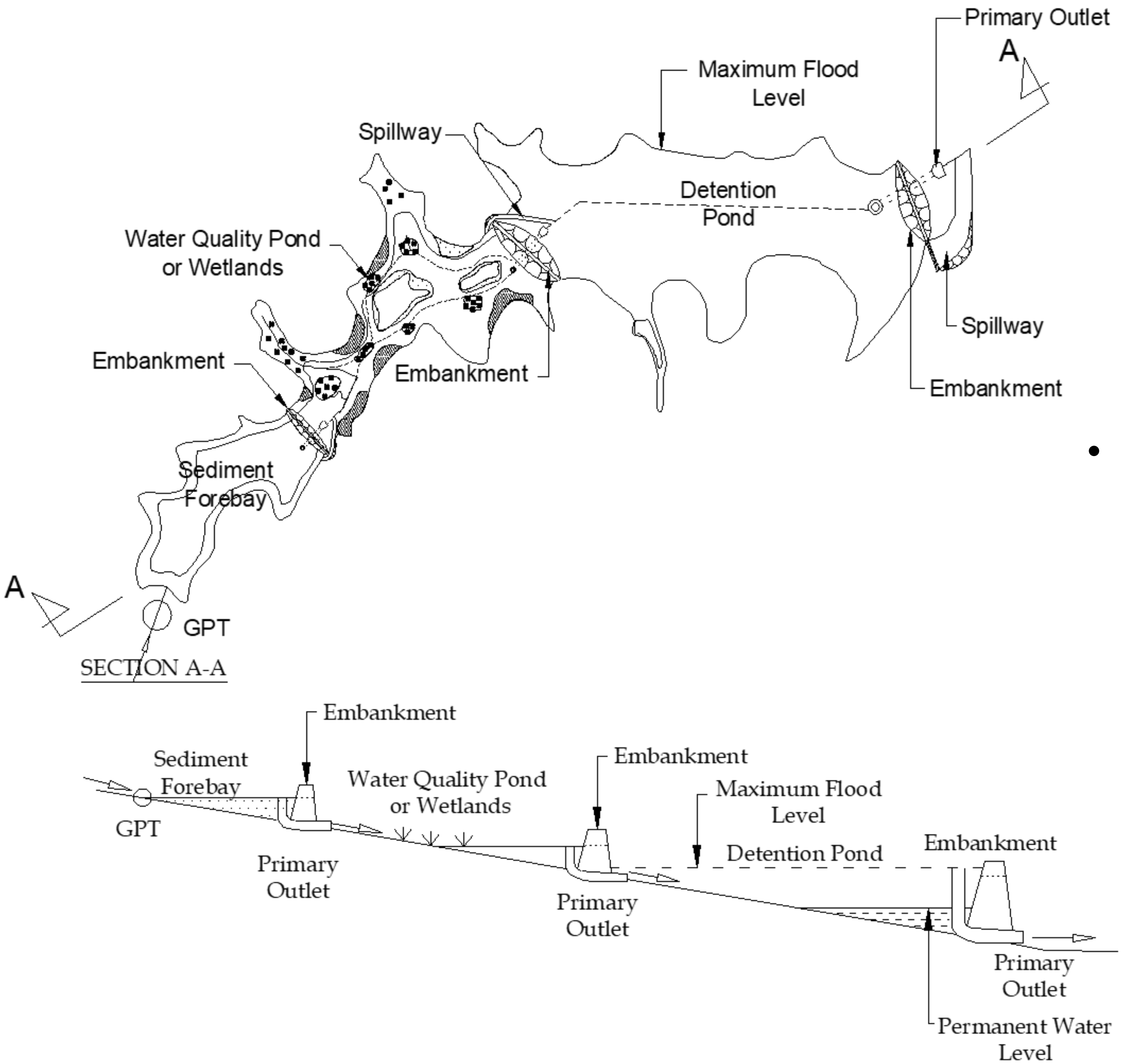
WATER QUALITY CONTROL REQUIREMENTS

Table 1.4: Pollutant Reduction Targets

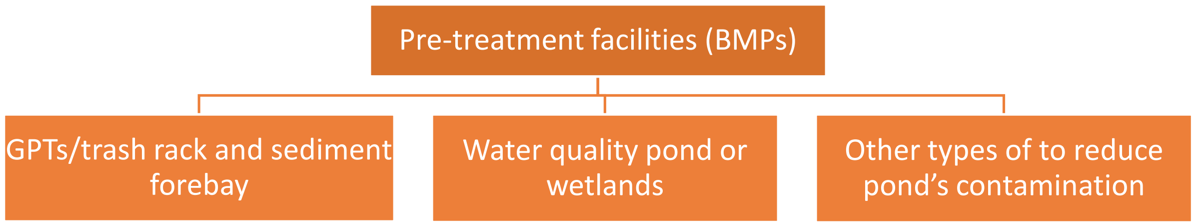
Pollutant	Reduction Targets (%)
Floatables/Litters	90
Total Suspended Solids (TSS)	80
Total Nitrogen (TN)	50
Total Phosphorus (TP)	50

Note: Relevant local regulatory authorities may set higher (stringent) targets depending on the sensitivity and level of pollution in the surrounding areas.

WATER QUALITY CONTROL REQUIREMENTS



- All detention ponds require pre-treatment facilities (BMPs)



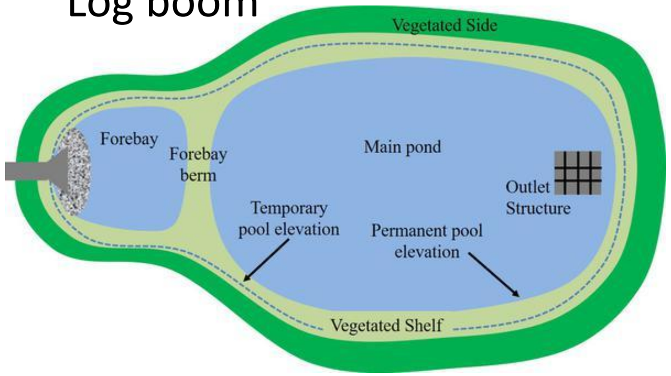
WATER QUALITY CONTROL REQUIREMENTS

- All detention ponds require pre-treatment facilities (BMPs)

Pre-treatment facilities (BMPs)

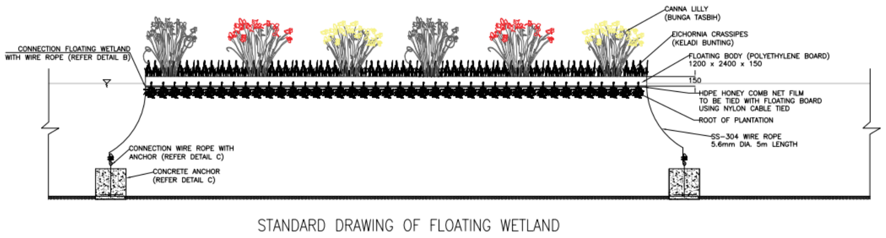
- GPTs/trash rack and sediment forebay
- Water quality pond or wetlands
- Other types of BMPs to reduce pond's contamination

Log boom



Sediment Forebay

Wetlands

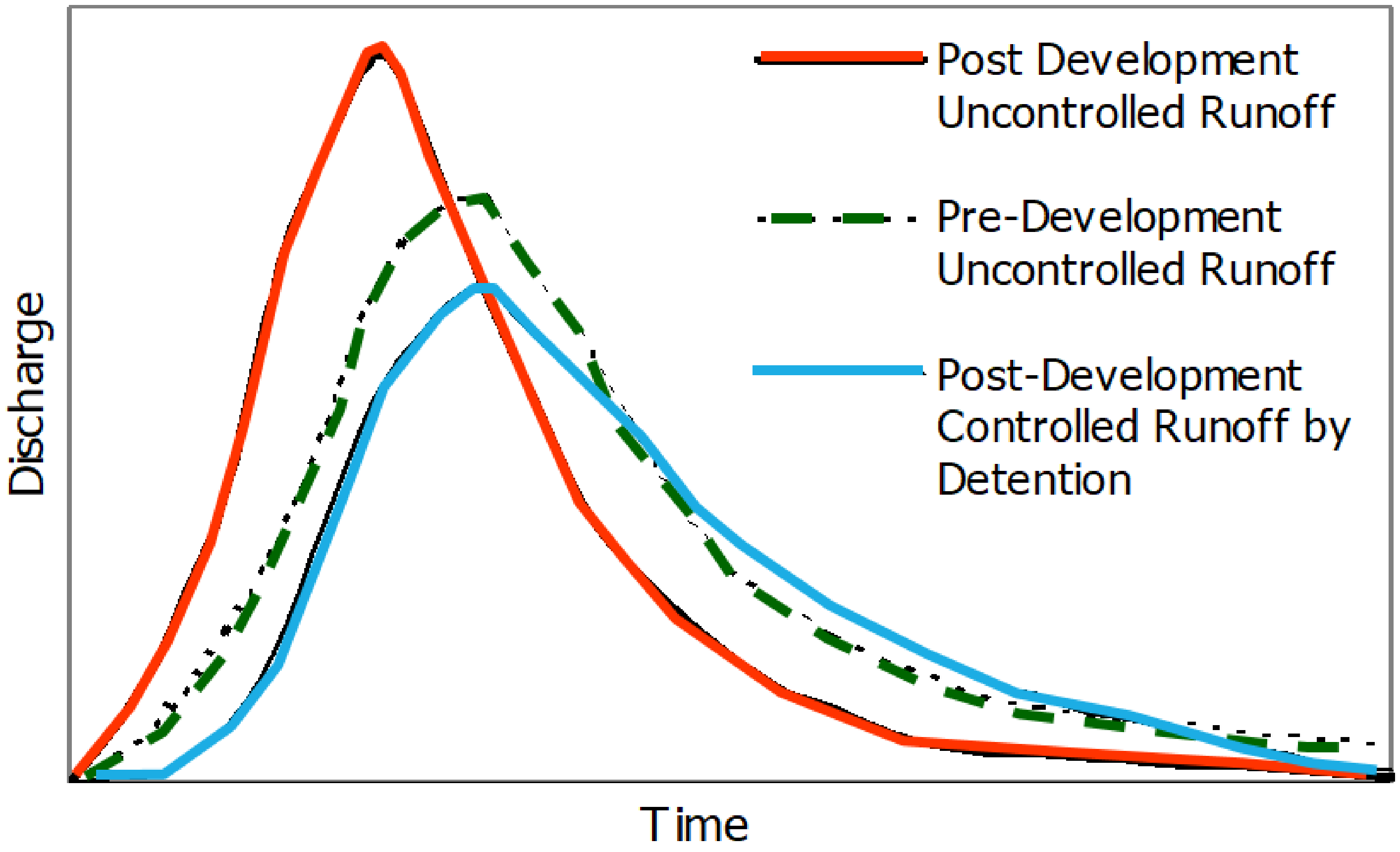


Floating Treatment Wetlands

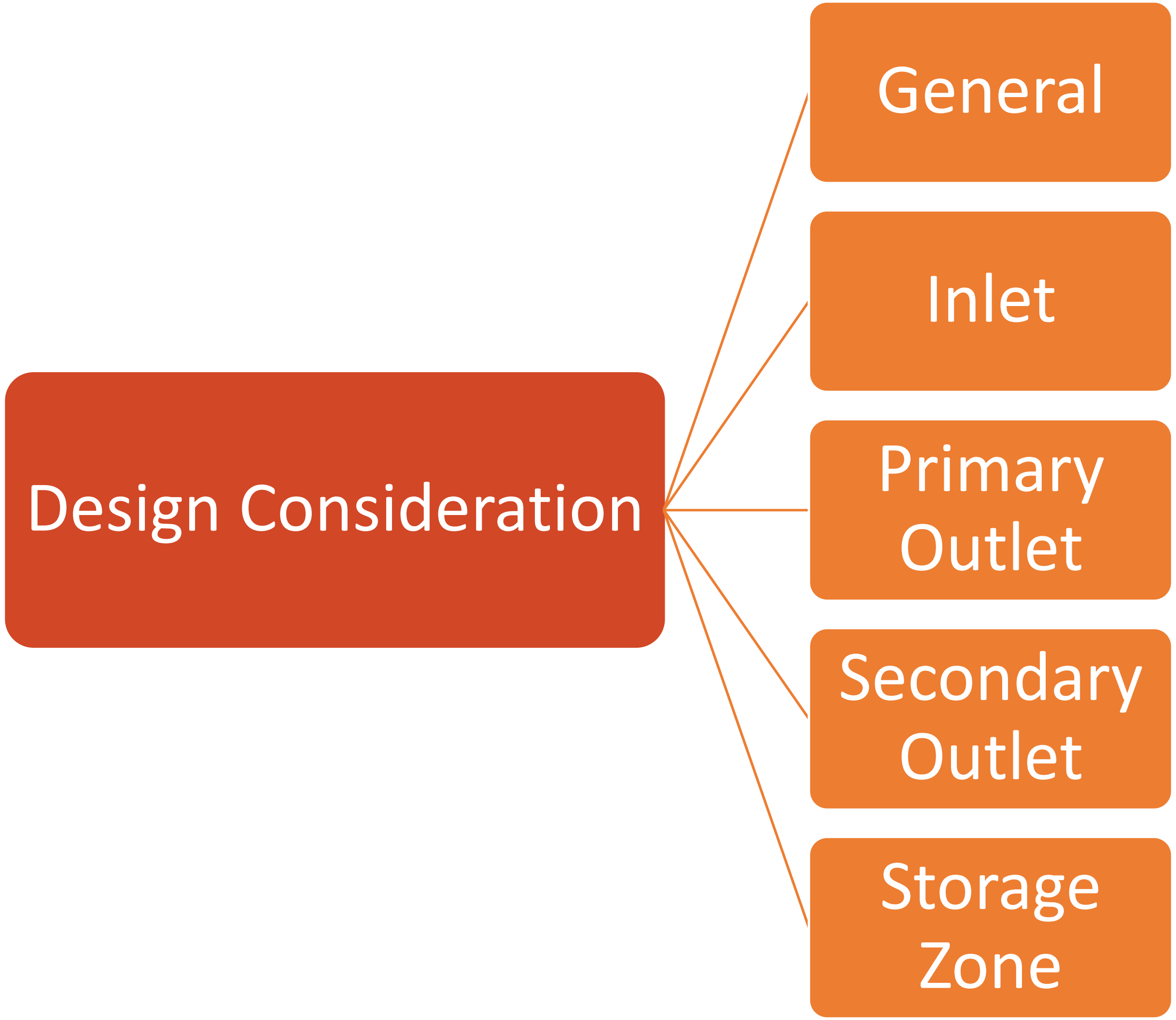
PEAK DISCHARGE CONTROL (Qpre and Qpost)

Runoff quantity control requirements for any size of development or re-development project is "Post development peak flow of any ARI at the project outlet must be less than or equal to the pre- development peak flow of the corresponding ARI ".

$$Q_{post} \leq Q_{pre}$$



DESIGN CONSIDERATIONS



DESIGN CONSIDERATIONS

Design Consideration (General)

Design and Analysis	- Depths and duration of ponding - Design underdrain - Probable maximum precipitation (PMP) - The effects of an embankment failure
Release Timing	The outflow hydrograph release time or empty time is within 24 hours
Multiple Design Storms	Applying storms of different durations and magnitudes ARIs
Extreme Floods	Dam break analysis using PMP data and a probable maximum flood (PMF)
Public Safety	- Depths of dry pond are limited to 1.2 m or 1.5 m - Side slope of ponds should not be steeper than 1(V):4(H) - Steeper slope → fence or handrail

DESIGN CONSIDERATIONS

Design Consideration (Inlet)

Inlet Structure

- Capacity (size) of the inlet ≥ the design capacity of the approach channel
- Invert level of the pond ≤ invert of the incoming channel
- Wings of the inlet structures should be protected

GPTs and Sediment Forebay

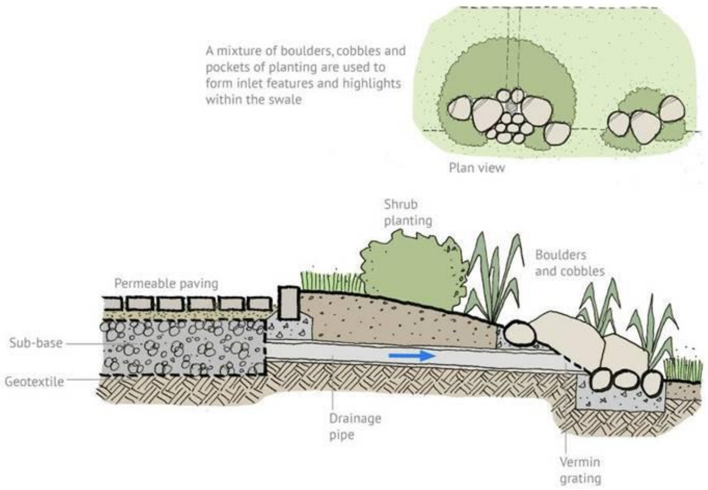
- Large catchment and pond system the facilities shall be designed according to site requirement
- Small drainage system proprietary devices can be adopted
- Sediment Forebay : size is about one-third (1/3) of water quality pond or wetlands volume, a minimum length to width ratio of 2:1.

Water Quality Pond or Wetlands

A sediment forebay together + water quality pond or wetlands → to trap particulate and dissolved pollutants before entering the detention pond

Boulders and Cobbles

at inlet structure



DESIGN CONSIDERATIONS

Design Consideration (Primary Outlet)

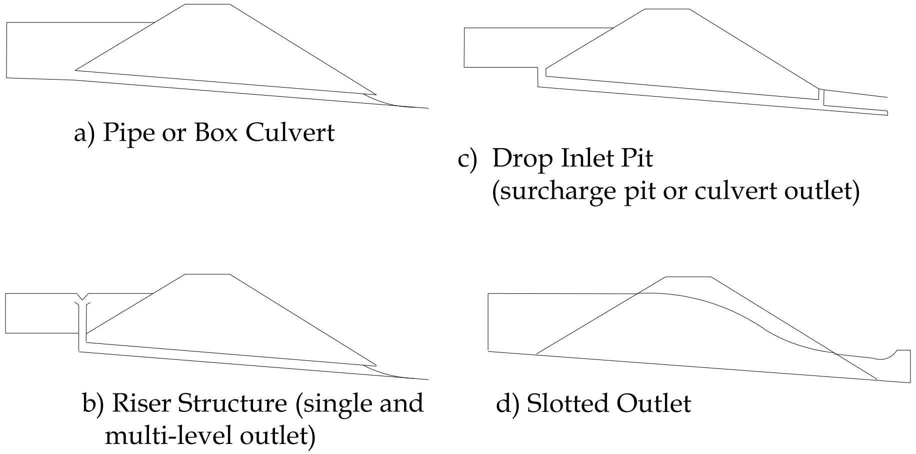
- Function : To reduce post-development peak flows
- Function : two-staged outlet configuration (minor and major system design flow)
  - design flows are typically orifice flow
  - higher flows are typically weir flow over the top of the control structure

Culverts

All culverts → suitable bedding and cutoff walls or seepage collars to prevent possible failure due to piping

Trash Racks

A high degree of maintenance is required



Typical Pond Primary Outlets

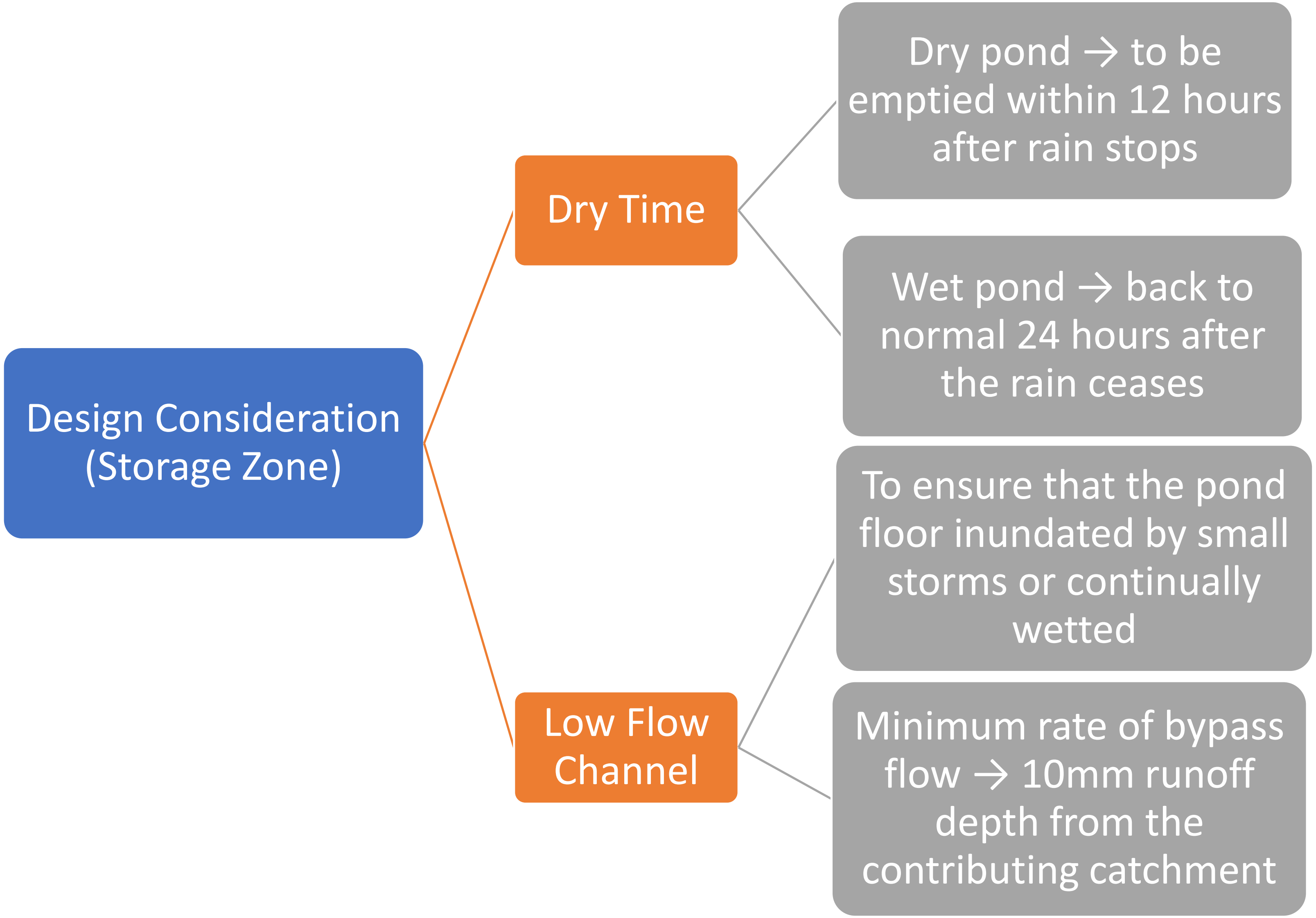
DESIGN CONSIDERATIONS

Design Consideration (Secondary Outlet)

Function: to provide a controlled overflow for flows in excess of the maximum design storm ARI

- Design ARI selected in accordance with the Federal Government or relevant State Government Dam Safety Guidelines
- Secondary outlets for all non-hazard small detention ponds shall be designed to safely pass a minimum design storm of 100 year ARI

DESIGN CONSIDERATIONS



DESIGN CONSIDERATIONS

- Design Consideration (Embankment)
  - Classification
  - Design Criteria
    - *Pond Water Depth*
      - normal operating conditions → maxi. pond water depth should not exceed 3.0 m
    - *Embankment Top Width*

Height of Embankment (m)	Top Width (m)
Under 3	2.4
3 to 4.5	3.0
4.5 to 6	3.6
6 to 7.5	4.2

    - *Side Slopes*
      - ease of maintenance → should not be steeper than 1(V):4(H)
    - *Bottom Grades*
      - a minimum grade of 1%
    - Freeboard
      - elevation of the top of the embankment shall be a minimum of 0.3 m above the water surface

EROSION PROTECTION (PRIMARY OUTLET DOWNSTREAM)

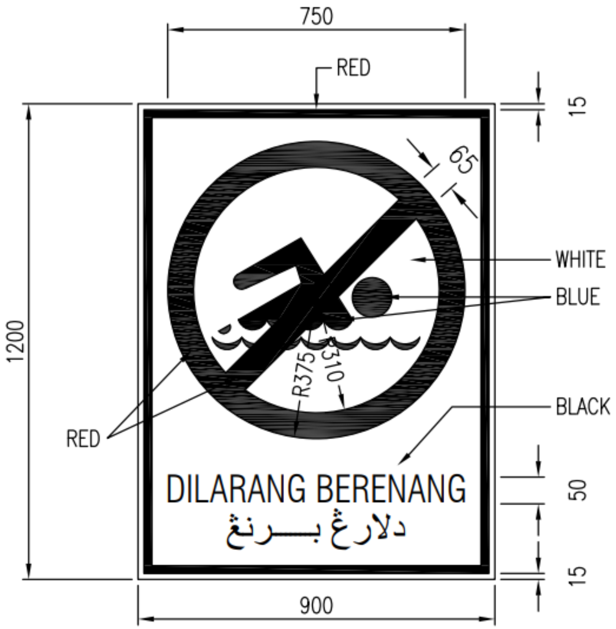
- Well-established turf → protection against velocities of up to 3 m/s , 9 hours
- The bank should be covered with a 0.15 m layer of topsoil
- Reinforcing turf (e.g. Geotextiles) enabling it to withstand velocities of up to 7 m/s
- Composite turf → concrete reinforcement + grass

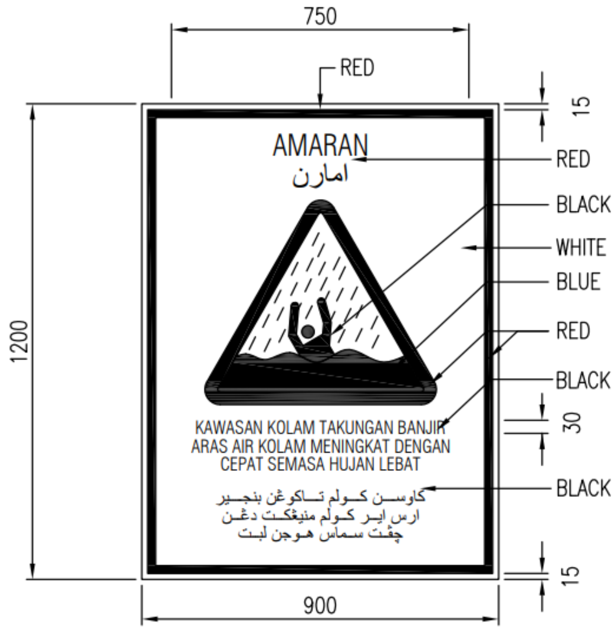
EROSION PROTECTION (PRIMARY OUTLET DOWNSTREAM)

- Stone pitching or other means → protection of the bed and banks for a few metres downstream
- Head exceeds 1 m → structure for dissipating energy
- Stilling basin → sufficient depth below the downstream tailwater level
- Channel bed and banks → protected by stone pitching or riprap

SAFETY AND AESTHETICS

- Signage - purpose and their potential danger during storms
- Inlet of a primary outlet structure creates a potential hazard C to prevent use Grating/trash Rack
- Downstream end of a primary outlet structure → Scour protection
- Designs → naturally shaped ponds
- Trees and shrubs should not be planted on pond embankments → Pond failure





EXAMPLES MSMA IMPLICATION

USM AND ECO-MEADOWS PENANG


Dry Pond


Wadding River + Flood Plain


Wetlands


Wetlands


Swales + WQ Drainage

SIZING DETENTION POND

Pond Volume Estimate → Final design of a detention facility

Final design of a detention facility:
- An inflow hydrograph
- A stage vs. storage curve
- A stage vs. discharge curve (Rating Curve)
- A storage indicator number curve

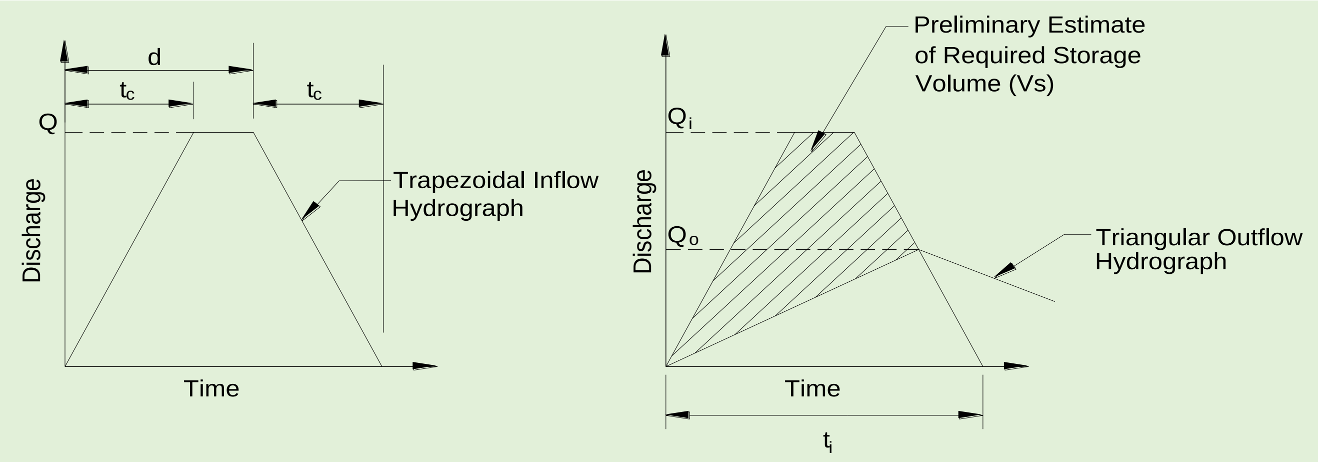
Major system →
required storage volume up to 100 yr ARI

SIZING DETENTION POND

– Pond Volume Estimate

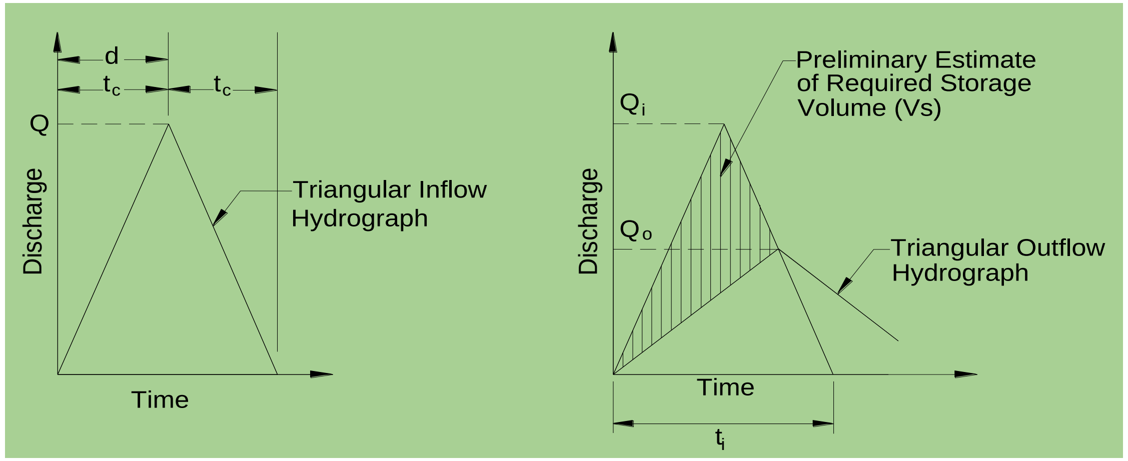
→ Detention storage design the inflow hydrograph, derived using Rational Hydrograph Method (RHM),

→ Approximated of facility discharge curves



a) Inflow Hydrograph **b) Storage Volume Estimate**

Estimating Detention Pond Storage by RHM for Type 1 Hydrograph



a) Inflow Hydrograph **b) Storage Volume Estimate**

Estimating Detention Pond Storage by RHM for Type 2 Hydrograph

SIZING DETENTION POND

- Pond-Stage Storage Curves Development

The storage volume for natural ponds in irregular terrain is usually developed for detention pond using a topographic map and the double-end area. The double-end area formula may be expressed as Equation :

where,

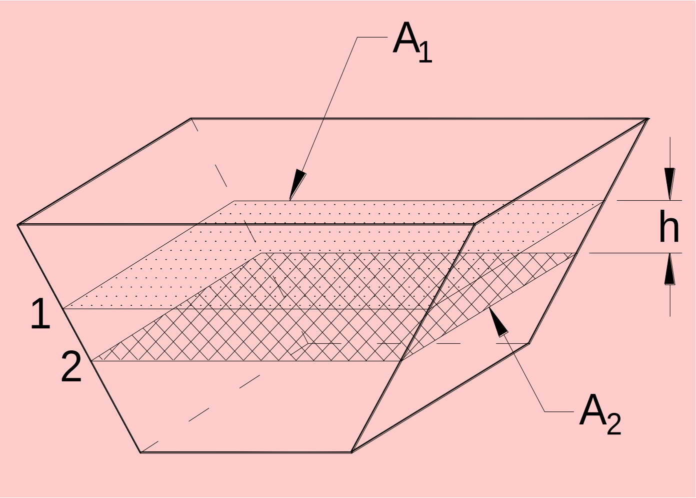
$V_{1,2}$ is storage volume between elevations 1 and 2 (m^3);

A_1 is surface area at elevation 1 (m^2);

A_2 is surface area at elevation 2 (m^2); and

h is change in elevation between points 1 and 2 (m).

The storage volume for excavated ponds with regular geometric shape (usually pyramid), is shown in Figure and may be expressed as Equation :



$V_{1,2} =$

where,

V is volume of frustum of a pyramid (m^3);

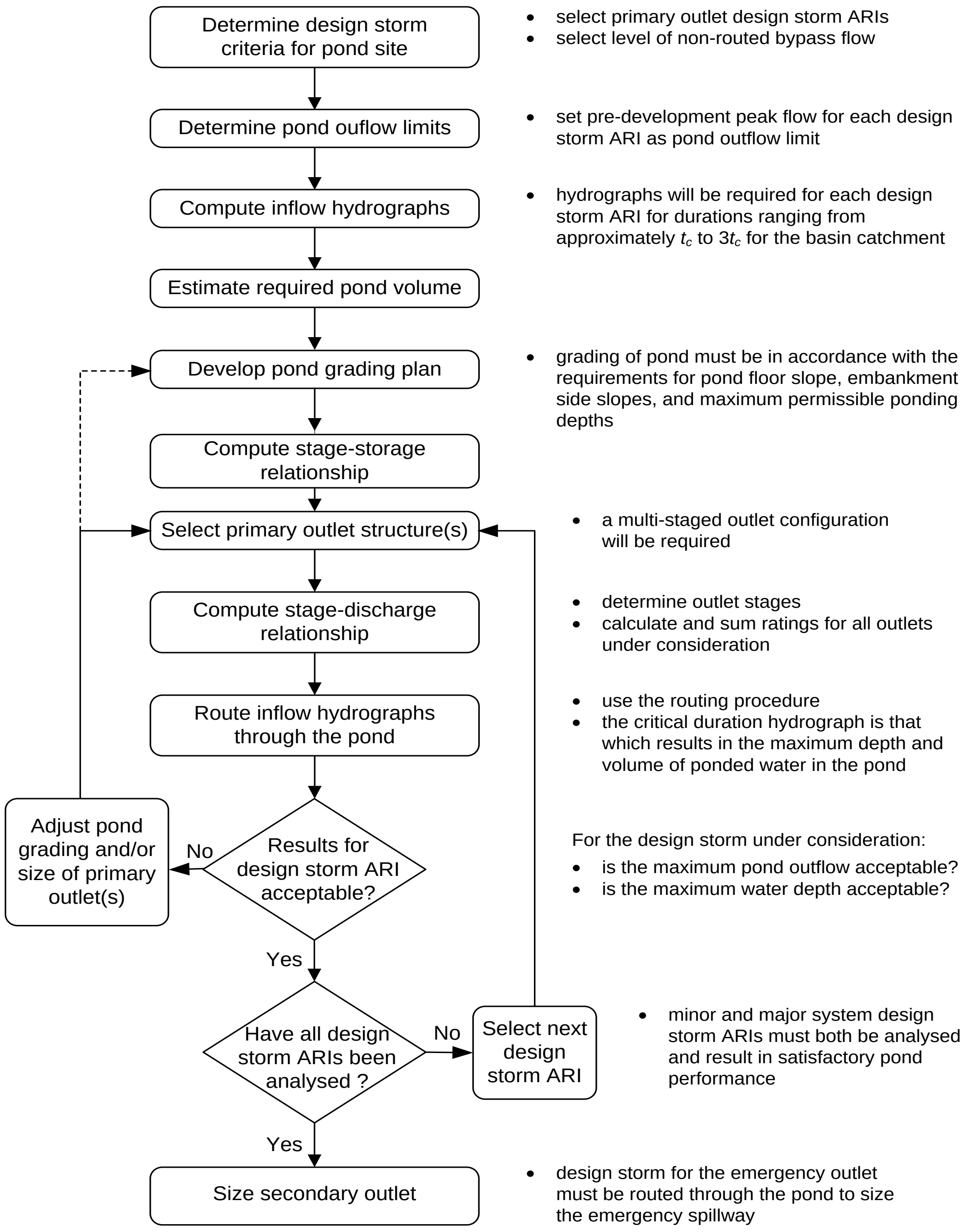
A_1 is surface area at elevation 1(m^2);

A_2 is surface area at elevation 2 (m^2); and

h is change in elevation between points 1 and 2 (m).

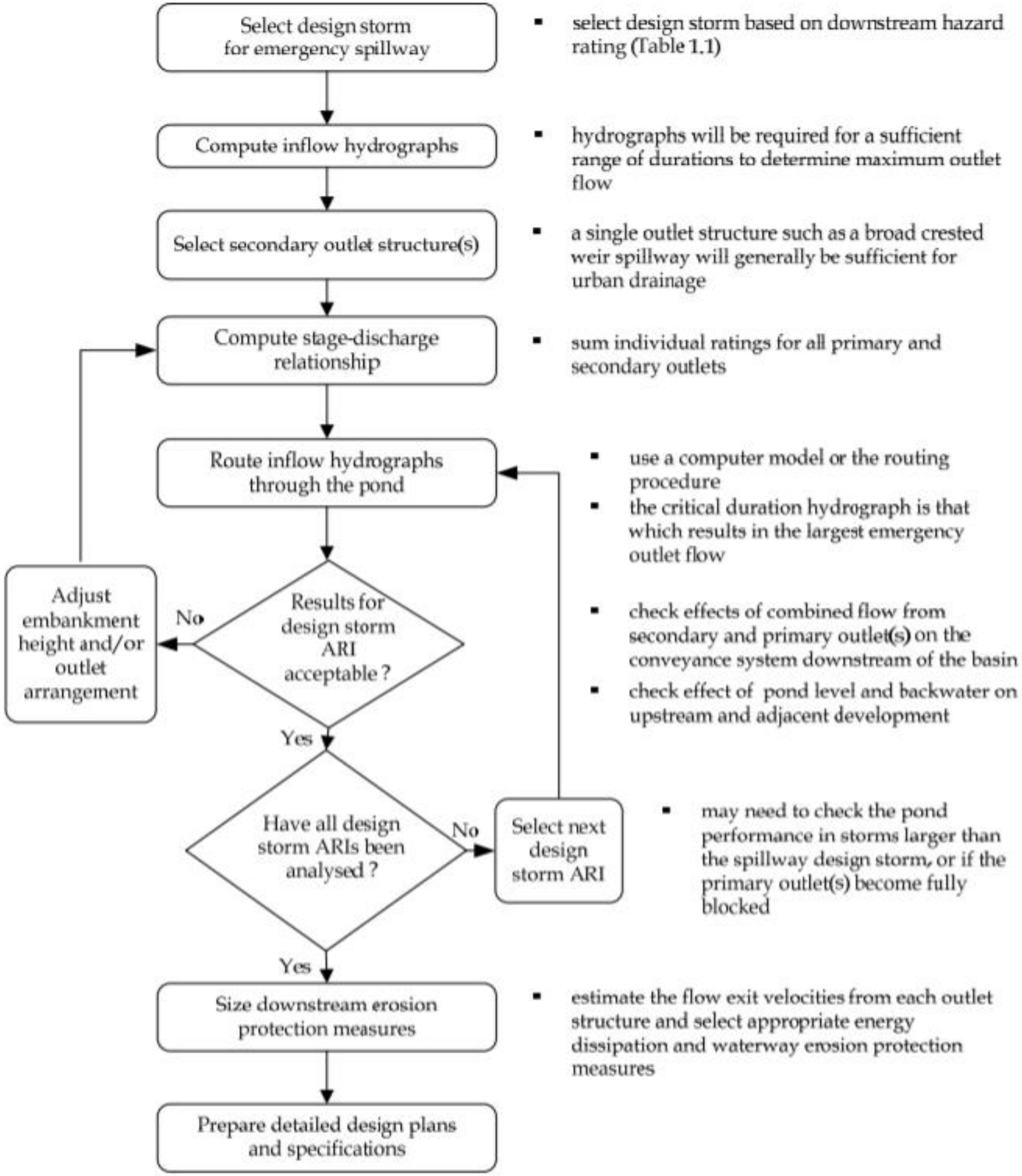
SIZING DETENTION POND

Sizing steps for volume and primary outlets



SIZING DETENTION POND

Sizing steps for Secondary outlets



HIDROLOGIC POND ROUTING

The most commonly used method for routing inflow hydrograph through a detention pond is the **Storage Indication** or **modified Puls method**. This method begins with the continuity equation which states that the inflow minus the outflow equals the change in storage (I-0=ΔS). By taking the average of two closely spaced inflows and two closely spaced outflows, the method is expressed by Equation 2.16. This relationship is illustrated graphically in Figure 2.11.

$$\frac{\Delta S}{\Delta t} = \frac{I_1 + I_2}{2} - \frac{O_1 + O_2}{2} \tag{2.16}$$

where:

ΔS = Change in storage (m^3);
Δt = Time interval (min);
I = Inflow (m^3); and
O = Outflow (m^3).

HIDROLOGIC POND ROUTING

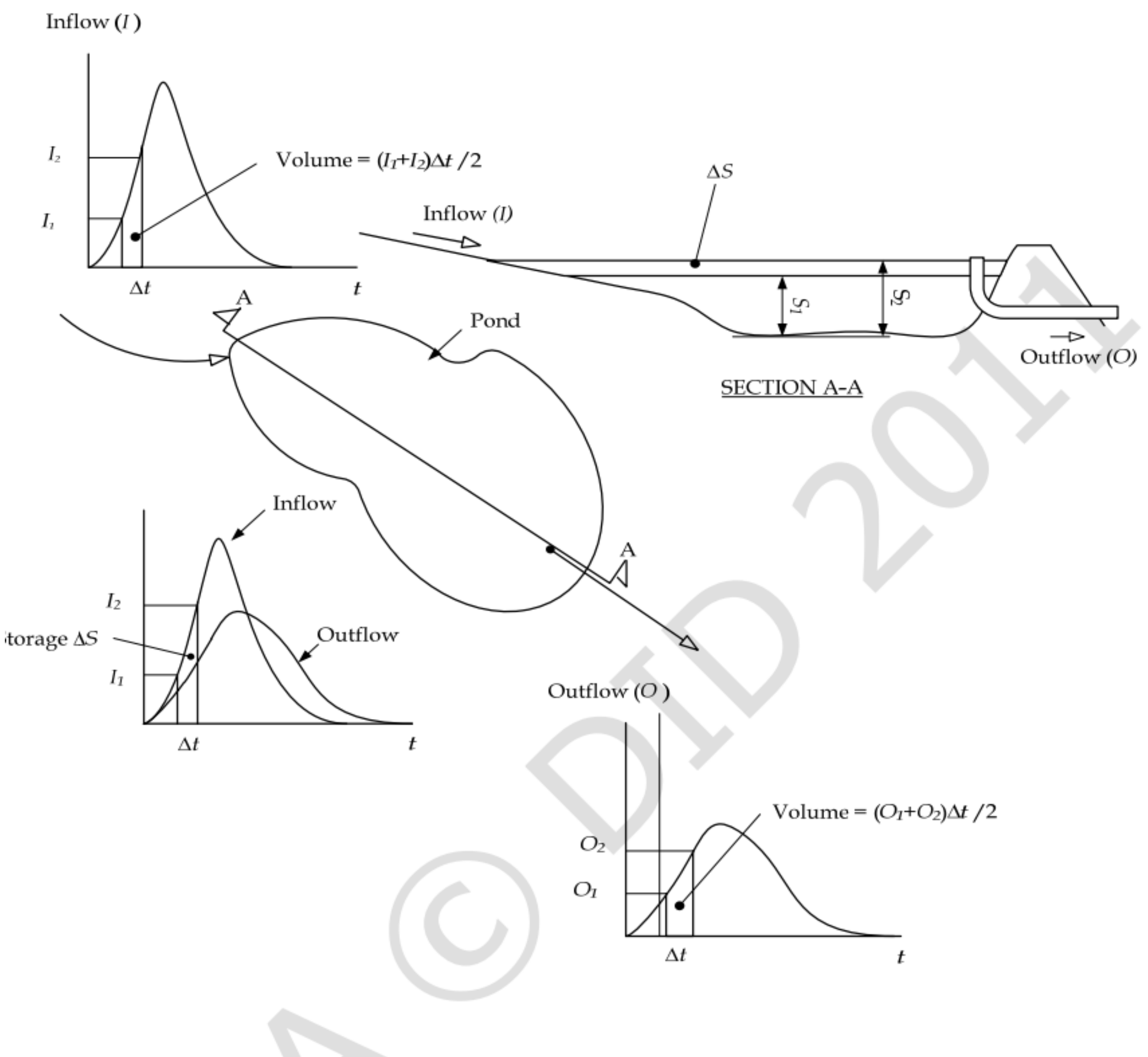


Figure 2.11: Development of the Storage-Discharge Function for Hydrologic Pond Routing

Equation 2.16 can be rearranged so that all the known values are on the left side of the equation and all the unknown values are located on the right hand side of the equation, as shown in Equation 2.17. Now the equation with two unknowns, S_2 and O_2, can be solved with one equation. The following procedure can be used to perform routing through a reservoir or storage facility using Equation 2.17.

$$\frac{I_1+I_2}{2}+\left(\frac{S_1}{\Delta t}+\frac{O_1}{2}\right)-O_1=\left(\frac{S_2}{\Delta t}+\frac{O_2}{2}\right) \tag{2.17}$$

Step 1: Develop an inflow hydrograph, stage-discharge curve, and stage-storage curve for the proposed storage facility.

Step 2: Select a routing time period, Δt, to provide a minimum of five points on the rising limb of the inflow hydrograph.

Step 3: Use the stage-storage and stage-discharge data from Step 1 to develop a storage indicator numbers table that provides storage indicator values, S/(Δt) + O/2, versus stage. A typical storage indicator numbers table contains the following column headings:

1 Stage (m)	2 Discharge (O_2) (m^3/s)	3 Storage (S_2) (m^3)	4 $O_2/2$ (m^3/s)	5 $S_2/\Delta t$ (m^3/s)	6 $S_2/\Delta t + O_2/2$ (Storage Indicator Number)

- Discharge (O) and storage (S) are obtained from the stage-discharge and stage-storage curves, respectively.
- Subscript 2 is arbitrarily assigned at this time.
- Time interval (Δt) must be the same as the time interval used in the tabulated inflow hydrograph.

Step 4: Develop a storage indicator numbers curve by plotting the outflow (column 2) vertically against the storage indicator numbers in column 6. An equal value line plotted as $O_2 = S_2/\Delta t + O_2/2$ should also be plotted. If the storage indicator curve crosses the equal value line, a smaller time increment (Δt) is needed (Figure 2.12).

Step 5: A supplementary curve of storage (column 3) vs. $S_2/\Delta t + O_2/2$ (column 6) can also be constructed. This curve does not enter into the mainstream of the routing; however, it is useful for identifying storage for any given value of $S_2/\Delta t + O_2/2$. A plot of storage vs. time can be developed from this curve.

HIDROLOGIC POND ROUTING

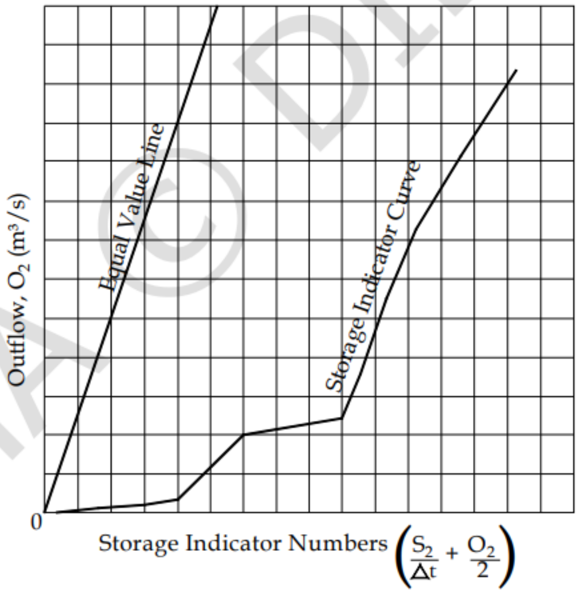


Figure 2.12: Storage Indicator Curve

Step 6: Routing can now be performed by developing a routing table for the solution of Equation 2.17 as follows:

1 Time (hr)	2 Inflow (m³/s)	3 $(I_1+I_2)/2$ (m³/s)	4 $(S_1/\Delta t+O_1/2)$ (m³/s)	5 O_1 (m³/s)	6 $S_2/\Delta t + O_2/2)$ (m³/s)	7 O_2 (m³/s)

- Columns (1) and (2) are obtained from the inflow hydrograph.
- Column (3) is the average inflow over the time interval.
- The initial values for columns (4) and (5) are generally assumed to be zero since there is no storage or discharge at the beginning of the hydrograph when there is no inflow into the basin.
- The left side of Equation 2.17 is determined algebraically as columns (3) + (4) -(5). This value equals the right side of Equation 2.17 or $S_2/\Delta t + O_2/2$ and is placed in column (6).
- Enter the storage indicator curve with $S_2/\Delta t + O_2/2$ (column 6) to obtain O_2 (column 7).
- Column (6) $(S_2/\Delta t + O_2/2)$ and column (7) (O_2) are transported to the next line andbecome $S_1/\Delta t + O_1/2$ and O1 in columns (4) and (5), respectively. Because $(S_2/\Delta t+ O_2/2)$ and O2 are the ending values for the first time step, they can also be said to be the beginning values for the second time step.
- Columns (3), (4), and (5) are again combined and the process is continued until the storm is routeh. Peak storage depth and discharge (O_2 in column (7)) will occur when column (6) reaches a maximum. The storage indicator numbers table developed in Step 3 is entered with the maximum value of $S_2/\Delta t + O_2/2$ to obtain the maximum amount of storage required. This table can also be used to determine the corresponding elevation of the depth of stored water.
- Designer needs to make sure that the peak value in column (7) does not exceed the allowable discharge as prescribed by the stormwater management criteria.

Step 7: Plot O_2 (column 7) versus time (column 1) to obtain the outflow hydrograph.

The above procedure is illustrated in Figure 2.13.

THANK YOU!

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