Assessment on the Stormwater Infrastructure Design Parameter based on the Existing Projects of Sarawak Urban Stormwater Management, SUStoM Facility

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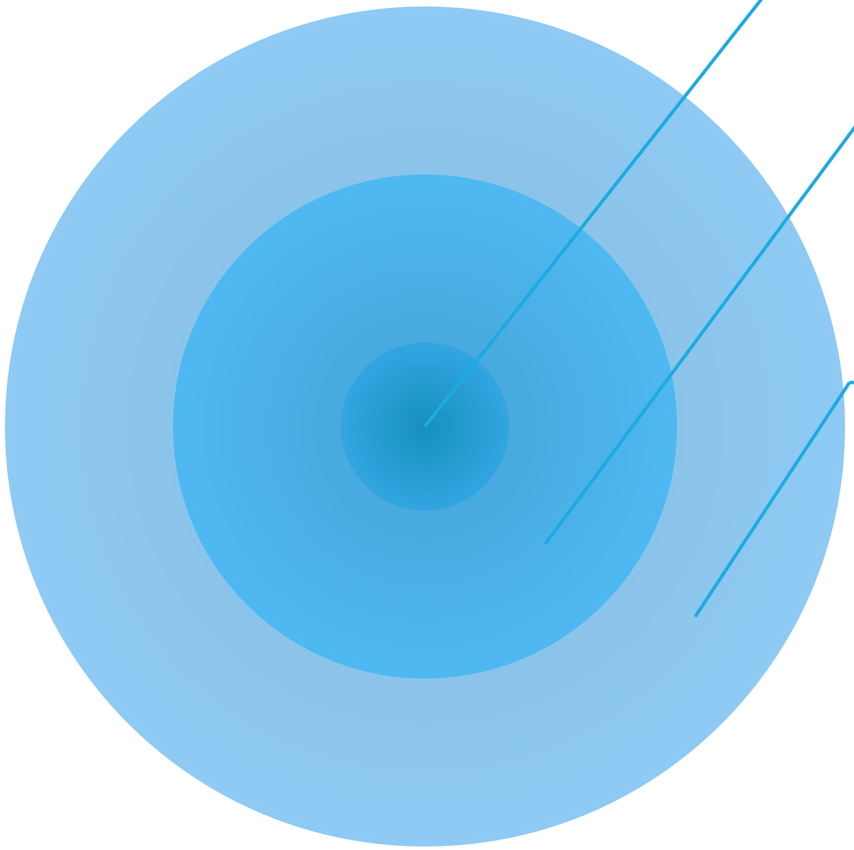
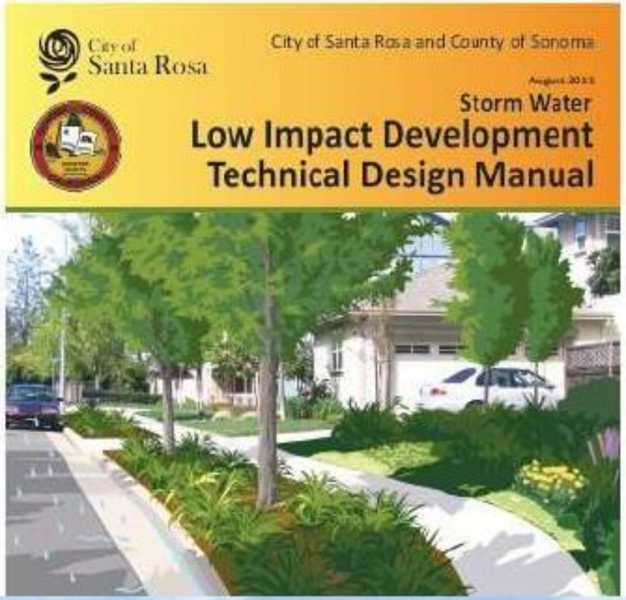
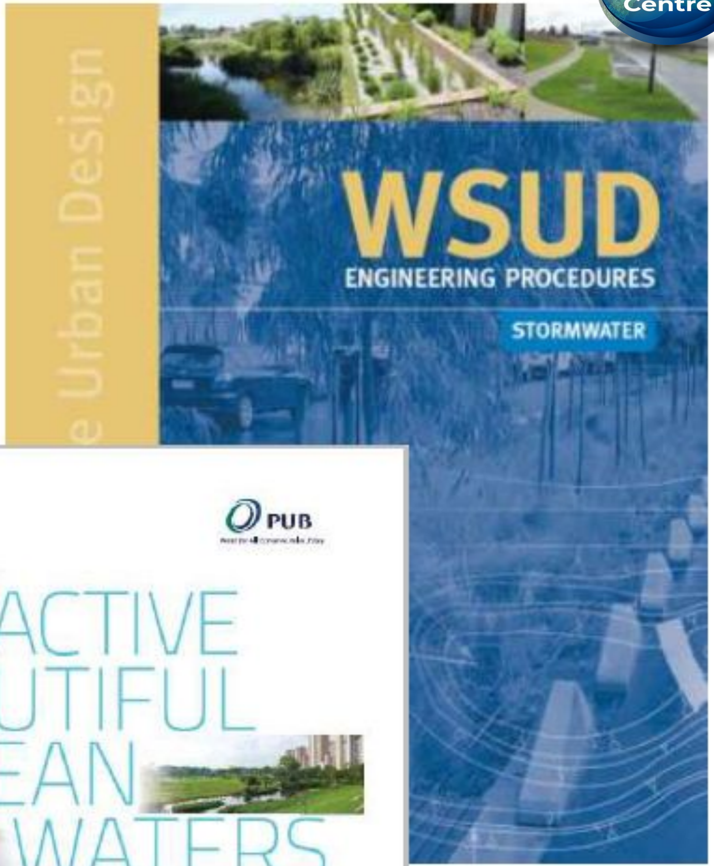
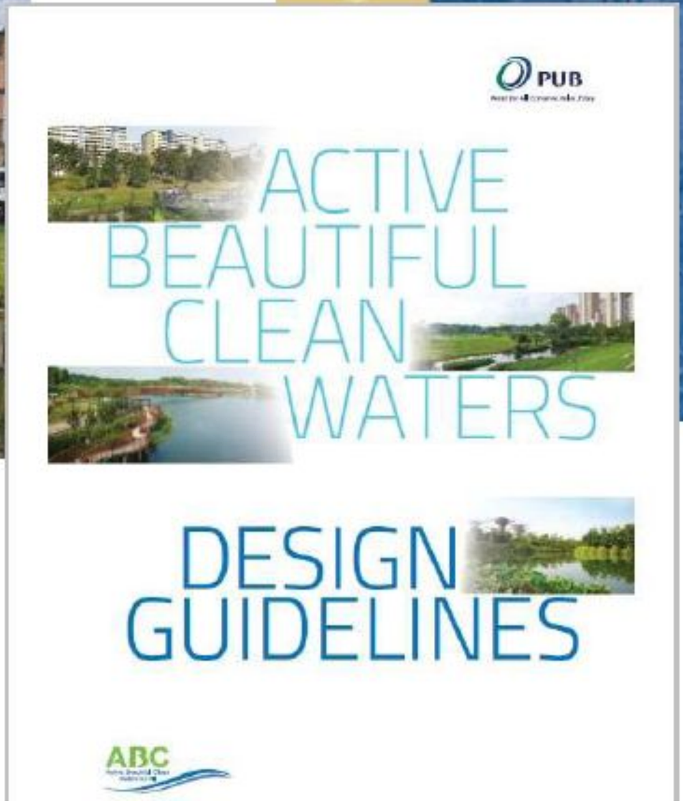
STORMWATER MANAGEMENT



STORMWATER MANAGEMENT/ GREEN INFRASTRUCTURE



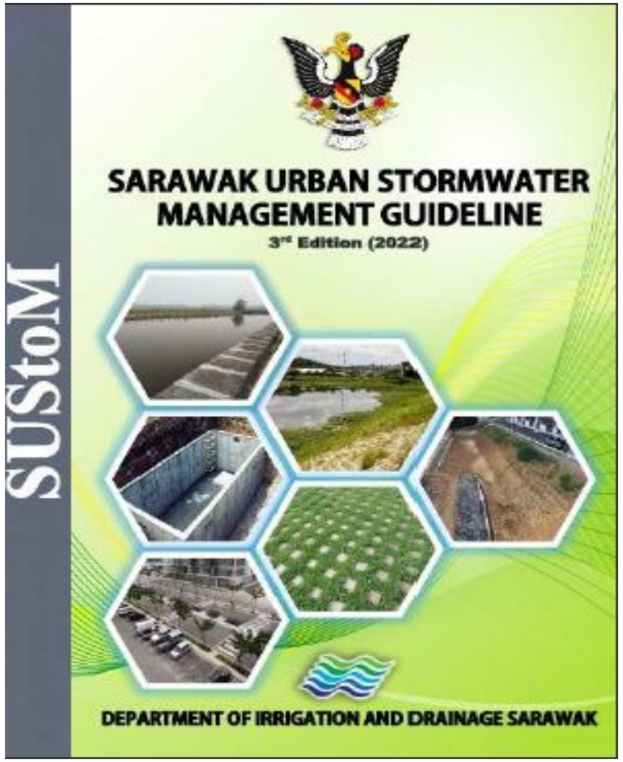


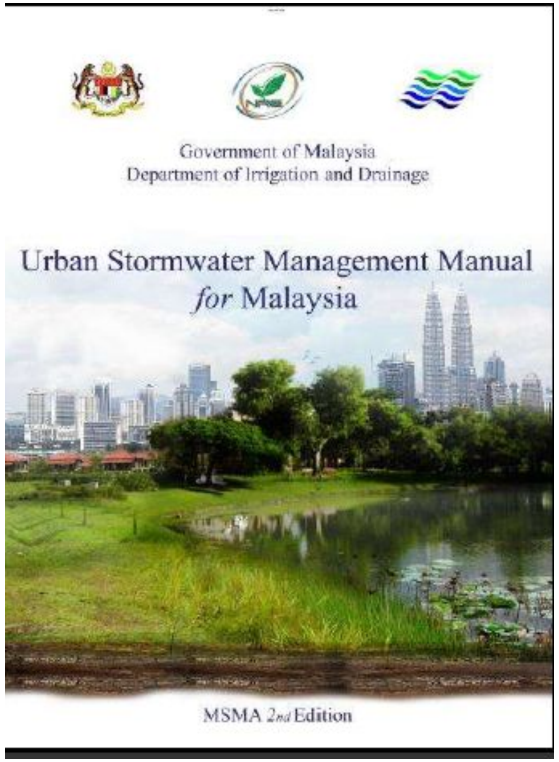


Stormwater Management/ Green Infrastructure

United States	Australia	Britain	New Zealand	Malaysia	Sarawak
LID	**WSUD**	**SUDS**	**LIUDD**	**MSMA**	**SUStoM**
Low Impact Development	Water Sensitive Urban Design	Sustainable Drainage Systems	Low Impact Urban Design and Development	Manual Saliran Mesra Alam	Sarawak Urban Stormwater Management

STORMWATER MANAGEMENT/ GREEN INFRASTRUCTURE





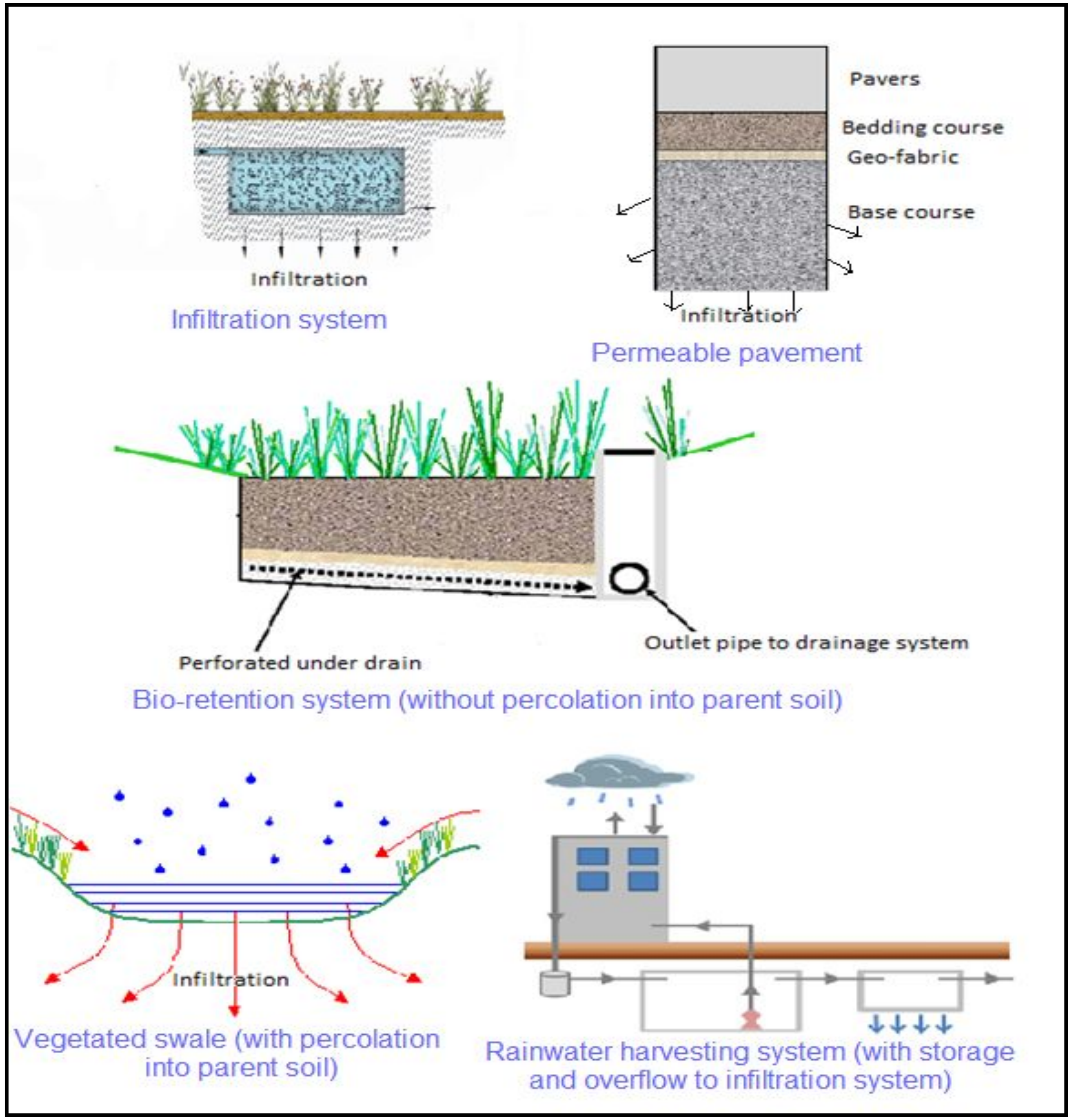
MANUAL SALIRAN MESRA ALAM (MSMA)

SARAWAK URBAN STORMWATER MANAGEMENT GUIDELINE (SUStoM)

MSMA/ SUStoM Key Elements

1. Quantity Control
2. Quality Control
3. Erosion and Sediment Control
4. Operation and Maintenance
5. Aesthetic Value

URBAN STORMWATER MANAGEMENT TECHNOLOGIES



Constructed wetlands

Green roofs

Stormwater Management/ Green Infrastructure

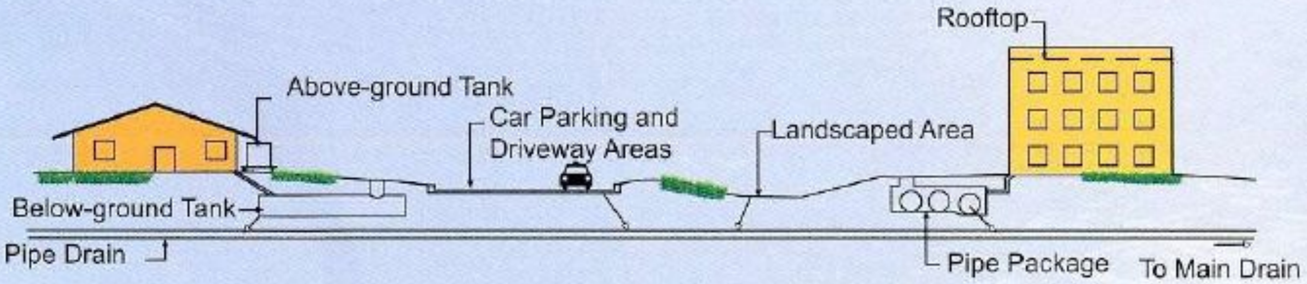






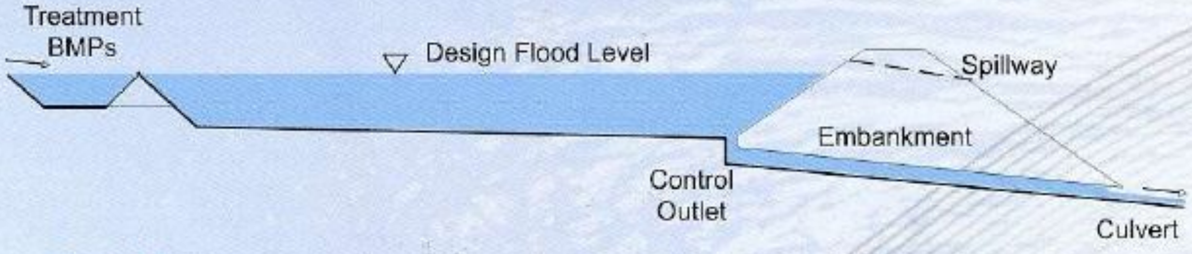


Quantity Control



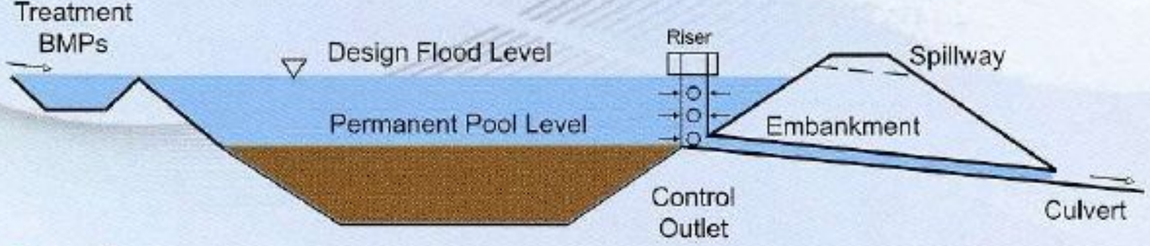
On-Site Detention

Recommended < 5 ha



Dry Ponds

Recommended 5 ha – 10 ha



Wet Ponds

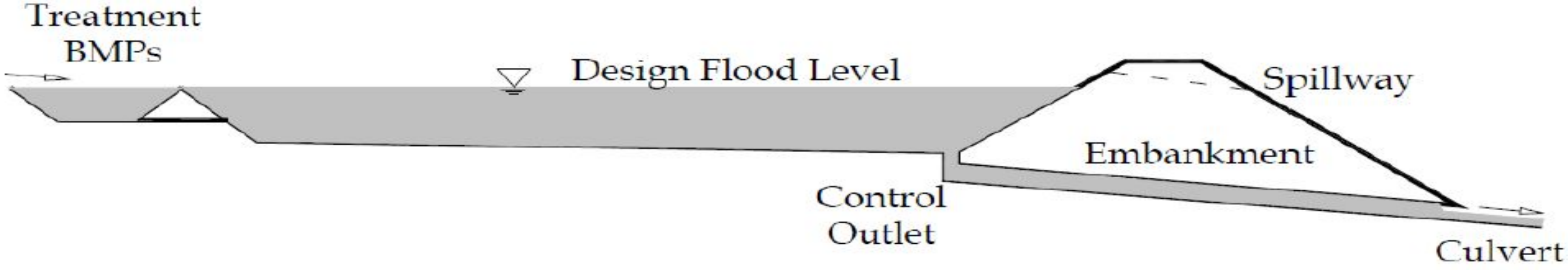
Recommended > 10 ha

The suitability of specific SUStoM facilities depends on

- **Topography** (natural slope/depression)
- **Geology** (type of soil & its properties, i.e. porosity, infiltration & conveyance)
- **Internal drainage**
- **Sub-catchments**
- **Connection to the main drain**

STORMWATER MANAGEMENT/ GREEN INFRASTRUCTURE

2. Detention pond reduces flood peak discharge downstream by temporary storage and gradual release using control outlet, usually ungated structure, riser or culvert, located at the base of the embankment.
3. Release Timing – Dry pond to be emptied within 12 hours while wet pond should be hours after rain ceases.



Chapter 7 – Detention Pond MSMA 2nd Edition

Stormwater Detention Tank System

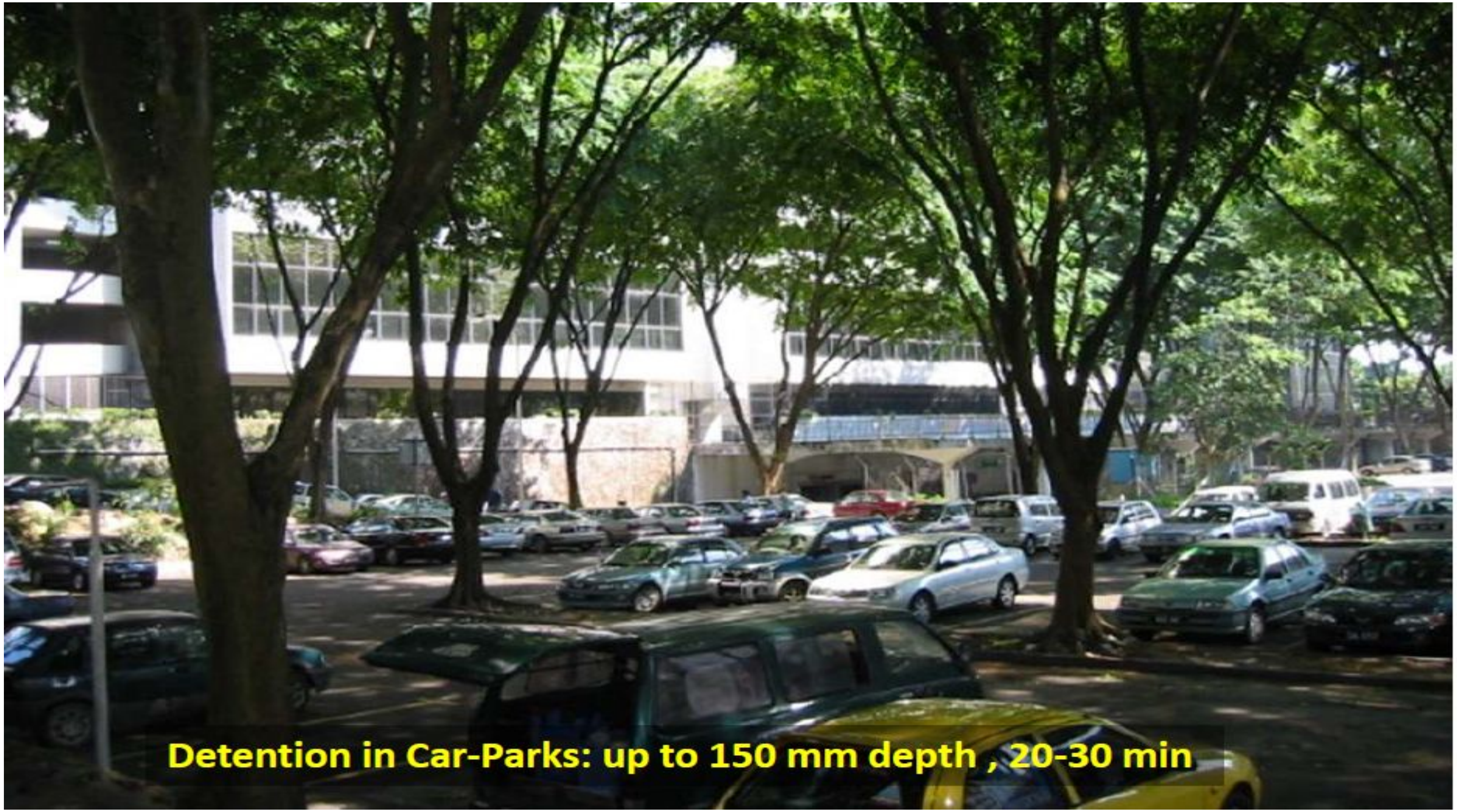
Not to Scale

- OSD would have to be placed at the most downstream end of the internal drainage network.

Source: On-Site Stormwater Detention Tank Systems, Technical Guide (Revision 3: Aug 2024) by Public Utilities Board, Singapore

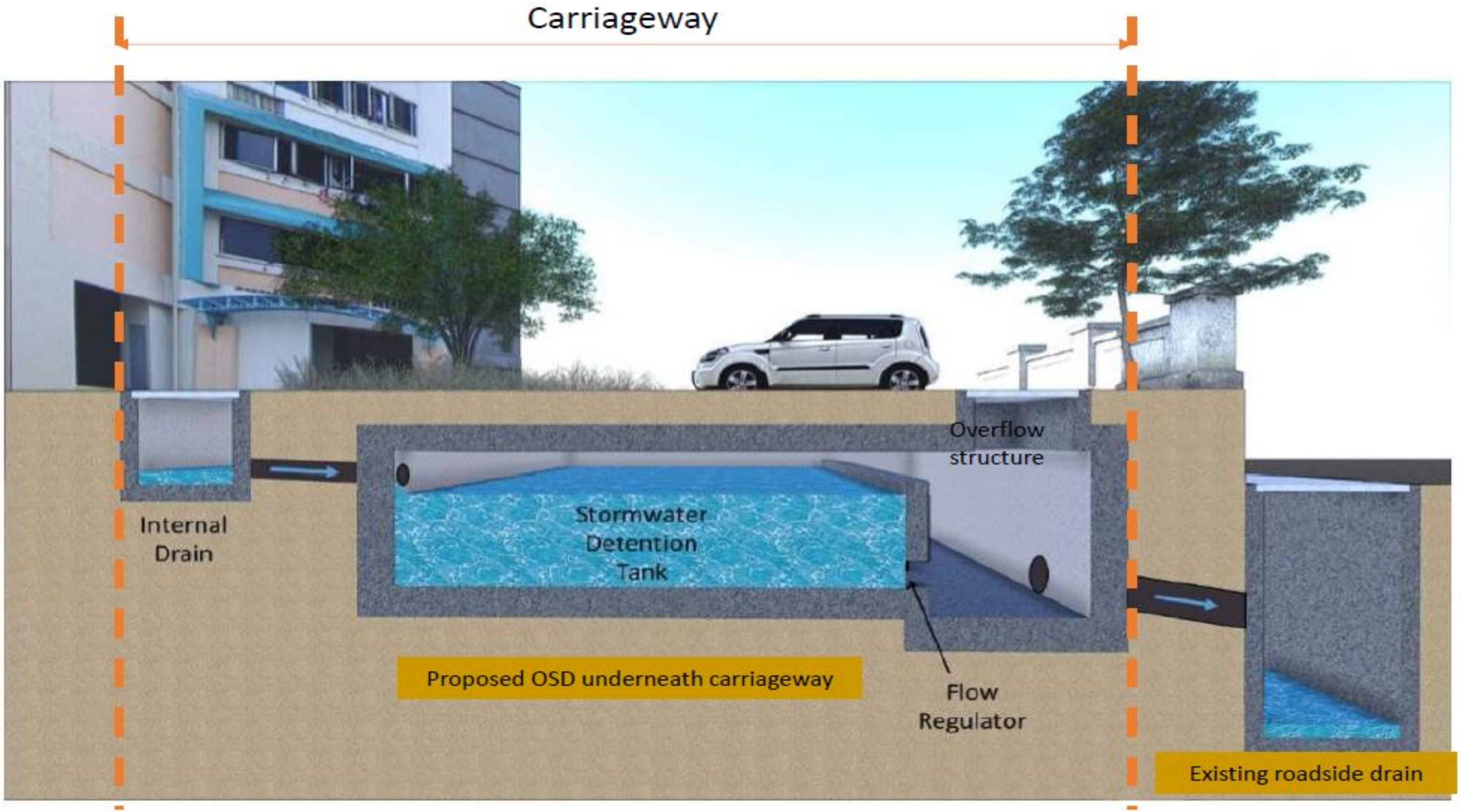
- Larger sites have greater flexibility of implementing one or more types of detention systems

Stormwater Detention Tank System



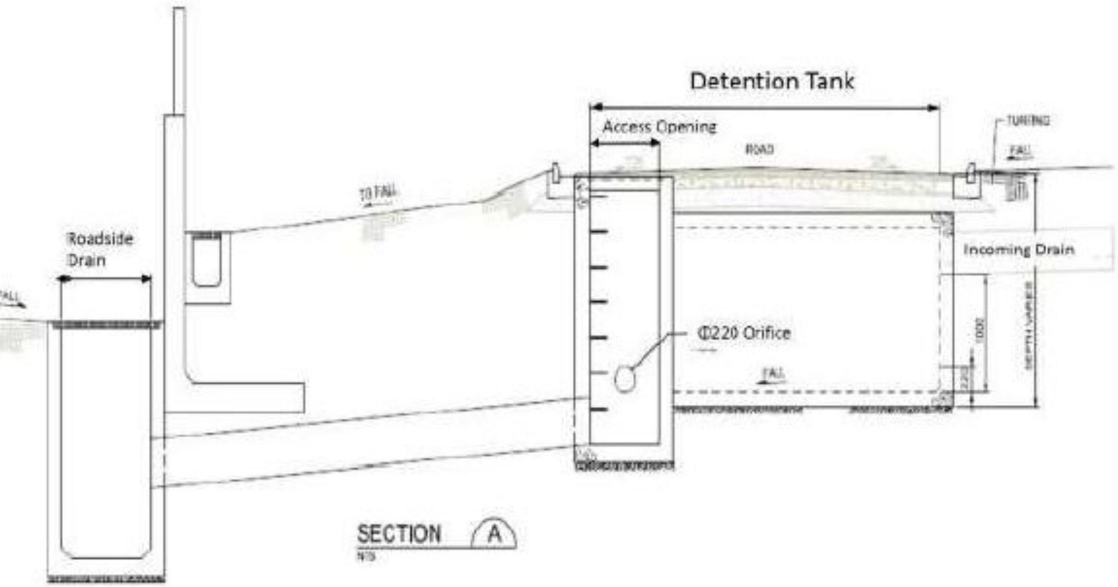
Sources: DID, Kuching, Sarawak

Stormwater Detention Tank System

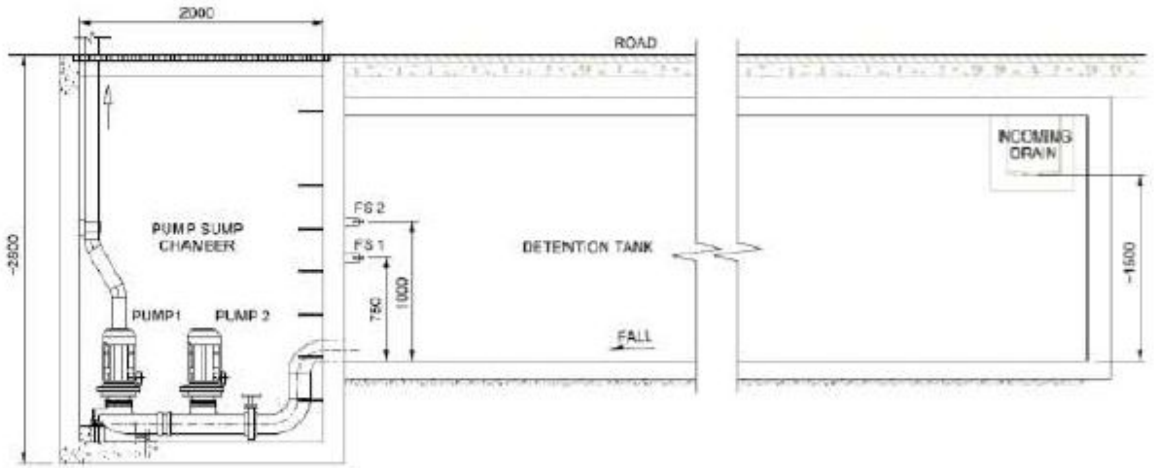


Source: On-Site Stormwater Detention Tank System, Technical Guide (Revision 1: May 2021) by Public Utilities Board, Singapore

Detention Tank Schematic Section



Gravity Discharge



Pumped Discharge

Stormwater Detention Tank System

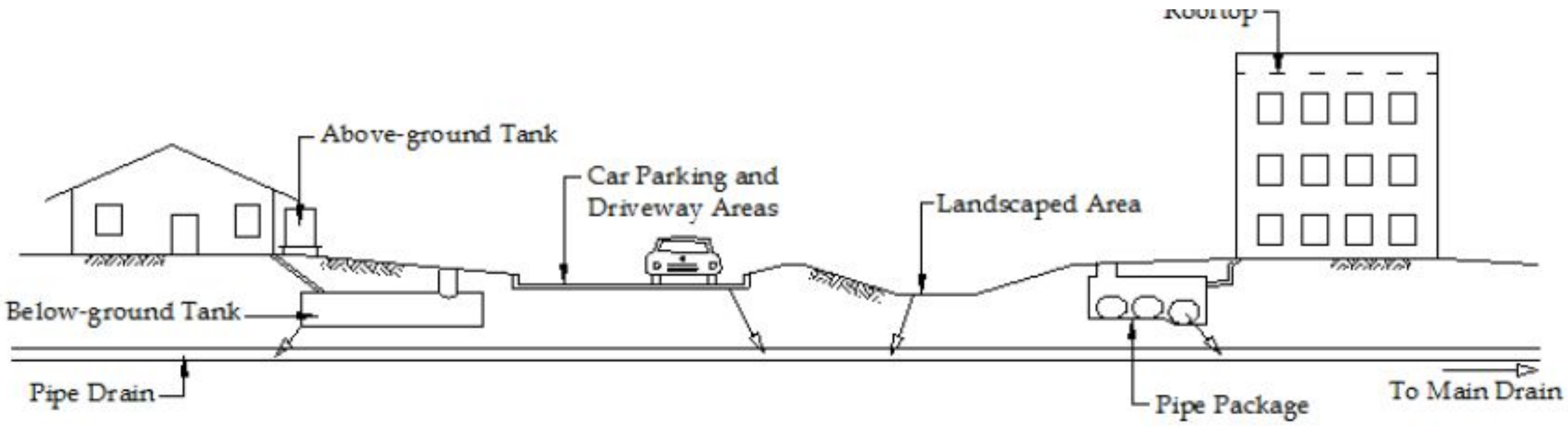


Figure 5.1: Typical OSD Storage Facilities

Stormwater Detention Tank System

Sources: DID, Kuching, Sarawak

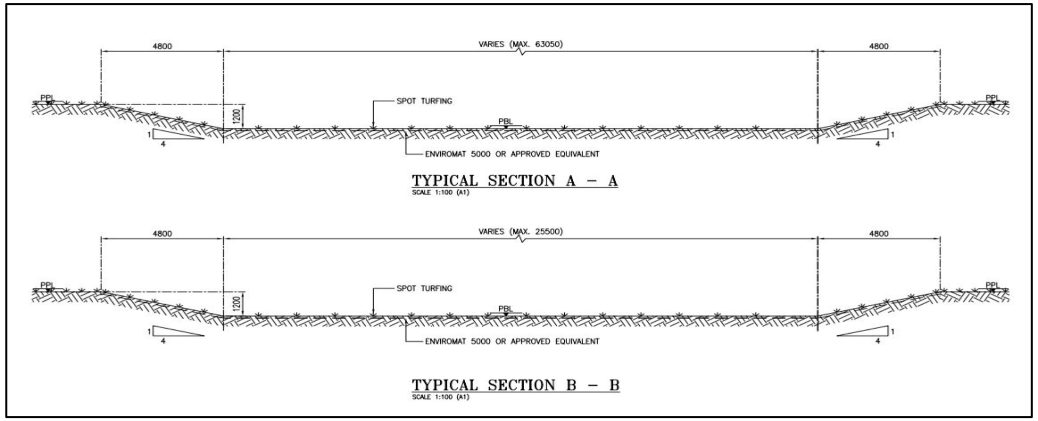
DRY DETENTION POND

Dry Detention Pond at SK Muara Tuang, Samarahan

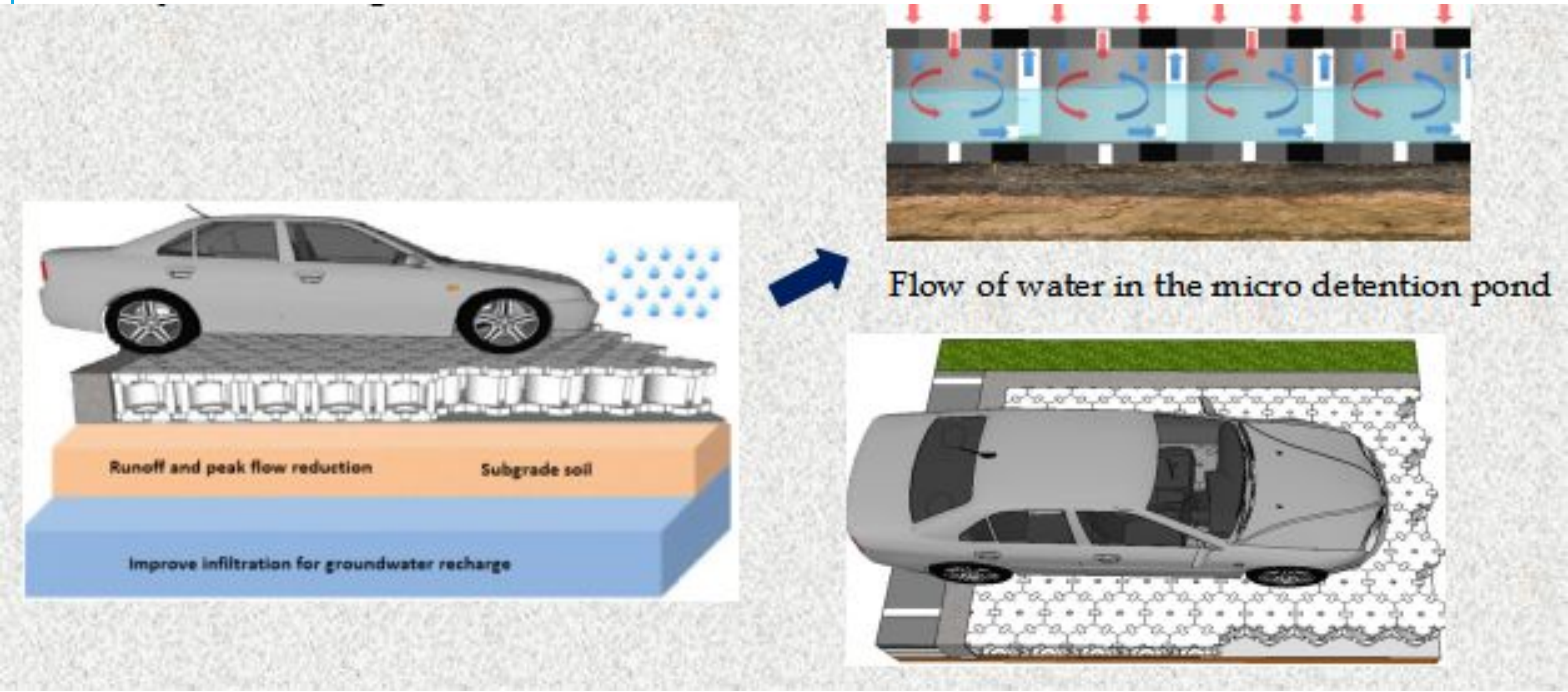
Dry Detention Pond at Dayak Chamber Of Commerce And Industry, Jalan Simpang Tiga

Sources: DID, Kuching, Sarawak

Dry Detention Pond



Permeable Pavement with Micro-Detention Pond Storage (StormPav)



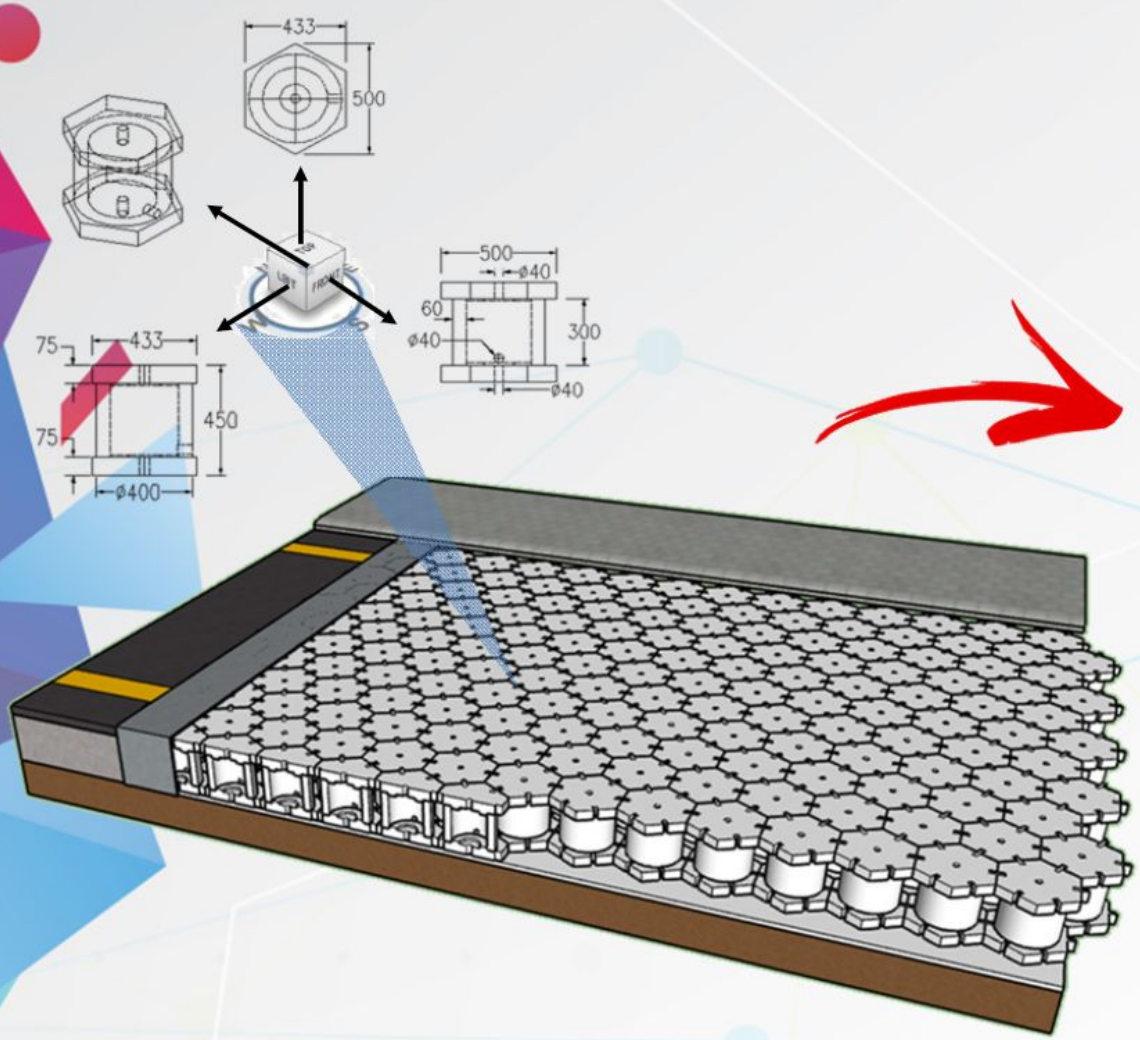
StormPav system (a) arrangement of StormPav assembled outside the laboratory

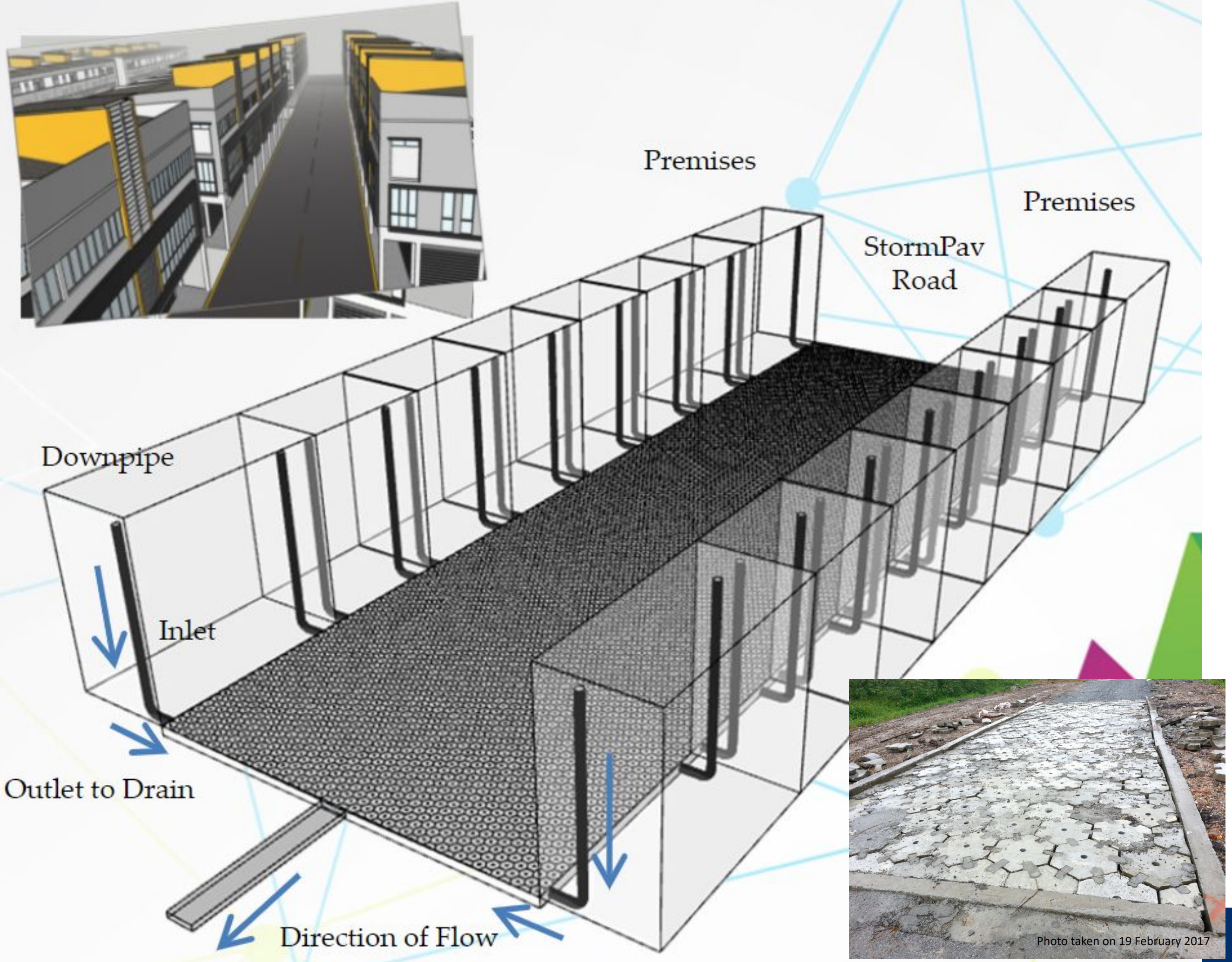
(b) StormPavprecast product single unit of a hollow cylinder and cover design.

PATENT APPLICATION NO. PI 2016704420

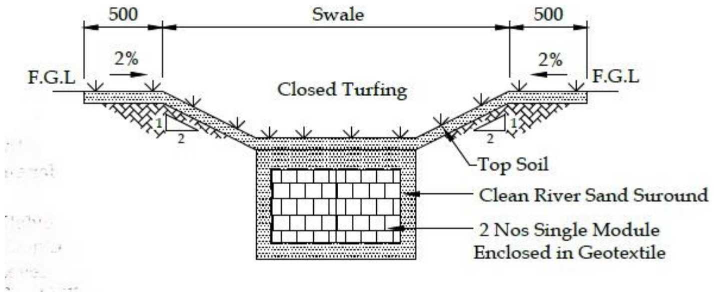
Stormwater Infrastructure: StormPav Green Pavement

StormPav Green Pavement offers an alternative construction method for roads.





MOVA subsurface stormwater



- Control at source by promoting infiltration
- Particulate pollutant is absorbed by vegetation and porous media at the top of the module
- MOVA subsurface module is suitable for both detention and conveyance.

OSD Taman Fajar, Kota Kinabalu, Sabah, Malaysia

Kampung Haji Baki, Kuching, Sarawak, Malaysia

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METHODOLOGY

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Design Calculation- Two main parameters involve in the design of the stormwater drainage system is the a) **estimation of a peak runoff (Peak flood flow)** and the b) **design of suitable structure to accommodate it.**

a) Hydrology Design for Runoff Quantity Design Fundamentals using Rational Method to include as follows;

Quantity Design Fundamentals (ARI yrs- minor and major storm), refer Table 1.1, Chapter 1, MSMA → Time of Concentration $T_c = t_d + t_o$, refer Table 2.1 (QUDM, 2007), Chapter 2, MSMA.

↓

Design Rainfall, i, refer Table 4.1/Fig 5.1-5.4, HP26 for Sarawak fitting constant of i and CCF Factor Table 7.1, HP26 → Peak Discharge Estimation using Rational Method, Q=CiA/360, C refer catchment land use to its' imperviousness and A is catchment area

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METHODOLOGY

UNIMAS Water Centre

b) Hydraulic Design of the Stormwater Management Facility-Detention Box design to accommodate **SUSTOM FACILITY**

Storage Capacity Design of SUStoM Facilities –drainage storage using Manning's Formula, Q=AV & V= 1/n(R^2/3S^1/2), Manning's roughness coefficients Table 2.3, MSMA

→ Select storage type- this project used below ground storage.

↓

Determine Catchment area drain to the Detention Box drain, Impervious and pervious area, t_c and t_{cs}, and calculate pre and post development flows, Qp and Qa from t_c

→ Determine required PSD and SSR using Equation 19.1 and 19.2, MSMA 1.

METHODOLOGY

c) Hydraulic Design of the Stormwater Management Facility-Detention Pond design to accommodate a)

Determine design storms for required storage volume (10 year Ari for this project) – select primary outlet design storm ARIs, and select level of non-routed bypass flow

Determine pond outflow limits, pond inflow hydrographs and preliminary estimate of the required pond volume .

Develop pond grading plan, compute stage storage relationship and size the minor design storm primary outlet

Size the major design storm primary outlet, size the secondary outlet arrangement

Determine the sizing procedure for secondary outlet

Select design storm for emergency spillway, inflow hydrographs, secondary outlet structure, stage discharge relationships

Prepare detailed design plans and specifications

CASE STUDY 1: INFLUENCE OF TC ON PEAK RUNOFF

Investigates how Tc affect the design and performance of detention ponds

$$T_c = t_d + t_o$$

T_c = Time of Concentration, min
t_d = drain flow time = L/V, min
L = Drain length, m
V = Assume velocity, m/s
t_o = Overland flow time = $107.n.Lo^{1/3}/s^{0.5}$, min
Lo = overland flow path, m
n = Manning Roughness coefficient
s = slope of overland surface, %

Parameters will be extracted from the existing design reports

- **Drain Length (m)**
- **Assume velocity (m/s)**
- **Overland Flow Path (m)**
- **Manning Roughness coefficient**
- **Slope of overland surface**

Table 2.2: Values of Horton's Roughness n* (QUDM,2007)

Land Surface	Horton's Roughness n*
Paved	0.0150
Bare Soil	0.0275
Poorly Grassed	0.0350
Average Grassed	0.0450
Densely Grassed	0.0600

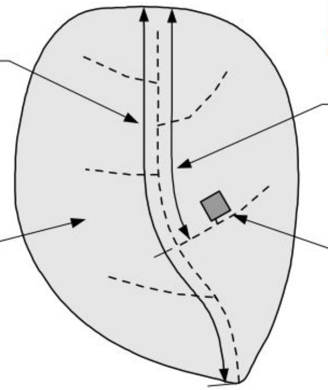

Table 2.3: Values of Manning's Roughness Coefficient (n) for Open Drains and Pipes

Drain / Pipe	Manning Roughness n
Grasses Drain	
Short Grass Cover (<150mm)	0.035
Tall Grass Cover (>150mm)	0.05
Stone Pitching	
Dressed Stone in Mortar	0.017
Random Stones in Mortar or Rubble Masonry	0.035
Rock Riprap	0.03
Brickwork	0.02
Pipe Material	
Vitri fied Clay	0.012
Spun Precast Concrete	0.013
Fibre Reinforced Cement	0.013
UPVC	0.011

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CASE STUDY 1: INFLUENCE OF TC ON PEAK RUNOFF

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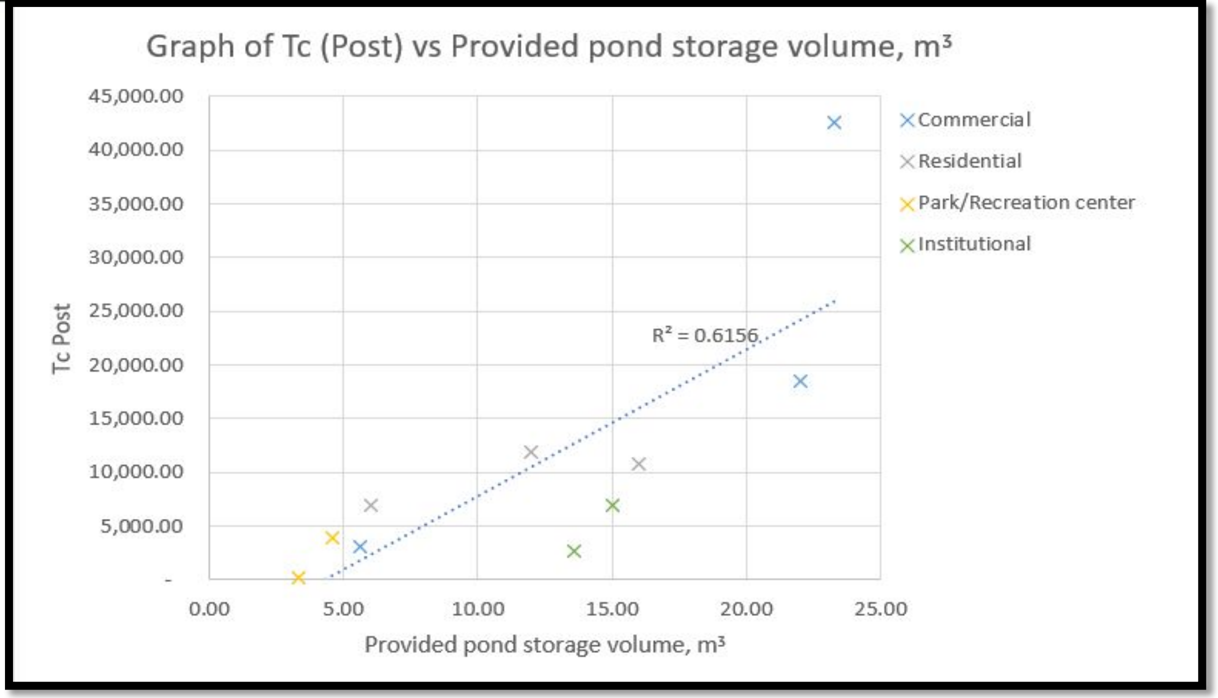
Table 4-1:
Factors Influencing Time of Concentration, Tc across Subcatchments

Catchment ID	Land Use	Lo (m)	n* (Horton)	So (%)	Ld (m)	n (Manning	Sd (%)	to (min)	td (min)	Tc (min)
DP1	Residential	35.00	0.0150	3.33	440.00	0.013	0.0033	4.1	7.2	12
DP2	Residential	34.50	0.0450	1.10	345.00	0.015	0.0033	15.4	0.5	16
DP3	Residential	20.00	0.0150	5.00	200.00	0.013	0.0033	3.2	2.7	6
DP4	Commercial	89.04	0.0450	4.50	915.00	0.015	0.0033	15.9	5.1	21
DP5	Commercial	3.00	0.0450	1.00	250.00	0.013	0.0020	6.9	2.8	10
DP6	Commercial	395.10	0.0275	2.60	1110.90	0.013	0.0033	17.8	5.5	24
DP7	Institutional	260.00	0.0150	0.38	220.00	0.013	0.0045	12.4	1.2	14
DP8	Institutional	45.00	0.0150	2.00	200.00	0.013	0.0020	5.0	1.3	7
DP9	Park/Recreation Center	0.00	0	0	251.00	0.017	0.0020	0	3.3	4
DP10	Park/Recreation	0.00	0	0	347.00	0.017	0.0020	0	4.6	5

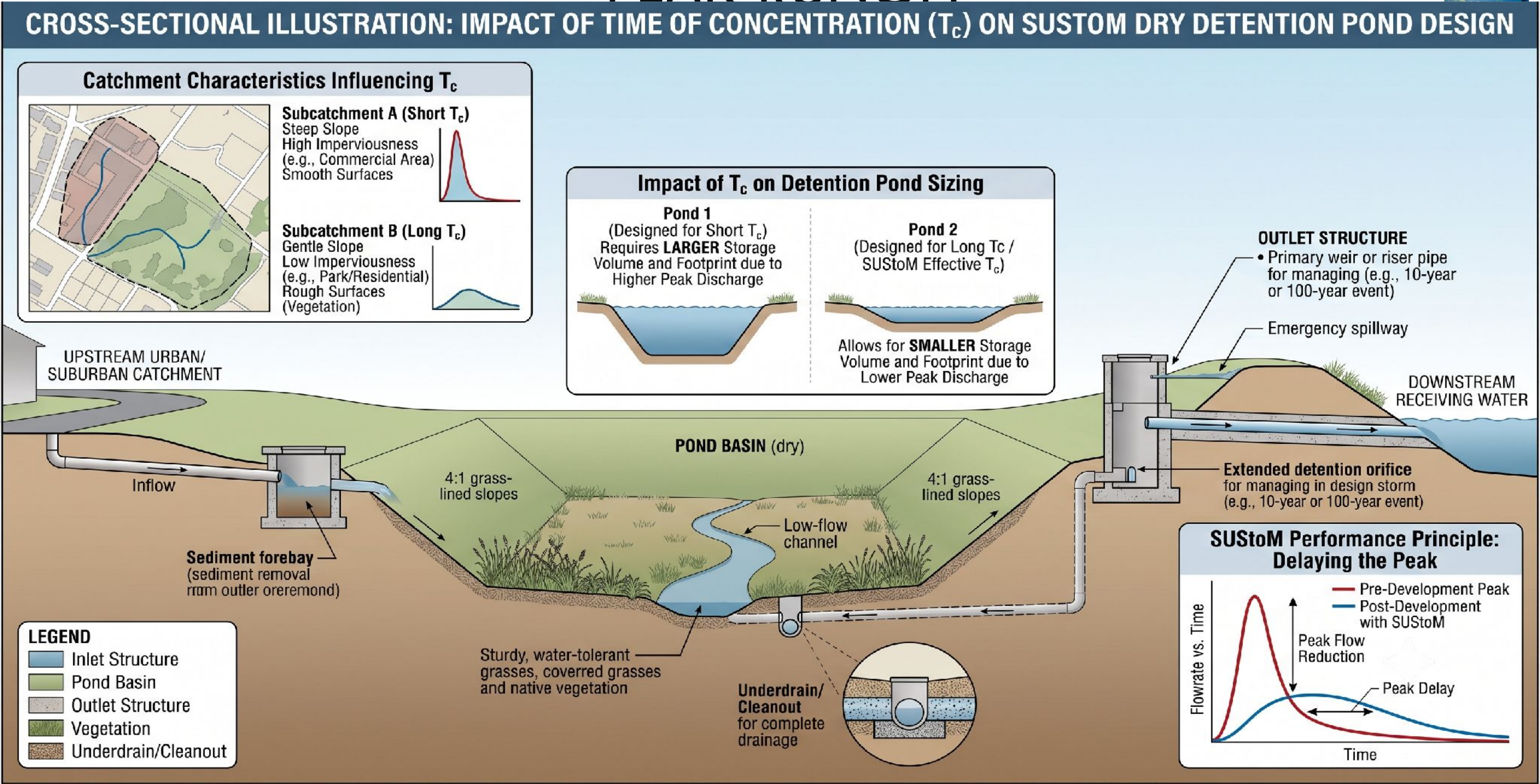
CASE STUDY 1: INFLUENCE OF TC ON PEAK RUNOFF

Detention Pond	Types of Development	Tc Pre	Tc Post	Estimated pond storage volume, m3	Provided pond storage volume, m3
DP1	Residential	22.35	7.00	10,844.41	11,948.76
DP2	Residential	20.34	16.00	9,693.90	10,827.44
DP3	Resedential	22.69	6.00	5,226.25	6,880.13
DP4	Commercial	33.13	22.00	12,458.66	18,505.08
DP5	Commercial	27.23	5.60	2,162.74	3,092.10
DP6	Commercial	38.37	**23.30**	**41,951.06**	**42,520.88**
DP7	Institutional	27.51	13.58	641.49	2,655.00
DP8	Institutional	22.30	7.00	11,561.49	11,948.76
DP9	Park/Recreation cente	12.18	**3.31**	**93.59**	**140.30**
DP10	Park/Recreation cente	28.00	4.60	2,619.41	3,868.60

Min Tc	3.31 DP9 (Park)
Max Tc	23.30 DP6 (Commercial)
Min. Provided pond storage volume, m3	140.30 DP9 (Park)
Max. Provided pond storage volume, m3	42520.88 DP6 (Commercial)

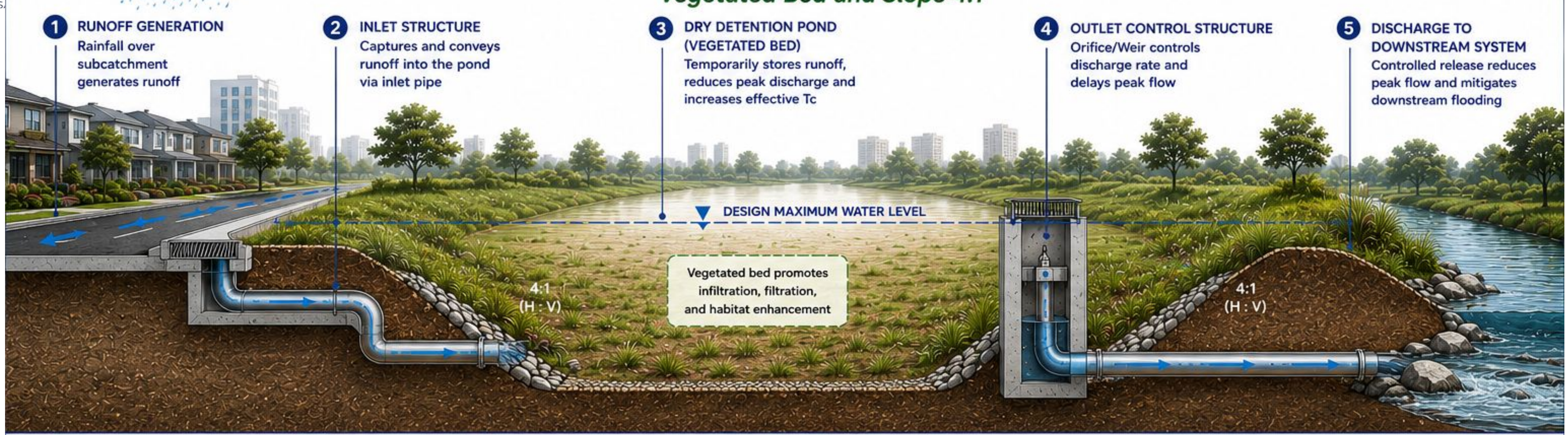


CASE STUDY 1: INFLUENCE OF TC ON PEAK RUNOFF



SUStoM FACILITY: CROSS-SECTIONAL ILLUSTRATION OF DRY DETENTION POND

Vegetated Bed and Slope 4:1



STUDY OVERVIEW (10 DRY PONDS)

- Residential (3 sites)
- Commercial (3 sites)
- Institutional (2 sites)
- Parks / Recreation (2 sites)

Total: 10 Existing SUStoM Dry Detention Ponds

Data validated using design reports, field verification and site observations

FACTORS INFLUENCING TIME OF CONCENTRATION (Tc)

- Surface roughness (n)
- Slope gradient (S)
- Flow path length (L)
- Land use type

- Tc mainly influenced by these factors.
- Urban areas (commercial/ residential) give shorter Tc.
- Parks / recreational areas give longer Tc.
- Accurate parameterization is critical for reliable stormwater design.

VARIATIONS IN TIME OF CONCENTRATION (Tc) ACROSS DIFFERENT SUBCATCHMENTS

SHORTER Tc ← → LONGER Tc

Parks / Recreation (short Tc)
Shorter Tc → Smaller pond volumes

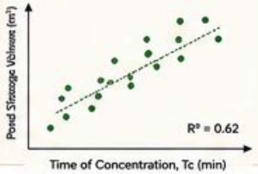
Commercial / Institutional (longer Tc)
Longer Tc larger pond volumes

KEY FINDING

Moderate correlation (R° = 0.62) between Tc and storage volume.

Tc vs storage volume explains most but not all storage needs.

Design must be tailored to catchment type.



IMPACT OF TIME OF CONCENTRATION (Tc) ON DESIGN AND PERFORMANCE

- Tc directly affects pond sizing and performance.
- Shorter Tc → faster runoff generates higher peak discharge → requires more immediate storage.
- Longer Tc → inflow is spread out → larger total volume needed for effective detention.
- Errors in Tc estimation → under/over-designed ponds → higher flood risk or wasted cost.

TYPICAL Tc RANGE OBSERVED (10 CASES)

Short Tc (Commercial / Residential)	5 – 15 min
Longer Tc (Institutional / Parks)	20 – 45 min

SUMMARY OF FINDINGS

- Tc varies significantly by land use and subcatchment characteristics.
- Commercial / institutional sites generally have longer Tc and larger pond volumes.
- Parks / recreational sites generally have shorter Tc and smaller volumes.
- Moderate correlation (R° = 0.62) between Tc and storage volume.
- Accurate determination of Tc is essential for optimal design and cost-effective performance.

BENEFITS OF WELL-DESIGNED DRY DETENTION PONDS

- Delay peak discharge
- Reduce downstream flooding
- Support infiltration and water quality
- Provide amenity and green space
- Cost-effective and sustainable solution

LEGEND (CROSS SECTION)

1. Runoff Generation
2. Inlet Structure
3. Dry Detention Pond (Vegetated Bed)
4. Outlet Control Structure
5. Discharge to Downstream System

- - - Design Maximum Water Level

→ Flow Direction

KEY MESSAGE: Accurate determination of Time of Concentration (Tc) and subcatchment Tc is critical for effective SUStoM design. By increasing the effective Tc, dry detention ponds delay peak discharge, allow runoff to be detained and released more gradually, thereby reducing peak flow and mitigating downstream flooding.

CASE STUDY 2 FACTORS INFLUENCE DRY POND & OSD

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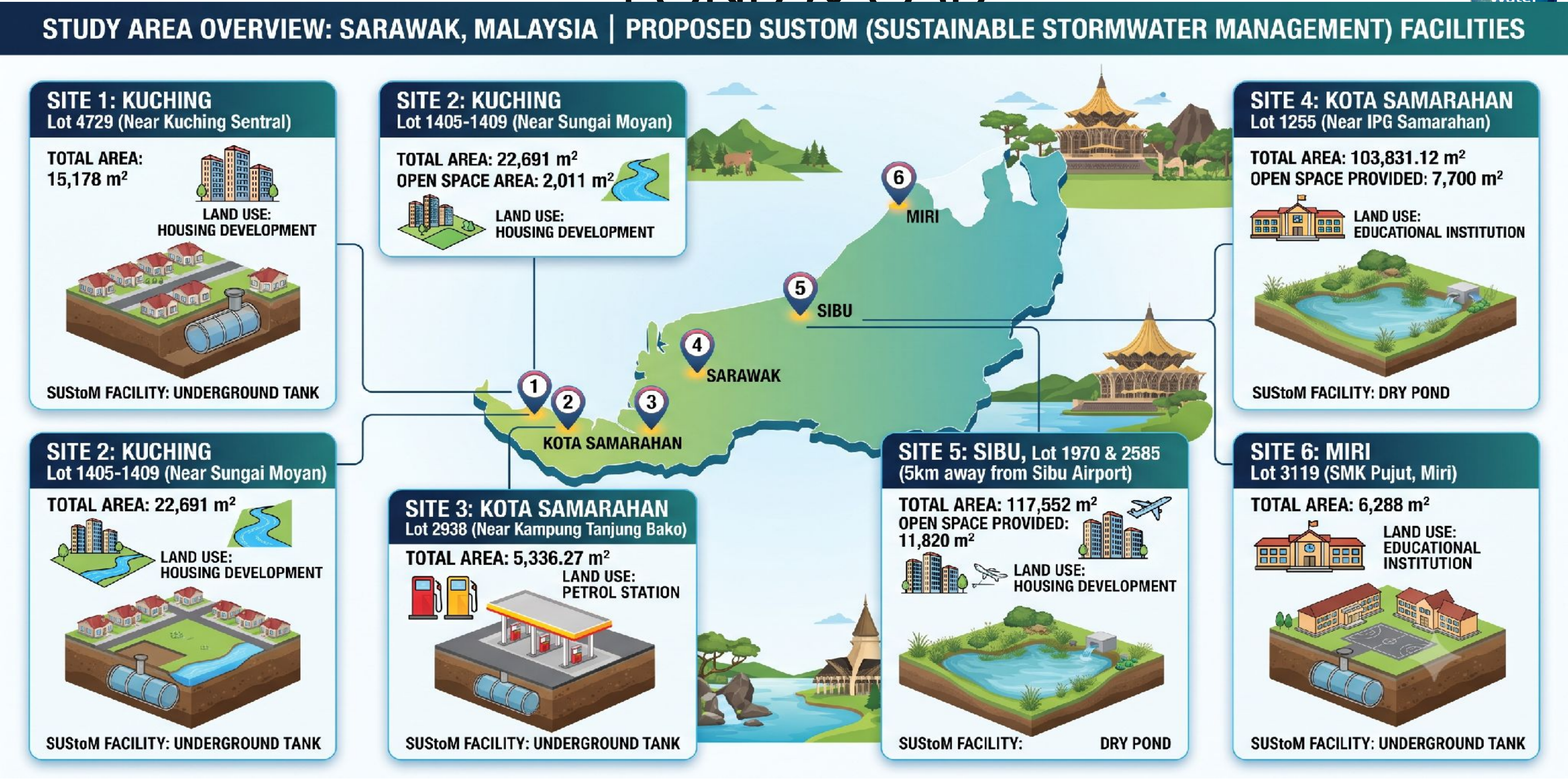


CASE STUDY 2 FACTORS INFLUENCE DRY POND & OSD

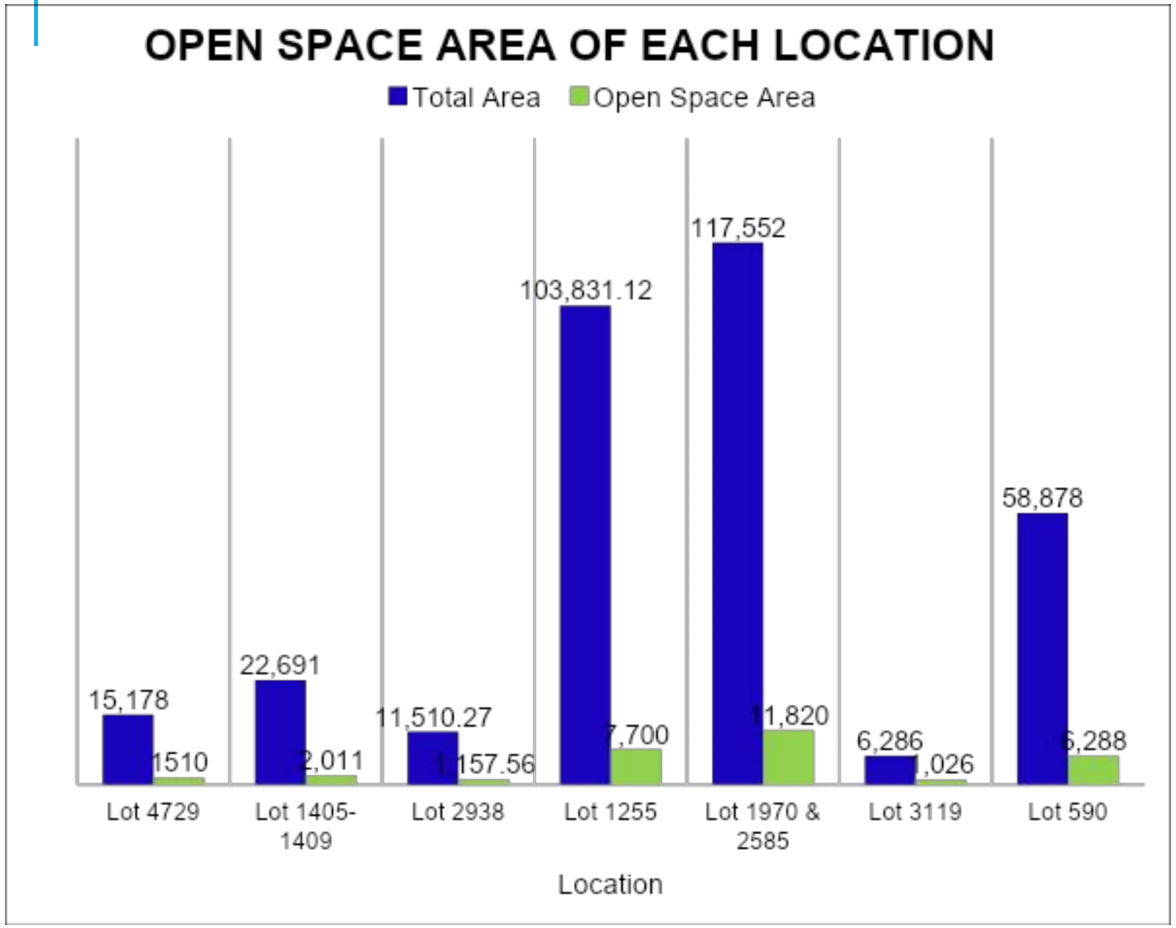
No.	Studied Area	Total Area (m2)	Rainfall intensity, i (mm/hr)	Flow, Q (m/s3)		Time of concentration	
			10 year ARI	Qpre	Qpost	Tc pre	Tc post
1	Lot 4729, Kuching North Land District	15,178	185.46	0.156	0.106	31.64	4.25
2	Lot 1405-1409, Matang Land District	22,691	203.56	0.263	0.178	24.18	7.68
3	Lot 2938, Muara Tebas Land District	5,336.27	222.58	0.056	0.038	29.81	3.65
4	Lot 1255, Samarahan Land District	103,831.12	143.18	0.978	0.433	40.97	21.25
5	Lot 1970 & 2585, Seduan Land District	117,552	241.47	0.924	0.639	20.00	8.00
6	Lot 3119, Miri	6,286	194.56	0.083	0.056	30.92	4.71
7	Lot 590, Kemena Land District	58,878	157.70	-	-	-	-

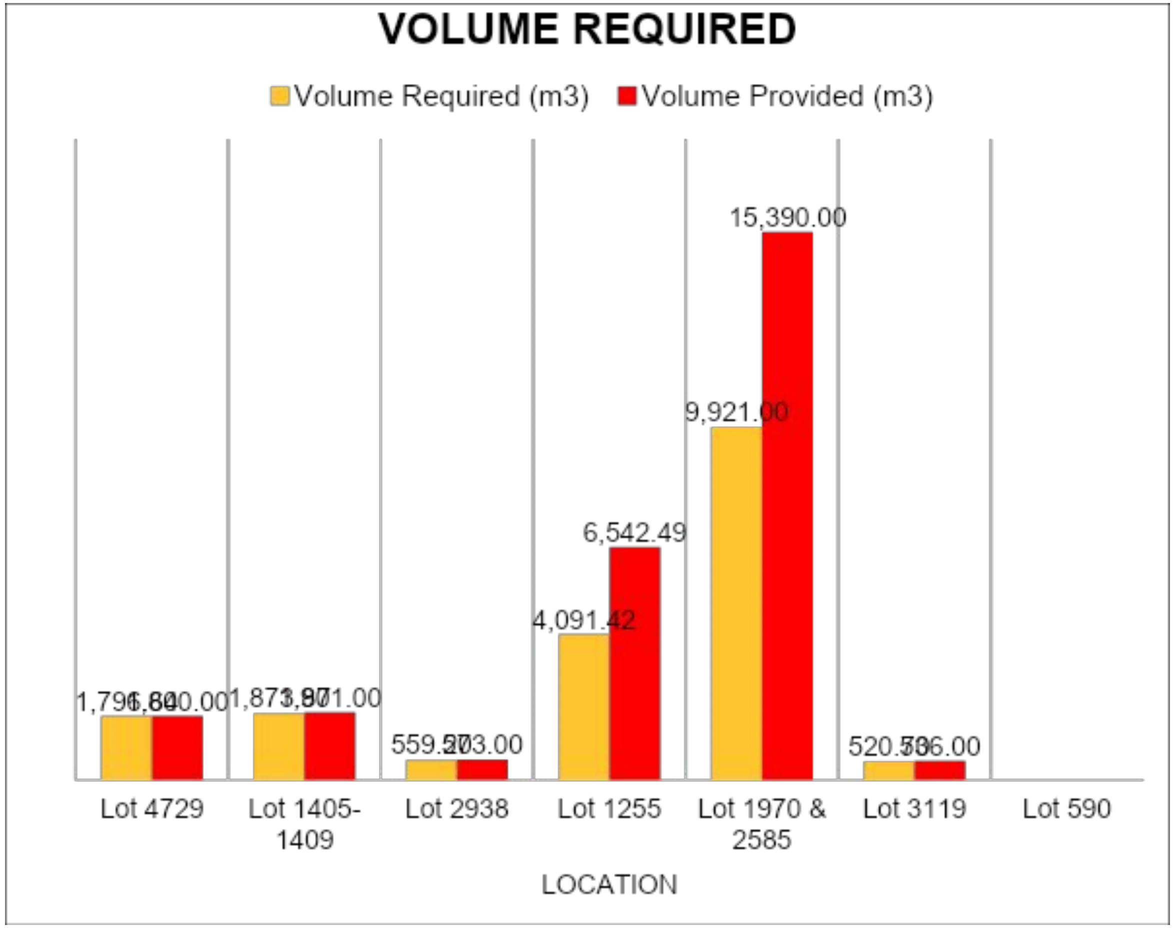
CASE STUDY 2 FACTORS INFLUENCE DRY POND & OSD

No.	Studied Area	Total Area (m^2)	Volume Required (m^3)	Volume Provided (m^3)
1	OSD Underground Tank	15,178 (1.5 ha)	1,796.64	1,800
2	OSD Underground Tank	22,691 (2.3 ha)	1,873.87	1,901
3	OSD Underground Tank	5,336.27 (0.5 ha)	559.20	573
4	Dry Detention Pond	103,831.12 (10.4 ha)	4,091.42	6,540
5	Dry Detention Pond	117,552 (11.8 ha)	9,921.00	15,390
6	OSD Underground Tank	6,286 (0.6 ha)	520.70	536
7	Direct discharge to nearby river	58,878 (5.9 ha)	0	0

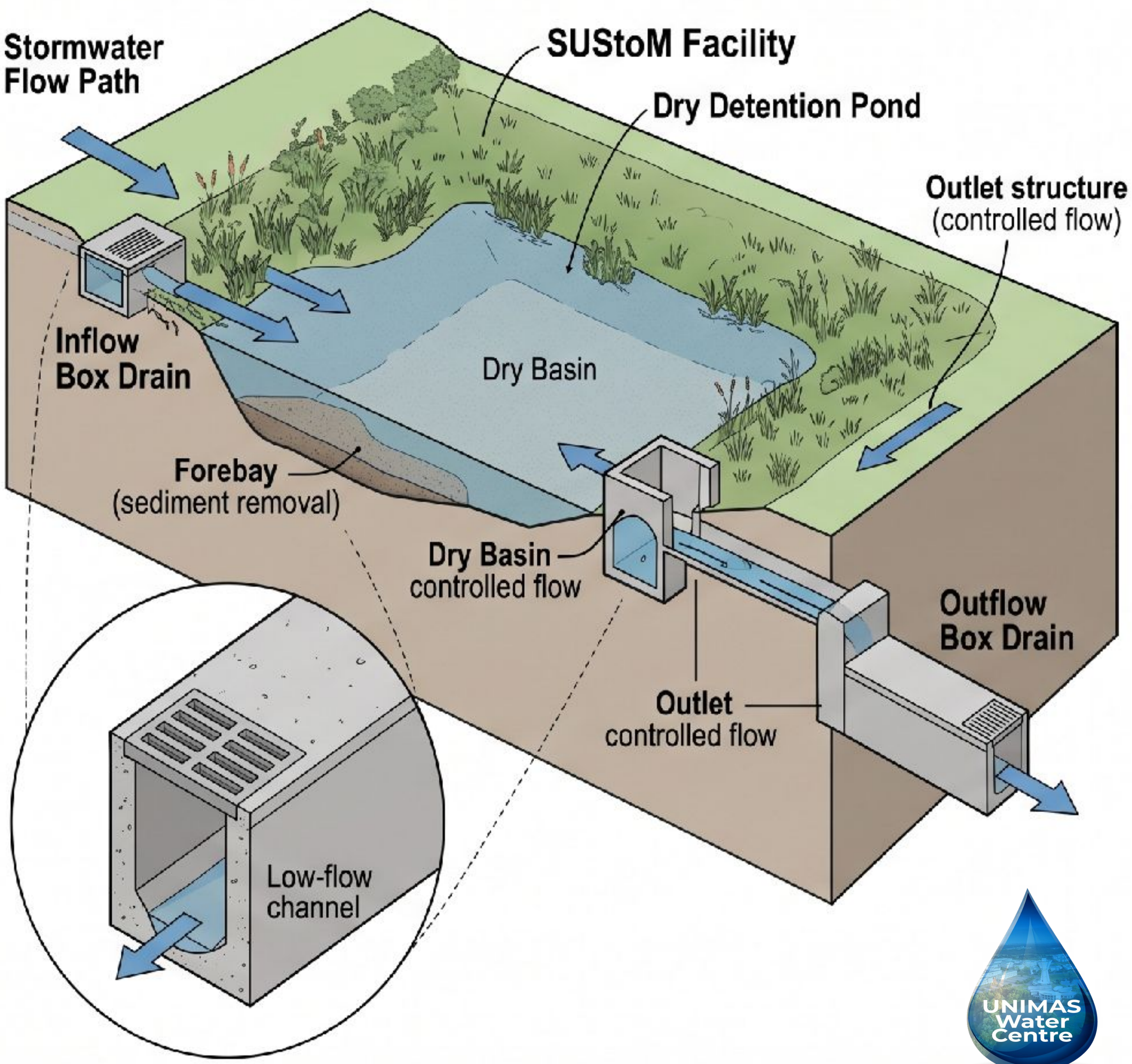
**Recommended area for 5ha to 10ha for Dry Pond and OSD <5ha (SUStoM 2018, DID)

CASE STUDY 2 FACTORS INFLUENCE DRY POND & OSD





SUStoM Facility Study Findings:
Dry Detention Pond & Box Drain



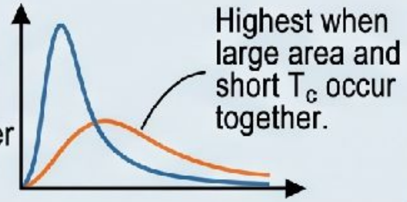
Study Overview
Performed at 6 Catchment Areas (0.5ha to 11.8ha)

Rainfall Intensity (I)
- Higher I contributes to more rainfall in a shorter time, resulting in higher peak flow (Q).
- SUStoM must provide larger storage volume for effectiveness.
- Effectiveness decreases with increasing I unless sufficient detention volume is provided.

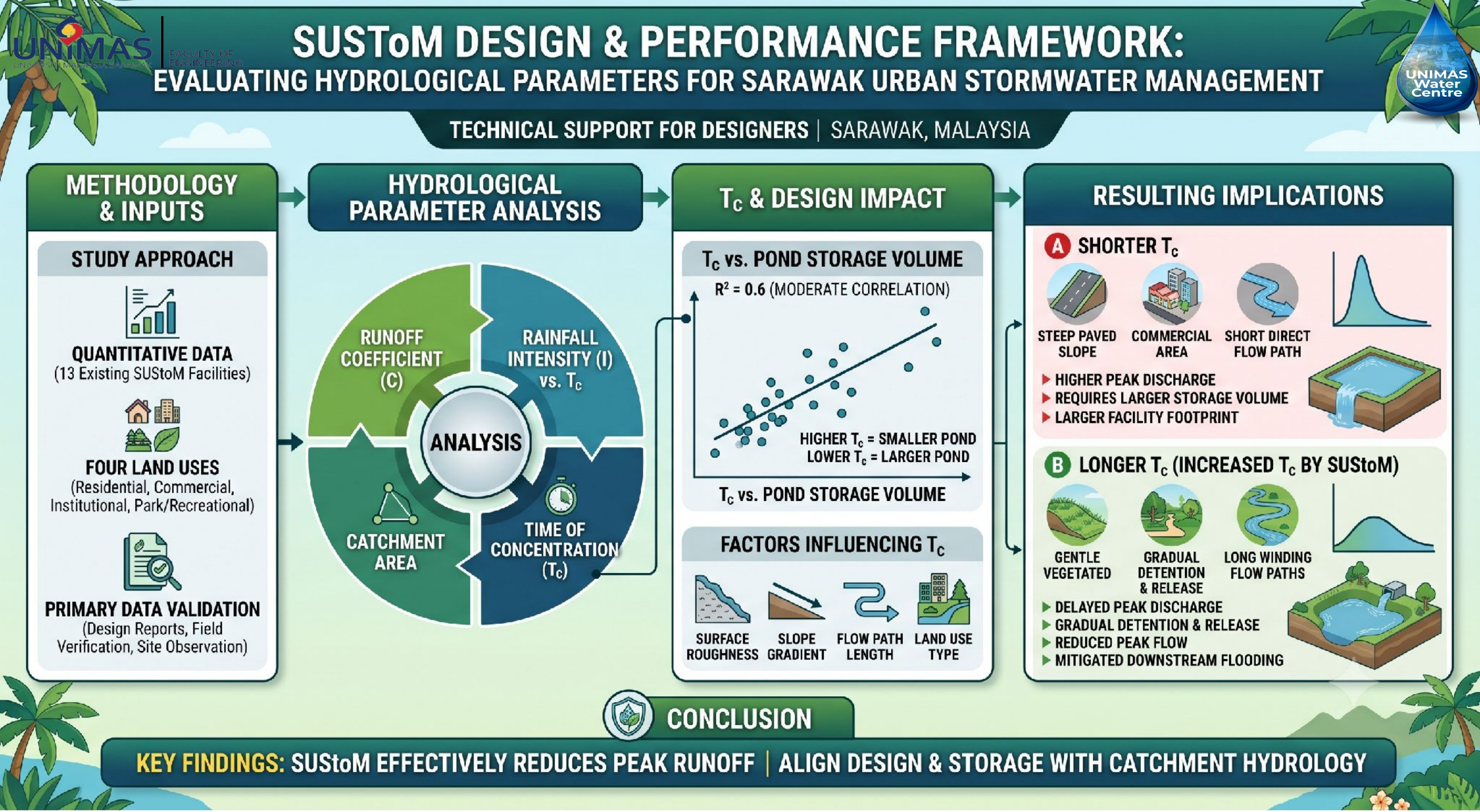
Runoff Coefficient (C)
vs
- Where higher C, more runoff contributes to higher peak flow (Q).
- High value of C (such 0.8-0.95 for residential or industrial building) means faster and higher volume of runoff.
- Higher impervious area will have higher C.

Catchment Area (A)
- Larger catchment areas generate higher total runoff volume, therefore, larger SUStoM storage is required.
- Catchment area controls the magnitude of peak flow.
- Larger areas usually have longer flow paths, which increase time of concentration (T_c).
- SUStoM effectiveness depends on adequate sizing relative to **A**.

Peak Flow (Q)
- A small catchment with very short T_C can produce a higher peak flow than a larger catchment with longer T_C.



Study Conclusion
- Catchment area and rainfall intensity (*i*) controls *how much* runoff is generated.
- Time of concentration controls *how fast* runoff reaches the outlet.
- Effective stormwater design aims to increase T_c, especially in large catchments.
- Pre- and post-development peak discharges are mainly controlled by rainfall intensity, catchment area, and runoff coefficient, with changes in runoff coefficient due to increased imperviousness being the primary factor causing higher post-development flows.


UNIMAS
UNIVERSITI MALAYSIA SARAWAK
FACULTY OF ENGINEERING
SUSToM DESIGN & PERFORMANCE FRAMEWORK:
EVALUATING HYDROLOGICAL PARAMETERS FOR SARAWAK URBAN STORMWATER MANAGEMENT
UNIMAS Water Centre
TECHNICAL SUPPORT FOR DESIGNERS | SARAWAK, MALAYSIA
METHODOLOGY & INPUTS
STUDY APPROACH
QUANTITATIVE DATA
(13 Existing SUStoM Facilities)
FOUR LAND USES
(Residential, Commercial, Institutional, Park/Recreational)
PRIMARY DATA VALIDATION
(Design Reports, Field Verification, Site Observation)
HYDROLOGICAL PARAMETER ANALYSIS
RUNOFF COEFFICIENT (C)
RAINFALL INTENSITY (I) vs. T_C
ANALYSIS
CATCHMENT AREA
TIME OF CONCENTRATION (T_C)
T_C & DESIGN IMPACT
T_C vs. POND STORAGE VOLUME
R^2 = 0.6 (MODERATE CORRELATION)
HIGHER T_c = SMALLER POND
LOWER T_c = LARGER POND
T_C vs. POND STORAGE VOLUME
FACTORS INFLUENCING T_C
SURFACE ROUGHNESS
SLOPE GRADIENT
FLOW PATH LENGTH
LAND USE TYPE
RESULTING IMPLICATIONS
A SHORTER T_c
STEEP PAVED SLOPE
COMMERCIAL AREA
SHORT DIRECT FLOW PATH
HIGHER PEAK DISCHARGE
REQUIRES LARGER STORAGE VOLUME
LARGER FACILITY FOOTPRINT
B LONGER T_c (INCREASED T_c BY SUStoM)
GENTLE VEGETATED
GRADUAL DETENTION & RELEASE
LONG WINDING FLOW PATHS
DELAYED PEAK DISCHARGE
GRADUAL DETENTION & RELEASE
REDUCED PEAK FLOW
MITIGATED DOWNSTREAM FLOODING
CONCLUSION
KEY FINDINGS: SUStoM EFFECTIVELY REDUCES PEAK RUNOFF | ALIGN DESIGN & STORAGE WITH CATCHMENT HYDROLOGY