PERFORMANCE EVALUATION ON CONSTRUCTED WETLAND AS WATER QUALITY IMPROVEMENT FOR TROPICAL CONDITION

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Abstract: Humid Tropic Centre (HTC) has taken proactive through collaborative efforts between HTC, Consulting Company and University to incorporate WSUD into urban development to manage the urban water cycle as a compliment to MSMA Manual. The storm water will be conveyed by grass swale and bio retention before discharging to the constructed wetland for the further treatment of storm runoff. The main objective of HTC constructed to investigate the characteristic of hydrology and hydraulics for constructing a wetland under tropical climate. This can be contributed towards evaluating the design performance of constructed wetland with respects to the characteristics of hydrology and hydraulics for Malaysia condition. This paper discusses the element that's involved in designing the constructed wetland and the removal efficiency of stormwater.

Key words Constructed wetland, design performance, removal efficiency, wetland design concept

1. INTRODUCTION

Malaysia has gone progressive development and has shifted the population in urban centers. Urbanization will increase the construction of impervious area that will change significantly the hydrology and hydraulic characteristics of catchments. Therefore, flash flood incidence in urban area becomes more severe from year by year. Some 29 720 km^2 or 9% of the country's land is flood prone and about 4.915 million people or 21% of the population reside in this area. The average annual damage and economic losses due to flood is estimated at RM 915 million with another RM 1.83 billion estimate consequential to economic drag effect losses. In addition, the phenomenon of these flash floods has become more common as the surface runoff from developed urban and industrial area has fully increased the peak discharges entering the rivers with shortened time of detention to peak flow (Abdullah, 2007). In order to overcome the flash flood problem, DID has taken a step ahead by introducing Stormwater Management Manual for Malaysia (MSMA). MSMA requires the application of Best Management Practices (BMPs) to control stormwater runoff from the aspect of quantity and quality to achieve zero development impact contribution. Several components that involved with BMPs are vegetative swale, constructed wetland, rainwater harvesting and etc. Stormwater BMPs is widely used in drainage planning in the United Kingdom, United State, Germany, Australia and Japan. BMP can be defined as a multi-disciplinary approach in applying appropriate technology to preserve the natural environment, enhancing living standard and improve quality of life. Constructed wetland is one of component of BMPs for water quality improvement and it is widely used for domestic wastewater and stormwater improvement

Constructed wetland in Malaysia can be considered as a new innovation and not widely implemented in all over Malaysia. There are only a few numbers of wetland all over Malaysia such Paya Indah Wetland, Putrajaya Wetland, pilot project of constructed wetland at USM Engineering Campus and the latest one is constructed wetland at Humid Tropics Centre, Kuala Lumpur. Study done by Bahaa eldin (2009) at Paya Indah Wetland was focused on numerical modeling of surface and subsurface flow interaction in Paya Indah Wetland, while at Putrajaya Wetland the studies had focused on erosion and sedimentation, bioavailability and bioaccumulation of heavy metals by macrophytes; Pragmites karka and Lepironia articulate, effect of water quality on the distribution of phytoplankton and nutrient removal using macrophytes ; Pragmites karka and Lepironia articulate (Abu Bakar, 2009; Mourad, 2009 ;Mohd Khalid, 2009; Sim, 2007). Mohd Noor (2010) and Ayub et al. (2010) have studied on water quality modeling and water balance for constructed wetland at USM Engineering Campus wetland. However, there is still lack of study to evaluate the hydraulics and hydrology characteristics for constructed wetland thus to evaluate design performance and guideline for constructed wetland under tropical climate. Although the MSMA guidelines already stated for constructed wetland, but they need to be revised with some changes and improvements for better removal

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Moreover, guidelines in MSMA currently are based on oversea study. Therefore, it is important to study on the fundamentals of hydrology and hydraulic characteristics of constructed wetlands to enhance the design procedures/guidelines under the tropical climates. Finally, this study will enhance the local knowledge and optimization of constructed wetland effectiveness. The local database for water quality performance using constructed wetland can be established throughout this study.

1.1 Objectives

The objectives of this study as follows;

i. To investigate the characteristic of hydrology and hydraulics for constructed wetland under tropical climate.
ii. To evaluate the design performance of constructed wetland with respects to the characteristics of hydrology and hydraulics for Malaysia condition.
iii. To establish the water quality and water balance model for a constructed wetland.
iv. To make recommendation on optimizing of constructed wetland design in MSMA Manual based on characteristics of ecohydrology of constructed wetland.

The constructed wetland is one of the components in an ecological drainage system. An ecological system or bio-ecological system is a combination of control in quality and quantity, which means that emphasis, on the quantity of water without ignoring its quality, before discharging the water into the water source. Constructed wetland can be defined as an engineered system designed to simulate natural wetland, to exploit the water purification functional value for human use and benefit (Hammer, 1992). Li (2009) defined constructed wetland as an engineered system comprised of wetland vegetation, soil (or other rooting media) and associated microbial and physiological ecosystem that colonize over time. While Zhang et al. (2009) defined that constructed wetland as a special designed system of production process in which the principle of the species symbiosis and the cycling and regeneration of substances in an ecological system are applied with adopting the system engineering technologies and introducing new technologies and excellent traditional production measures. Constructed wetland consists of former upland environments that have been modified to create poorly drained soil and a wetland flora and fauna for the primary purpose of contaminant or pollutant removal from wastewater or runoff. These systems can potentially tolerate variable volumes of water and varying contaminant levels and it can be divided into two categories; which are Subsurface Flow System (SF) and Free Water Surface System (FWS). (www.pwri.go.jp/team/rrt/eng/contentnew 4)

1.2 Free Water Surface (FWS) Constructed Wetlands

FWS wetlands are shallow, man-made impoundments planted with emergent, rooted vegetation and this can be seen through Figure 1. These wetlands may be planted efficiency and suitability under Malaysia condition. manually or naturally colonized by "volunteer" plant communities. Some FWS contain monocultures of cattails (Typha spp.) or bulrushes (Scirpus spp.); while others are planted with more diverse plant communities that have greater stability under changing seasonal and water quality conditions. A FWS wetland can be designed to regulate water depth and residence time, two of the most important factors in wetlands treatment design. Also, the design of FWS wetland systems can feature parallel cells or cells in series. Such a system can be operated to rotate discharge points or to use the slightly different treatment capabilities of the various available plant species groups. SF wetlands have relatively low construction, operation, and maintenance costs compared with conventional advanced treatment technologies. However, it is difficult to adopt the FWS, wetland system in urban areas or places where land is insufficient or limited like Japan, since FWS system requires larger area.(www.pwri.go.jp/team/rrt/eng/contentnew 4)

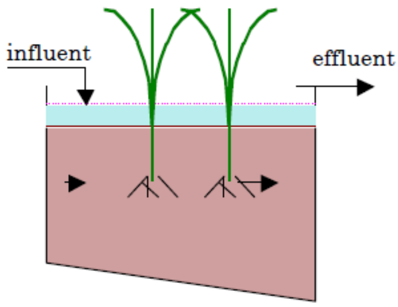

Figure 1: Free Water Surface Wetland

(source: www.pwri.go.jp/team/rrt/eng/contentnew 4)

1.3 Subsurface Flow (SSF) Constructed Wetlands

SSF wetlands are gravel- or soil-based wetlands in which the water passes through the porous substrate rather than above an impermeable substrate and this can be seen through the Figure 2. SF type comprises a plant bed of sand or other material with aquatic plant growing. The difference is that water is dosed on the bed in a large batch evenly and then gradually drains down through the bed and collected by a drainage network at the base. The large surface area of the media and the plant roots provides ample sites for microbial activity. SSF systems use many of the same emergent plant species as FWS systems. When treating an equivalent volume of flow, gravel-based SSF wetlands use less land than FWS constructed wetlands. Due to this reason, it was favored by many researchers and especially adapt to urban areas or land limited areas for pollution treatment SSF wetland systems have an advantage in cooler climates because so much of the treatment occurs below the ground surface. Also, gravel-based systems may be relatively low in maintenance requirements and are less likely to have odour and mosquito problems than are lagoons. When properly designed, gravel-based wetland systems have matter and nitrate-nitrogen. Major disadvantages of SSF constructed wetland systems include their tendency for plugging and overall system costs, which can be as much as five times more than an SF system for a certain pollutant mass removal

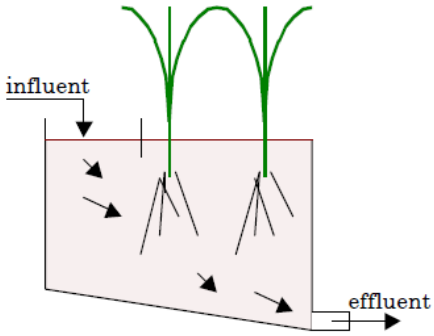

Figure 2: Sub Surface Constructed Wetland (source: www.pwri.go.jp/team/rrt/eng/contentnew 4)

1.4 Zone in Constructed Wetland

Constructed wetland normally can be divided into 3 zones as in Figure 3; inlet zone, macrophytes zone and open water zone in order to remove stormwater pollutant before discharging to the nearest water course.

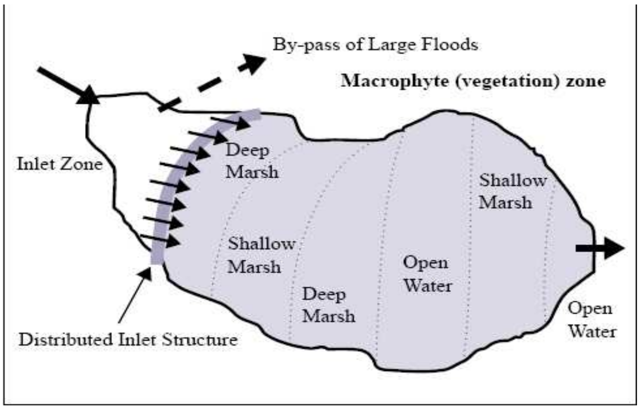

Figure 3: Zones in constructed wetland (WSUD, 2009)

Inlet zone

The inlet zone is designed as a sedimentation basin and has two key functional rules. The first function is to remove coarse to medium sized sediment which is around 125µm or larger prior to flow entering the macrophytes zone. Second function is to control and regulation of flow entering the macrophytes zone and bypass of flow during above design flow condition. The outlet structure from inlet zone is designed such that flows up the design flow 1 year ARI entering the macrophytes zone (JPS, 2001).

Macrophytes zones

Macrophytes are large aquatic plants. Planting should be on the perimeter, arranged so that there is opportunity for water in the open pond zone to circulate through the macrophyte zones. Beds of macrophytes filter out finer 0.25- 0.5m, while for littoral zone the depth range between the depth range between -0.5m to 0.2m and -1.5m to -0.5m respectively. high efficiency rates for removing biodegradable particles and directly take up contaminants. The macrophyte zones should be provided around the pond edges downstream of the main inlets to filter out sediments and nutrients to disperse the inflowing water and reducing its velocity. Macrophyte zones should be from 25-50% of total pond area. (JPS, 2001)

Open water zone

An open water zone is deeper area that allows time for fine particles to flocculate to the bed and allow sunlight to kill bacteria. Decomposition and grazing of organic matter will occur in this zone. Periodic algal growth may occur here and this will also trap dissolved nutrients and allow them to enter the food chain or to settle to the bed of pond. A minimum depth of 2.4m is recommended for open water zones. The open water has the potential for some recreational activity, especially in the larger ponds and urban lakes. Water quality however will generally be unsuitable for body contact recreation (JPS, 2001).

1.5 Design Guidelines

The design guidelines and performances are an important element in order to produce the optimum removal efficiency for constructed wetland. A better design criteria will produce a good performance of constructed wetland and the importance factors that need to consider in design criteria are hydraulic loading rate, detention time, runoff volume and wetland size (area and volume) (Carleton et al., 2001). Greater Adelaide Region Technical Manual (2009) stated that design considerations that need to be considered during the designing stage of constructed wetland are hydrology, water quality, maintenance, landscape and vegetation. These design guidelines will help the urban water engineer to design and construct the constructed wetland with optimum removal efficiency.

Detention time is the element to evaluate the performance of constructed wetland with the function as detained the short duration storm for maximum detention period, ensuring that high flow can be accommodate by the constructed wetland without overland flow. The longer detention process ensuring that the first flush containing the heaviest pollution load receives an adequate treatment (Shutes et al., 1999). The important factors that influencing the detention time are slope of bed, hydraulic conductivity, porosity of substrate, vegetation, aspect ratio (width : length) and depth of water. Shutes et al.(1999) suggested that the minimum detention time is 30 min of the design storm event with annual storm 3- 5 hour, and the good performance removal between 10-15 hours. While in order to achieve better detention time, the suitable flow velocity are not more that 0.3-0.5 m/s at inlet zone, the higher flow velocity more than 0.7 m/s may damage the plants physically., suggested that suitable detention time between 48 hours to 72 hours with the various depth of water depending on the different zones. For example for extended detention depth the suggested depth between 0.2m to 0.5m, for macrophytes zone and wetland zone

Length to width ratio is very important in wetland design, because of its effect on flow distribution and on hydraulic short circuiting. A good hydraulic performance obtained through a good design of the shape and of the hydraulic structures increases pollutant removal efficiency.
Flow linear velocity is another important design parameter, where for instance TSS removal efficiency it depends on sedimentation and trapping within the wetland. Excessive velocities can lead to large particle to resuspension. It is recommended that velocity should be kept below a value which would resuspend, v=1000 m/d, even if existing wetlands operate at a very safe velocity lower than this, mostly below 100 m/d. The presence of some higher velocity areas creates habitat diversity (Kadlec & Knight, 1996).

Table 1 showed the previous study about design criteria for the constructed wetland by Reed et al., 1998; Watson et al., 1989; Watson and Hobson, 1989; Hammer, 1989; Crites, 1994; Kadlec and Knight, 1996 while Table 2 showed the guideline for constructed wetland in Australia, USA and Malaysia.

Table 1: Design Criteria based on literature

Design Criteria	
Detention time (for soluble pollutants removal, d)	5- 14 day
Detention time (for suspended pollutant removal, d)	0.5-3 day
Hydraulic loading rate m/d	0.01-0.05
Aspect ratio	2:1 to 10:1
Water depth (average)	0.1 to 0.50
Bottom slope (%)	0 to 0.5

Table 2: Guideline of Constructed from Various Countries

Guideline	Detention time	Velocity	Depth	L:W ratio	slope
Adelaide Region, 2009	72 hours and not less than 48 hours		0.25m-0.5 m		>3(h): 1(v)
EPA ,2000	2-3 days		0.6-0.9m	3:1 to 10:1	
Melbourne , 2005		1.0m/s	1.2m (macropyhtes zone) >0.9m for open water body		5 (H):1(V)
Wollonggong, 2009	48 to 72 hr		Macrophytes depth (0.5m-0.75m) Open water body (>1.5m)		8 (H):1(v) (inlet zone)
WSUD queensland , 2006	2-3 days		0.25m	>5:1 for macrophytes zone	
JPS , 2001	less than 3 to 5 days	0.05m/s to 0.1m/s	0.5 m (average)	3:1 to 5:1	1 in 10 to 1 in 20.

1.6 Performance of constructed wetland in Australia, United Kingdom, Ireland and Malaysia: an Experience

UK Experience

Wetlands (both natural and constructed) have been used for treatment of sewage and for urban, industrial and agricultural runoff within the UK and Europe .Studies were done by Cutbill, 1994 on Constructed wetland at Anton Crescent, Surrey ; Mungur et al., 1998 on the constructed wetland at Great Notley Garden Village, Essex; Tucker, 1999 on the constructed wetland at Keytec 7 Business Park, Worcestershire; Mc Kissock et al., 1999 on the constructed wetland at DEX, Fife and Revitt et al., 1999 on the constructed wetland at Brentwood, Essex. Flood storage is the main function of these systems and the design criteria and percentage removal efficiency through the studies can be seen through Table 3

Table 3 Design Criteria and Percentage Removal Efficiency For UK
(Cutbill, 1994; Mungur et al., 1998; Tucker, 1999; Mc Kissock et al.,1999; Revitt et al, 1999).

Design Features		Percentage of Removal
Length to width ratio Discharge Maximum storage Wetland area Detention time	1:5 to 1:100 $1.9\ x10^{-3}\ m^3/s$ - $0.272\ m^3/s$ $10\ 000m^3$- $30\ 000m^3$ $13m^2$-$204m^2$ 15 hours to 10.8 days	Zn =10%-99% Pb=7%-97% SS 56% N= 19% Cu= 94%-97%

China Experience

In China, study on performance of constructed wetland was done by Li (2009) and Zhang et al (2009). Li (2009) had suggested that with the design criteria of detention time 7.5 days (with 4 days for water quality treatment and 3.5 days for stabilization days), design flow rate with $50m^3$/hr, depth of water was 0.75 m and area of constructed wetland $800m^2$ gave the good performance on total suspended solid and ammonia with 70% removal and 76% removal respectively. While performance of constructed wetland based on design criteria was studied by Zhang et al. (2009) and the result shown in Table 4.

Australia Experience

A few Australian studies were found such as Shatwell & Cordery (1998) that studied a pond in Centennial Park in Sydney, which achieved typical phosphorus removal of 60-95%, with sediment removal of 80-99%. However, they pointed out that due to lack of hydrologic control, it would be likely that trapped loads would be re-suspended during very high flows. Stewart and Hackney (2002) then undertook an assessment of stormwater wetlands at Riverside Park, for Liverpool City Council and the concentrations of TSS, TP and TN were found to reduce by an average of 96, 82 and 74% respectively, whilst turbidity and faecal coliforms dropped by 97%

and total grease was reduced by 17%. Geary et al. (2003) found fairly consistent TSS load removal with export during one storm. TP removal averaged 66%, and was highly correlated with TSS removal. While studied done by Greenway and Woolley (1999) on a few constructed wetlands in Queensland such as constructed wetland at Cairns, Ingham, Townsville, Mackay, Emu Park, Black all, and Goondiwind showed about 16.7%- 80.4% percentage of pollutant removal for BOD, 8.3%-77% for SS, 0-15.7% for TP, 18.02%-82.6% for TN and 8.42%-80.9% for Ammonia Nitrate. Detail design criteria and percentage of removal based on studied in Queensland done by Greenway and Woolley (1999) shown in Table 5.

Table 4: Design Criteria and Percentage Removal Constructed Wetland in China (Zhang et al., 2009)

Location of constructed wetland	Design criteria	Percentage of Removal
Chang Ping	HLR= 500m^3/d HRT= 7.3 days	TSS= 93.8% TN= 64.6% BOD = 85.8% TP = 55.1% COD= 0%
Qinghe	HLR= 120m^3/d HRT= 5.6 days	TSS= 83.8% TN= 29.2% BOD = 37.3% TP = 53.9% COD= 0%
Tianjin	HLR= 200m^3/d HRT= 1.5-3.0 days	TSS= 79.9% TN= 50.6% BOD = 84.9% TP = 70.3% COD= 0%
Public Park	HLR= 0 m^3/d HRT= 1.2 days	TSS= 79.9% TN= 50.6% BOD = 84.9% TP = 70.3% COD= 0%
Liaohe	HLR= 18.75 m^3/d HRT= 15 days	TSS= 0 % TN= 86% BOD = 88% TP = 0% COD= 80%
Taihu	HLR= 500m^3/d HRT= 0 days	TSS= 0% TN= 19.8% BOD = 0% TP = 35.1% COD= 16.5%

Ireland Experience

The similar researches which was to evaluate the performance of constructed wetland were done on thirteen constructed wetland sites in Ireland with the width to length ratio 1:2.2, found that the average pollutant removal rate to be between 76.8% to 99.8% for Biochemical Oxygen Demand, 76.3% to 99.7% for Chemical Oxygen Demand and 67% to 99.9% for Ammonium Nitrate (NH_4-N) (Babatunde et al., 2008).

Table 5: Design Criteria and Percentage of Removal for Constructed Wetland in Queensland (Greenway and Woolley, 1999)

Location of constructed wetland	Design Criteria	Percentage of Removal
Cairns	Length: width= 13:1 Depth= 500mm HRT= 17 days HLR=458 m^3 ha^{-1} d^{-1}	BOD = 22.2 % SS = 20% TP=0, TN=82.6% Ammonia Nitrate=33%
Ingham	Length : width = 8:1 Depth : 500mm HRT: 12 days HLR: 391 m^3 ha^{-1} d^{-1}	BOD = 50 % SS = 0% TP=8.82%, TN=50% Ammonia Nitrate=29.8%%
Townsville	Length : width = 15:1 Depth : 400mm HRT: 7- 10 days HLR: 0 m^3 ha^{-1} d^{-1}	BOD = 56% SS = 72% TP=0, TN=78.1% Ammonia Nitrate=80.9%
Mackay	Length : width = 16: 1 Depth : 300mm HRT: 3 days HLR: 1355 m^3 ha^{-1} d^{-1}	BOD = 0 % SS = 0 % TP=0, TN=0 % Ammonia Nitrate=70%
Emu Park	Length : width = 16:1 Depth : 400mm HRT: 7 days HLR: 20 m^3 ha^{-1} d^{-1}	BOD = 20 % SS = 0% TP=0, TN=0% Ammonia Nitrate=8.42%
Blackall	Length : width = 20:1 Depth : 600mm HRT: 3 days HLR: 736 m^3 ha^{-1} d^{-1}	BOD = 16.7 % SS = 8.3% TP=0, TN=18.07% Ammonia Nitrate=59.7%
Goondiwind	Length : width = 12:1 Depth : 500mm HRT: 7 days HLR: 391 m^3 ha^{-1} d^{-1}	BOD = 80.4% SS = 77% TP=15.7%, TN=51.4% Ammonia Nitrate=59.7%

Malaysia Experience

Constructed wetland in Malaysia can be considered as a new innovation and not widely implemented in all over Malaysia. There was a pilot project of constructed wetland through collaboration between Drainage and Irrigation Department (DID) and USM where situated at USM Engineering Campus, Nibong Tebal and Putrajaya Constructed Wetland. The design storm for this wetland is 3 month ARI based on Stormwater Management

Manual for Malaysia. The design inflow rate for the wetland was $0.25m^3/s$ based on design calculation (Zakaria et al., 2003). The detail design features and percentage of removal as shown in Table 6.

Table 6: Design Features and Percentage Removal for USM Constructed Wetland (Mohd Noor, 2010; Zakaria et al., 2003)

Design Parameter		Percentage of Removal
Catchment area	1.214 km^2	BOD=9.7% -80%
Length	155m	COD=5.7% - 62.9%
Width	60m	DO= 6.5% - 17.8%
L:W	3:1	TSS= 50% -100%
% catchment area	0.7	TP=24%- 46%
Mean residence time	3 days	Turbidity=21%- 72.3%
Bed depth	0.6	

The Putrajaya constructed wetland a 200ha constructed wetland system which comprising 24 cells were created in the valley of Chuau and Bisa River from agricultural land of oil palm and rubber plantation. Putrajaya Wetlands are a vegetated horizontal surface flow multi cell wetland system, designed with different water levels in each cells that are separated by weir (Shutes, 2001) The design features and pollutant removal efficiency of Putrajaya constructed wetland was showed in Table 7.

Table 7: Design Features and Pollutant Removal For Putrajaya Wetland (Sim et al., 2007; Khor, 2002; Selamat, 2001)

Design Features		Pollutant Removal
Wetland area (ha)	14.3 to 54.1	
Volume (million litre)	130- 1200	TSS=10.25mg/l - 137.5mg/l
Depth (m)	0.3 to 1.0 m (macrophytes zone) 1.0 to 3.0 m (open water zone)	BOD=0.38mg/l-1.65mg/l TP=84.32%. DO=0.78mg/l - 13.25mg/
Mean Residence Time (d)	8.2 to 31.4	
Hydraulic Loading Rate (cm/d)	6.2-15.1	

1.7 Humid Tropic Centre Constructed Wetland

Humid Tropic Centre (HTC) has taken proactive through collaborative efforts between HTC, Consulting Company and University to incorporate WSUD into urban development to manage the urban water cycle as a compliment to MSMA Manual. WSUD is about designing the urban environments to more closely match the original water cycle that exist prior to development. The idea is to more closely match the pre development stormwater runoff regime- both quality and quantity. Constructed wetland is one of component WSUD. This site is located near the DID headquarters, Kuala Lumpur. Basically the components of WSUD can be seen through the Figure 4, comprises of constructed wetland, bio-retention, grass swale, rain water harvesting, green roof, porous pavement and greywater reuse system. While Figure 5 showed the component of constructed wetland. Stormwater will convey to constructed wetland through the grass swale and bio retention before discharging to the water course.

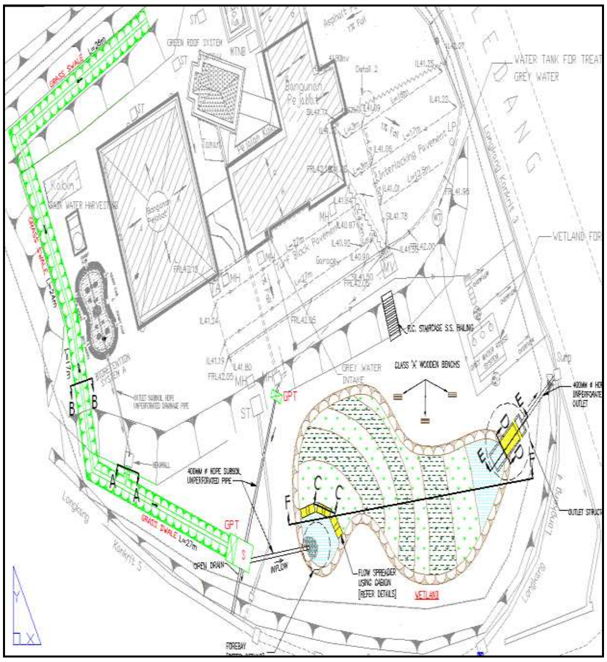

Figure 4: Component of WSUD

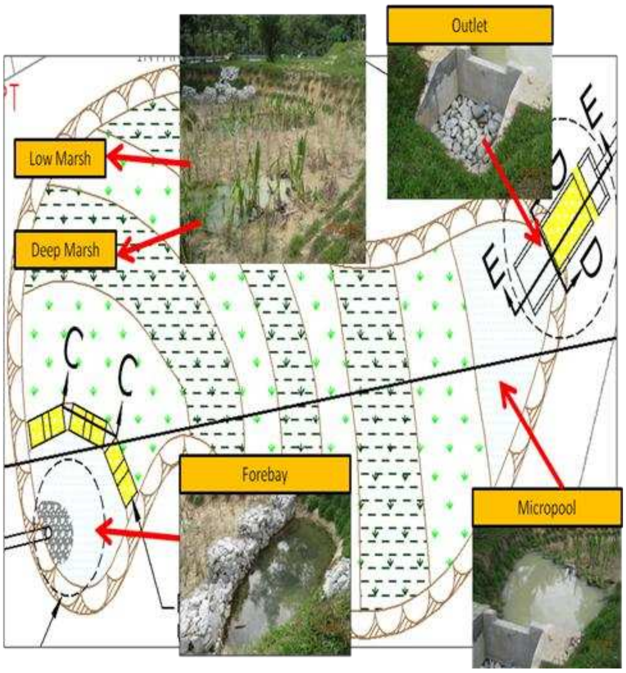

Figure 5: Component of constructed wetland

Before performance evaluation of constructed wetland can be made, the constructed wetland should be constructed based on design criteria in Table 8.

Table 8: Design Criteria for HTC constructed wetland

Catchment area	5,800 m^2
Design storm (3 Month ARI)	74.9 mm/hr
Length	41 m
Width	14 m
Wetland surface area	574 m^2
Volume	355.73 m^3
% Catchment area	9.9 %
Design Inflow rate (3 Month ARI)	0.084 m^3/s
Depth: • Forebay / Pool • Low Marsh • High Marsh • Micro Pool	 1.2 m 0 m – 0.3 m 0.6 m – 1.0 m 1.8 m
Area (in percent of wetland area) • Forebay • Low Marsh • High Marsh • Micro Pool	 7% 45% 37% 11%
Embankment • Height • Top Width	 3 2.4
Mean residence time (d)	1.2 hrs
Slope of wetland bed (average)	1:6
Bed depth	0.6 m
Media	Pea gravel and soil mixture
Hydraulic conductivity of sand	10^{-3} to 10^{-2} m/s

Plant species at HTC Wetland

Constructed wetland intend to imitate the function of natural wetland which can effectively remove larger quantity of pollutant using natural filtration, sedimentation and other processes of the wetland plants through absorption and assimilation. Basically constructed wetland should consist of vegetation that can adapted to the local climate and soil, can tolerance to pollutants in water or wastewater, having higher biomass production and rapid growth but should avoid of usage noxious species such as Mimosa pigra, Eichornia crassipes and Limnocharis flava (Mitch and Gosselink ,2000). The number of plants species that might be suitable for treatment wetland is large and evaluation studies are a few to date. Species of choice are certain to vary with the design and purpose of the wetland and with the inflowing water quality. Water plays a major reason why macrophytes do not become well established in constructed wetland. When the plants are first establishing themselves, the optimum condition are moist soil or very shallow (<5 cm) water depth. If the water is too deep, the new macrophytes will be flooded out. If there is inadequate water and topsoil dries out, the macrophytes will not survive (Mitch and Gosselink, 2000). Figure 6 showed the macrophytes species that planted in HTC constructed wetland

Figure 6: Macrophytes species that planted in HTC

2. METHODOLOGY

There are 3 stages of methodology involved in this study in order to achieve all the objectives. It started from data collection, laboratory and in situ analysis, consideration and establishment on suitability of design parameter and statistical analysis in order to establish the relationship between water budget and water quality. The details of procedures as follows;

i. Laboratory Analysis for Water Quality and Water Balance

Samples will be taken from inlet and outlet of the constructed wetland by collecting manually or automatically for each storm event. Meanwhile, pH and temperature will be measured in the field using electronic meter or thermometer respectively. The samples for BOD, COD, TSS, Turbidity, TP, TN, Heavy Metals, E- Coli and DO will be stabilized in the field and transported on ice, along with samples for laboratory experiments based on APHA 19th Edition (APHA, 1995). While water budget components for hydrology and hydraulic characteristics will be measured using on site apparatus such as automatic rain gage, evaporation pan and flow meter.

ii. Characteristics of Hydrology & Hydraulic to Design Parameters of Constructed Wetland

Consideration and establishment on suitability of design parameter such as detention time, length to width ratio, hydraulic loading rate, depth of water, inflow, outflow and velocity related to design of constructed wetland. The fundamental knowledge obtained can be used to develop new design chart for optimizing constructed wetland design under local conditions.

iii. Water Quality to evaluate the Performance of Constructed Wetland

Statistical method such as correlation, regression and significant test will be used based on collected data and performance analysis to establish the relationship between water quality and water balance model.

3. CONCLUSION

The outcome of this study can be used to improve the Design Guideline for Constructed wetland in future Manual Saliran Mesra Alam (MSMA). In the long term, the urban water systems will be improved and meet the target of DID to Class II of clean, living and vibrant river. The findings of this study will definitely contribute significantly to the enhancement of knowledge in constructed wetland. Constructed wetland can serve as effective and integrated solutions for managing urban runoff at source to rehabilitate river. In the long term, this study supports the government aspiration to promote green technology in Malaysia.

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