BIO-ECOLOGICAL DRAINAGE SYSTEM (BIOECODS): CONCEPT, DESIGN AND CONSTRUCTION

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ABSTRACT

The USM Engineering Campus is set as a pilot project of an ecologically sustainable development in terms of urban storm water management. The concept, based on integrating storm water Best management Practices (BMPs) namely "Control-at-Source" approach, into urban planning and designed to achieve multiple objectives, is the most promising approach in newly developing or urbanizing areas. This paper aims to introduce such an alternative namely the "Bio-Ecological Drainage System (BIOECODS)". The main function of BIOECODS is to promote storm water infiltration from impermeable areas (e.g. roof tops, car parks) by using bio-ecological swales. The second function is to release gradually the storm water through the use of bio-ecological swales, on-line underground bio-ecological detention storages and bio-ecological dry ponds. Finally, the third function of BIOECODS is to enhance treatment of storm water quality using treatment train concept by utilizing bio-ecological swales and bio-ecological pond (e.g. wet pond, wetland) as the storm water moves downstream. In short, BIOECODS is an example of an innovative sustainable drainage system that will help restore the natural environment, maintain river flow, and control ground subsidence. By integrating storm water utilities with the green away and lanscape, the drainage system will also enhance the Healthy Campus Concept in USM Engineering campus. The application of BIOECODS in a new development attempts to solve three major problems commonly encountered in Malaysia namely flash flood, river pollution, and water scarcity. It is hope that new developments in Malaysia will implement BIOECODS to achieve Department of Irrigation and Drainage (DID)'s aim of "Zero Flash Flood" by 2010 and help preserving the natural characteristics of the existing rivers in line with the national "Love Our Rivers Campaign". This paper first

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inytroduce the basic principles of the concept followed by a description of design criteria adopted and finally highlights the construction experience.

1. INTRODUCTION

The USM Engineering Campus is located in Mukim 9 of the Seberang Perai Selatan District, Pulau Pinang. It lies between latitudes 100° 29.5' South and 100° 30.3 North and between longitudes 5° 9.4' East and 5° 8.5' West. The locality is known as Sri Ampangan, Nibong Tebal, Pulau Pinang which is about 2 km south-east of the town of Nibong Tebal, about 1.5 km north-east of the town of Parit Buntar (Perak) and about 1.5 km north-west of the town of Bandar Baharu (across Sg. Kerian in Kedah). The area of the campus is about 320 acres and made up of mainly oil palm plantation land and is fairly flat.

The USM Engineering Campus project has taken a series of measures to reduce runoff rates, runoff volumes and pollutant loads by implementing a source control approach for stormwater management as suggested in the Stormwater Management Manual for Malaysia. This include a series of components namely ecological swale, on-line underground storage, and dry ponds as part of the Bio-ecological drainage systems (BIOECODS) that contribute to the treatment of the stormwater before it leaves the campus. This system was designed to combine infiltration, delayed flow, storage and purification as pre-treatment of stormwater before discharging to constructed wetlands. In addition to source controls, these measures include integrating large-scale landscapes into the development as a major element of the stormwater management system. The concept of the bio-ecological drainage systems (BIOECODS) is to integrate with the Ecological Ponds (ECOPOND) for further treatment of the stormwater runoff. In combination, these increase runoff lag time, increase opportunities for pollutant removal through settling and biofiltration, and reduce the rate and volume of runoff through enhanced infiltration opportunities.

As a whole, BIOECODS is designed to provide time for the natural processes of sedimentation, filtration and biodegradation to occur, which reduces the pollutant load in the surface water runoff. In addition, BIOECODS can be designed to fit into their environmental setting, adding considerably to the local amenity and/or local biodiversity. Stormwater from the built areas is routed overland into open conveyance swales planted with native cow grass and underground conveyance made from special materials, rather than through storm sewers. The swales provide initial stormwater treatment, primarily infiltration and sedimentation. The landscape dry ponds are the second component. The landscape and dry ponds diffuse the flows conveyed by the swales, and the reduced stormwater velocities maximize the campus sedimentation, infiltration and evaporative water treatment. Additionally, the natural adsorption and absorption of the landscape soils enables the soil to hold many contaminants. The aerobic condition of the soil promotes hydrocarbon breakdown. The landscape lands able to infiltrate a substantial portion of the annual surface runoff volume due to the increased soil permeability that is created by the deep root systems of the landscape vegetation. The detention pond provides the function of a stormwater detention, solids settling, and biological treatment. Finally, wetlands provide both stormwater detention and biological treatment prior to the runoff entering the recreational pond. All of these benefits help to ensure that the final discharge from a sustainable urban drainage system will not pollute rivers, nor create flooding downstream. Although BIOECODS are drainage devices that rely on natural processes, BIOECODS must be designed, built and maintained in the context of the development control system in Malaysia.

2. DESIGN CONCEPTS

Planning was carried out with the help of the rainfall-runoff model XP-SWMM, which contains information needed for designing BIOECODS. The schematic diagram of BIOECODS for USM Engineering Campus is shown in Figure 1 and the flow sequence can be summarized as follows (Figure 2).

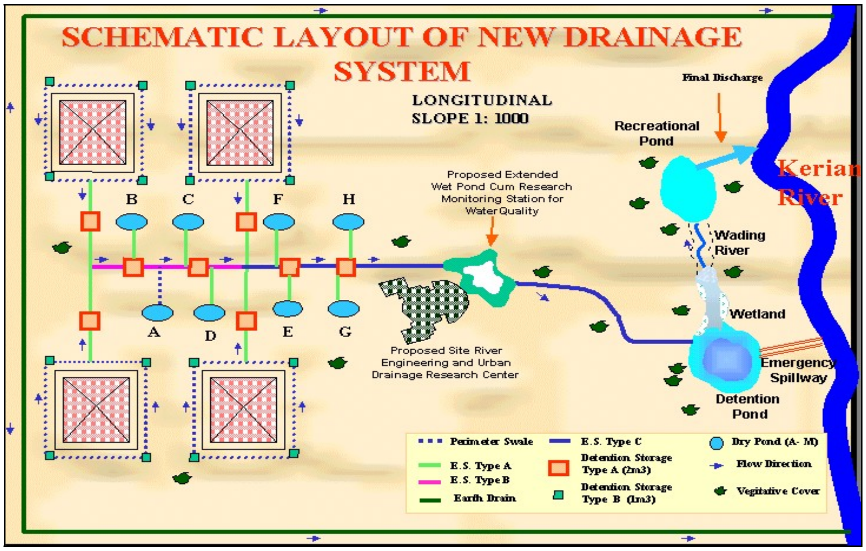

Figure 1 Schematic layout of BIOECODS

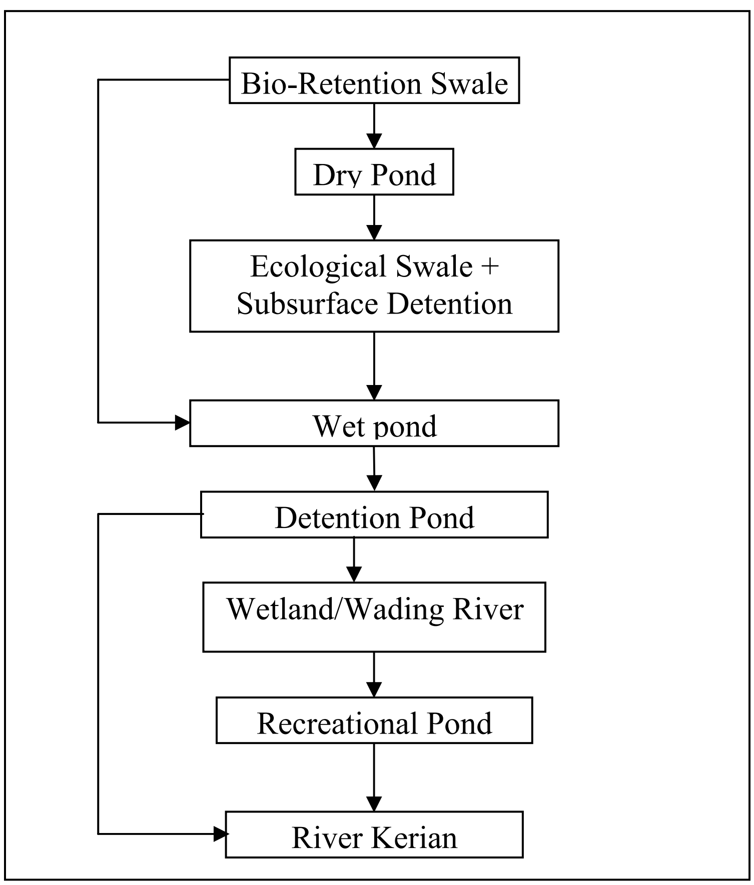

Figure 2 Flow sequences of BIOECODS

a) *The Perimeter swale* (Figures 3) *is used to cater for any excess water from individual buildings, whilst the flow from impermeable surface will be directed to the individual swale*. The perimeter swale is defined as a grass-earthen channel combined with a subsurface twin Geo-strip enclosed within a permeable geotextile design.

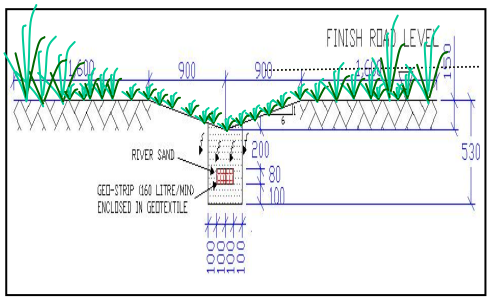

Figure 3a Typical cross section of perimeter swale

Figure 3bTypical view of perimeter swale

b) *The flow from an individual swale (perimeter swale) will be conveyed to an inter-lot swale (ecological swale) as a main conveyor*. The ecological swale is a grass-earthen channel, combined with a subsurface module enclosed within a permeable geotextile design. The ecological swale is categorized as Type A, Type B (Figure 4) and Type C depending on the size and capacity. Type A consists of one single module, Type B consists of two single modules and Type C consists of three single modules.

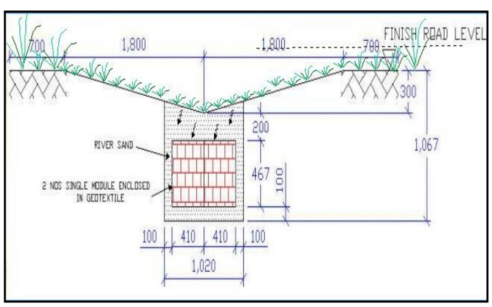

Figure 4a Typical cross section of ecological swale Type B

Figure 4b Typical view of Ecological Swale Type B

c) *The excess stormwater is stored as subsurface detention storage*. The storage modules have been designed to be placed at the connecting point, junction and critical point of the system. The storage module is categorized into Type A and Type B with different storage capacities and can be arranged accordingly to suit the site conditions.

d) *The excess stormwater is also stored on the dry ponds constructed with a storage function*. The dry pond (Figure 5) is a detention pond, which has been integrated with the ecological swale to temporarily store the storm runoff. The modular storage tank is placed beneath the detention basin where the stormwater is drained out by infiltration. The outflow path of the storage module is connected to the ecological swale at the lowest point, in order to drain the dry pond system in less than 24 hours.

e) All of the excess water from built-up areas flows via a wet pond (Figure 6) to a detention pond (Figure 7).

f) *With respect to the need for water quality improvements, the wetland* (Figure 8) *is designed as a community treatment facility.* As much as 90% of the total volume of annual stormwater runoff will flow through an area supporting growing plant material (Figure 9). Contaminants are removed either by direct absorption into plant tissues (soluble nutrients) or by physical entrapment and subsequent settlement on the wetland bed. The end product is expected to improve the aesthetic value for surrounding areas with the existence of the “Crystal Clear Blue Water Lake’ at the most downstream end of the drainage system.

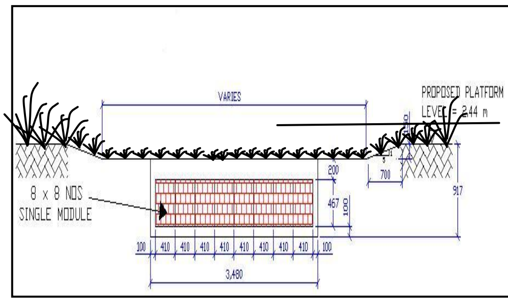

Figure 5a Typical cross section of dry pond

Figure 5b View of constructed dry pond

Figure 6 View of wet pond

Figure 7 View of detention pond

Figure 8 View of wetland

Figure 9 Wetland cell

g) *The excess stormwater is drained from the detention pond into River Kerian through two stage outlet designed to manage the minor (10-year ARI) and major (50- year ARI) storm events.*

3. DESIGN CRITERIA

The design criteria adopted for the components of BIOECODS namely ecological swale, dry pond, wet pond, detention pond and wetland are given in Tables 1 to 4 respectively.

Table 1 Design criteria for ecological swale

Design Parameter	Criteria
Longitudinal slope	1: 1000
Manning roughness coeffcient	Surface swale = 0.035 Subsurface drainage module = 0.1
Design rainfall	10-year ARI and Check for 100-year ARI
Maximum period of surface water inundation at surface swale	24 hours

Table 2 Design Criteria for Dry Pond, Wetpond and Detention Pond

BIOECODS Components	Design Parameter	Criteria
Dry Pond	Maximum period of surface water inundation	24 hours
	Maximum depth of water inundation	150 mm
Wet Pond	Surface area	4500 m^2
	Volume capacity	5000 m^3
	Design rainfall	10-year ARI
Detention Pond	Surface area	10,000 m^2
	Volume capacity	18, 000 m^3
	Design rainfall	50-year ARI

Table 3 Wetland plant species

Type	Plant Name
Type 1 (0.3m depth)	Eleocharis Variegata
Type 2 (0.3m depth)	Eleocharis Dulchis
Type 3 (0.3m depth)	Hanguana Malayana
Type 4 (0.6m depth)	Lepironia Articulata
Type 5 (0.6m depth)	Typha Augustifolia
Type 6 (1.0m depth)	Phragmites Karka.

Table 4 Design criteria for the constructed wetland

Design Parameter	Criteria
Catchment area	1.214 km^2
Design storm (3 month ARI)	22.5mm/hr
Length	155m
Width	60m
Wetland surface area	9,100 m^2
Volume	9,100 m^3
% Catchment area	0.7
Design Inflow rate	0.25 m^3/s
Mean residence time	3 days
Slope of wetland bed	1%
Bed depth	0.6m
Media	Pea gravel and soil mixture
Hydraulic conductivity of gravel	10^{-3}m/s to 10^{-2} m/s

4. ECOLOGICAL SWALE COMPONENTS

Table 5 gives a short description of the components (Figure 10) of an ecological swale namely Geostrip, Module, Hydronet Filter Fabric, clean river sand, topsoil and cow grass.

Table 5 Components of An Ecological Swale

Swale Components	Specifications	Details
Geostrip (*parameter swale*)	Dimension	100 mm x 80mm x 550 mm
	Flow rate at 1 % gradient	80 l/min
	Compressive strength	12 tons/m^2
	Material	Recycled polypropylene
Module (*ecological swale*)	Dimension	405mm x 465mm x607 mm
	Flow rate at 1 % gradient	2280 l/min
	Compressive strength	8 tons/ m^2
	Material	Recycled polypropylene
Hydronet Filter Fabric	Permeability	9.30 mm/s
	Screening capability	0.38 mm
Clear Sand River	Sieve analysis according to BS1377	Mean size between 0.5 mm and 2.0 mm
Top soil	Thickness	One to Two inches
Grass	Species	Cow grass

5. CONSTRUCTION EXPERIENCE

An example of the construction of an ecological swale is shown in Figure 11. This involves tasks such as excavation, slope determination, module or geostrip placement, sand bedding and grass planting.

6. CONCLUSION

By minimizing the surface runoff at source through the provision of on-site facilities the peak runoff can be reduced at the downstream area. Treatment of storm water at the source will give a better water quality at the downstream area. Water quality of Standard Class II can be achieved if new developments in Malaysia use the concept of sustainable urban drainage system such as the Bio-Ecological Drainage System.

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(a) Geostrip

(b) Module

(c) Hydronet

(d) River sand

(e) Topsoil

(f) Cow grass

Figure 10 Components of an ecological swale

a) Excavation

b) Module placement

c) Online subsurface detention

d) Sand bedding

e) Grass planting

Figure 11 Construction of an ecological swale