THE USE AND DEVELOPMENT OF BIO-ECOLOGICAL DRAINAGE SYSTEMS (BIOECODS) UNDER TROPICAL CLIMATE

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ABSTRACT

This paper outlines the national approach to stormwater management in Malaysia, and evolving implementation practices by State and Local government authorities. The research focused on new concepts for the urban stormwater runoff and the water quality management based on integrated stormwater solutions. The USM Engineering campus is a pilot project for urban stormwater management strategy as an example of an ecologically sustainable development based approach to urban stormwater management.The concept is based on open and natural drainage systems integrated into multipurpose open space/environmental corridors or greenways, is the most promising approach in newly developing or urbanizing areas. This paper aims to introduce such an alternative - the "Principle of Control-at-Source". With respect to its technical implementation the term "Bio-Ecological Drainage Systems”), further in this text referred to BIOECODS) has prevailed. With this new approach, the main bulk of stormwater is stored at its source and then gradually released downstream to reduce impact on river capacity.

BIOECODS is implemented at USM's Engineering Campus with multi-function adopted the guideline in the new Stormwater Management Manual for Malaysia. The main function is to promote stormwater infiltration from impermeable areas (e.g. roof tops, car parks) by using bio-ecological swales. The second function is to release gradually the stormwater through the use of bio-ecological swales, on-line underground bio-ecological detention storages and bio-ecological dry ponds. Finally, the function of BIOECODS is to enhance treatment of stormwater quality using treatment train concept by utilising bio-ecological swales and bio-ecological ponds (e.g. wet pond, wetland) as the storm water moves downstream.

Presently, this project is an example for the development of new urban areas by implementing several components of BIOECODS at once that can meet the new concept of Urban Stormwater Management Manual for Malaysia (USWMMM) to manage and control stormwater quantitatively and qualitatively at its source. Therefore, the flash flood and water quality problems can be reduced immediately and in the long term it can save the huge cost for flood mitigation project in Malaysia. This paper first introduces the basic principles of the concept followed by a description of technical details. Through the research some engineering problems are identified, the importance of which should not be underestimated to avoid failures.

Key word: Best Management Practice; on-site management; bio-ecological swale; detention storage; constructed wetland; infiltration systems; hydrological impact; bio-retention

1.0 INTRODUCTION

The management of urban watersheds has become increasingly complex in recent years. Rapid urbanization in Malaysia has been accompanied by dramatic hydrologic changes. With the development of urban areas have come land-disturbing activities and an increase in the degree to which watersheds are composed of impervious surfaces such as streets, parking lots, and roof-tops. Natural drainage patterns have been altered, and changes have occurred in the quantity and velocity of stormwater runoff. Smisson (1979) stated that the effect of a reduction in the catchment response time due to development is to increase the maximum rate of flow discharging to the conventional drainage system or alternatively increase the frequency of significant floods. Thus, the natural cleansing systems and biological processes which reduce pollution are disturbed by the high runoff flows and become ineffective. A variety of problems accompanies these changes. Increased stormwater velocity and peak flow can cause urban streambanks to become eroded and undermined. The streams become wider and shallower. Streams are polluted by sediments, nutrients, bacteria, heavy metals, and other contaminants. The frequency and magnitude of flooding increase. Study by Drainage and Irrigation Department (DID, 2000) showed that 9% of the country’s land mass is prone to floods which affect about 12% of the population. As a result, frequent occurrences of flash flood occur at downstream of new development areas resulting in an average loss of RM 100 million.

Conventionally storm water drainage has been designed to provide the fastest possible transport (rapid disposal approach) of storm water runoff out of the catchments into receiving waters. The design philosophy of the conventional drainage system is based on solving localized floods either by transferring excessive flows in drainage systems downstream by upgrading the sewer pipes or relieving localized problems by constructing storm overflows. The consequence of removing the storm water from the land surface so quickly is to increase volumes and peak rates of flow discharged, overloading the conventional drainage systems. This cause severe damages not only to downstream areas but to the environment as a whole. In addition, the amounts of storm water to deal with are such that drainage schemes have become unaffordable for the community. The conventional drainage systems can cause problems of flooding, pollution or damage to the environment and are not proving to be sustainable. The current estimated costs to mitigate all existing flood problems by the Federal Drainage and Irrigation Department (DID) Malaysia is reaching RM 10 billion not inclusive projects by DID state and local authorities (News Straits Times, 22 June 2000). Therefore there is a need to seek holistic and sustainable solutions not only to mitigate existing flood problems but also to prevent the occurrences of such problems in new areas to be developed.

In order to solve the current problems DID is embarking on new approach of managing storm runoff called 'control at source'. The sustainable urban drainage is a concept that includes long term environmental and social factors in decisions about drainage. It takes account of the quantity and quality of stormwater runoff, and the amenity value of surface water in the urban environment. The 'control at source' approach has been described by Andoh,1994 as follows:

> ***By mimicking nature's way, inspired by the concept of 'natural distributed control system', this alternative strategy looks at ways in which flows into and through the urban centers can be reduced or attenuated before they arrive at the problem areas: the further upstream a control measure, the closer it is to source and hence the closer it is to nature's way of a spatially distributed control system.***

The implementation of integrated measures of storm water Best Management Practices (BMP's) in Malaysia is still at early stages. Department of Drainage and Irrigation (DID) is producing a new urban drainage manual known as Storm Water Management Manual for Malaysia or SWMMM effectively being used by 1st Jan 2001. Thereafter, approval for all Federal, State and private development will depend on compliance with new and comprehensive guidelines on drainage. This new guidelines are focusing on managing the storm water instead of simply draining it away and therefore is more comprehensive. It takes into consideration the present problems facing will mimics the nature described by Andoh, 1997 as follows:

'Nature utilizes its wide range of natural features to store, attenuate and absorb into the soil, the runoff before release into the receiving water courses. Its drainage system is composed of an accumulation of small volumes of 'system' storage which, all together, provide an efficient natural distributed control system to slow down the rate of runoff'

Therefore, the quality and quantity of the runoff from developing area can be maintained to be the same as predevelopment condition.

These comprehensive Best Management Practices (BMPs) for stormwater management are becoming very popular topic development for urban drainage overseas. Stormwater BMP's are widely used in drainage planning in United Kingdom (Bettess, 1996), United States (Stahre & Urbanos, 1995), Germany (Grotehusmann et.al., 1993), Australia (Argue and Pezzanti, 1998) and Japan (Akagawa et.al., 1997). The BMPs can be defined as a multi-disciplinary approach in applying appropriate technology to preserve the natural environment, enhance living standards and improve the quality of life. The implementation of integrated measures of stormwater's BMP's in Malaysia is still at early stages. There is a lack of the research and field data that would provide a basis for sound design practices under Malaysian hydrological condition as Malaysia has tropical climate with a very high intensity rainfall. USM has taken proactive step to implement the BMP's Bio- ecological Drainage System (BIOECODS) in its USM Engineering campus and become the first university with this concept as demonstration project for source control concept in Malaysia.

The BIOECODS is the example of sustainable drainage systems which has been developed in line with the ideals of sustainable development, by balancing the different issues that should be influencing the design. Surface water drainage methods that take account of quantity, quality and amenity issues are collectively referred to as BIOECODS. These systems are more sustainable than conventional drainage methods because they manage runoff flowrates, reducing the impact of urbanization on flooding, protect or enhance water quality, sympathetic to the environmental setting and the needs of the local community, provide a habitat for wildlife in urban watercourses and encourage natural groundwater recharge. The mechanism to achieve the above target is to deal with runoff close to where the rain falls (control-at-source), managing potential pollution at its source now and in the future and finally protecting water resources from point pollution and diffuse sources. The BIOECODS is moving away from the conventional thinking of designing for flooding to balancing the impact of urban drainage on flood control, quality management and amenity as shown in Figure1.

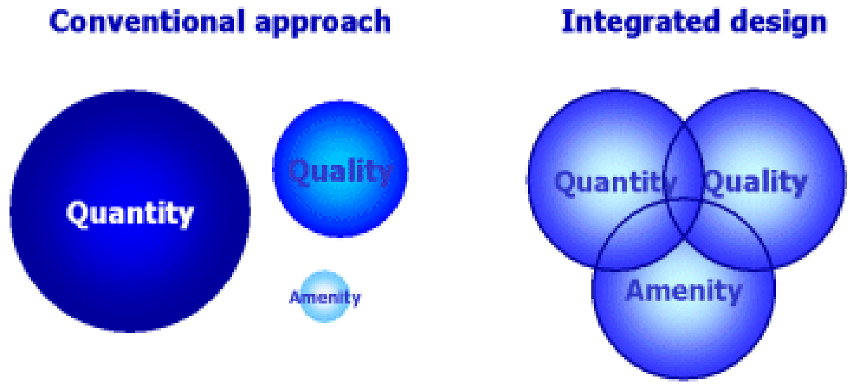

Figure 1: Conventional Approach vs Sustainable Approach (Source: USEPA, 2000)

The BIOECODS will use 'control at source' approach therefore simulate the natural hydrological cycle in urban area by combining infiltration, on-line and off-line detention storage, delayed flow as well as runoff treatment techniques. The new system will also help restore the natural environment, maintain river flow, and control ground subsidence. By integrating stormwater management planning with green way and open space planning as USM Engineering Campus is doing, we can have parks and walking paths that incorporate stormwater management facilities as water amenities, and add value to the aesthetic and recreational experience that person gain from visiting these facilities. It is hope this study will provide database to support the New Storm Water Management Manual and to evaluate the effectiveness of the comprehensive Bio-Ecological Drainage Systems (BIOECODS) and BIO-Ecological ponds to control stormwater runoff quantitatively and qualitatively. This paper presents information about a recent bio-ecological drainage systems concept including BMPs for a USM Engineering campus in Southern Penang State.

2.0 OBJECTIVES

This project was proposed with the following prime objectives:

1. As a pilot project for the use of new ecological drainage systems at private and public buildings.
2. To assess the performance, potential application and continued use of integrated ecological drainage systems consists of different components such as perimeter and ecological swale, dry pond, on-site detention storage (OSD), wetpond, detention pond and wetland under Malaysian condition
3. To monitor and study the effectiveness of individual components of new ecological drainage systems for attenuating the hydrograph and improving the water quality on the aspect of storage efficiency, infiltration, conveyance and purification
4. To develop a modeling procedure for the analysis, design and optimization of the integrated ecological drainage systems.
5. To evaluate the cost effectiveness of the integrated ecological drainage systems
6. To provide guidelines of new ecological drainage systems for local use

3.0 ALTERNATIVE STORMWATER MANAGEMENT FOR PILOT STUDY AT USM ENGINEERING CAMPUS

USM Engineering Campus (Figure 2) is located in Mukim 9 of the Seberang Perai Selatan District, Pulau Pinang. It lies at about 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 Ampang Jajar 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 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 project initially implemented the conventional drainage type. Later Drainage and Irrigation Department (DID) in cooperation with Unit Kejuruteraan Sungai dan Saliran Bandar (UKSSB) has proposed the new ecological drainage concept to be implemented. The required drainage planning specifies that alternative new ecological drainage systems should be used in line with the university-planning concept. The project objective was to develop and test an alternative drainage systems to the conventional drainage system appropriate to the climate and ground conditions in the area. Due to the local boundary conditions, the storm runoff should be infiltrated into ground where possible or otherwise drained only with a significant delay. Particular stress was laid on the opportunity to create attractive and integrated drainage planning into the 'green planning' for the whole site. This means that the building of the university campus will take consideration towards eco-development by which, some of the oil palm trees and 'nypah' palm forests along the riverbank will be preserved (HLA et. al., 1997).

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 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 stormwater before it leaves the campus. This systems was designed to combine infiltration, delayed flow, storage and purification as pre treatment of stormwater before discharging to the 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 (BIOECOSD) 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.

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 conventional drainage. The swales provide initial stormwater treatment, primarily infiltration and sedimentation. The landscape lands and dry ponds are the second component. Landscape lands 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 are able to infiltrate a substantial portion of the annual surface runoff volume due to their increased soil permeability which is created by the deep root systems of the landscape vegetation. The detention pond provides stormwater detention, further solids settling, and biological treatment. Finally, wetlands provide both stormwater detention and biological treatment prior to runoff entering the recreational pond.

Based on published BMP effectiveness information and hydrologic modeling, the USM Engineering Campus development can be expected to reduce surface runoff volumes by 65% and reduce solids, nutrients, and heavy metals loads by 85% to 100%. Source controls will minimize the impacts of the development even further (Stahre, 1990)

The long term result is not only reduces costs to the developer, but also reduces maintenance costs for the community. There is also a substantial benefit to downstream neighbors. By treating stormwater where it falls on the land, the USM campus is reducing its contribution to downstream flooding and sedimentation.

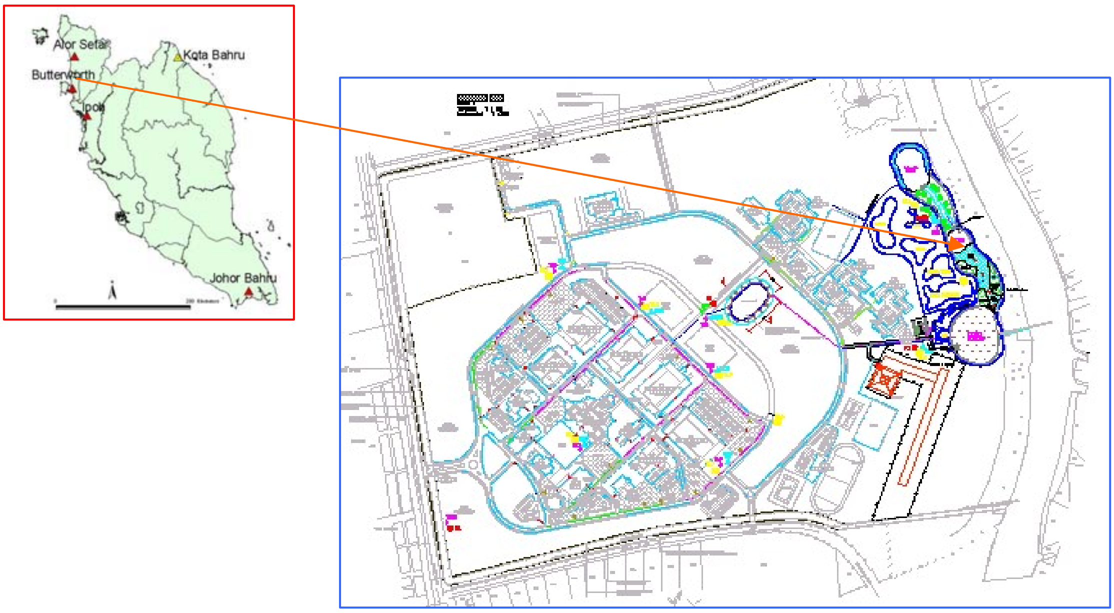

Figure 2. Pilot study area at USM Engineering Campus

3.0 DESIGN CONCEPT

Planning was carried out with the help of rainfall-runoff model SWMM, which contains information needed for designing BIOECODS. The schematic diagram of Bio- ecological drainage system for USM Engineering Campus is shown in Figure 3 and is divided into seven steps as follows:

Step 1 : Per*imeter swale is to cater any excess water from individual building whilst the flow from impermeable surface will be directed to the individual lot swale*. The perimeter swale is defined as grass earth channel combined with subsurface twin Geo-strip enclosed within a permeable geotextile designed

Step 2 : *The flow from individual swale (perimeter swale) will be conveyed to inter-lot swale (ecological swale) as main conveyor*. The ecological swale is a grass-earth channel combined with a subsurface module enclosed within a permeable geotextile. The ecological swale is categorised as Type A, Type B and Type C depending on sizes and capacities. Type A consists of one number of single module, Type B consists of two numbers of single module and Type C consists of three numbers of single module. The design criteria for ecological swale is given in Table 1.0.

Step 3 : *The excess stormwater is stored in the sub-surface 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 capacity and can be arranged accordingly to suit site condition.

Step 4 : *The excess stormwater is also stored on the dry pond constructed with a storage function*. Dry pond is a detention basin which has been integrated with the ecological swale to temporarily store the storm runoff. This detention basin is designed to store to the surface that of 150mm of excess rainfall and designed to blend with surrounding landscape. The outflow path of the storage module should be connected to ecological swale at the lowest point in order to drain the dry pond system in less than 24 hours.

Step 5 : *With respect to the need for water quality improvement, the flow from ecological swale goes into detention pond and wetland for further water treatment.* Wetlands are constructed to pass water through an area supporting growing plant material. 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 values for surrounding area with the existence of the "Crystal Clear Blue Water Lake'.

Step 6 : Tidal gate will be incorporated at the outlet of the recreational pond into Sg. Kerian.

Step 7 : *In the case of flood event, the excess water from detention pond will be directed to Sg. Kerian via emergency spillway*

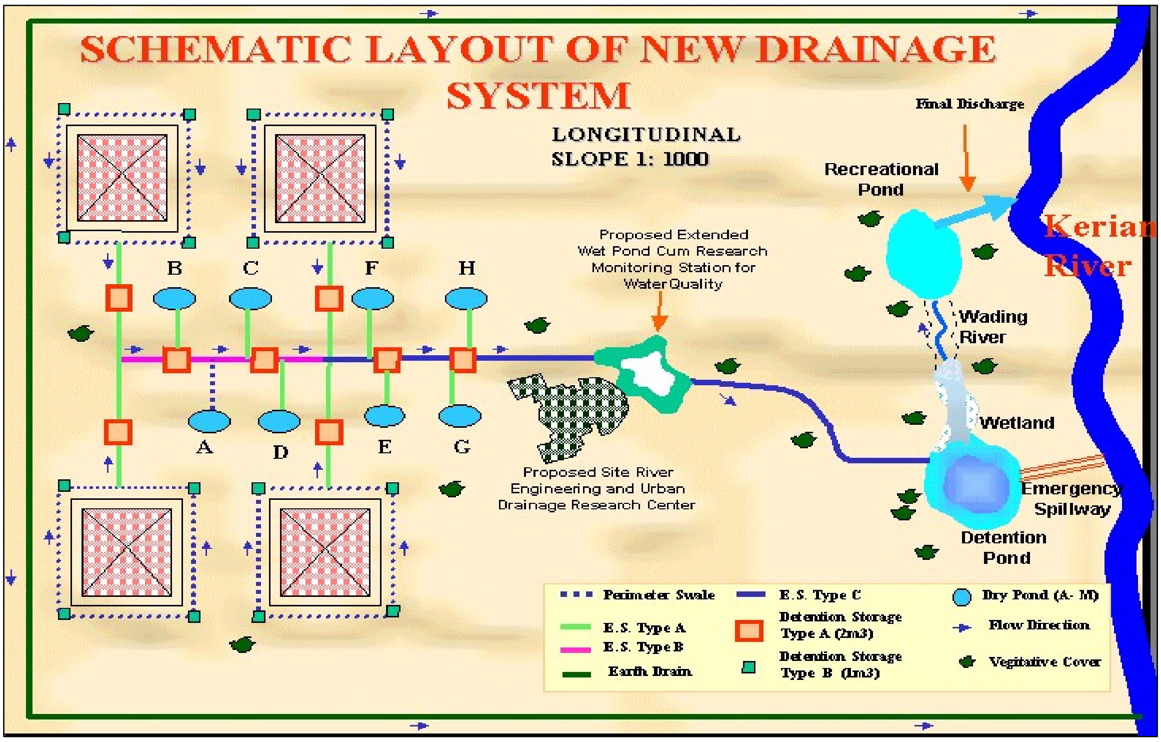

Figure 3. Schematic layout of Bio-ecological drainage systems (BIOECODS)

Table 1: Design Criteria for Ecological Swale based on MSMA (JPS 2001)

Design Parameter	Criteria
Longitudinal Slope	2 %-4% <2% if using under drain conveyor e.g perforated paip
Maximum depth of water	150 mm (Water Quality)
Manning's Coeficient	0.1
Bed Width	06-3 m
Minimum Residence Time	2 min
Swale length minimum	60m
Height of grass in swale	150 mm

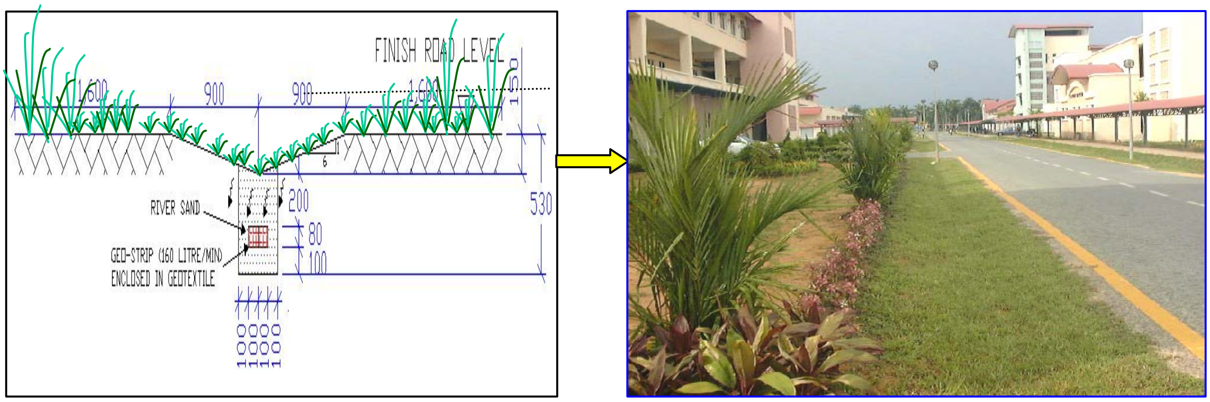

Figure 4.0 : Perimeter swale cross section and the completed perimeter swale blended with the landscaping

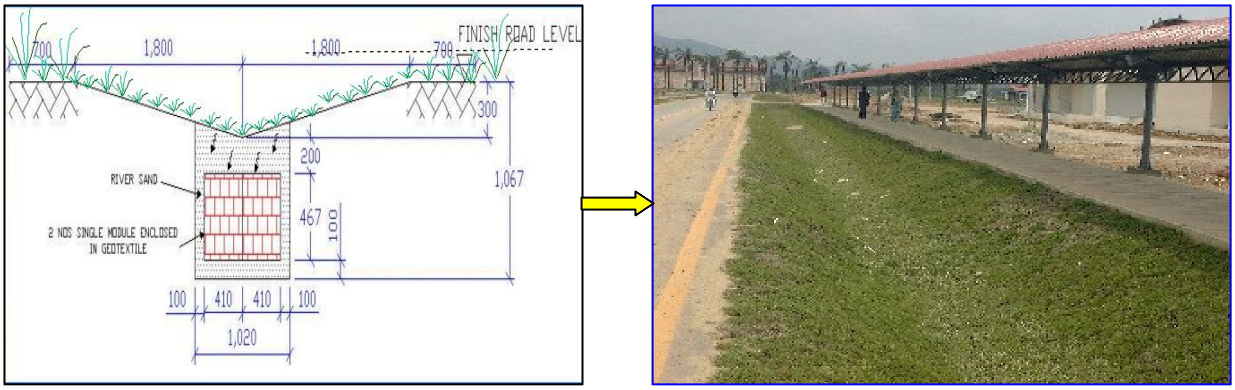

Figure 5.0 : Ecological swale cross section and the completed ecological swale

5.0 CONCLUSIONS

The proposed bio-ecological drainage system (BIOECODS) is an almost applicable concept and an alternative to conventional drainage system. BIOECODS adopted an integrated approach to obtain both practical and cost effective solutions to minimize the impact of urbanization on the environment. As a rule it combines three elementary engineering techniques to manage rainfall-runoff, infiltration, storage and conveyance draining by ecological swales. Widespread of this techniques in new developments would result in a long-term improvement in the quality of urban rivers and a reduction in the risk of flooding. In addition, our urban environment would not only be more sustainable, but also more varied and attractive, with water a feature rather than being hidden underground. It has been proved overseas that new ecological drainage system has a positive value, it involves no major problems and can even be beneficial. The experience so far showed that the systems is functioning very well even under the high intensity rainfall.

It is hoped that the findings from the study will support the data base in the New Stormwater Management Manual for Malaysia, as the manual is lacking of local data. This is very important to ensure that design practices are accurate, and to avoid failure in design.

6.0 ACKNOWLEDGEMENT

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