# POLLUTANT REMOVAL CAPABILITY OF AN ECOLOGICAL SWALE

By

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# ABSTRACT

As development and impermeability increase in an area, it can have significant impact on hydrologic and hydraulic process as well as degradation of water quality on receiving waters. In order to solve the entire problem caused by the conventional drainage system, a new approach has been introduced to manage the storm water. Bio-Ecological Drainage system (BIOECODS) forms an alternative method based on control at source approach to manage storm water quality at USM Engineering campus, Nibong Tebal by using ecological swales and ecological pond. However this study only focuses on the capability of an ecological swale in terms of pollutant removal. A storm water quality monitoring at an ecological swale is being carried out by using sampling method. Samples are taken from upstream and downstream along ecological swale. And then, samples are analyzed in laboratory to identify the level of pollutant. Parameter analyzed in laboratory includes TSS, TP and Pb. Reduction in the concentration of pollutants from upstream to downstream show that ecological swale is very effective to remove pollutant. The performance of swales in term of pollutant removal diminished with increasing flow rate for TSS, due to the importance of physical process (sedimentation and filtration) in their removal. TP and Pb removal also decrease because of the increasing of flow rate.

# ABSTRAK

Pembangunan dan peningkatan kawasan tak boleh telap akan memberi kesan kepada proses hidrologi dan hidraulik dan mengurangkan kualiti air di sungai. Untuk menyelesaikan masalah yang timbul akibat dari sistem perparitan konventsional, satu pendekatan baru telah diperkenalkan untuk menguruskan air larian ribut .Sistem Saliran Bio-Ekologikal (BIOECODS) membentuk satu alternatif yang berdasarkan konsep kawalan pada punca dengan menggunakan ekologikal swale dan kolam ekologikal untuk menguruskan air larian ribut di USM Kampus Kejuruteraan di NIbong Tebal. Walau bagaimana pun kajian ini hanya memfokus kepada keupayaan ekologikal swale dalam menyingkirkan bahan enap cemar. Kajian mengenai kualiti air ribut di ekologikal swale telah dijalankan menggunakan kaedah pensampelan secara rawak. Sampel diambil di hulu dan hilir di sepanjang ekologikal swale dan kemudian di bawa ke makamal untuk dianalisis. Parameter yang terlibat ialah TSS, TP dan Pb. Pengurangan kepekatan bahan enap cemar dari hulu ke hilir membuktikan bahawa ekologikal swale amat berkesan dalam menyingkirkan bahan enap cemar. Keberkesanan swale menyingkirkan TSS adalah berkurangan jika berlakunya peningkatan kadar alir akibat dari proses fizikal (contohnya pemendapan dan penyusupan). Penyingkiran TP dan Pb juga berkurangan sekiranya kadar alir meningkat.

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# CHAPTER 1

# INTRODUCTION

## 1.1 General

Malaysia receives a large quantity of rainfalls every year (3000 mm on average) that need to be managed properly to avoid flash flood especially in developed areas. Urbanization will increase the storm water runoff and increase the occurrence of flash flood in urban area. Rapid developments not only increase the storm water runoff due to increase in impermeable areas but also decrease the quality of water.

In order to mitigate flash flood in urban area, a conventional drainage system has been designed to provide the fastest possible transport of storm water out of the catchments into the receiving water (Rapid Disposal Approach). The increases of surface run off discharge directly into the river causes overland and stream banks erosion. Land use change from forest and agricultural areas into urban and industrial areas can have significant impact on hydrologic and hydraulic process and a degradation of water quality on receiving water.

Rapid disposal approach has caused many problems related to storm water runoff such as:

- Increase of sedimentation in the river system
- Flash Flood
- Water pollution and ecological damage
- Garbage and floating litters

Due to this problem, a new approach of drainage system has been introduced by Department of Drainage (DID) Malaysia known as Storm Water Management Manual for Malaysia (Manual Saliran Mesra Alam, MSMA). This manual proposes the concept of Best Management Practices (BMPs) known as Control Source approach.

## 1.2 Bio-ecological Drainage Systems (BIOECODS)

The USM Engineering Campus is set as a pilot project that applied the concept of BMPs as suggested in MSMA. 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. Major components of BIOECODS systems are ecological grassed swale, dry pond and ecological pond. There are 3 types of ecological swale. There are Type A, Type B and Type C depending on the number of modules underneath the swale. Type A consists of 1 single module (Figure 1.1), Type B consists of 2 single modules (Figure 1.2) and Type C consists of 3 single modules (Figure 1.3). The design criteria for ecological swale are given in Table 1.1.

**Table 1.1: Design Criteria for Ecological Swale (Zakaria et al, 2004b)**

| Design parameter | Criteria |
|---|---|
| Longitudinal Slope | 1:1000 |
| Manning roughness coefficient | Surface swale = 0.035<br>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 |

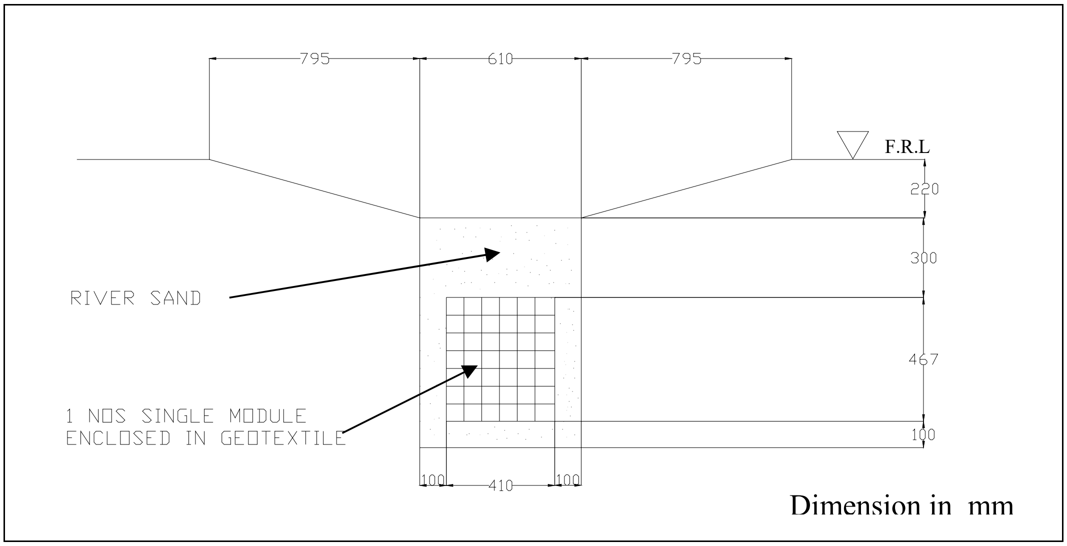


Figure 1.1: Cross Section of Ecological Swale Type A

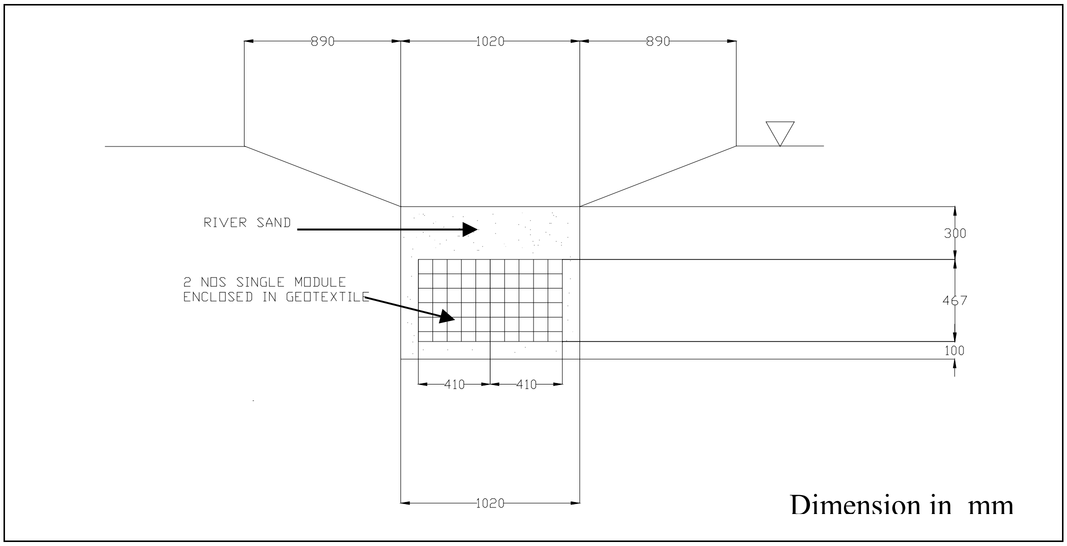


Figure 1.2: Cross section of Ecological Swale Type B

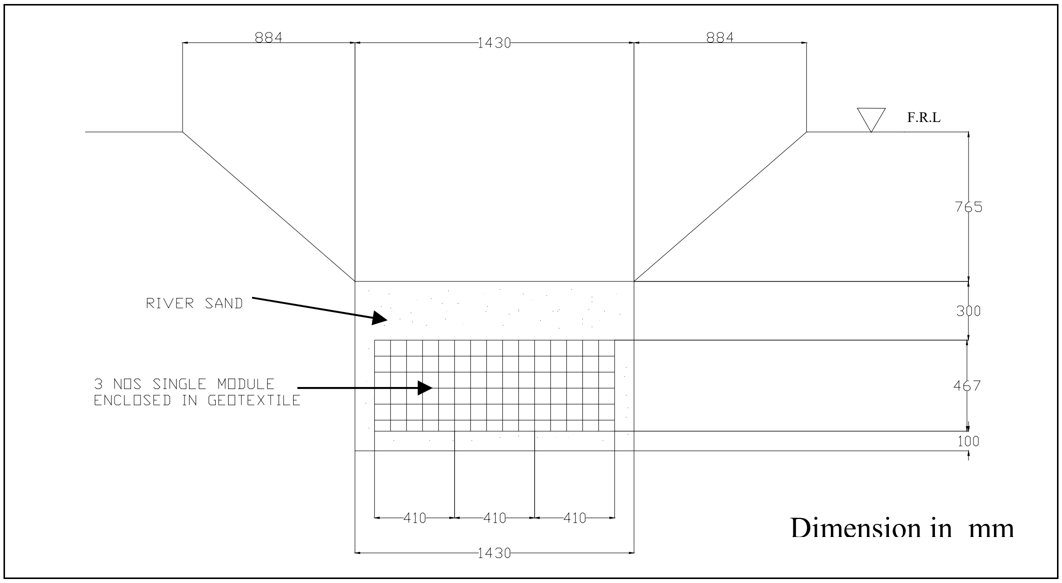


Figure 1.3: Cross Section of Ecological Swale Type C

There are 6 components of an ecological swale. Table 1.2 shows the Ecological Swale components and its description.

**Table 1.2: Components of an Ecological Swale (Zakaria et al, 2004b)**

| Swale Components | Specifications | Details |
|---|---|---|
| Geostrip (parameter swale) | Dimension | 100 mm x 80 mm x 550 mm |
| | Flow Rate at 1% gradient | 80 l/min |
| | Compressive strength | 12 tons/m$^2$ |
| | Material | Recycled polypropylene |
| Module (ecological swale) | Dimension | 405 mm x 465mm x 607mm |
| | 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 |

The application of BIOECODS in a new approach of drainage system to solve three major problems namely flash flood, river pollution and water scarcity during dry period which is commonly encountered in Malaysia. The advantages of BIOECODS are:-

- Storm water runoff purification
- Peak hydrograph attenuation
- Increment of dissolved oxygen level
- Alternative of water source for domestic use
- Re-augmentation of ground water
- Increasing aesthetic value to environmental via green landscape

## 1.3 Objective

The objective of this study is:

- To identify the effectiveness of an Ecological Swale in term of pollutant removal and its relationship to flow rate.

## 1.4 Scope of study

The scopes of this study include water sampling at inlet and outlet of an ecological swale in USM Engineering Campus, analyzing the sample in laboratory to identify the level of pollutant and measuring the water level at inlet and outlet to determine the flow depth and flow discharge.

Parameters analyzed in laboratory include:

a) Total Phosphorus (TP )
b) Lead (Pb)
c) Total Suspended Solids (TSS)

# CHAPTER 2

# LITERATURE REVIEW

## 2.1 Introduction

Storm water best management practices (BMPs) are techniques, measures or structural controls that are used for a given set of conditions to manage the quantity and improve the quality of storm water runoff in the most cost-effective manner. Proper designed, constructed and maintained structural BMPs can effectively remove wide range pollutants from storm water run off. These systems are more sustainable then conventional drainage methods because they:

- Protect or enhance water quality
- Manage run off flow rates, reducing the impact of urbanization on flooding
- Encourage natural ground water recharge
- Provide a habitat for wildlife

An introduction of a New Urban Storm Water Management Manual (known as MSMA) in Malaysia emphasizes the implementation of the concept of BMPs. The main objective of MSMA is to manage storm water in more environmentally approach known as Control-Source approach.

## 2.2 Application of Best Management Practice (BMPs) Concept in Malaysia

Bio-Ecological Drainage System (BIOECODS) is the first application of storm water management concept in Malaysia and has been constructed at the Engineering Campus of Universiti Sains Malaysia, Nibong Tebal, Pulau Pinang. There are the three main functions of BIOECODS. The main function is to promote storm water infiltration from impermeable areas by utilizing bio-ecological swales. Second, BIOECODS help to release slowly the storm water through the use of bio-ecological swales, online underground bio-ecological detention storages and bio-ecological dry ponds. And the third function is this system is to enhance treatment of storm water quality using treatment train concept by using bio-ecological swales and bio-ecological pond (e.g. wet pond, wet land) as the storm water moves downstream.

A storm water quality-monitoring program was carried out at 10 sampling points known as GS1 to GS10 (Figure 2.1) to present the storm water quality of one of the BIOECODS components (Zakaria et al. 2004a). The results of the storm water quality of ecological swale are as shown in Table 2.1 and Table 2.2.

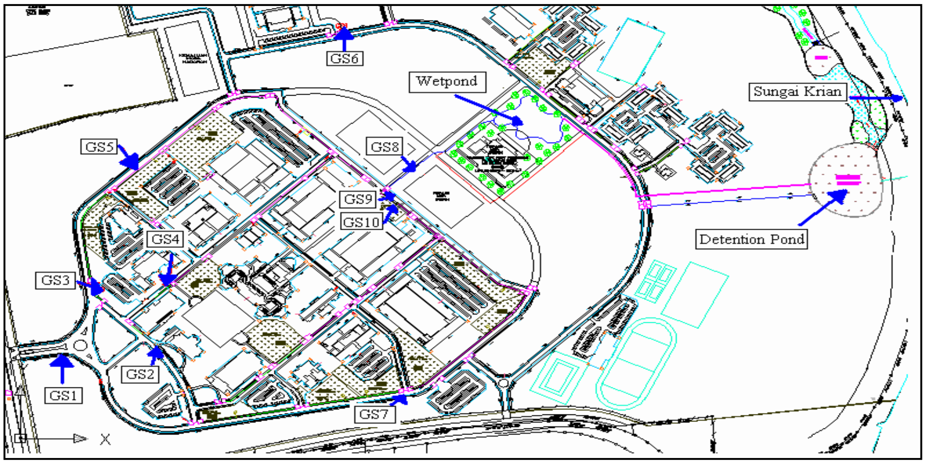


**Figure 2.1: Sampling Location GS1-GS10 at USM, Engineering Campus (Zakaria et al. 2004a)**

**Table 2.1: Storm water Quality Result on 28 June 2003 at ecological swale (Zakaria et al, 2004a)**

| Station | Parameter | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | pH | DO (mg/L) | TSS (mg/L) | COD (mg/L) | BOD (mg/L) | $NH_3$-N (mg/L) | $NO_3$-N (mg/L) | $PO_4^3$ (mg/L) | Zn (mg/L) | Pb (mg/L |
| GS1 | 5.88 | 6.9 | 3 | 76.8 | 4 | 0.23 | 0.87 | 0.06 | 0.122 | 0.856 |
| GS2 | 6.35 | 5.6 | 2 | 92.3 | 6 | 0.19 | 0.67 | 0.03 | 0.147 | 0.977 |
| GS4 | 6.08 | 5.4 | 10 | 57.6 | 3 | 0.46 | 1.09 | 0.22 | 0.077 | 0.962 |
| GS7 | 6.25 | 5.9 | 10 | 61.4 | 4 | 0.3 | 0.97 | 0.15 | 0.139 | 0.831 |
| GS8 | 6.39 | 6.4 | 6 | 23.0 | 2 | 0.34 | 0.87 | 0.15 | 0.120 | 0.851 |
| GS9 | 6.34 | 7.9 | 7 | 57.6 | 5 | 0.27 | 1.37 | 0.13 | 0.510 | 0.750 |
| GS10 | 6.32 | 6.9 | 26 | 108.2 | 9 | 0.58 | 1.17 | 0.92 | 0.15 | 0.804 |

**Table 2.2: Range of water quality for each parameter (July - October 2003) (Zakaria et al, 2004a)**

| Parameter | Sampling Points at Ecological Swales | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | GS1 | GS2 | GS3 | GS4 | GS5 | GS6 | GS7 | GS10 | GS9 | GS8 |
| pH | 5.66-7.88 | 5.44-7.82 | 5.53-8.22 | 5.36-7.87 | 5.38-8.13 | 5.42-8.69 | 5.53-7.43 | 5.42-8.24 | 5.62-7.80 | 5.40-7.43 |
| Temperature (°C) | 26.1-30.1 | 25.6-30.5 | 24-31.9 | 24.6-30.1 | 25-32.1 | 25.0-32.1 | 25.6-31.5 | 24-28.7 | 24.9-26.7 | 26-29.6 |
| DO (mg/L) | 2.69-3.80 | 1.74-6.03 | 2.14-4.36 | 1.84-6.08 | 1.95-5.97 | 1.71-5.83 | 1.76-5.71 | 1.58-5.09 | 2.48-5.38 | 1.50-5.45 |
| BOD (mg/L) | 3-9.50 | 0-12.00 | 2-8.5 | 1-7.5 | 0-11 | 0-6 | 0-5 | 1.5-7.0 | 0-11.5 | 1.00-4.00 |

**Table 2.2: Range of water quality for each parameter (July - October 2003) (Zakaria et al, 2004a) (Continued)**

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| COD (mg/L) | 0-99.05 | 5.59-129.52 | 16.78-72.38 | 11.19-144.76 | 0-80 | 0-110.48 | 2.8-190.48 | 16.78-87.62 | 13.99-110.48 | 2.80-83.81 |
| TSS (mg/L) | 0-19 | 0-3 | 0-27 | 0-10 | 0-13 | 0-28 | 0-19 | 5-48 | 0-60 | 0-9 |
| Turbidity (NTU) | 8.3-13.2 | 6.4-21.8 | 7.5-33.6 | 15.8-28.5 | 9.6-19.9 | 10.9-128.0 | 10.7-22.9 | 22.7-66.3 | 13.7-23.7 | 9.6-18.9 |
| Pb (mg/L) | 0-1.459 | 1-1.480 | 1-1.426 | 0-1.422 | 0-1.181 | 0-1.177 | 0-1.133 | 0-1.407 | 0-1.287 | 0-1.471 |
| Zn (mg/L) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0-0.034 | 0 |
| Cu (mg/L) | 0-1.899 | 0-1.989 | 0-1.694 | 0-1.835 | 0-1.724 | 0-1.684 | 0-1.989 | 0-1.765 | 0-1.649 | 0-1.687 |

From the result of the previous monitoring, Table 2.1 and Table 2.2 show that storm water quality from outlet Swales Type C (GS 8) which is the most downstream end of the ecological swale has a range of pH between 5.88 and 6.39, TSS between 3-26 mg/L, DO between 5.4 and 7.9 mg/L, COD between 23.0 to 108.2 mg/L, BOD between 2-9 mg/L. This range falls under Class 11A Standard Classification by the Department of Environment (DOE) Malaysia. The good water quality monitored from the outlet type C (GS 8) gives an indication that some purification occurs along the system.

The implementation of BMPs is also applied at Putrajaya (Shaaban & Zaiton Ibrahim, 2000). The Putrajaya Wetlands and Lake System are constructed to improve the run off and enhance the water quality of the lake and also as an attractive landscape. And recently, The Government of Malaysia is planning to construct a new building forensic wad of Tanjung Rambutan Hospital, Ipoh and construct a drainage system that applies MSMA concept.

## 2.3 Sources of Storm Water Pollution

Among the pollutants that are found in storm water are heavy metals, sediment, toxic substances, nutrients, organic matter and bacteria. The pollutants that are found in storm water come from variety sources. The possible sources of storm water pollution are:

- **Litter**

  Shopping centers, stores, malls, pedestrian access ways, retail centers, car parks, leaf-fall from trees, lawn mowing, schools, waste collection, storage, public bins, fast food outlets & restaurants, Council recreational areas – lookouts, parks, sporting fields
- **Organic Material**

  Residential areas (gardening), Council open space (mowing), leaf fall from trees.
- **Coarse Sediment (>0.5mm)**.

  Land-disturbance during construction particularly building and excavation, erosion, some industrial activities such as sand blasting and concrete sawing, deposition from motor vehicles & car park
- **Fine Particulates**

  Industrial areas, scrap yards, car parks, streets and highways, construction sites, atmospheric deposition.

- **Nutrients.**

  Residential and council gardens (fertilizers), septic tanks and illegal connections, car washing, soils, nutrient released from natural sources such as natural and constructed wetlands connected to the drainage system.

- **Oil and Grease.**

  Roads, car parks, food waste storage areas, heavy equipment and machinery, fast food outlets, Council operations (e.g. depots), home mechanics.

- **Acid Sulfate**

  Soil disturbance with construction, De-watering, Drains constructed through acid sulfate soil areas.

- **Chemicals and Metals.**

  Residential Gardening (Herbicides and Pesticides), Council Operations (e.g. Weed Control & Depot), Specific Industrial Activities, Car Washing Facilities, Car Parks, Rods, Motor Vehicles, Heavy Equipment and Machinery, Areas Treated with Pesticide.

- **Faecal Contamination (Coliforms)**

  Septic Tanks, Illegal connection to the storm water system, Dogs, Ambient sources e.g. birds.

## 2.4 Swale Performance in Removing Run off Pollution

Grassed swales are employed as a new technique to control quantity and quality of urban run off. The primary mechanisms for pollutant removal in swales are filtration by the vegetation, settling of particulates, and infiltration into the subsurface zone (Yu et al, 2001). As run off travel through the swale, the vegetation reduces peak velocity while infiltration reduces flow volumes. Attenuation of run off flow promotes the pollutant removal.

Most studies show that long swales with gradual slopes are more effective at removing pollutants because of increased time settling and physical sites for infiltration. Kaighn and Yu (1996) compared swales of equal length but having different slopes. One of the swales also contained a check dam. Results indicated that pollutant removal was impacted more by the presence of the check than by changes in slope. Yousef et. al, (1985) also agreed that inclusion of check dams in swale design would have significant impact on pollutant removal performance. Another (Colwell 2001) found sufficient flow convergence at slopes greater than 2.5% to result in channelization.

The work of Yu et al. (2001) is reasonably consistent with Kahn et al. (1999). They tested swales with controlled flows at detention times of 5.5, 7, 10, and 18 minutes. Removal efficiencies for TSS were 48%, 70%, 67%, and 86% respectively. These are mass reductions. The role of infiltration was not defined. Backstrom (2002) developed a relationship between performance and detention time using laboratory and field swales. The relationship suggests that if high (about 90%) removal of particles down to 15 microns is desired, a detention time on the order of 8 minutes is necessary for swales with modest or no infiltration. Consistent removal of particles smaller than 15 microns requires a considerably larger detention time according to Backstrom

(2002). A swale with high infiltration appears to require a lower detention time (Backstrom 2002) to obtain the desired performance.

In general, swales show good performance for removal of large particles, such as suspended solids (TSS), however during intense storm, settled particles are potentially subject to resuspension, resulting in net export of pollutant. Export of pollutant has also been reported for nutrients. Investigation of total phosphorus (TP) and total nitrogen (TN) removal swales has indicated that the vegetation itself or fertilization might contribute to nutrient loads, particularly after moving (Patron, 1998). Table 2.3 shows the result of field test at Taiwan and Virginia.

From Table 2.3 we can see, for Taiwan Swale that the most prominent swale feature that enhanced pollutant removal was the presence of the check dam in experiments TA and TB. For all pollutants tested, removal over the entire length of the swale has higher than for tests without the check dam (TC and TD). From this we can concluded that mass removal at the check dam in most cases was higher that at the outlet for the no-check dam experiments.

For Virginia swale, Table 2.3 shows the upper GC swale is the poorest average pollutant removal efficiency. The lower section and entire swale showed good performance as a storm water BMP. This trend demonstrates the significance of swale length and the presence of check dams in terms of quantity and quality of improvements.

## Table 2.3: Pollutant Mass Removal For Test Swales: TSS, COD, TN. and TP (Yu et al, 2001)

| Experiment | Length (in) | Mass Removal % | | | |
|---|---|---|---|---|---|
| | | TSS | COD | TN | TP |
| TA | check dam | 75.2 | 55.7 | 24.2 | 41.2 |
| | outlet | 69.7 | 62.9 | 20.9 | 76.9 |
| TB | check dam | 74.4 | 48.0 | 136 | 340 |
| | outlet | 86.3 | 45.6 | 23.1 | 58 1 |
| TC | outlet | 47.7 | 33.9 | 20.0 | 50.3 |
| TD | outlet | 67.2 | 42.7 | 13.8 | 28.8 |
| GC | upper | 29.7 | NT | NT | 73.4 |
| GC | lower | 9/.2 | NT | NT | 96.8 |
| GC | entire swale | 94.0 | NT | NT | 986 |

Note: "TA, TB, TC, TD" designates Taiwan Swale and “GC” designates Virginia Swale
NT= not tested

One of the researches of the performance of grassed swales was conducted in Central Florida by Harper (1998). Table 2.4 shows the result of Harper’s study. Table 2.4 shows the comparative pollutant mass removal of each swale. It shows that both the wet swale and the dry swale were very effective in removing particulate pollutants contained in highway run off. The dry swale was the best performer in removing pollutants, with mass reduction rates of 70 % or greater for all parameters sampled.

**Table 2.4: Comparative Pollutant removal Performance of Two Swale Systems (Percent Pollutant Mass Removed) (Harper, 1998)**

| Pollutants | Wet Swale (%) | Dry Swale (%) |
|---|---|---|
| Suspended Solids | 81 | 87 |
| BOD (5-day) | 48 | 69 |
| Total Nitrogen | 40 | 84 |
| Total Phosphorus | 17 | 83 |
| Nitrate-N | 52 | 80 |
| Organic nitrogen | 39 | 86 |
| Ammonia | (-11) | 78 |
| Ortho-phosphorus | (-30) | 70 |
| Cadmium | 42 | 89 |
| Copper | 56 | 89 |
| Chromium | 37 | 88 |
| Lead | 50 | 90 |
| Nickel | 32 | 88 |
| Zinc | 69 | 90 |

A study of pollutant removal from vegetated swales was conducted in Texas, USA using laboratory experiments (Walsh et al, 1997), and field monitoring of 34 storms is 86% for TSS, 35% for TP and 37% or TN. And from the laboratory experiment, the result of the pollutant removal is 73-87 % for TSS, 55-65 % for TP and 16-31 % for TN. Increase of flow rates generally decreased the efficiency of pollutant removal.

Another research and controlled experiment on grass swales was taken in Brisbane, Australia (Fletcher et al, 2002). A constant-head tank, discharging through a v-notch weir, provided steady flows in rage of 2 - 15 L/s. Inflows were dosed with a synthetic mix of pollutants similar to the storm water characteristic as follows.

- Total Suspended Solid (TSS) = 150 mg/L
- Total Nitrogen (TN) = 2.6 mg/L
- Total Phosphorus (TP) = 0.3 mg/L

Water quality samples were taken at the inlet, outlet and three points along the swales. Result shows that vegetated swales were effective to decrease pollutants concentration. Reduction in the concentration of pollutants covered the range from 73 - 94 % for TSS, 44 - 57 % for TN and 58 - 72 % for TP. As for load reduction, the ranges were 57 - 88 % for TSS, 40 - 72 % for TN and 12 - 67 % for TP. Removal of TSS is dependent on flow where as the effectiveness of the treatment decrease as the flow rate increase. From the result, we can see that sedimentation and filtration are important for removal of TSS while TP and TN were less effect by flow.

## 2.5 Parameter of Water Quality

Stormwater analysis parameters selected for this study were Total Suspended Solids, TSS, total phosphorus, TP and lead, Pb.

### 2.5.1 Total Phosphorus, TP

TP – Total Phosphorus – Includes inorganic and organic types of phosphorus. An essential chemical element that can contribute to the eutrophication of lakes and other water bodies. Increased phosphorus levels result from discharge of Phosphorus containing materials into surface waters (Csuros, 1994).

### 2.5.2 Total Suspended Solids (TSS)

Total suspended solids (TSS) give a measure of the turbidity of the water. We cannot see pH or other kinds of water qualities, but we can observe TSS directly. Suspended solids cause the water to be milky or muddy looking due to the light scattering from very small particles in the water. Sometimes it is mixed with color, but colored waters can also be clear. Normally, we notice suspended solids before we notice anything else. Polluted waters are commonly turbid and improvement is usually marked by greater clarity. Of course, good and useful waters may be turbid, and many clean rivers are never clear because they contain fine suspended minerals that never settle.

### 2.5.3 Heavy Metal

Heavy metals are elements from a variety of natural and human sources. Some key metals of concern and their primary sources are listed below (Cole et al, 1984):

- Arsenic from fossil fuel combustion and industrial discharges;
- Cadmium from corrosion of alloys and plated surfaces, electroplating wastes, and industrial discharges;
- Chromium from corrosion of alloys and plated surfaces, electroplating wastes, exterior paints and stains, and industrial discharges;
- Copper from corrosion of copper plumbing, anti-fouling paints, and electroplating wastes;
- Lead from leaded gasoline, batteries, and exterior paints and stains;
- Mercury from natural erosion and industrial discharges; and
- Zinc from tires, galvanized metal, and exterior paints and stains

# CHAPTER 3

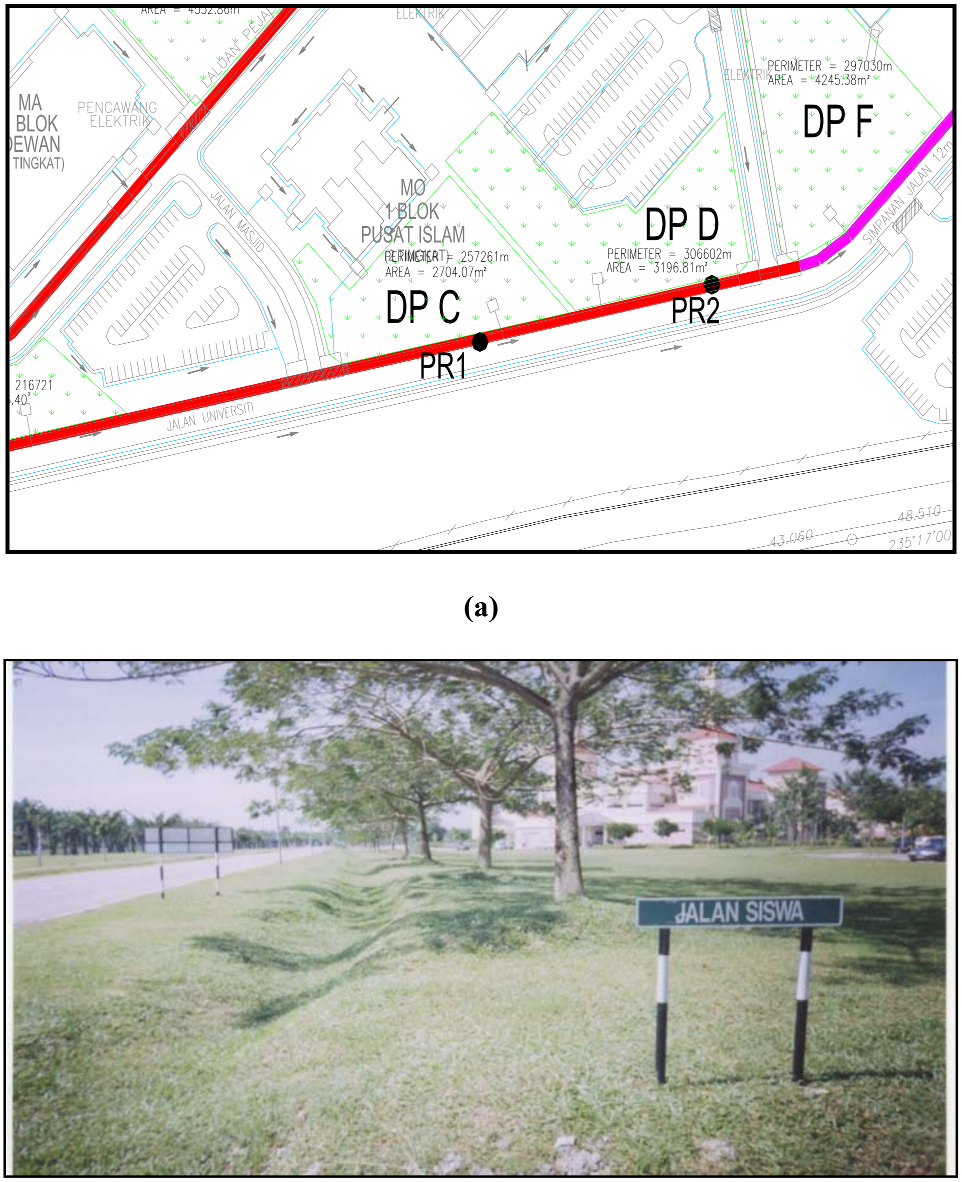
# METHODOLOGY

## 3.1 Location of Study

The study area is located in USM Engineering Campus, Penang. The campus covers 320 acres in Seberang Perai Selatan, located 1.5 km north-east of Parit Buntar Town, 2.0 km south-east of Nibong Tebal Town and 1.5 km north-west of Bandar Baharu Town. Water quality samples were taken at the inlet and outlet of an ecological swale Type A along Jalan Universiti (Figure 3.1), ecological swale Type B along Jalan Ilmu (Figure 3.2) and ecological swale Type C along Permatang Pelajar (Figure 3.3). All the test swale length are75 m. Table 3.1 shows the description of the sampling location for all types of swale.

**Table 3.1: Description of the Sampling Location**

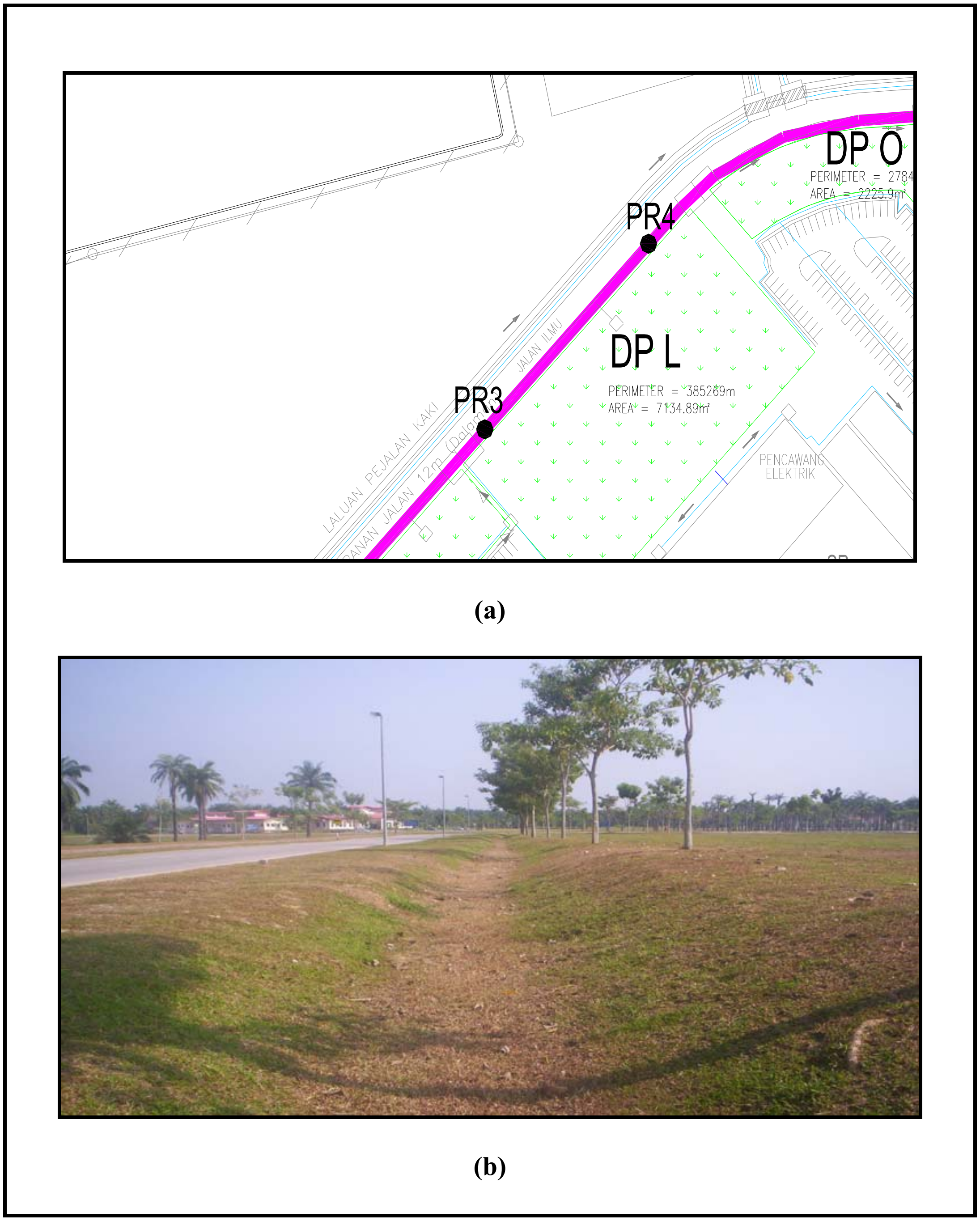
| Type of Ecological Swale | Location | Inlet | Outlet | Swale Length (m) |
|---|---|---|---|---|
| Swale Type A | Jalan Universiti | PR1 | PR2 | 75 |
| Swale Type B | Jalan Ilmu | PR3 | PR4 | 75 |
| Swale Type C | Permatang Pelajar | PR5 | PR6 | 75 |



(a)

(b)

**Figure 3.1: Ecological Swale Type A along Jalan Universiti: (a) Sampling Location; (b) View of ecological swale Type A.**



(a)

(b)

**Figure 3.2: Ecological Swale Type B along Jalan Ilmu: (a) Sampling Location; (b) View of ecological swale Type B.**

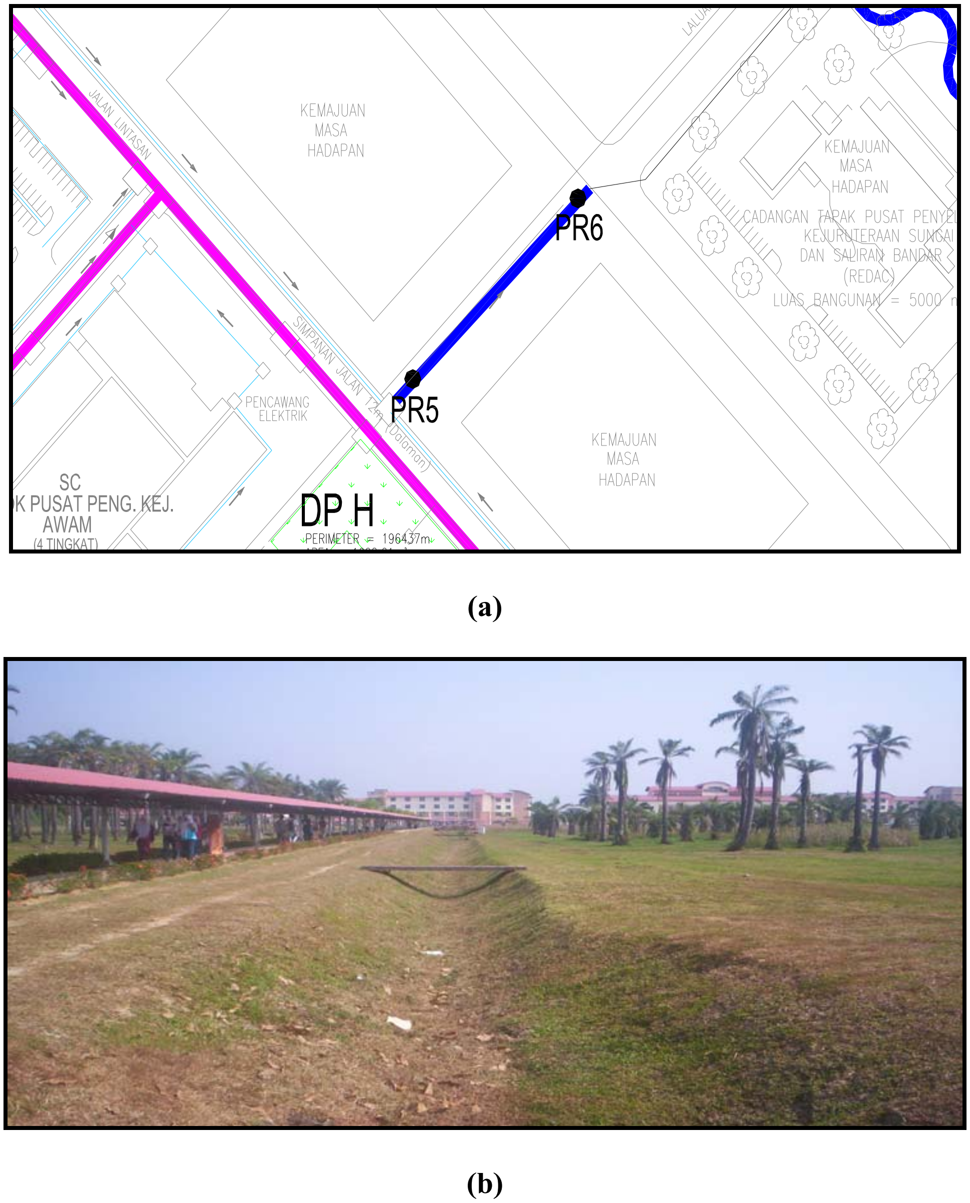


**Figure 3.3: Ecological Swale Type C along Permatang Pelajar: (a) Sampling Location; (b) View of ecological swale Type C.**

## 3.2 Sampling Method

A storm water quality-monitoring is being carried out since August 2004. The water level was measured using measuring tape before sampling was carried out. Samples were taken at inlet and outlet of the selected swale. An amount of 1.5 liters of sample were taken at each sampling point in 1.5 ml plastic bottles. After 10 minutes, samples were taken again at the same points. The samples were stored in cold room at temperature 4° C while awaiting analysis to be conducted.

## 3.3 Analytical Method

Laboratory analyses of the sample were carried out in accordance with the Standard Method for The Examination of Water and Waste Water by The American Public Health Association, 18th Edition, 1992. Monitoring parameters include TSS, TP and Pb.

### 3.3.1 Total Suspended Solids, TSS

The objective of Total Suspended Solids, TSS experiment is to determine the total of suspended solids in the samples. Measurement of suspended solids is done according to gravimetric methods (filter, dry, weight – dominated by large particles) (see Appendix A).The Filtration apparatus is shown in Figure 3.4.

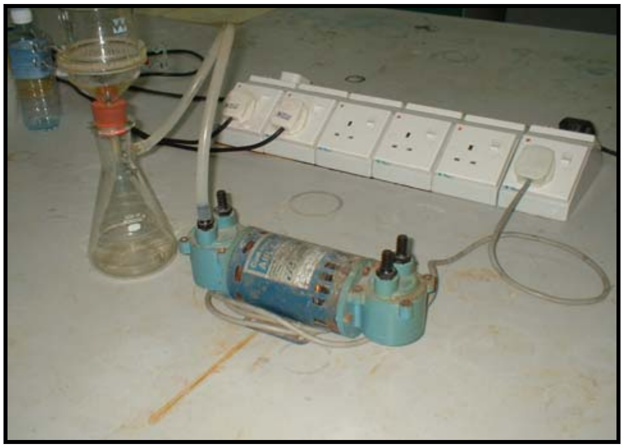


Figure 3.4: Filtration Apparatus

### 3.3.2 Total Phosphorus, TP

The objective of Total Phosphorus, TP experiment is to determine the total of inorganic particles and organic particles in the samples. Samples were pipette into a reaction cell (phosphorus cell) and analyzed according the Standard Method for The Examination of Water and Waste Water by The American Public Health Association, 18th Edition, 1992 (see Appendix A). Spectroquant Nova 60 is used to get the reading of TP (Figure 3.5).

Figure 3.5: Spectroquant Nova 60