PEAK FLOW ATTENUATION USING DRY POND FOR EXISTING HOUSING SCHEMES

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PEAK FLOW ATTENUATION USING DRY POND FOR EXISTING HOUSING SCHEMES

by

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In the name of Allah the Most Gracious and the Most Merciful. Praise and blessings be upon the Holy Prophet Muhammad S.A.W. It is with the Grace and Blessings of Allah that I have been able to complete this thesis finally.

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LIST OF ABBREVIATION

ARI	=	Average Recurrence Interval
BMPs	=	Best Management Practices
BIOECODS	=	Bio-ecological Drainage System
DEM	=	Digital Elevation Model
DID	=	Department of Irrigation and Drainage
Ecopond	=	Ecological Pond
LiDAR	=	Light Detection and Ranging
MSMA	=	Urban Stormwater Management Manual for Malaysia
RMSE	=	Root Mean Square Error
SUDS	=	Sustainable Urban Drainage System
SWMM	=	Stormwater and Wastewater Management Model

LIST OF SYMBOLS

Symbol	Definition
f_o	Initial infiltration capacity
f_c	Final infiltration capacity
K	Horton's Constant
n, N	Manning’s roughness coefficient
P	Total rainfall
Q	Flow rate
R^2	Correlation coefficient
S	Slope
t	Time
W	Width

LIST OF APPENDICE

PENGECILAN PUNCAK ALIRAN MENGGUNAKAN KOLAM KERING BAGI KAWASAN PERUMAHAN SEDIA ADA

ABSTRAK

Pengurusan Saliran Bandar di Malaysia sejak 1975 adalah berdasarkan Manual Rekabentuk Saliran Bandar yang mencakupi perencaan, asas rekabentuk, luahan banjir, rekabentuk saluran terbuka, struktur, storan, dan kawalan hakisan dan endapan. Sehingga 2001, kaedah pengurusan secaran penyaliran cepat telah menyebabkan peningkatan kejadian banjir kilat di kawasan pembangunan baru akibat kenaikan mendadak puncak aliran.

Jabatan Pengairan dan Saliran Malaysia (JPS) mengambil langkah proaktif dengan memperkenalkan manual saliran bandar baru berkuatkuasa 2001 yang dikenali sebagai Manual Saliran Mesra Alam (MSMA). Semua pembangunan baru adalah diharapkan akan menggunakan MSMA dalam merekabentuk sistem Saliran Bandar yang menyarankan kaedah Amalan Pengurusan Terbaik (BMPs). Pelancaran MSMA membolehkan kaedah mampan dilaksanakan yang boleh menyelesaikan masalah banjir kilat yang sering terjadi di kawasan pembangunan baru ketika ini.

Penyelidikan ini menggunakan kaedah mampan bagi sebuah rumah lot di Kota Bharu, Kelantan. Objektif penyelidikan ini adalah untuk mengkaji keberkesanan suatu sistem *swale* – kolam takungan kering dalam mengecilkan puncak dan isipadu aliran selain melihat kesesuaian penggunakan permodelan berasaskan perisian *Stormwater Management Model (SWMM)*. Sistem *swale* – kolam takungan kering telah dibina pada 2001 bagi sebuah rumah lot yang mempunyai keluasan 1556 m^2. Kadaralir yang memasuki sistem itu diukur menggunakan alat aras dan kedalaman hujan direkodkan menggunakan sebuah tolok hujan. Pencerapan data telah dilakukan selama dua

tahun iaitu 2002 dan 2003 dimana sembilan belas kejadian hujan telah berlaku terutama bagi bulan Oktober, November dan Disember.

Keputusan analisis data menunjukkan sistem *swale* – kolam takungan kering yang dibina telah berjaya mengecilkan puncak aliran pada kadar antara 2.94 % hingga 100 % manakala isipadu aliran telah dikurangkan padar kadar 11.69 % hingga 100 %. Bagi kejadian hujan yang kecil, kesemua aliran telah menyusup kedalam kolam kering. Bagi kejadian hujan lebat, terdapat aliran keluar ke longkang di bahagian hilir. Aplikasi perisian XP-SWMM pula telah dapat menyelaku kejadian hujan dan aliran bagi sistem yang dibina tersebut. Keputusan penyelakuan menunjukkan sistem ini mampu untuk mengurangkan puncak dan isipadu aliran bagi kejadian hujan dengan ARI 10 tahun.

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ABSTRACT

Stormwater management In Malaysia has been largely based on 1975 DID Urban Drainage Design Manual that covers essentially the planning, basis of design, flood discharge, hydraulic design of open channels, structures, storm drainage for urban streets, detention storage, erosion and sediment control and information to be submitted with design. Rapid disposal approach adopted in the first manual has led to higher occurrence of flash floods as a result of the increase in surface runoff, peak discharges, shorter flow duration and others.

Department of Irrigation and Drainage (DID) Malaysia is taking a proactive step by introducing new urban drainage manual known as Storm Water Management Manual for Malaysia (Manual Saliran Mesra Alam or MSMA). Effective from 1st January 2001 all new development in Malaysia must comply with the new guideline, which requires the application of Best Management Practices (BMPs) to control stormwater from the aspect of quantity and quality runoff to achieve zero development impact contribution. It is hope that this new strategy will be a sustainable solution to mitigate the existing flood problems but also to prevent the occurrence of such problem in the new developed area.

The present study embarked on using the stormwater management BMPs for an individual house in Kota Bharu, Kelantan. The objectives of the present study on the application of MSMA for an individual house were to seek the attenuation effect of biological swales - dry pond system and the suitability of applying the Stormwater Management Model (SWMM) in simulating rainfall-runoff for the biological swales - dry pond system. The house is actually an old government quarters occupying a land area

of about 1556 m^2. The house was retrofitted to accommodate biological swales and a dry pond with biological subsurface infiltration modular tanks in 2001. The open channel flow was then monitored using ultrasonic water level sensor and an automatic rainfall recorder was also established on site. Data collection was started in 2002 until 2003. Nineteen events were observed especially in the months of October, November and December during the two-year study period.

The flow volume in the swale and dry pond was reduced from 2.94 % to 100 % while the reduction in peak flow ranges from 11.69 % to 100 %. For low depth rainfall events the percentages of volume captured and peak reduction are found to be totally absorbed but for higher depths there will be an outflow which is consistent within the designed limits for the system that is the system should be able to cater for a flow of 10-year ARI before development. Application of SWMM model shows that it is able to simulate the rainfall-runoff of the events for the biological swales - dry pond system used in the present study. The simulations show that the system is capable of attenuations peak flow and volume for events up to 10-year ARI.

CHAPTER 1

INTRODUCTION

1.1 Background

Malaysia is a developing country that aspires to be a developed nation by the year 2020. With this vision Malaysia has embarked on major economic reforms that have transformed many townships into major bustling cities like Kuala Lumpur, Penang and Johor Bharu. The growth of these cities has contributed to extensive growth of impermeable coverage over the ground with building, roads and pavements.

Malaysia is located within the equatorial belt and has a yearly rainfall of approximately 2500 mm/yr for Peninsular Malaysia and 3500mm/yr for Sabah and Sarawak. However the rainfall is unevenly distributed and this has contributed to floods. In early 1926 Kuala Lumpur suffered a major flood due to the Klang and Gombak rivers overflowing their banks. However in 1971 flood of Kuala Lumpur saw the flooding not only caused by the overflowing of the two main rivers but also the inadequacy of urban drains. In the late 1990's and 2000's Kuala Lumpur saw the emergence of flash floods which have caused extensive damage like those of 10th June 2003.

After the 1971 floods the Department of Irrigation and Drainage (DID) was entrusted with the task of flood mitigation. The method then was to quickly dispose of the excess storm water to the receiving water bodies. This traditional technique also called the Rapid Disposal technique have resulted in rivers unable to cope with their increase in runoff due to the rapid expansion of cities. This traditional technique would require cities to enlarge their rivers and drains and the process would be perpetual as long as development continues. It was estimated that to overcome the existing flood problem using this Rapid Disposal technique would cost the government RM10 billion. Thus in 2001 DID introduced a new technique where the storm water will be controlled at source. A new manual called “Storm Water Management Manual for Malaysia” (Manual Saliran Mesra Alam or MSMA) was introduced emphasizing the “control at source” approach utilizing a series of Best Management Practices (BMPs) facilities such as infiltration, detention storage and water quality treatment trains.

Stormwater Management has been practiced in the United States of America, the United Kingdom and Australia. These countries have applied storm water management not only to the overall storm water management facilities like regional ponds and wetlands but to individual homes through Best Management Practices. Their holistic approaches toward storm water management have resulted not only in the reduction of floods especially flash floods but also improved the environment through maintenance of groundwater table levels.

The present study describes the results on the application of a dry pond to attenuate peak flow and temporarily store the storm water for an individual lot house located in Kota Bharu, Kelantan (Ahmad Nasir et al., 2004).

1.2 Research Objectives

The objectives of the research are:

- to study the possibility of using dry ponds on single unit house for reduce peak flow attenuation
- to apply Stormwater Management Model (SWMM) in simulating the rainfall-runoff characteristics of the dry ponds

1.3 Research Methodology

The research methodology is to use a swale to discharge storm water into a dry pond with synthetic modular tanks placed beneath it. The pond is located in a government quarters along Jalan Raja Dewa, Telipot, Kota Bharu in the state of Kelantan. The layout plan of the house shows the storm water facilities provided. The facilities are roof gutters that discharges storm water into swales located at the bottom left and right hand side of the quarters. The swale then leads into the inlet sump which combines the storm water discharges from the left and right side swales. The storm water in the inlet sump is again released into a rectangular concrete channel where storm water inlet flow is measured and recorded. The storm water that is retained in the retention pond will then flow into the synthetic modular tanks where it would later discharge through an outlet channel into the municipal drain located just outside the house fence. The storm water flowing through the outlet channel is again measured and readings are recorded. An automatic pump was placed at the municipal drain to discharge water from the municipal drain should is drain be too full to allow discharges from the outlet channel.

The equipment required for measuring the storm water flow is as follows-

- Open channel flow monitoring system
- Remote data logger
- Rainwise rain logger
- Data acquisition system

1.4 Research Needs

The housing industry has developed tremendously in Malaysia. The technique applied for its drainage system is using rapid disposal system. As the country developed new housing and industrial areas will increase the impermeable layer of the area. The increase in impermeable layer would result higher quantity of runoff that would directly discharge into the rivers and this would the need for the river to be widened. Thus as an area develops there would be a perpetual need to widen the river and this is unsustainable. Therefore a new approach called controlling storm water at source is introduced which could stop this perpetual need to widen the river.

One of the techniques of controlling at source is introducing dry or wet ponds within the development area. However for areas that have already been developed this may be difficult due to space constrained. This study will concentrate at the possibility of building the pond within existing developed areas, the problems associated with its construction as well as its storm water management characteristics.

1.5 Structure of Thesis

This thesis is divided into six (6) chapters. Chapter 1 briefly introduces the research, including objectives and needs for the study. Chapter 2 contains literature review of relevant studies regarding to Urban Stormwater Management Manual for Malaysia (MSMA), control at source approach for several studies in seeking its effectiveness in flow attenuation and few examples of calibration and validation of computer models for urban modeling. Chapter 3 describes the research methodology which was used in this research and site description, including system design, system construction and installation of measurement equipment. In Chapter 4, the results of data collection from 2002 to 2003 confirm the ability of source-control-approach in attenuating peak flow and volume of the runoff. Chapter 5 presents stormwater management model (XP-SWMM) in simulating rainfall-runoff for the swales - dry pond system and Chapter 6 contains conclusions and recommendations for this research. Appendix A provides the nineteen events rainfall collected at the study site from year 2002 to 2003.

CHAPTER 2

STORMWATER MANAGEMENT

2.1 Introduction

The Malaysian economy has gone through rapid structural change since independence in 1957. The urban growth is dynamic in accordance with the rapid economic growth and industrialization. The infrastructure has been strained by rapid urban growth, and there are high need for improvement of amenities, e.g. water supply, electricity, transportation, environment and drainage. In order to make living and transportation possible development by introducing of large impervious areas are constructed. This will result in changes of hydrological cycle. Infiltration and ground water recharge decreases, pattern of surface and river runoff also changes which imposing high peak flows, large runoff volumes and accelerated transport of pollutants and sediment from urban areas. Thus the city influence on the runoff pattern and the state of the ecological systems occurs not only within the city area but also in and around the whole river system downstream.

In 1971, Malaysia suffered serious damage over the whole country due to flood and the importance of effective urban drainage was strongly recognized. The government of Malaysia gave the DID the task of planning and implementation of urban drainage work as part of overall flood mitigation programme (Zakaria et al., 2004).

2.2 Sustainable Urban Drainage System (SUDS) Manual

2.2.1 Background

Rapid disposal, localized, reactive and mono-functional drainage concepts have been widely practiced in Malaysia. The traditional approach widely practiced in

Malaysia is to allow developers to put in drains where appropriate. In Malaysia the architect has more or less to put alignment for drainage, after packing in the most number of housing units allowable in the area. The engineer’s job is only to determine drain size to comply with drainage capacity and final discharge outlet requirements. To further maximize housing density, developers normally channel all drainage to one or large trunk drains. All drains to trunk drains are normally concrete-lined and of the open channel type to minimize the land area required (Embi & Kassim, 1998).

In Malaysia, urban drainage practice has been largely based on the Urban Drainage Design Manual (DID, 1975) that covers essentially the planning, basis of design, flood discharge, hydraulic design of open channels, structures, storm drainage for urban streets, detention storage, erosion and sediment control and information to be submitted with design. The peak discharge estimation method has been widely used, even for large and complex hydraulic structure in large catchment. As a result, cost-effective design and construction has seldom been realized. Practices in Malaysia have thus far relied very much on slight adaptation or even direct use of temperate region-based urban rainfall/runoff design procedures and computer model.

The approaches to the design procedure, in terms of method and technique employed, have not been reviewed and upgraded although advances in urban drainage and stormwater management technologies are being practiced widely in overseas. In relation to the contents of the former manual, some recognized weaknesses are associated with institutional and legal issues, strategic/ master planning concepts, discharges estimation, minor and major drainage facilities, computer simulation and runoff quantity and quality controls. These were either inadequately covered or not included in the manual.

Rapid disposal approach as adopted in the first manual has led to an increase in the occurrence of flash floods as a result of the higher surface runoff, peak discharges, shorter flow duration and others. Beside that, polluted water, garbages and floating litters and sedimentation in the river system are on the rise because of the weakness in the current practice. Widening and channeling rivers and drain to cater for increased discharges as the urban area develops are inherently defective from the environmental point of view. As the urban areas continue to expand in all towns in Malaysia the demand will continue to increase. DID have estimated RM10 billion to mitigate the current existing flood problem. If the country continues to urbanize, the flood problem continue to increase (Zakaria & Ainan, 2000).

Due to this problem, Department of Irrigation and Drainage (DID) Malaysia is taking a proactive step by introducing a new urban drainage manual known as Urban Stormwater Management Manual for Malaysia (MSMA). Effective from 1st January 2001 all new development in Malaysia must comply with new guideline, which requires the application of Best Management Practices (BMPs) to control stormwater from the aspect of quantity and quality runoff to achieve zero development impact contribution. It is hoped that this new strategy will be a sustainable solution to mitigate the existing flood problems besides inhibits the occurrence of such problem in the new developed areas. The introduction of this new concepts for application for the new development, DID has received a good response from the other agencies such as developers, local authorities and Non-government body (NGO) as it covers wider scope and need to consider all factors of development that can give rise the occurrence of flood. The challenge is to ensure that the administration of the planning, design and maintenance of stormwater management systems is consistent across the relevant local, State and Federal Authorities and the professions of planning, environmental and civil engineering and landscape architecture.

2.2.2 MSMA Overview

Urban Stormwater Management Manual for Malaysia or better known in Malaysia as *Manual Saliran Mesra Alam (MSMA)* is prepared by Department of Irrigation and Drainage Malaysia to replace the old Manual “Planning and Design Procedure No.1: Urban Drainage Design Standard for Peninsular Malaysia” (DID, 1975). The main focus of Urban Storm Water Management Manual (DID, 2000) is to manage the stormwater instead of draining it away as fast as possible to a more environmentally approach known as control at source approach. This approach utilizes detention/retention, infiltration and purification processes. The quality and quantity of runoff from developing areas could be maintained to be the same as pre-development condition from the aspect of quantity and quality runoff, which is also known as uncontaminated zero contribution to the peak discharge. This manual also considers the current existing problem such as flash flood, river pollution, soil erosion, hill development and etc. Various department, non-government department and expertise from overseas have evaluated this manual. A new technology that is based on control at source method was documented in this manual.

This new approach is more environmental and capable of integrating other facilities. Examples are landscape area and temporary stormwater storage facilities in car parks and play grounds. At the Federal Government Administrative Center in Putra Jaya, this new approach has been applied by incorporating the lake and wetland as storage and purifier of stormwater. This new approach in other development but this new approach is still new in Malaysia and is expected that it will probably take fifteen (15) years without proactive initiatives this method will accepted widely among the Malaysian. Department of Irrigation and Drainage has prepared this manual with the hope this concept would be immediately implemented and administered in a systematic manner with a faster approach. Therefore the goal of this manual is to provide guidance to all regulators, planners and designers who are involved in the stormwater management in urban areas in Malaysia.

Under this new direction, stormwater management in Malaysia will have a multiple objectives including to (Zakaria et al., 2004):

- Ensure the safety of the public
- Control nuisance flooding and provide for the safe passage of less frequent and larger flood events.
- Stabilize the landform and control erosion
- Optimize the land available for urban development
- Minimize the environmental impact of urban runoff on water quality
- Enhance the urban landscape.

The concept of stormwater management control is relatively new in Malaysia and a paradigm shift would be required to turn around traditional concept of drainage engineering practices based on rapid disposal towards this new concept. The new manual draws on various approach of "Best Management Practices (BMPs)" now is being practices worldwide, to control the quantity and quality runoff through detention/retention storage, infiltration facilities, engineered water way which are capable to retard the flow. The manual explains the design of each stormwater management control component in separate chapters. Figure 2.1 shows some typical measures suggested in the manual. The manual also has its limitation in that being newly introduced it may be lacking in many aspects representing the peculiarities of the stormwater process/practices occurring in the country.

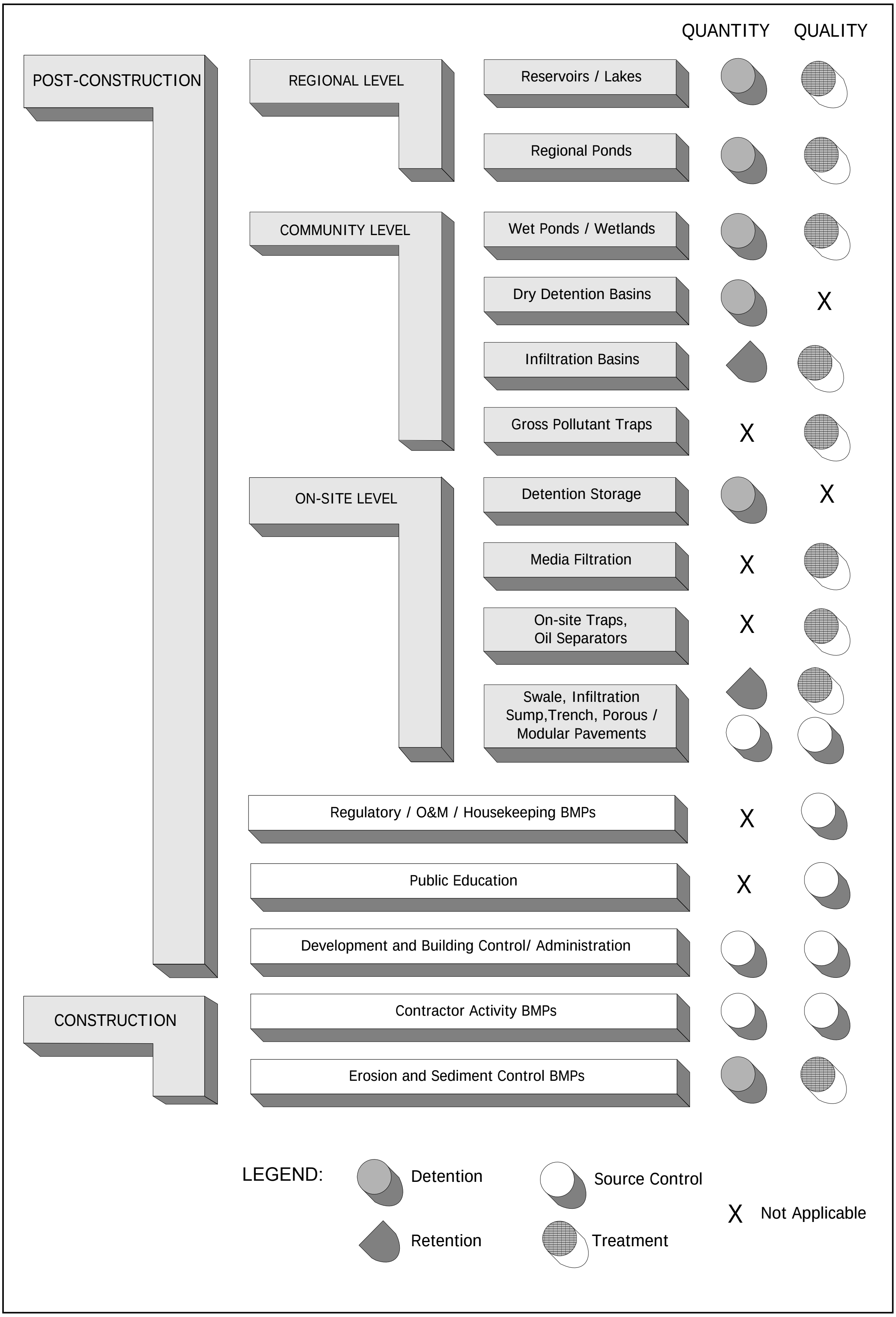

Figure 2.1: Measures to control Quantity and Quality Runoff (DID, 2000)

The manual has forty eight (48) Chapters. It is divided into nine (9) Parts according to different main topics that from the manual. The manual is published in twenty (20) volumes with each part A, B, and C in one volume, Part E and H in two volumes and Part D. F. G and I in three volumes. The last volume contains references, glossary, subject index and abbreviations.

The first three parts contain background information on environmental process and stormwater management, administration aspects and planning processes. The remaining parts contain detailed information on hydrology and hydraulic, runoff quantity control and conveyance, source and treatment runoff quality controls, runoff quality controls during construction and special stormwater applications. Figure 2.2 shows the requirement that the quantity and quality of runoff from developing area should be maintained to be the same as pre-development condition. Figure 2.2 shows suggested measure to achieve the aim of uncontaminated zero peak discharge contribution.

A technical visit to Sydney and Canberra, Australia was made in August 2001 by DID headed by its Director General, Datuk Ir. Hj. Keizrul Abdullah. Figures 2.3 to 2.7 show some of the stormwater management measures constructed in Sydney and Canberra.

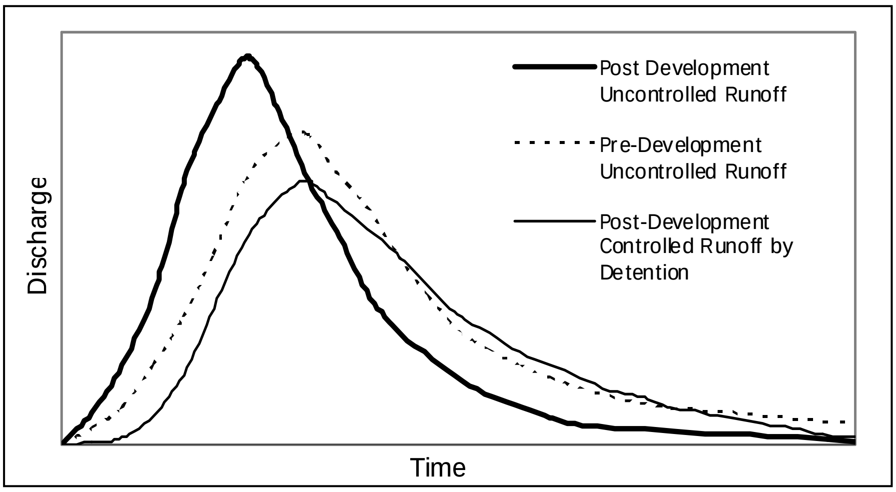

Figure 2.2: Zero Uncontaminated Discharge Principle (Zakaria et al., 2004)

Figure 2.3: Gross Pollutant Trap (After DID Malaysia)

Figure 2.4: Swale (After DID Malaysia)

Figure 2.5: Wet Pond (After DID Malaysia)

Figure 2.6: Dry Ponds (After DID Malaysia)

Figure 2.7: Wetland (After DID Malaysia)

2.2.3 Bio-Ecological Drainage System (BIOECODS)

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 Seri 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 Sungai Kerian in Kedah). The area of the campus is about 320 acres, formerly an oil palm plantation and the land 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 into a constructed wetland. 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, this system will increase runoff lags time, increase opportunities for pollutant removal through settling and biofiltration, and reduce the rate and volume of runoff through enhanced infiltration opportunities (Ab. Ghani et al., 2004).

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. 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 areas are 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, the wetland provides 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 at downstream. Although BIOECODS are drainage devices that rely on natural processes, it must be designed, built and maintained in the context of the development control system in Malaysia.

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 2.8a and the flow sequence can be summarized in Figure 2.8b. The present study considers swale and dry pond system for a single house.

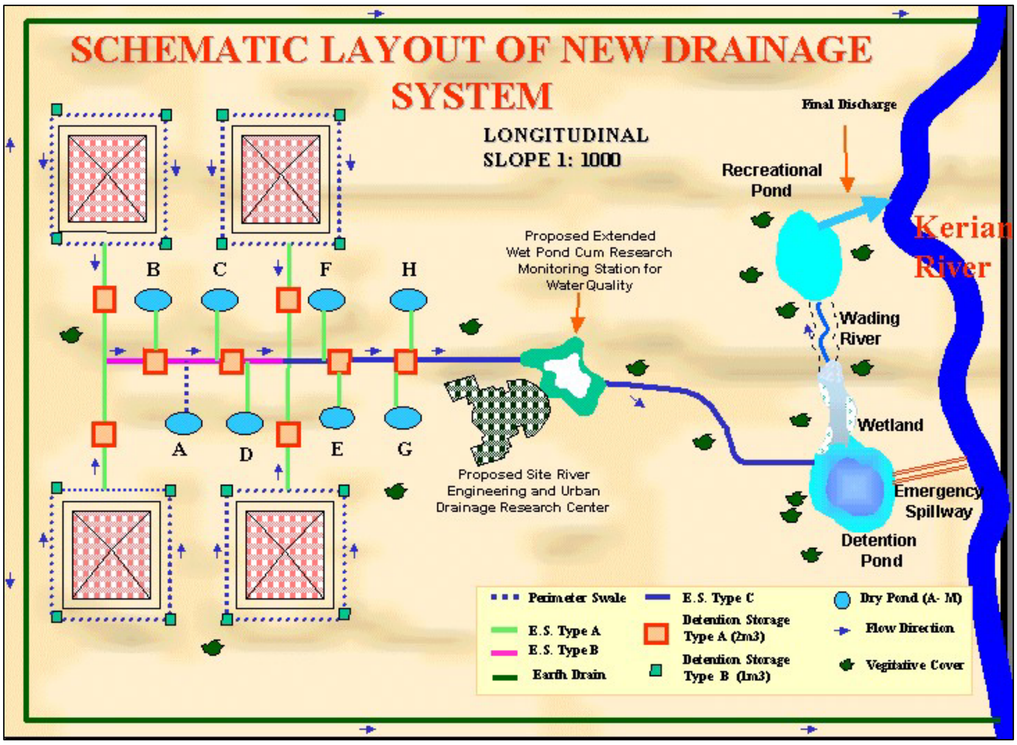

Figure 2.8a: Schematic Diagram of BIOECODS

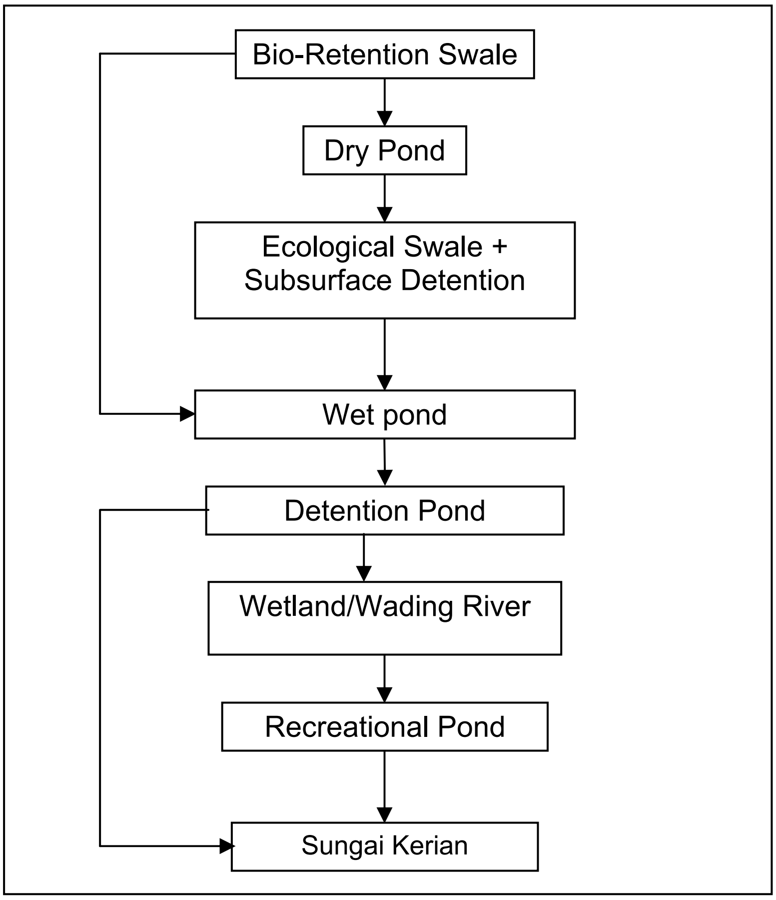

Figure 2.8b: Flow Sequences of BIOECODS

a) The perimeter swale (Figures 2.9) 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 geostrip enclosed within a permeable geotextile design.

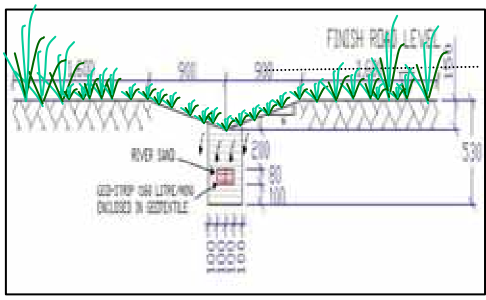

Figure 2.9a: Typical Cross Section of Perimeter Swale

Figure 2.9b: Typical 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 2.10) and Type C depending on the size and capacity. Type A consists of one module, Type B consists of two modules and Type C consists of three modules.

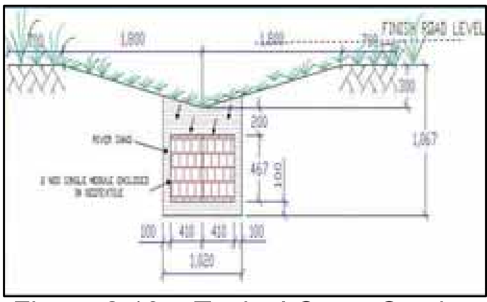

Figure 2.10a: Typical Cross Section of Ecological Swale Type B

Figure 2.10b: 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 2.11) 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.

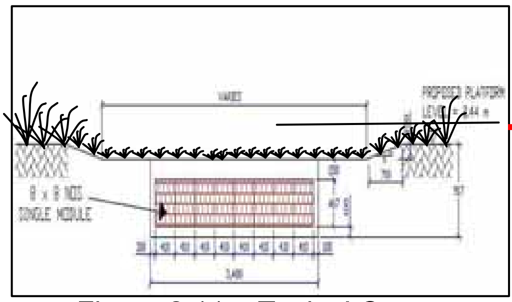

Figure 2.11a: Typical Cross Section of Dry Pond

Figure 2.11b: View of Constructed Dry Pond

e) All of the excess water from built-up areas flows via a wet pond (Figure 2.12) to a detention pond (Figure 2.13).

Figure 2.12: View of Wet Pond

Figure 2.13: View of Detention Pond

f) With respect to the need for water quality improvements, the wetland (Figure 2.14) 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. 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 2.15).

Figure 2.14: View of Wetland

Figure 2.15: Recreational Pond

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

h) The material that is being used in this BIOECODS construction (Figure 2.16) are:

- Module – size of 410mm x 467mm x 610mm
- Hydronet Filter Fabric – permeability capacity of 9.30mm/s
- Clean/washed river sand – passed sieving test of BS 1377 (0.5mm - 0.2mm)
- Topsoil – thickness of 25mm-50mm
- Cowgrass

(a) Geostrip

(b) Module

(c) Hydronet

(d) River sand

(e) Topsoil

(f) Cow grass

Figure 2.16: Components of an Ecological Swale

2.3 Overseas Studies

Parkinson & Mark (2005) summarize the objectives of sustainable urban drainage system as given in Table 2.1. The design of sustainable urban drainage system is based upon principles of ecological engineering, which aim to preserve natural drainage patterns and emulate the natural hydrological cycle. Prevention or mitigation of runoff problems at source (both in terms of quantity or quality) is regarded as the key principle for the design of sustainable urban drainage. From a perspective of control runoff this involves the use of infiltration and reuse of stormwater runoff, which results in other benefits, related to groundwater recharge and reduced demands for water supply. From a perspective of reducing the polluting impacts of runoff, source control strategies involve measures to reduce the contamination of runoff by various pollutants that are commonly found in stormwater discharges. Table 2.2 summarizes the benefits of these technologies and Table 2.3 provides an overview of their mode of operation in relation to their location in the catchment.

Table 2.1: Objective of Sustainable Urban Drainage (Parkinson & Mark, 2005)

Objective	Description
Reduce runoff and protect urban areas from flooding	Minimise changes to the hydrological characteristics of a catchment caused by new developments and introduce technologies, which aim to restore natural runoff flow characteristics.
Conserve water resources	Promote infiltration of rainwater to replenish groundwater and utilize technologies to collect and store runoff to use for various low-grade applications.
Preserve natural habitat and biodiversity	Maximize the extent of flora and fauna in and surrounding urban watercourses to promote nature conservation and biodiversity.
Promote amenity value of water in the urban environment	Encourage the use of urban watercourses as areas for leisure, amenity and environmental awareness.

Table 2.2: A Comparison of the Benefits of Various Technologies (Parkinson & Mark, 2005)

	Runoff control	Water resources	Pollution control	Conservation	Amenity
Runoff reuse	√	√			
Permeable paving	√	√			
Infiltration trench	√	√			
Soakaway	√	√			
Swale	√	√	√		
Infiltration basin	√	√			
Constructed wetlands	√	√	√	√	√

Table 2.3: Description of Various Technologies for Control of Runoff and Pollution from Urban Areas (Parkinson & Mark, 2005)

Source Control	
Rainwater reuse	Reuse of rainwater on-site by household collection and storage of roof runoff or off-site collection in ponds for communal low-grade use
Permeable paving	Permeable paving utilizes porous materials for urban surface (e.g. porous asphalt, or concrete), which allow stormwater infiltration into the surrounding soils.
On-site	
Infiltration trench	Infiltration trenches are ditches filled with porous media designed to encourage infiltration of runoff to the groundwater
Soakaway	A soakaway is filled with a porous media, which allows runoff to infiltrate into pervious soils. It may require drilling impervious layers to reach lower pervious layers, which allow surface water to infiltrate into groundwater.
Swale	Swales are open drainage channels containing vegetation on the bottom to trap pollutants.
Off-site	
Infiltration basin	A type of detention basin that stores stormwater runoff to promote infiltration and restore groundwater resources.
Constructed wetland	Wetland basins are areas designed to store and attenuate flow with the use of reeds or other type of wetland vegetation to trap sediments and associated pollutants.

Abida et al. (2007) presents the modeling approach, model calibration and validation using experimental and field data (Figure 2.17), and finally a sensitivity analysis that examines the effects of the various design parameters, resulting in the development of design guidelines. The presented model, ANSWAPPS, is developed for the analysis of grass swales and perforated pipe systems. It was calibrated and validated against laboratory and field data. The model was also tested with various theoretical scenarios and was found to give consistent results. Nevertheless, in view of the model's computational procedures and theoretical background, the model does have limitations and should, like any other model, be used with care and good engineering judgment. The model is developed on a lot by lot basis with pipe lengths less than 150 m and selected computational time steps varying between 1 and 2.5 min. Simulated flows to be conveyed in the pipe should not exceed the pipe capacity, and the pipe and swale slopes must be positive.

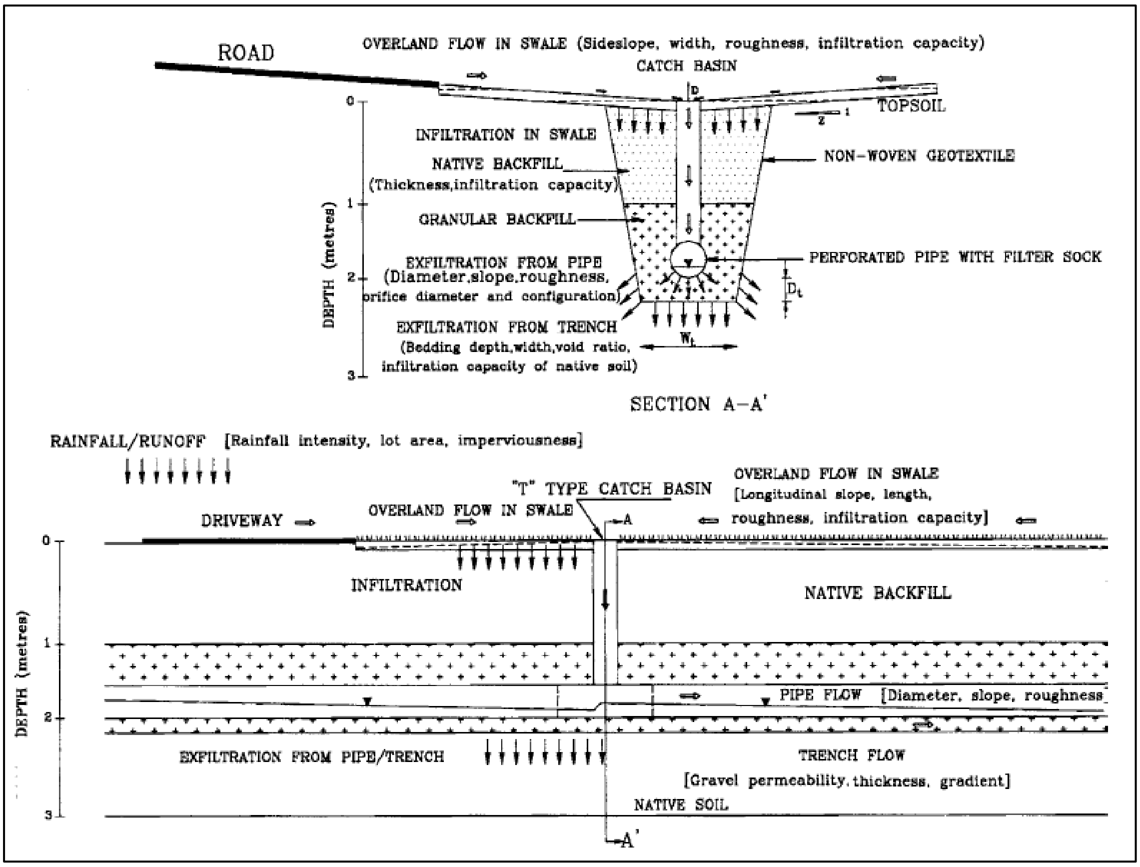

Figure 2.17: Schematic of Grass Swale-perforated Pipe Drainage System