CERTIFICATION OF APPROVAL

NPS MODELING OF SUNGAI PINANG CATCHMENT AREA
&
WATER QUALITY IMPROVEMENT BY USING BIORETENTION

by

Salihah Binti Sombar @ Abdul Hamid

A project dissertation submitted to the
Civil Engineering Programme
Universiti Teknologi Petronas
in partial fulfillment to the requirement for the
BACHELOR OF ENGINEERRING (Hons)
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Approved by,

....

(Assoc.Prof. Dr. Nasiman Bin Sapari)

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TRONOH, PERAK
July 2008

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the *original work in my own respect as specified in the references and* acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

....

(SALIHAH BT. SOMBAR @ ABDUL HAMID)

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ABSTRACT

One of the major problems facing the Department of Environment nowadays is the pollution of rivers with suspended solid coming from non-point source pollution in urban areas. This project is related to the improvement of water quality inside the river by applying the bioretention before the runoff from construction areas enters the river. It will involve the quality modeling by using specific software that was developed in Australia called the Model of Urban Stormwater Improvement Conceptualization (MUSIC) in order to predict the percentage removal of TSS (Total Suspended Solid), TN (Total Nitrogen) and TP (Total Phosphorus). The other methods involved in this project which are data gathering, construct the physical model of bioretention, laboratory and data analysis. From the predicted and laboratory analysis, bioretention can removes about 80-90% of TN, 80-85% of TSS, and 70%-83% of TP. The laboratory model was tested under Malaysia condition using soil in Seri Iskandar area. The testing was based on column studies representing bioretention to improve the water quality of a stream in UTP campus. The predicted model represents the water quality of Sungai Pinang in Penang. The performance of the laboratory model was comparable to the predicted model but the performance of laboratory model was slightly lower probably due to acclimatization period. The bioretention should be acclimatizing at least two months in order to achieve the good results.

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In the name of ALLAH S.W.T, The Most Gracious and The Most Merciful for the blessings and strength to complete this project.

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TABLE OF CONTENTS

LISTS OF ILLUSTRATIONS

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDIXES

CHAPTER 1

INTRODUCTION

1.1 Introduction

Nonpoint source (NPS) pollution unlike pollution from industrial and sewage treatment plants comes from many diffuse sources. NPS pollution is caused by rainfall or snowmelt moving over and through the ground. As the runoff moves, it picks up and carries away natural and human-made pollutants, finally depositing them into lakes, rivers, wetlands, coastal waters, and even our underground sources of drinking water.

The extents of NPS pollution issue were based on the nature and land uses on which the rain falls. The volume and rate of runoff increases as the amount of paved impervious surface area increased. Storm water flowing over roofs, streets, lawns, commercial sites, industrial areas, and other permeable or impermeable surfaces transport many kind of pollutants into surface and ground waters. Rain washes sediments from bare soil; picks up nutrients from fertilized lawns and crops; and carries coliform bacteria from animal wastes into receiving waters, transports heavy metals, oils, and greases deposited on streets and parking lots by motor vehicles.

These pollutants include:

- the source from agricultural lands (such as excess fertilizers, herbicides, and insecticides) and residential areas;
- the urban runoff and energy production (such as oil, grease, and toxic chemicals)
- eroding stream banks, sediment from improperly managed construction sites, crop and forest lands, and;
- salt from irrigation practices and acid drainage from abandoned mines;

- bacteria and nutrients from livestock, pet wastes, and faulty septic systems;

Non-point pollution can give harmful effects on drinking water supplies, recreation, fisheries, and wildlife.

This project has been started by preparing the modeling simulation with ***MUSIC (Model for Urban Stormwater Improvement Conceptualization) application***. The results that can be computed by using MUSIC are the water quality of Sg. Pinang, curve for TSS, TP and TN concentration and the percentage removal of those parameters after applying the treatment measures. The predicted results in MUSIC will be compared with the actual result in the laboratory by using the real physical model of bioretention. The effectiveness of the bioretention in improving the water quality in the polluted river in tropical environment is expected to vary according to flow rate and residence time.

The study area named ***Sungai Pinang Catchment*** lies within the Latitude of 5° 21′ 32″ to 6° 26′ 48″ N and Longitude of 100° 14′ 26″ to 100° 19′ 42″ E. It is located on the north-eastern coast of Penang Island. This project area mainly comprises the urban areas of Georgetown, Air Itam, Paya Terubong towns and their vicinity. The satellite image over Sungai Pinang Catchment is shown in Figure 1.

Based on the topographic map, the natural Sungai Pinang catchment has a total area of approximately 51 sq. km. However due to Sg. Jelutong river diversion, the study area is reduced to approximately 47 sq. km. The topography of study area is shown in Figure 2. The study area is located within the North-East District of Timur Laut and comprises 7 sub-districts as shown in Figure 3.

Figure 1: Satellite Image over Sungai Pinang Catchment

Figure 2: Topographic Map of Sungai Pinang Catchment Area

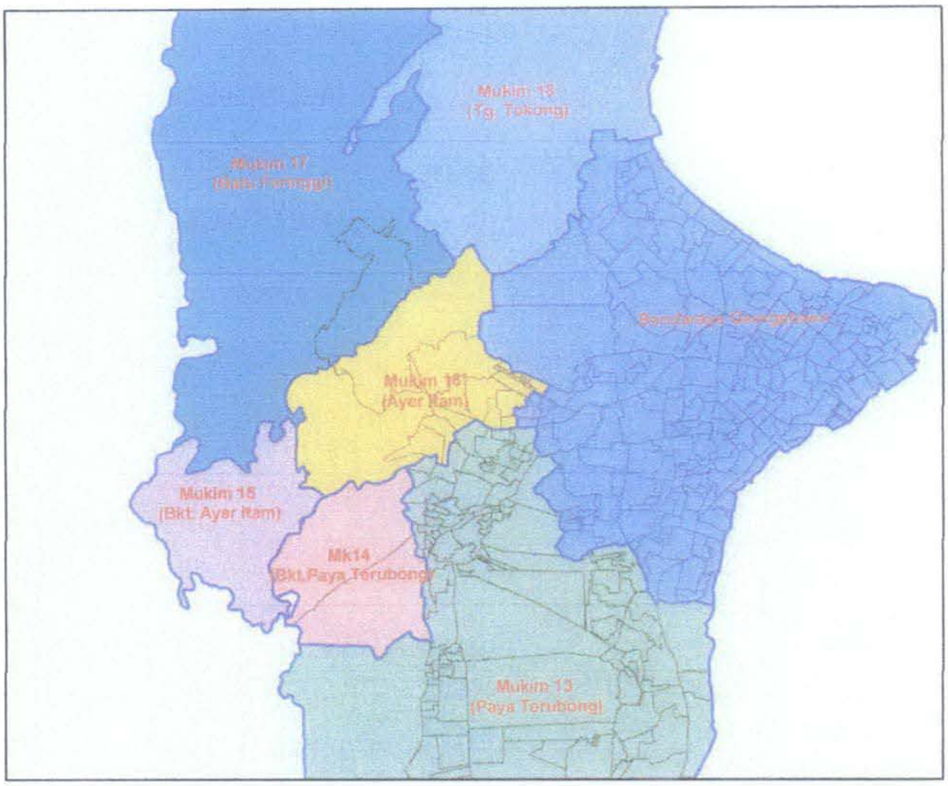

Figure 3: Sub-district of the Study Area

Sg. Pinang basin is heavily urbanized in certain areas, especially at the lower part of the catchment and at the some part in upper part of Sg. Dondang. The urbanized area is more than 40% of the total urban areas in Penang Island and consists of residential, commercial, industrial, administrative and institution, recreation/open spaces and cemeteries. The extent of clearing in the basin through the progressive development of urban and agricultural land and associated infrastructures has been enormous. The built up areas mainly serves the residential and commercial needs, but concentrated industrial areas exist within some of the urban areas. The hilly slopes and the upper catchments retain largely the rural character.

Sg.Pinang consists of several tributaries. These tributaries are Sg. Jelutong, Sg. Air Terjun, Sg. Air Itam, Sg.Dondang, Sg. Air Putih and Sg.Kecil. The river system along with its catchment boundaries are shown in Figure 4.

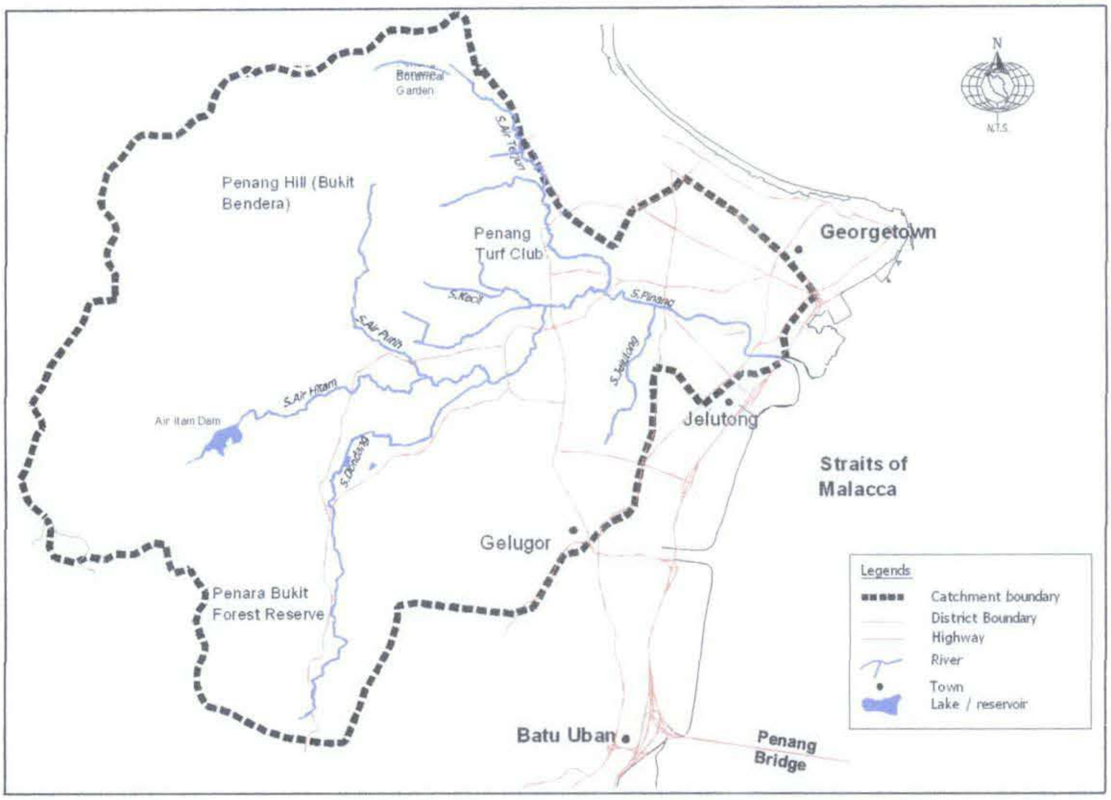

Figure 4: River System within Sg. Pinang Catchment

Among these tributaries, Sg. Air Itam is the largest and it has a length of 11 km. Sg. Kecil is the smallest tributary with its length 4 km. The length, size of sub-catchment and as average flows are shown in Table 1. Sg. Air Itam is regulated by a water supply dam located at the upstream part. Most of Sg. Pinang and its tributaries have been channelized and straighten during the development of the surrounding area.

Table 1: Physical Parameters of Sg. Pinang and Its Tributaries

Name River/Tributary	Catchment Area (sq. km)	Length (km)	Slope (%)
Sg. Jelutong	6.59	5.94	2.2
Sg. Air Itam	11.69	12.88	3.7
Sg. Air Terjun	10.76	9.30	6.9
Sg. Dondang	11.33	6.97	1.9
Sg. Air Putih	**4.56**	**3.89**	**8.6**
Sg. Kecil	2.42	2.64	8.8

1.2 Objectives

The objectives of the project are as follows:

1. To determine the water quality of Sungai Pinang catchment using MUSIC software;
2. To predict the performance of bioretention as a treatment measure (by *simulation using* MUSIC);
3. To assess the efficiency of bioretention using laboratory model in order to improve the water quality of the river.

1.3 The Scope of Studies

The scope of studies covers on the quality improvement include Total Suspended Solid, Total Phosphorus (Phosphorus is a nutrient that occurs in many forms that are bio available) and Total Nitrogen. The preliminary task which is predicating the water quality had been successfully completed in the first semester and during the second semester the focus was to find the actual result from the laboratory model.

The result of percentage reduction of TSS, TP and TN value will be presented in the form of the graph and will be compared with the model of bioretention generated by the MUSIC software. The cross-section has been properly scaled as compared with the real specific sub-catchment of the Sg. Pinang **(Sg. Air Putih).** The total area of bioretention on the site is about 2-3% of that specific river catchment area. Figure 5 shows the Sungai Air Putih catchment area presented in water quality modeling by using MUSIC software.

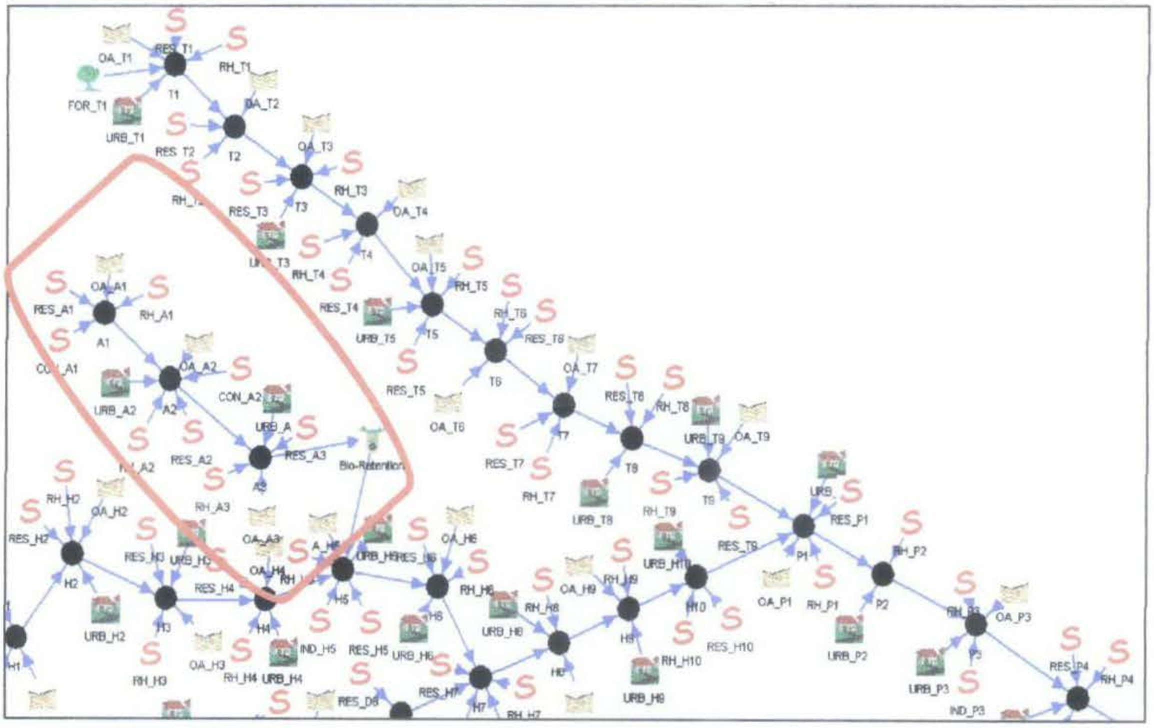

Figure 5: Sungai Air Putih Catchment Area in Water Quality Modeling (by using MUSIC software)

CHAPTER 2

LITERATURE REVIEW

2.1 MUSIC APPLICATION

2.1.1 Introduction

MUSIC is the Model for Urban Stormwater Improvement Conceptualisation, developed by the MUSIC Development Team of the Cooperative Research Centre for Catchment Hydrology (CRCCH) in Australia.

MUSIC provides a simulation tool for quantity and quality of runoff from catchments. It was designed to operate at a range of temporal and spatial scales ranging from a single house block up to many square kilometres or to be more specific it can cater for catchment areas from 0.01 km^2 to over 100 km^2.

2.1.2 Background

Most of the current initiatives to protect the aquatic environment have focused on point sources of pollution, such as sewage discharge and industrial effluent.

Building on the success of these initiatives, the attention is now turning to diffuse sources of pollution, such as urban stormwater which is recognized as a major carrier of urban pollutants. (MUSIC-Help, 2000)

The initiatives to manage stormwater require a *catchment-wide* approach and the diffuse sources of stormwater pollution also demand a *multi-disciplinary* approach. It may also necessary to integrate a range of urban planning and design disciplines, including urban hydrology, land-use planning, and landscape design and asset life-cycle economics. (Wong T.H.F, 2001)

Unfortunately, many planning department do not have sufficient knowledge or skills in relevant disciplines, in order to fully integrate the various discipline.

The main purposes of the MUSIC application in urban stormwater management are as follows:

i. To determine the likely water quality emanating from specified catchment;
ii. To predict the performance of the specific stormwtaer treatment measures in protecting receiving water quality;
iii. To design an integrated stormwater management plan for each catchment;
iv. To evaluate the success of specific treatment measures or the entire catchment plan, against a range of water quality standards.

The Cooperative Research Centre for Catchment Hydrology (CRCCH) organized the Urban Stormwater Quality Research program to further discuss about these deficiencies. The program's research has concluded in MUSIC. MUSIC can be used to predict the performance of stormwater systems as an aid to decision-making. This alternative is intended to help organizations to plan and design (at a conceptual level) their appropriate urban stormwater management systems for their specific catchments. Figure 6 shows the broad framework defining the structure of the MUSIC model and the research projects undertaken by the CRCCH in order to continually improve the predictive capability of the model.

Wong et al. (2001) describe that MUSIC had been developed for urban catchment to evaluate stormwater management systems in integrated manner. It is not a detailed design tool but it just a decision support system. It is one of the tools that can be used to evaluate conceptual design of possible stormwater management system for their catchments. This evaluation is needed in order to ensure that management meet the pre-specified water quality objectives, and obtain analytical size of the various stormwater quality treatment facilities selected.

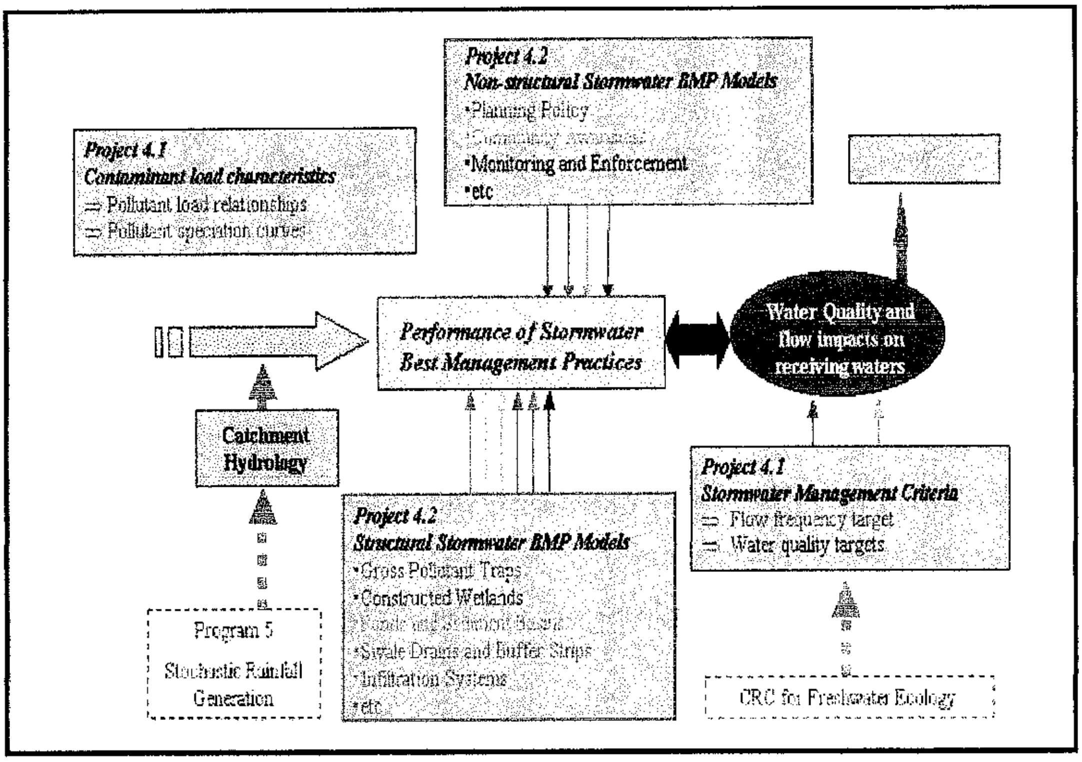

Figure 6: Framework of the MUSIC Model and Associate CRCCH Research
(after Wong T.H.F, 2001)

2.1.3 Modeling Philosophy

As stated before MUSIC is an aid to decision-making which enable the users to evaluate conceptual designs of stormwater management systems for their catchments. MUSIC determines whether the proposed system can meet specified water quality objectives by simulating the performance of stormwater quality improvement measures.

MUSIC will simulate the performance of group of stormwater management measures, whether it was configured in series or parallel in order to form a "treatment train". Basically, MUSIC runs as continuous basis and on an event, allowing accurate analysis of the proposed strategies over the short-term and long-term. (MUSIC Help, 2000)

The effectiveness of a stormwater management system is evaluated based on a risk-based approach associated with examination of:

(i) the long-term frequency in which the receiving aquatic ecosystem is subjected to exposure of pollutant concentrations above a pre-specified threshold level and/or

(ii) the long-term mean annual pollutant load delivered to the receiving waters.

As stated before, MUSIC is designed to simulate stormwater systems in urban catchments and to operate at a range of temporal and spatial scales suitable for catchment areas from 0.01 km^2 to 100 km^2. Modeling time steps can range from 6 minutes to 24 hours to match the range of spatial scale.

There are two cautionary notes about appropriate application. Firstly, MUSIC is not a detailed design tool because it does not contain the algorithms necessary for detailed sizing of structural stormwater quantity or quality facilities. MUSIC is just a conceptual design tool. MUSIC does not currently incorporate all aspects of stormwater management that decision-makers must consider. That is why MUSIC should be only one of several tools used in Water Sensitive Urban Design because factors other than stormwater quality (e.g. land and soil characteristics, amenity, passive recreation, and landscape design) also influence Water Sensitive Urban Design. Hydraulic analysis for stormwater drainage, indicators of ecosystem health, and the integration of urban stormwater management facilities into the urban landscape are not considered in the model.

2.1.4 Modeling Catchment Hydrology

Most of the stormwater runoff in urban catchments is generated from the impervious surfaces. The important key in estimating runoff is the fraction of effective impervious area. All the rainfall on the effective impervious surface becomes runoff after an initial loss satisfied. It is due to water filling the surface depression pore.

Average annual runoff can be estimated by the following equation;

$$\text{Runoff} = r_{ci}\, A_i\, \text{Rainfall} + r_{cp}\, (1-A_i)\, (\text{Rainfall} + \text{Outdoor Water Use})$$

A_i : fraction of effective impervious area in the catchment

r_{ci}, r_{cp} : runoff coefficient (proportion of rainfall that becomes runoff) in the impervious area and pervious area, respectively.

Chiew et al. [1997] developed the algorithm that can be adopted to generate urban runoff, which is based on a simplified model involving definition of the impervious area and two soil moisture storages like the shallow and deep soil moisture storages, as shown in Figure 7. That model was initially developed as a daily model and then was modified to enable disaggregation of the generated daily runoff into sub-daily temporal patterns.

Runoff routing through the catchment is undertaken using the *Muskingum-Cunge* flood routing algorithm.

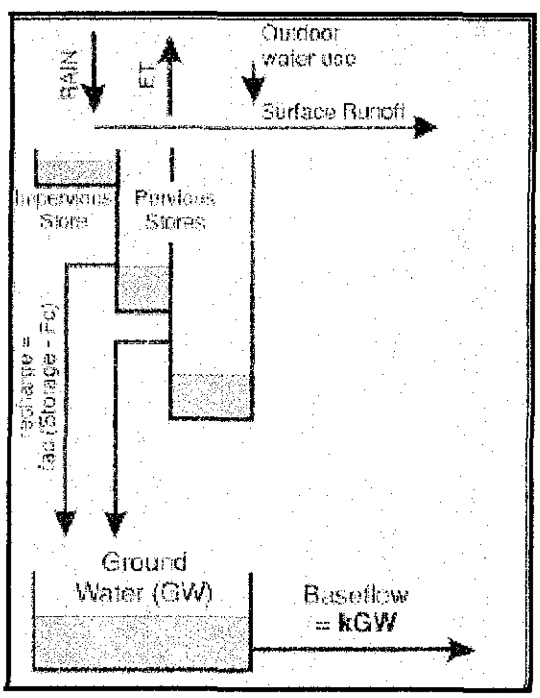

Figure 7: Conceptual Rainfall-Runoff Model adopted for MUSIC

(after Chiew et al., 1997)

Based on the model above, there are three different parts. As mention before, all the daily rainfall in the effective impervious area becomes runoff once the daily initial loss is satisfied. The remaining areas are two separate parts with different storage capacities (related to soil depth). The first has a smaller storage capacity and represent parts of the catchment that saturates easily. The second represents the remainder of the catchment with greater soil storage capacity. Surface runoff occurs when the storage capacities are exceeded (when saturation occurs).

Besides, water from soil stores recharges a groundwater store when the storage exceeds a certain amount ('field capacity'). Recharge is calculated as a parameter (hydraulic conductivity) times the amount the storage exceeds the 'field capacity'

2.2 BIORETENTION

2.2.1 Definition of bioretention and purposes

The definition of bioretention areas are the landscaped features adapted to treat stormwater runoff on the development site. It was claimed to be one of the best management practices (BMP) in the early 1990's by the Prince George's County, Managing Director of Department of Environmental Resources (PGDER, 1993). This treatment measures functions as a soil and plant-based filtration device that removes pollutants through a variety of physical, biological, and chemical treatment processes. These facilities normally consist of a grass buffer strip, sand bed, ponding area, organic layer of mulch layer, planting soil, and plants. The basic bioretention design is shown in Figure 8.

The concept of bioretention, the runoff's velocity is reduced by passing over or through buffer strip and subsequently distributed evenly along a ponding area. Exfiltration of the stored water in the bioretention area planting soil into the underlying soils occurs over a period of days.

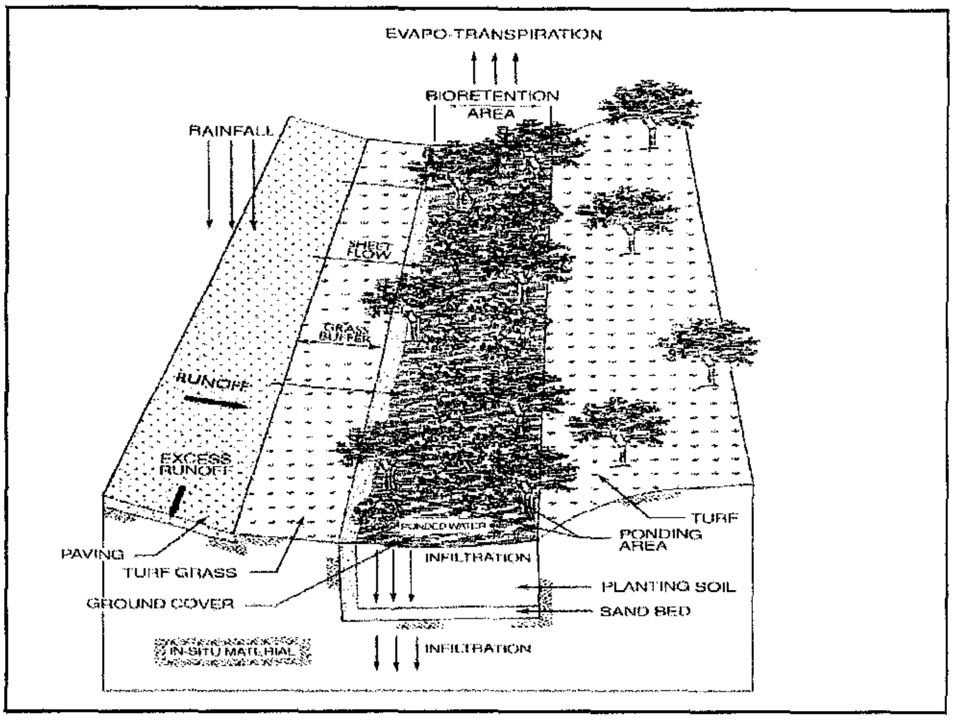

Figure 8: Bioretention Area
(after PGDER, 1993)

The design of bioretention can be modified to accommodate more specific needs. As an example impervious subsoils and marine clays prevented complete infiltration in the soil system. This modified design makes the bioretention area act more as a filter that discharges treated water than as an infiltration device. Design modifications are also being reviewed that will potentially include both aerobic and anaerobic zones in the treatment area. The anaerobic zone will promote denitrification.

2.2.2 Applicability

In terms of applicability, bioretention typically treats storm water that has run over impervious surfaces at commercial, residential, and industrial areas. So that, it is an ideal storm water management BMP for median strips, parking lot islands, and swales. These areas can be designed or modified, so that the runoff is either diverted directly into the bioretention area or conveyed into the bioretention area by a curb and gutter collection system.

The criteria of the site in constructing the bioretention is graded in a manner that minimizes erosive conditions as sheet flow is conveyed to the treatment area, maximizing treatment effectiveness. Thus, it is best suited to the sites where grading or excavation will occur in any case so that the bioretention area can be readily incorporated into the site plan without further environmental damage. It should be used in stabilized drainage areas to minimize sediment loading in the treatment area. As with all BMPs, a maintenance plan must be well developed.

2.2.3 Advantages and disadvantages

Bioretention is not an appropriate to be constructed at locations where the water table is within 1.8 meters (6 feet) of the ground surface and where the surrounding soil stratum is unstable. It is also not recommended for areas with slopes greater than 20 percent, or where mature tree removal would be required. Clogging may be a problem, particularly if the bioretention receives runoff with high sediment loads. Besides, it provides storm water treatment that enhances the quality of downstream water bodies.

2.2.4 Design criteria

Each of the components of the bioretention area is designed to perform its specific function.

- The **grass** buffer strip → reduces incoming runoff velocity and filters particulates from the runoff.
- The **sand bed** → reduces the velocity, filters particulates, and spreads flow over the length of the bioretention area.
- Aeration and drainage of the **planting soil** are provided by the 0.5 meter (18 inch) deep sand bed.
- The **ponding area** → provides a temporary storage location for runoff prior to its evaporation or infiltration.
- The **organic or mulch layer** → filters pollutants and provides an environment conducive to the growth of microorganisms, which degrade petroleum-based products and other organic material. This layer acts in a

similar way to the leaf litter in a forest and prevents the erosion and drying of underlying soils.

- **Planted ground cover** → reduces the potential for erosion as well, slightly more effectively than mulch.
- The **clay in the planting soil** → provides adsorption sites for hydrocarbons, heavy metals, nutrients and other pollutants. Storm water storage is also provided by the voids in the planting soil. The stored water and nutrients in the water and soil are then available to the plants for uptake.

Vegetation is required to cover the whole bioretention filter media surface, be capable of withstanding minor and major design flows, and be of sufficient density to prevent preferred flow paths, scour and resuspension of deposited sediments. Additionally, vegetation that grows in the bioretention filter media functions to continuously break up the surface of the filter media through root growth and wind induced agitation, which prevents surface clogging. The vegetation also provides a substrate for biofilm growth within the upper layer of the filter media, which facilitates biological transformation of pollutants (particularly nitrogen). Ground cover vegetation (e.g. sedges and tufted grasses) is an essential component of bioretention basin function.

Generally, the greater the density and height of vegetation planted in bioretention filter media, the better the treatment provided especially when extended detention is provided for in the design. This occur when stormwater is temporarily stored and the contact between stormwater and vegetation results in enhanced sedimentation of suspended sediments and adsorption of associated pollutants.

The layout of the bioretention area is determined after considered the site constraints such as location of utilities, underlying soils, existing vegetation, and drainage. Bioretention is suitable at the sites with loamy sand soils because the excavated soil can be backfilled and used as the planting soil, thus eliminating the cost of importing planting soil. Basically, an unstable surrounding soil stratum and soils with clay content greater than 25 percent may stop the use of bioretention, as would a site with slopes greater than 20 percent or a site with mature trees that would be removed during construction of this bioretention. Figure 4 and Figure 5 are shown the design of bioretention in profile and plan view.

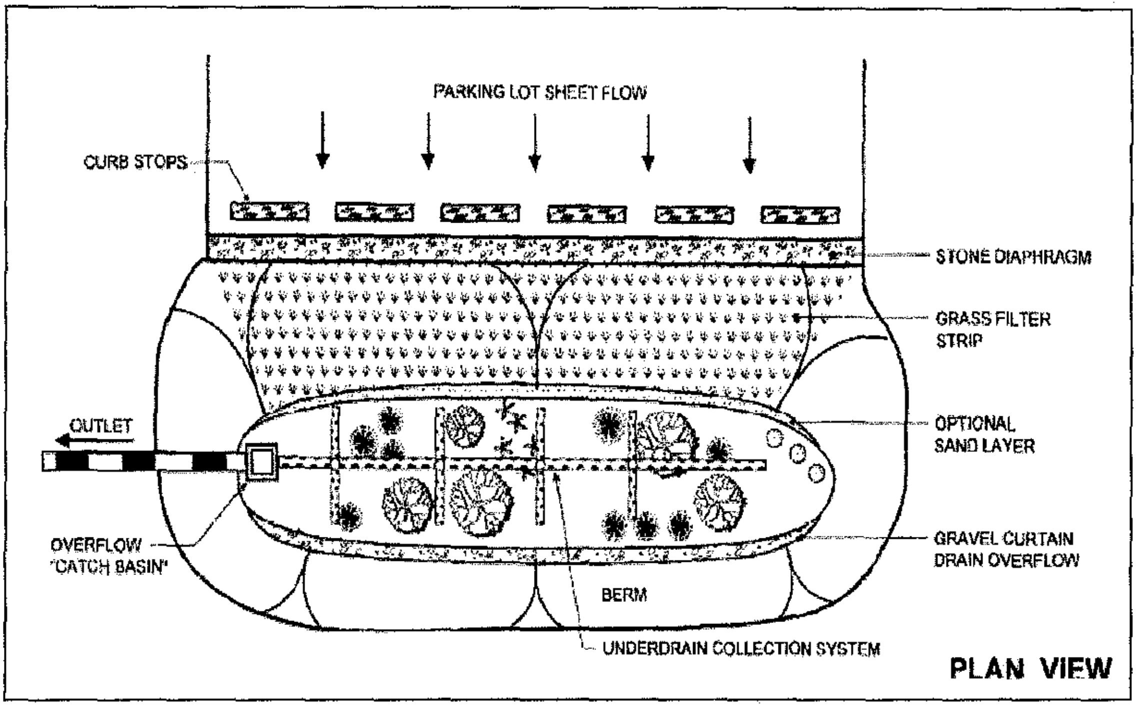

Figure 9: Design of Bioretention (plan view)

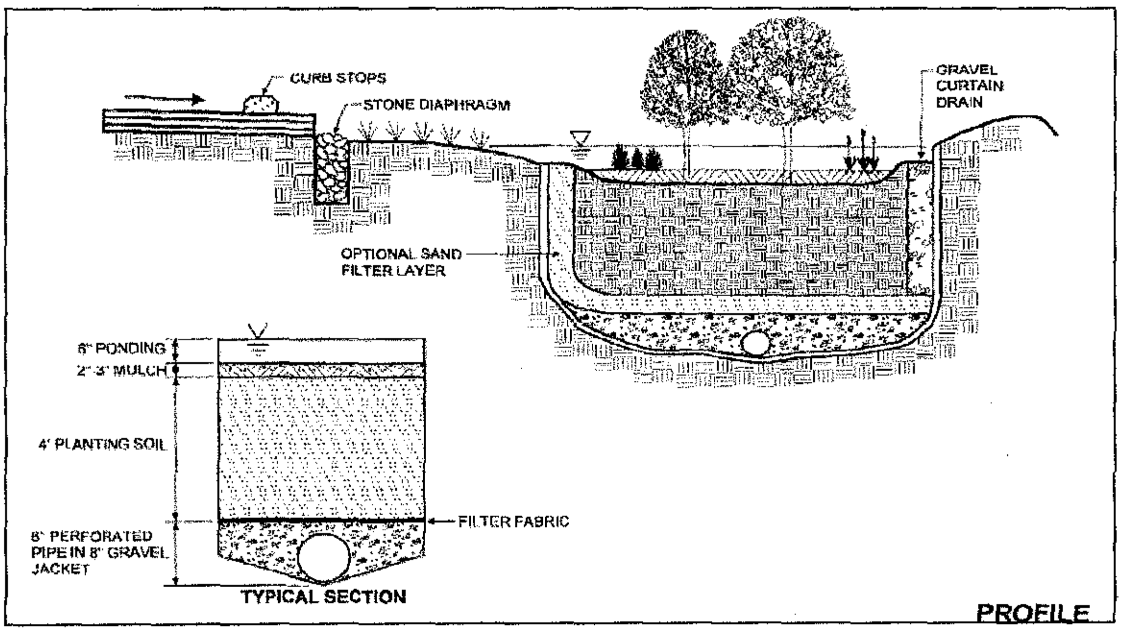

Figure 10: Design of Bioretention (profile view)

2.2.5 Performance

The main function of bioretention is to remove storm water pollutants through physical and biological processes, including adsorption, filtration, plant uptake, microbial activity, decomposition, sedimentation and volatilization. Adsorption is the process whereby particulate pollutants attach to soil or vegetation surfaces. Adequate contact time between the surface and pollutant must be provided in the design of the system for this removal process to occur successfully. Therefore, the infiltration rate of the soils must not exceed those specified in the design criteria or pollutant removal may decrease. Pollutants that will be removed by adsorption process include metals, phosphorus, and some hydrocarbons.

Filtration occurs as runoff passes through the bioretention area media, such as the sand bed, ground cover and planting soil and it will trap particulate matter and allow water to pass through. The filtering effectiveness of the bioretention area may decrease over time. Common particulates removed from stormwater are particulate organic matter, phosphorus, and suspended solids.

Plant growth is sustained by the uptake of nutrients from the soils. Microbial activity within the soil also contributes to the removal of nitrogen and organic matter. Nitrogen is removed by nitrifying and denitrifying bacteria, while aerobic bacteria are responsible for the decomposition of the organic matter (e.g., petroleum). Microbial processes require oxygen and can result in depleted oxygen levels if the bioretention area is not adequately aerated.

Removal rates for heavy metals and nutrients are shown in Table 1. As shown, the bioretention removed between 93 and 98 percent of metals, between 68 and 80percent of TKN and between 70 and 83 percent of total phosphorus. For all of the pollutants analyzed, results of the laboratory study were similar to those of field experiments. Doubling or halving the influent pollutant levels had little effect on the effluent pollutants levels (Davis et al, 1998).

As shown, the bioretention could potentially achieve greater than 90 percent removal rates for total suspended solids, organics, and bacteria. The microbial activity and plant uptake occurring in the bioretention area will likely result in higher removal rates than those determined for infiltration BMPs.

TABLE 2 LABORATORY AND ESTIMATED BIORETENTION

Pollutant	Removal Rate
Total Phosphorus	70%-83% [1]
Metals (Cu, Zn, Pb)	93%-98% [1]
TKN	68%-80% [1]
Total Suspended Solids	90% [2]
Organics	90% [2]
Bacteria	90% [2]

Source: [1]Davis et al. (1998)
[2]PGDER (1993)

2.2.6 Bioretention system in MUSIC application

Bioretention systems promote the removal of particulate and soluble contaminants by passing stormwater water through a filter medium. The systems are modelled in MUSIC as a surface detention system (eg. pond, swale etc.) in which the low flow orifice or riser outlet has been replaced by the discharge characteristics associated with the soil which detained water infiltrates into. The filtered flow is assumed to be collected by an underdrain and returned to the watercourse; it is not lost from the system to groundwater. Hence there are two locations for water quality improvement in the storage over the filter, and in the filter itself. Figure 11 and 12 shows the design of bioretention in MUSIC software.

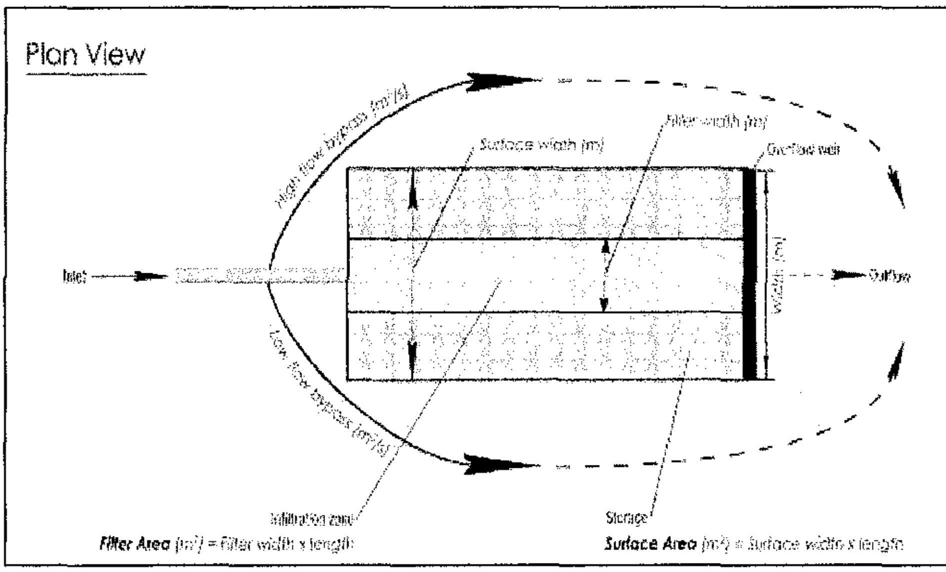

Figure 11: Design of Bioretention in MUSIC Application (plan view)

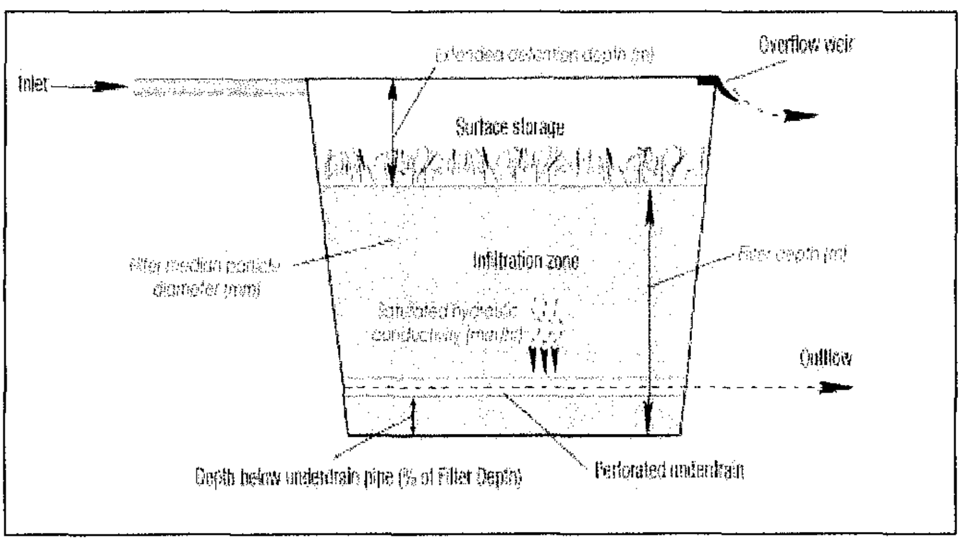

Figure 12: Design of Bioretention in MUSIC Application (longitudinal section)

CHAPTER 3
METHODOLOGY

There are four important methods that need to be completed in this final year project. In using MUSIC model it is necessary to obtain sufficient data of the catchment area as input into the system. The data must include hydrological data and land use data. The methods below covered from data gathering until data analysis.

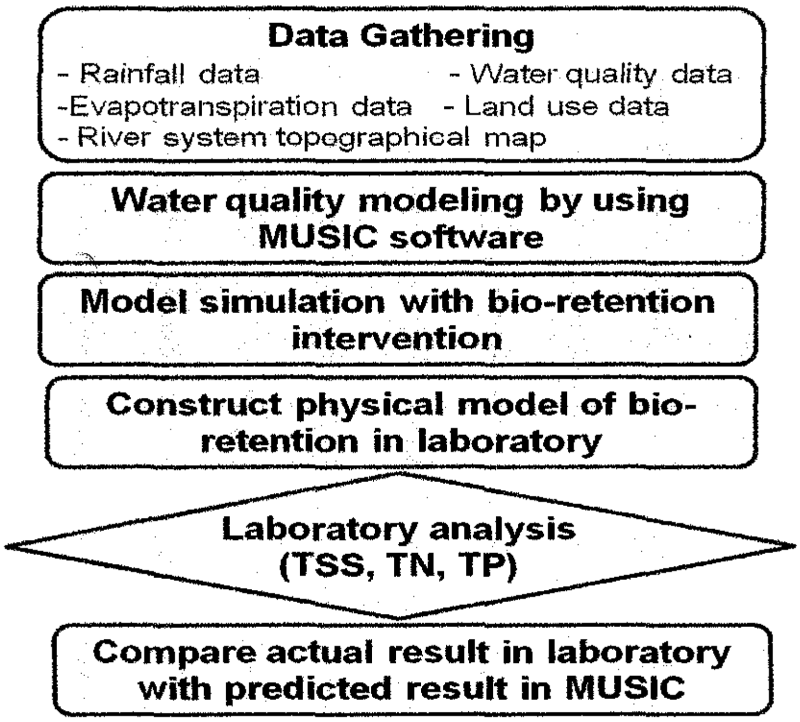

Figure 13: Methodology

3.1 DATA GATHERING (from Jurutera Perunding Zaaba Sdn Bhd)

There are several important data used as the input in the MUSIC model. All those data were obtained from Jurutera Perunding Zaaba Sdn. Bhd at Kampung Baru, Kuala Lumpur. Below are the types of data used in the simulation;

i. **Rainfall Data** - Under the national network, DID Malaysia have several rainfalls recording stations within and surrounding the catchment area. Most of the stations are manual and few are automatic. Nine rainfall stations are selected for the study, which have various lengths of data records.

Rainfall historical data was initially screened to determine the representative dry year and wet year data and the model will be run by using those selected dry year and wet year.

ii. **Evapotranspiration Data** - Long term mean values of daily evapotranspiration data (obtained from the Drainage and Irrigation Department) is used in this study.

iii. **Landuse Data** - The existing landuse distribution, in terms of location and area, was obtained from the map published in topographical map, structure plan as well as from the aerial and satellite pictures of the study area.

iv. The landuse pattern was subdivided into six categories namely, Urban, Industrial, Agricultural & rural, forest & open space, construction sites and water bodies.

Residential, commercial and institutional usages were combined as urban landuse. However a more comprehensive land use map for the area was obtained from private sources.

v. **River System Topographical Map** – These are available in hard and digital copy from the Department of Survey and Mapping or JUPEM.

vi. **Water Quality Data** - The event mean concentration or EMC which is basically the indicator for the stormwater generated pollution from diffuse sources is derived from stormwater samples collected within the river basin.

HSE analysis had been done for the journey to Jurutera Perunding Zaaba and attached in the Appendix A.

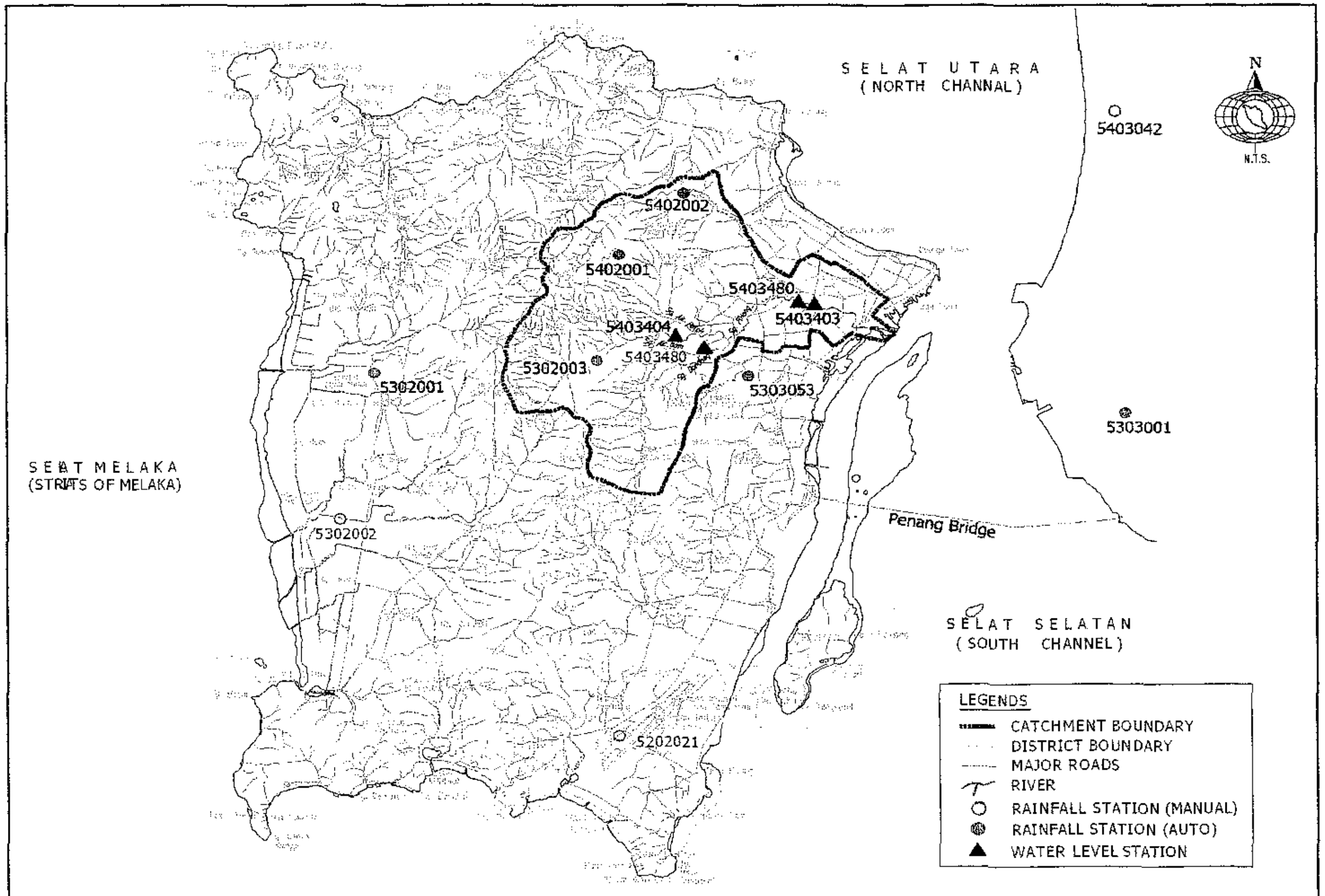

Figure 14: Locations of Rainfall and Water Level Stations in the Sungai Pinang Catchment Area

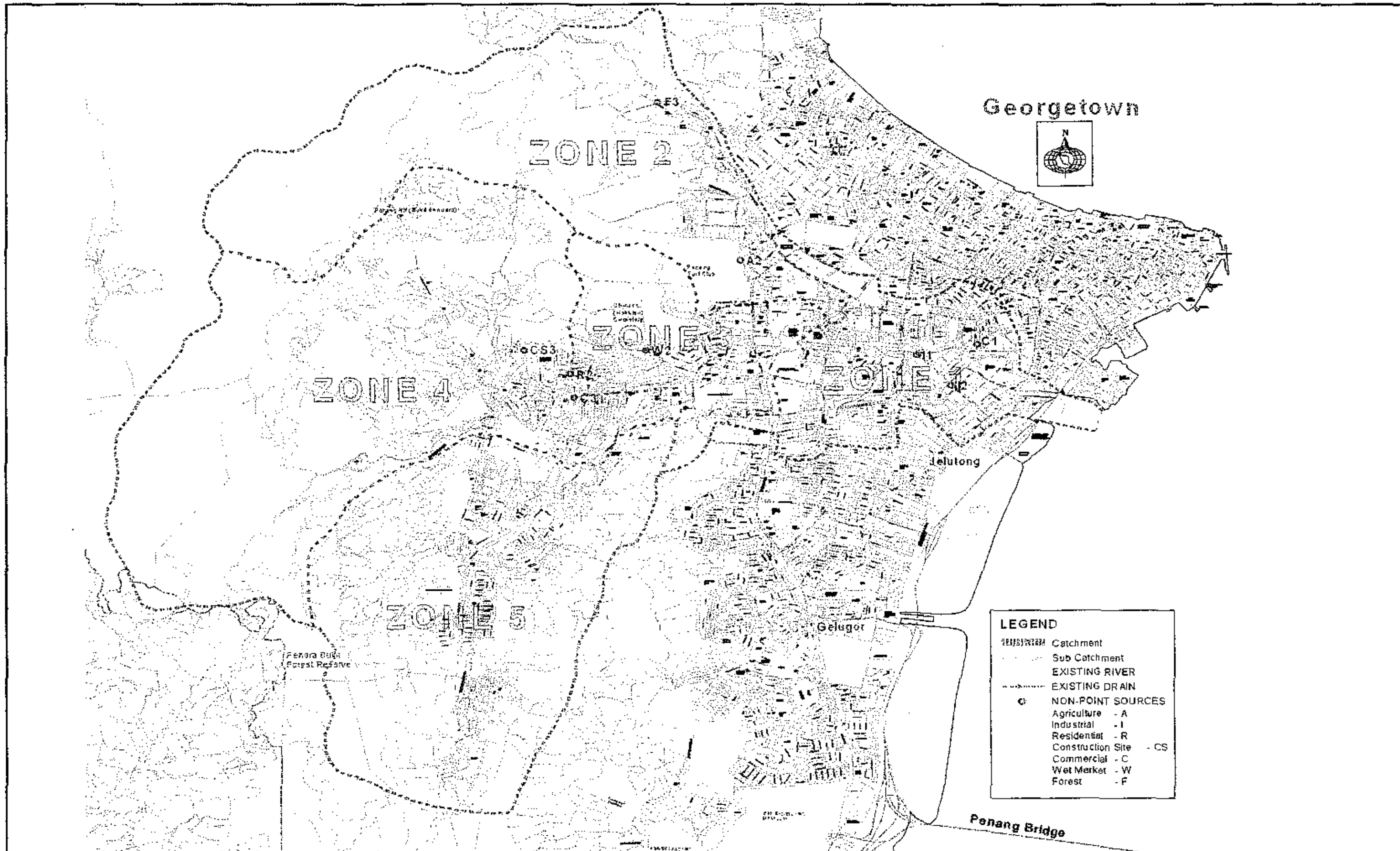

Figure 15: Non-point Sampling Locations in the Sungai Pinang Catchment Area

3.2 MODELING USING MUSIC SOFTWARE

i. Overview of Terminology, Toolbars and Menu Items

Before using MUSIC, it is necessary to understand the basic modeling components and their associated terminology were studied. Once a Catchment File has been created or opened, the users are presented with a Toolbar, which contains all of the commonly used tools needed to run MUSIC. The toolbar item is shown in Figure 14.

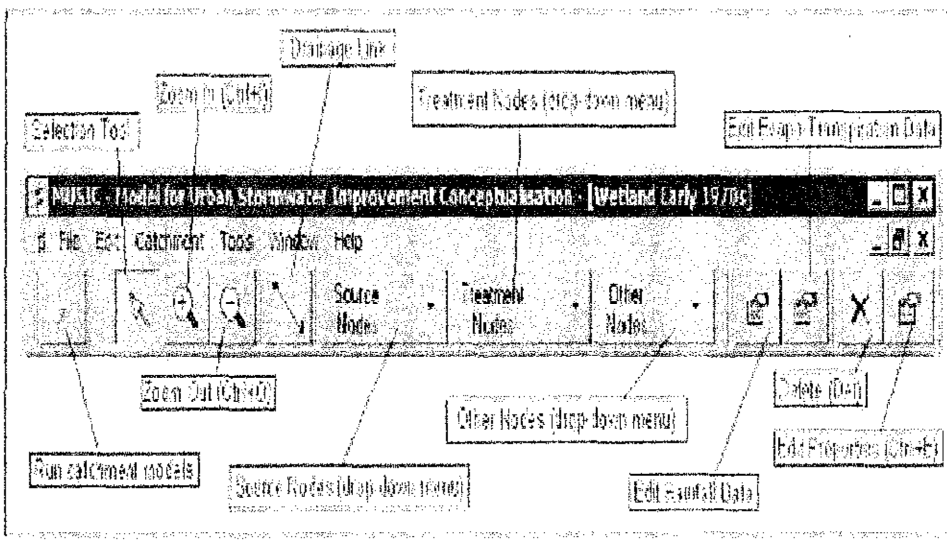

Figure 16: Toolbar Item in MUSIC Application

ii. Insert the Meteorological Data

The meteorological data file was created associated with the creation of a MUSIC **Catchment** file in the first step.When created a new **Catchment** file (**File** menu -> **New**), the dialogue box was appeared which prompts to choose a meteorological data template to build the **Catchment** file from. Besides, there are several templates *(from the Templates folder)*, differing in their location, time step and duration. Figure 13 is shows how to insert the meteorological data.

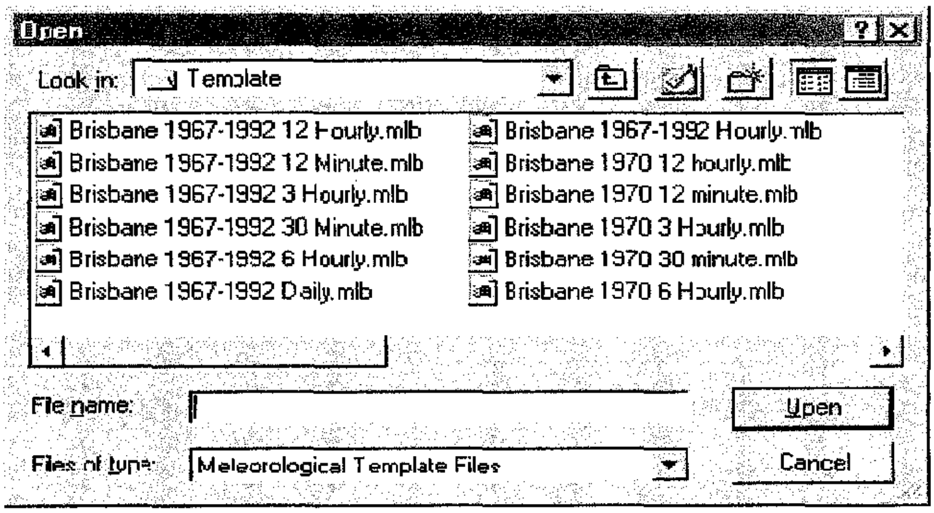

Figure 17: The Step of Inserting the Meteorological Data

iii. Select an Appropriate Model Time Steps

The time step for a Catchment File was selected when creating Meteorological Templates, and when choosing from the list of available meteorological templates to use (when select **New** from the **File** menu).

iv. Creating Nodes and Links

There were few simple rules which the user should be aware of in creating nodes and links within MUSIC, one of them was there were separate source nodes for urban, agricultural and forested sub-catchments. Each of these three source nodes has its own default discharge pollutant concentrations.

Therefore, represent a sub-catchment made up of differing component land-uses, the separate source nodes should be created to *represent each of these dominant land-uses* such as:

- Open Area - consist of 20% of impervious area
- Forest - consist of 15% of impervious area
- Residential Area - consist of 90% of impervious area
- Construction Area - consist of 65% of impervious area
- Industrial Area - consist of 90% of impervious area

- Road & Highway - consist of 95% of impervious area
- Urban Area - consist of 90 % of impervious area

*v. **Running and Saving MUSIC Simulations***

MUSIC can be run in two modes: Auto Run or Manual. To switch between modes, go to the **File** menu and set **Auto Run Models** to on (ticked) or off (un-ticked).

*vi. **Setting Catchment Defaults***

MUSIC incorporates many parameters which can be edited. For example source node, rainfall-runoff properties, source node water quality parameters and treatment node parameters. MUSIC contains default values for these parameters, in a file called "music.ini", located in the same directory as the MUSIC.exe program. The setting catchment default is shown in Figure 14.

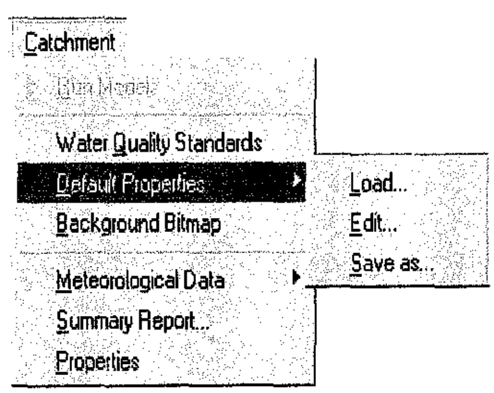

Figure 18: The Setting Catchment Defaults

3.3 CONSTRUCT PHYSICAL MODEL OF BIORETENTION

The physical model of bioretention is designed based on the scaled with the actual size of bioretention on the site in Sg. Air Putih. The area of the actual bioretention is about 2-3% of the total developed area in the specific sub-catchment. Sg.Air Putih has undergone 40 % development.

Total length, L: 82 cm

Diameter, D : 4 in (10.16 cm)

Area, A : $\pi r^2 = 81.07\ cm^2 \approx 8.107 \times 10^{-3}\ m^2$

The actual flow of the Sg. Air Putih, Q_1 $= 28.38 m^3/s$ (see Appendix A)

The actual area of bioretention on site, A_1 = 2% x (40% developed area of Sg. Air Putih)

$= (0.02) \times (0.4 \times 4.56\ km^2)$

$= 0.03648\ km^2 \approx 36\ 480\ m^2$

The area of bioretention model, A_2 $= 8.107 \times 10^{-3}\ m^2$

The flow of bioretention model, Q_2 $= Q_2$

$$\frac{Q_1}{A_1} = \frac{Q_2}{A_2}$$

$\therefore$ **$Q_2 = 6.307 \times 10^{-6}\ m^3/s$**

Scale → Laboratory: Actual = 1: 4,500,000
Detention time → 3 hours

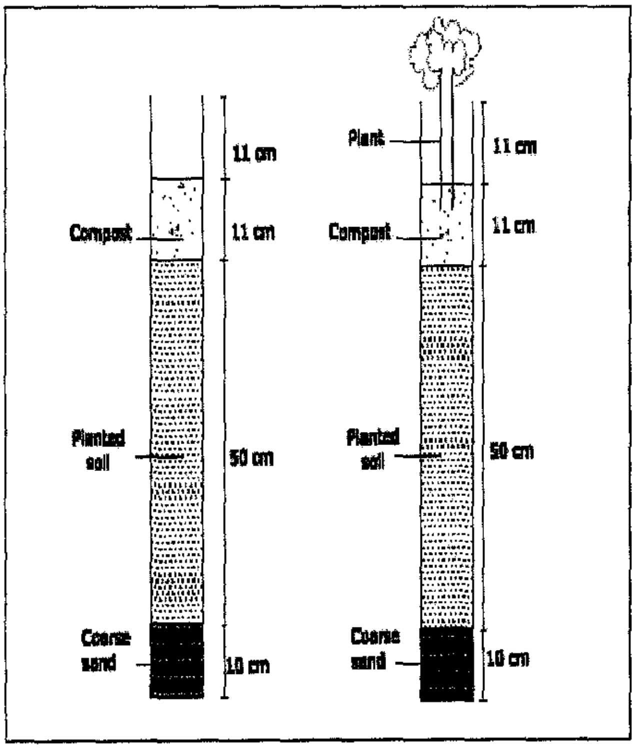

Figure 19: The Design of Bioretention in Laboratory (Variety 1)

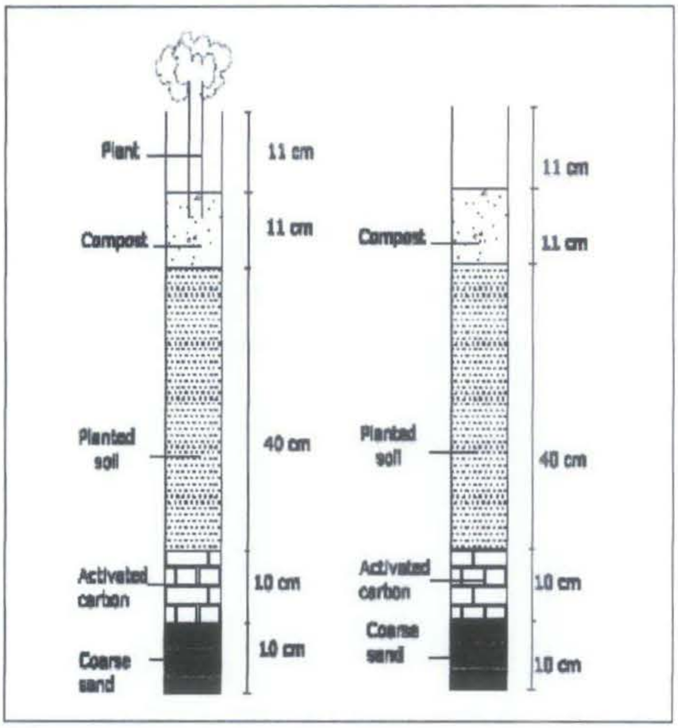

Figure 20: The Design of Bioretention in Laboratory (Variety 2)

(a) (b) (c)

Figure 21: The Components of Filter Media;

(a) coarse sand, (b) compost, (c) planting soil

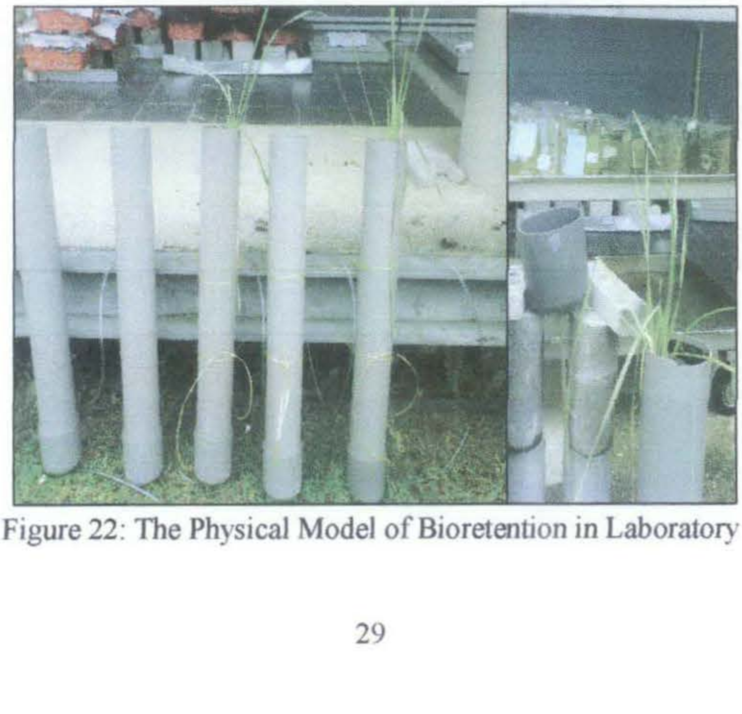

Figure 22: The Physical Model of Bioretention in Laboratory

The plant that had been used is *Carex stricta* or tussock sedge. The details of this type of plant are inconspicuous flowers; upright, narrow female inflorescences; attracts songbirds; tolerates periodic drought and flooding; grows in clumps or tussocks.

3.4 LABORATORY ANALYSIS

The effluent that flow out from the bioretention were collected and analyzed in the laboratory. There are 3 parameters that had been analyzed which are TSS, TP and TN. The complete procedure and HSE analysis had been attached in the Appendix A. Table 3 shows the method involved in the laboratory analysis.

Table 3: The Method for Laboratory Analysis

Parameter	Method
TSS	Quantitative method
TP	Calorimetric method using HACH procedure
TN	Digestion, distillation, titration

3.5 DATA ANALYSIS

Data analysis is the comparison between the predicted results in the MUSIC software with the actual results that had been conducted in the laboratory.

For the laboratory data;

% reduction in concentration (mg/L)

$$= \frac{[\text{concentration}_{(after)} - \text{concentration}_{(before)}]}{\text{concentration}_{(before)}} \times 100\%$$

CHAPTER 4
RESULTS & DISCUSSION

4.1 MODELING USING MUSIC SOFTWARE

4.1.1 Water Quality from MUSIC software

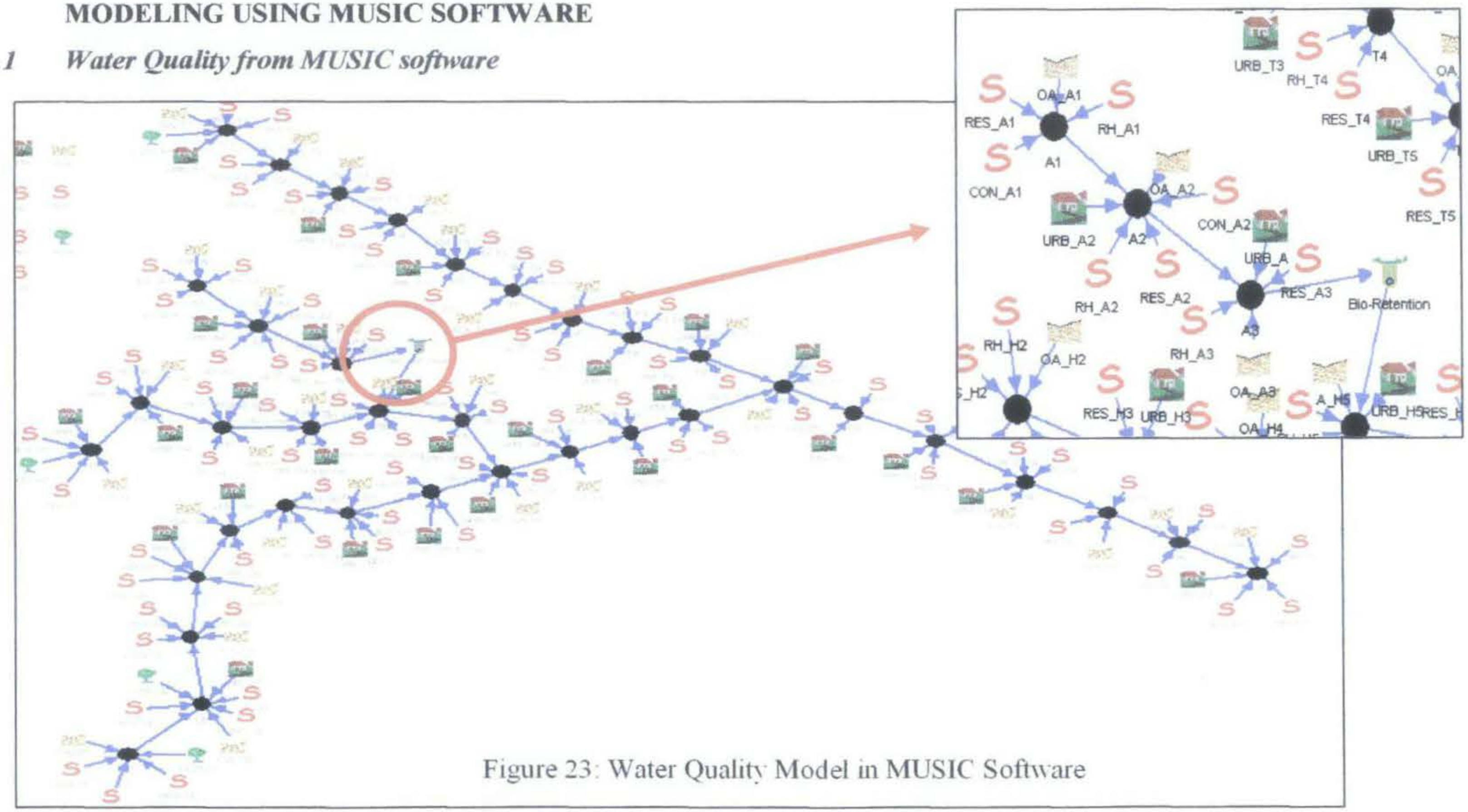

Figure 23: Water Quality Model in MUSIC Software

Water Quality of Sg.Pinang

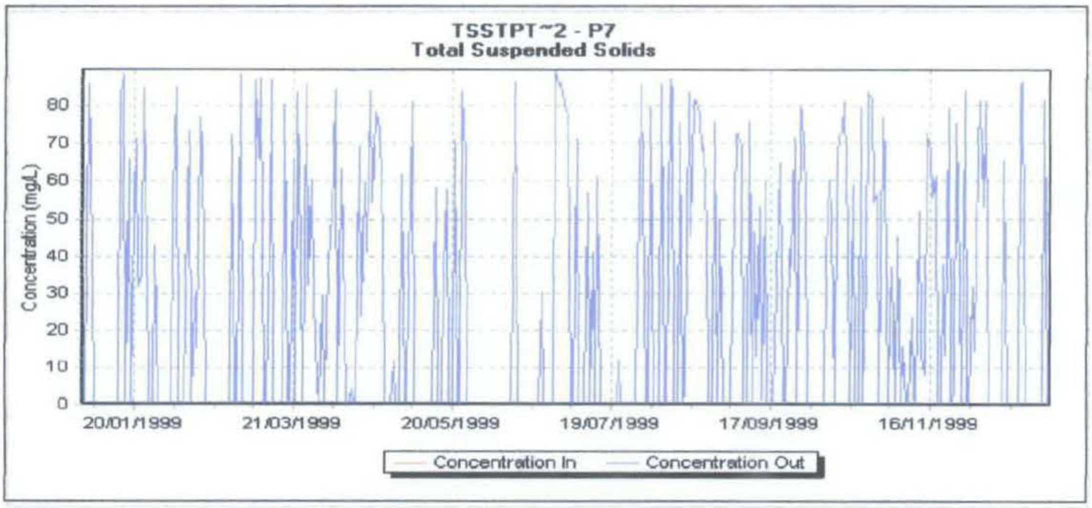

Figure 24: Time-Series Graph of TSS for Sg.Pinang

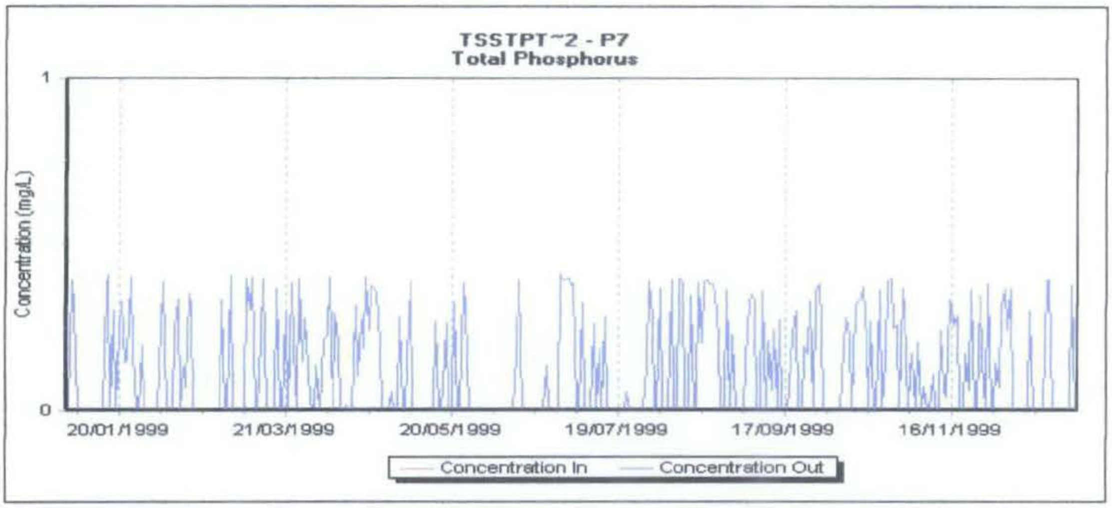

Figure 25: Time-Series Graph of TP for Sg.Pinang

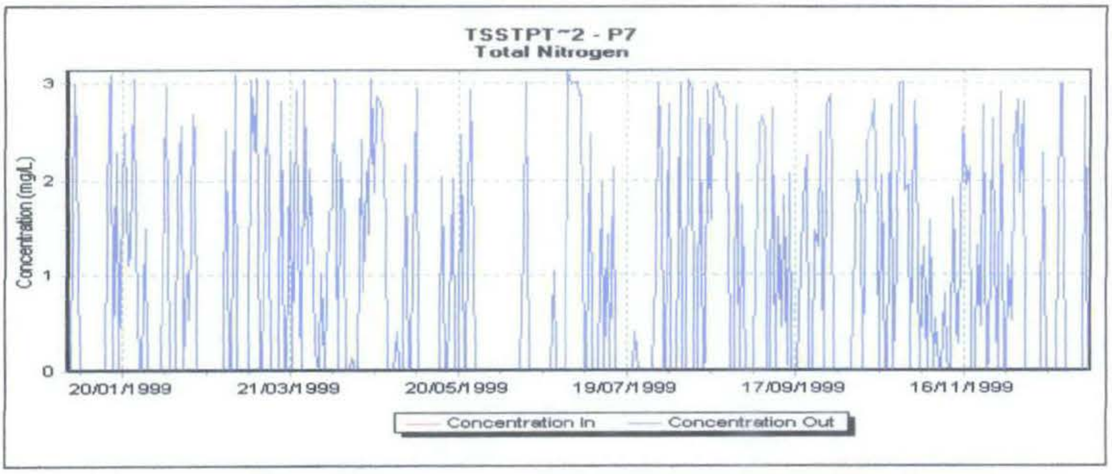

Figure 26: Time-Series Graph of TN for Sg.Pinang

For the Figure 27 until 38 are the graphs of the predicted results for both dry and weather flow before intervention. The concentration in and concentration out are same because there is no treatment measures applied at the downstream of the river.

Dry Weather Flow

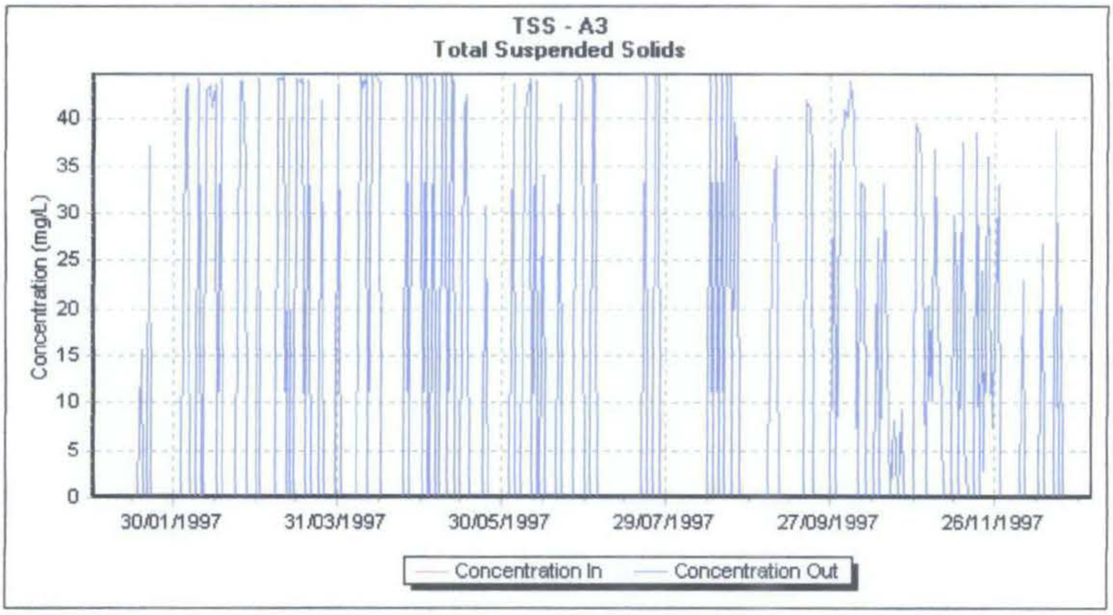

Figure 27: Time-Series Graph of TSS for Sg.Air Putih (Dry)

Mean : 11.40mg/L
Maximum: 44.50 mg/L
Minimum : 0.00 mg/L

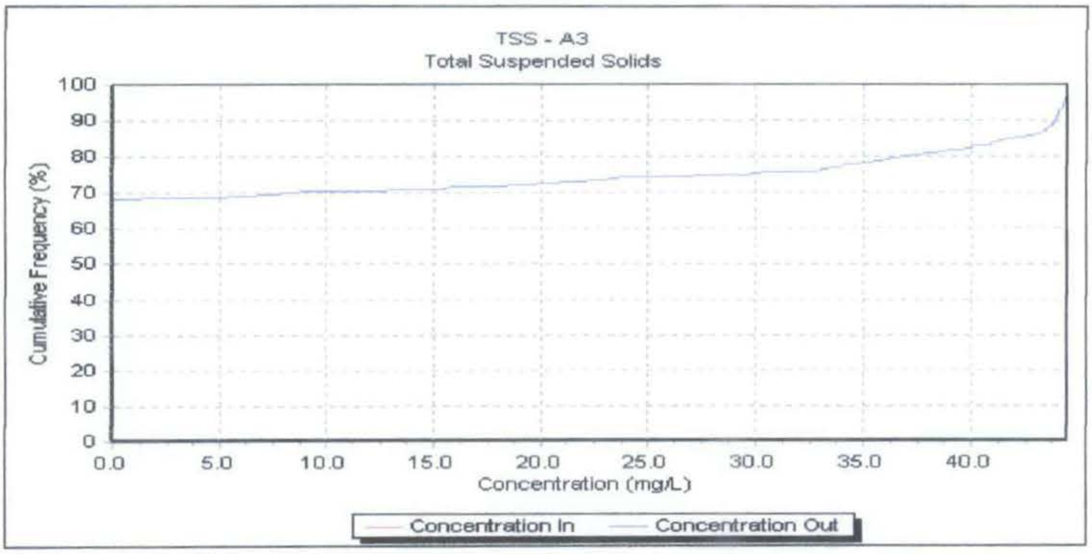

Figure 28: Cumulative Frequency Graph of TSS for Sg.Air Putih (Dry)

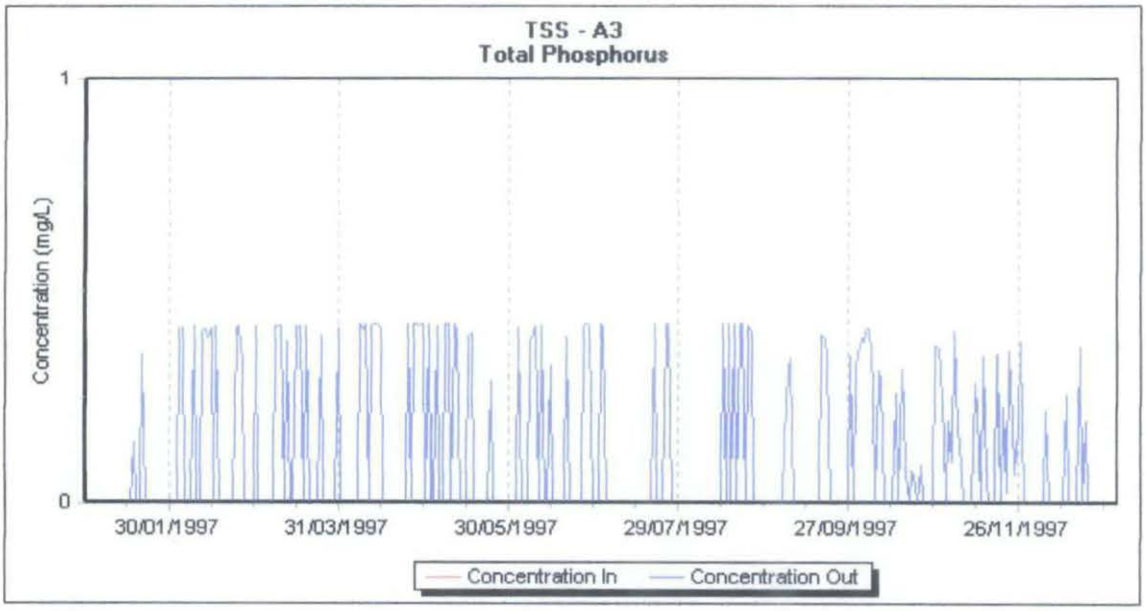

Figure 29: Time-Series Graph of TP for Sg.Air Putih (Dry)

Mean : 0.109 mg/L
Maximum: 0.423 mg/L
Minimum : 0.00 mg/L

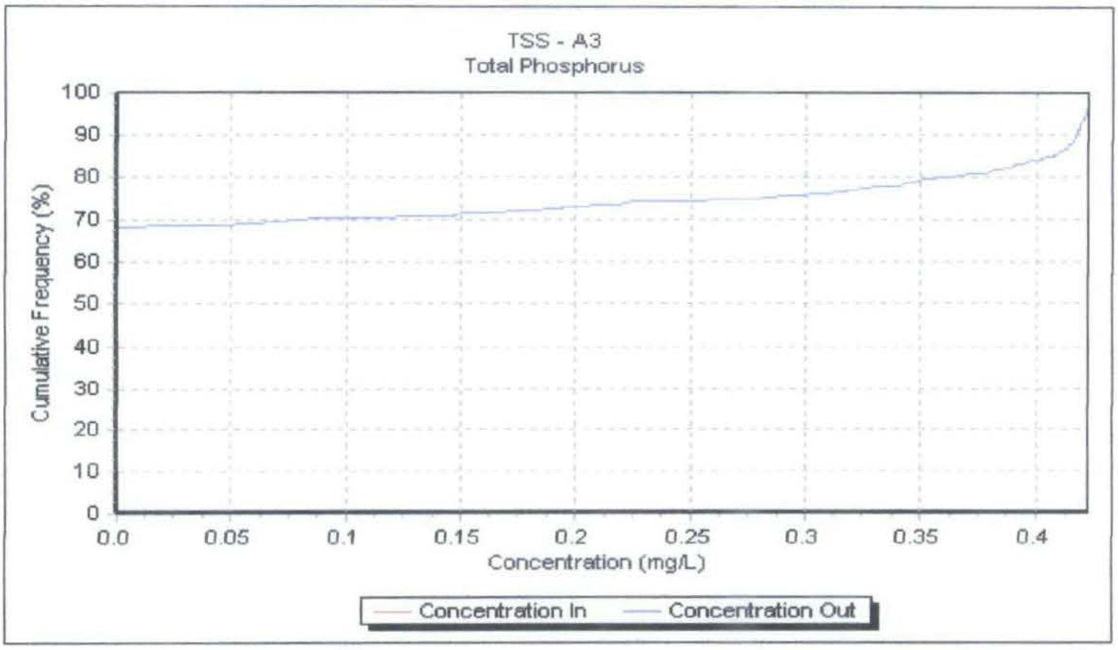

Figure 30: Cumulative Frequency Graph of TP for Sg.Air Putih (Dry)

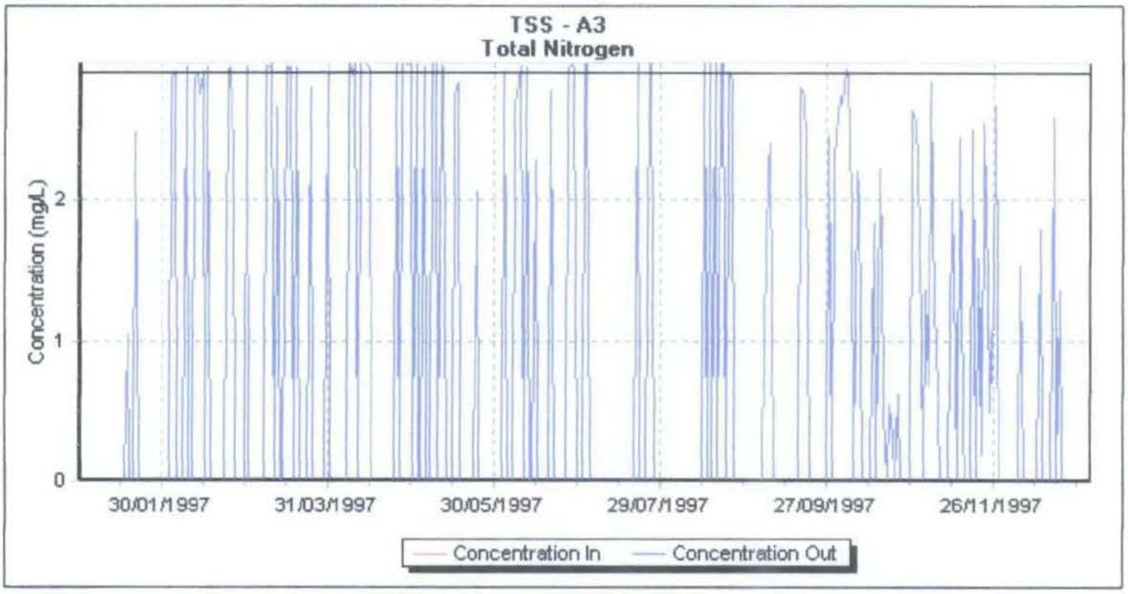

Figure 31: Time-Series Graph of TN for Sg.Air Putih (Dry)

Mean : 0.768 mg/L
Maximum: 2.99 mg/L
Minimum : 0.00 mg/L

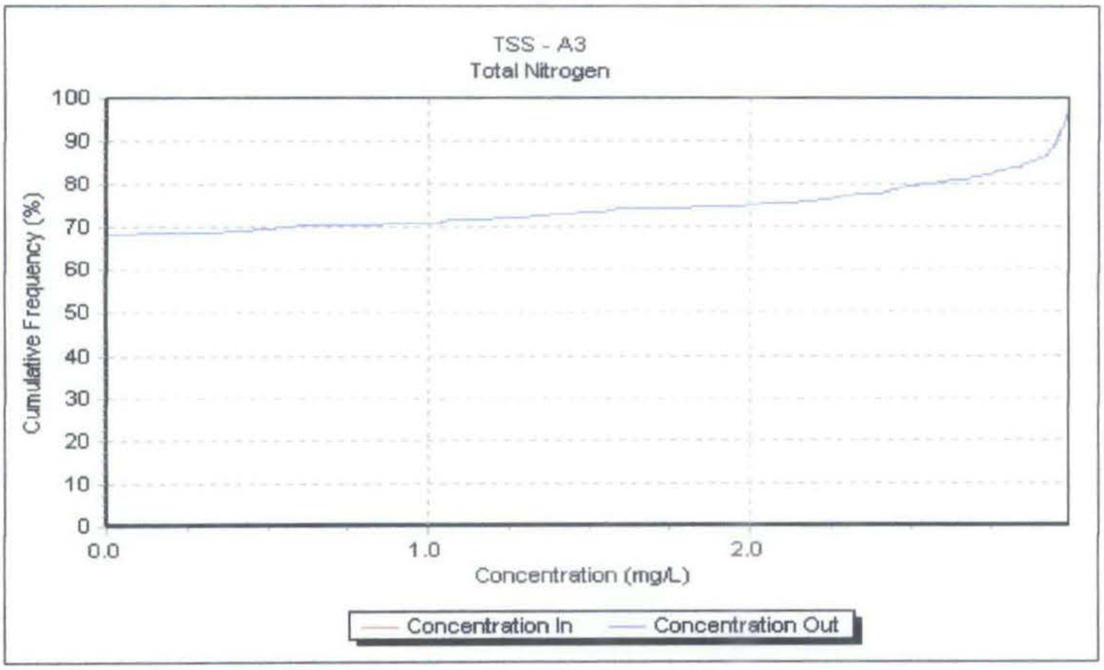

Figure 32: Cumulative Frequency Graph of TN for Sg.Air Putih (Dry)

Wet weather flow

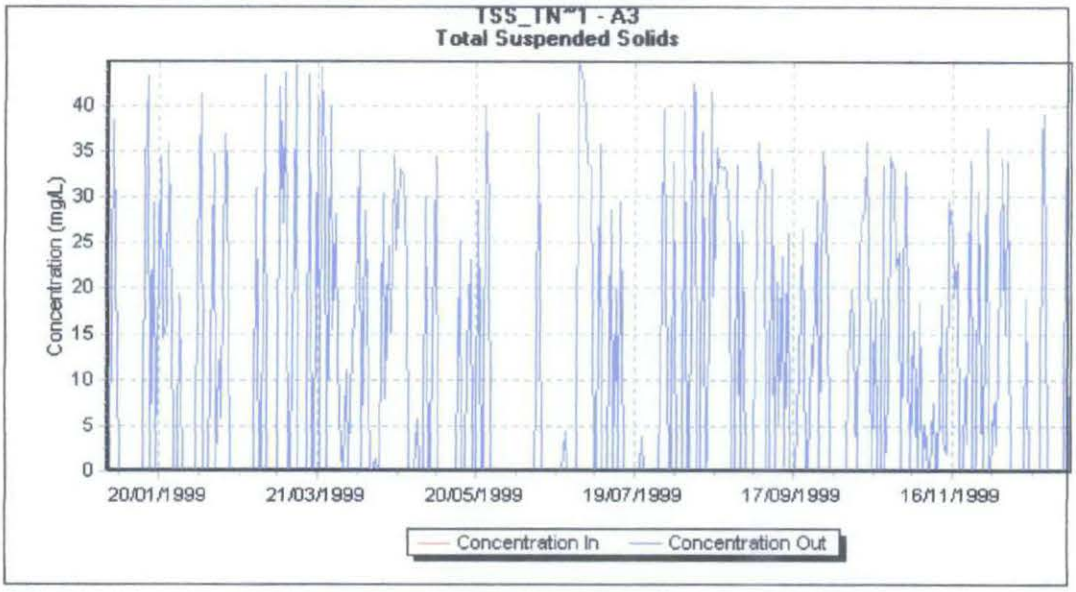

Figure 33: Time-Series Graph of TSS for Sg.Air Putih (Wet)

Mean : 11.10 mg/L
Maximum: 44.70 mg/L
Minimum : 0.00 mg/L

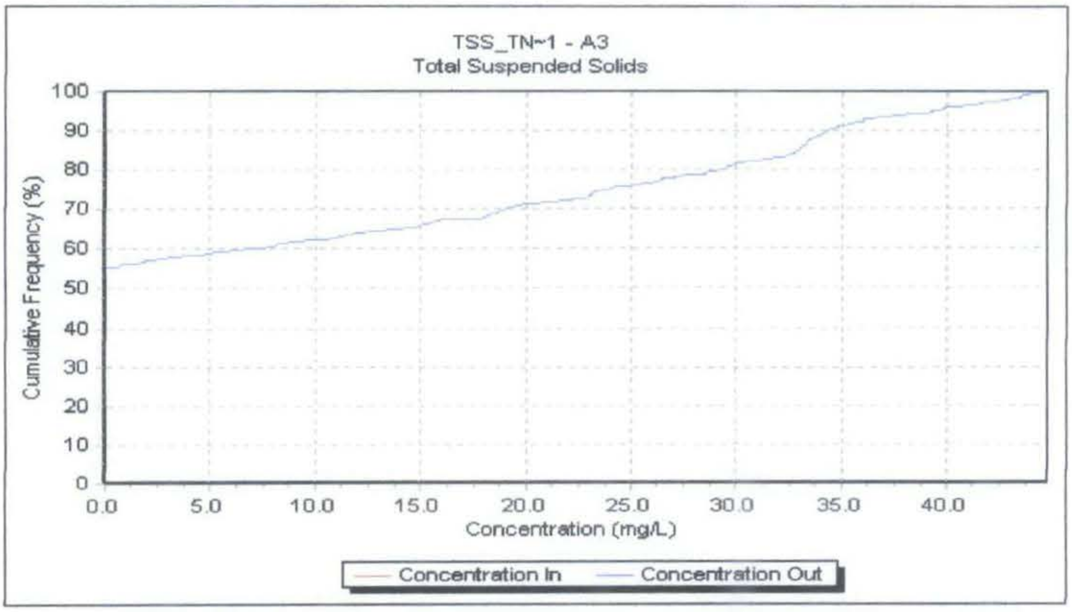

Figure 34: Cumulative Frequency Graph of TSS for Sg.Air Putih (Wet)

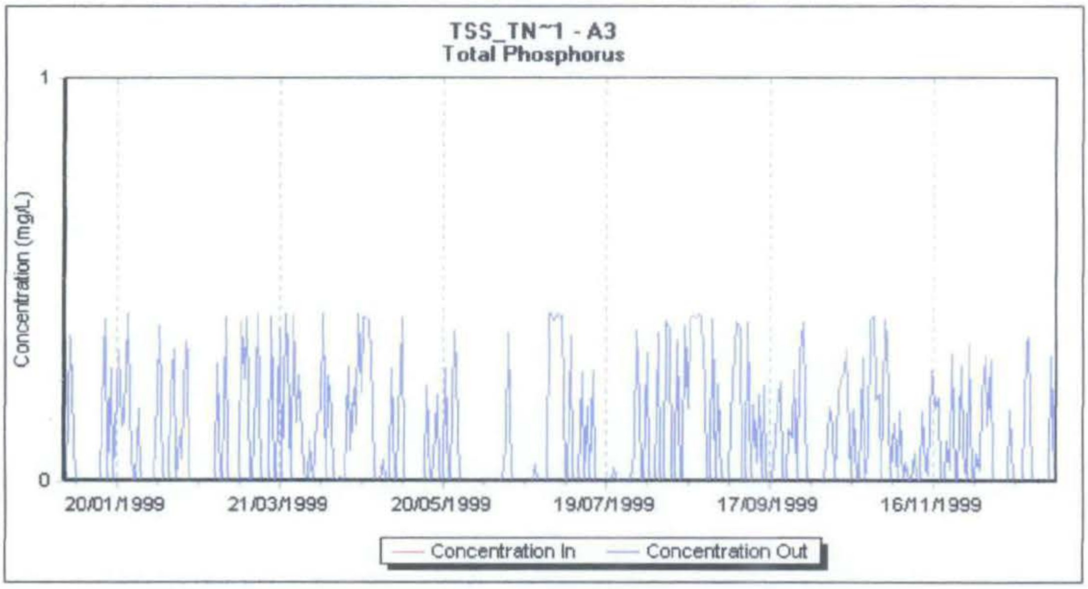

Figure 35: Time-Series Graph of TP for Sg.Air Putih (Wet)

Mean : 0.109 mg/L
Maximum: 0.418 mg/L
Minimum : 0.00 mg/L

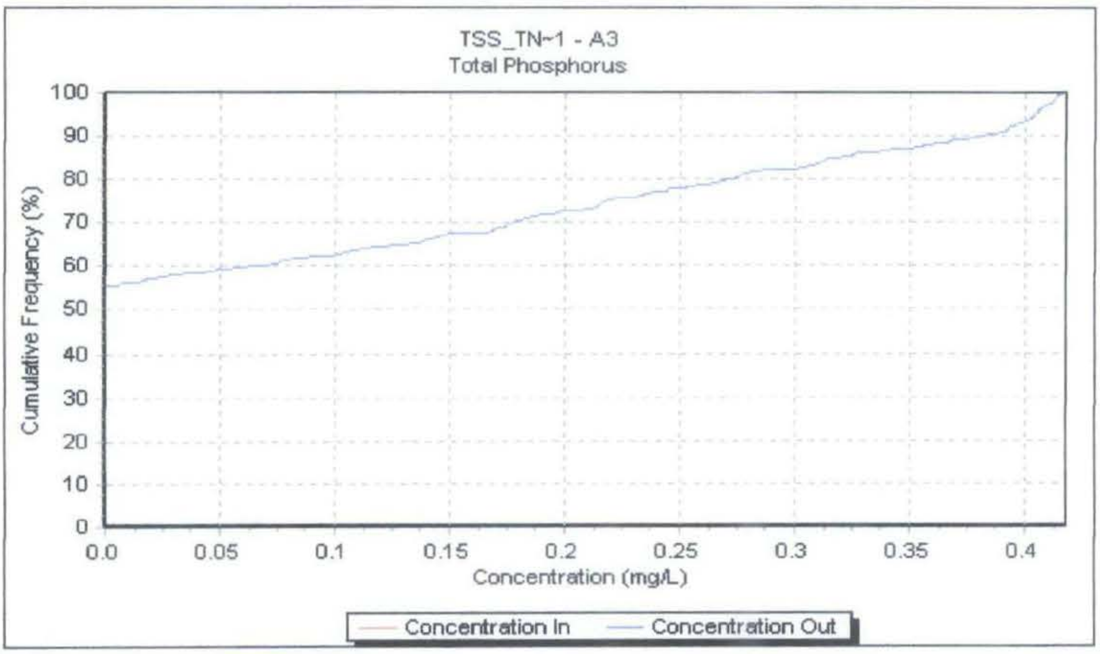

Figure 36: Cumulative Frequency Graph of TP for Sg.Air Putih (Wet)

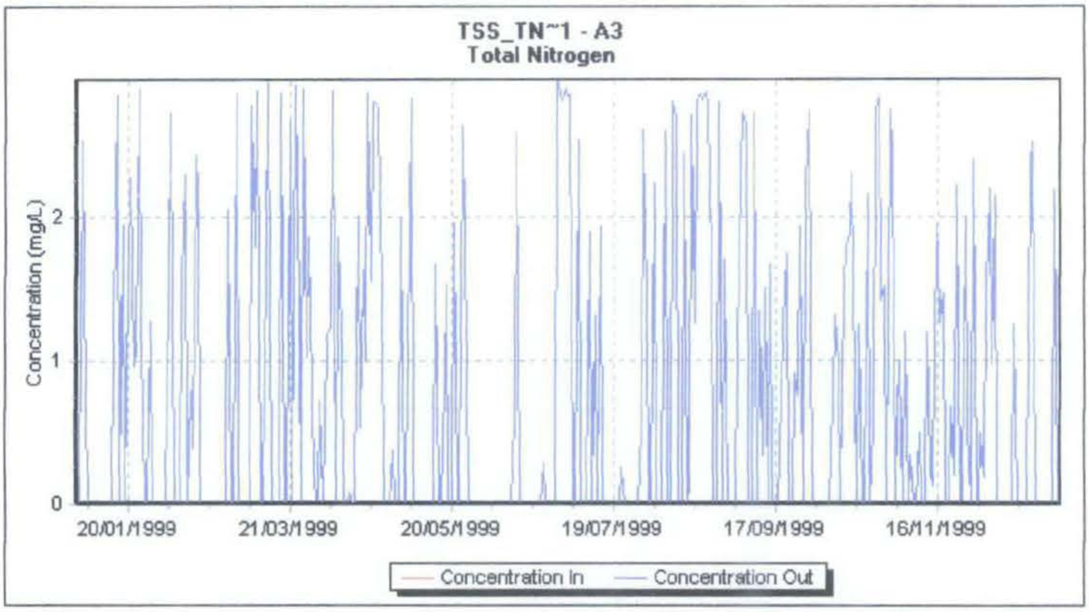

Figure 37: Time-Series Graph of TN for Sg.Air Putih (Wet)

Mean : 0.775 mg/L
Maximum: 2.97 mg/L
Minimum : 0.00 mg/L

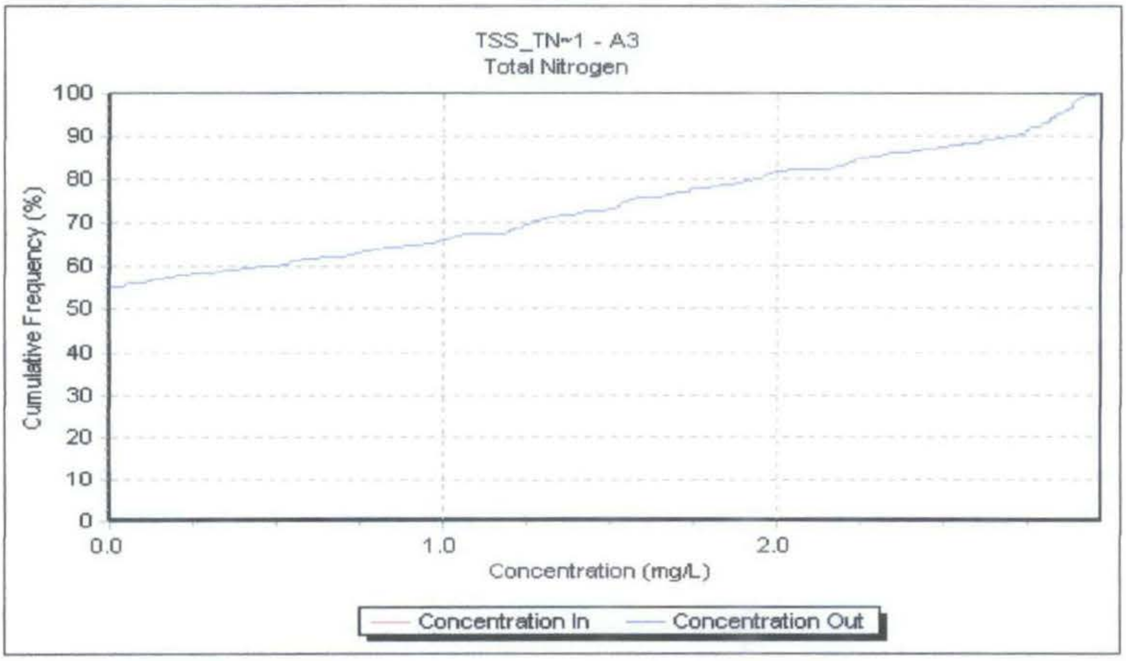

Figure 38: Cumulative Frequency Graph of TN for Sg.Air Putih (Wet)

4.1.2 From MUSIC with intervention using bio-retention

Figure 39 until 50 show the predicted results after using the intervention of bioretention. From that, the difference between concentration in and concentration can be analyzed in order to predict the percentage removal for TSS, TP and TN.

Dry weather flow

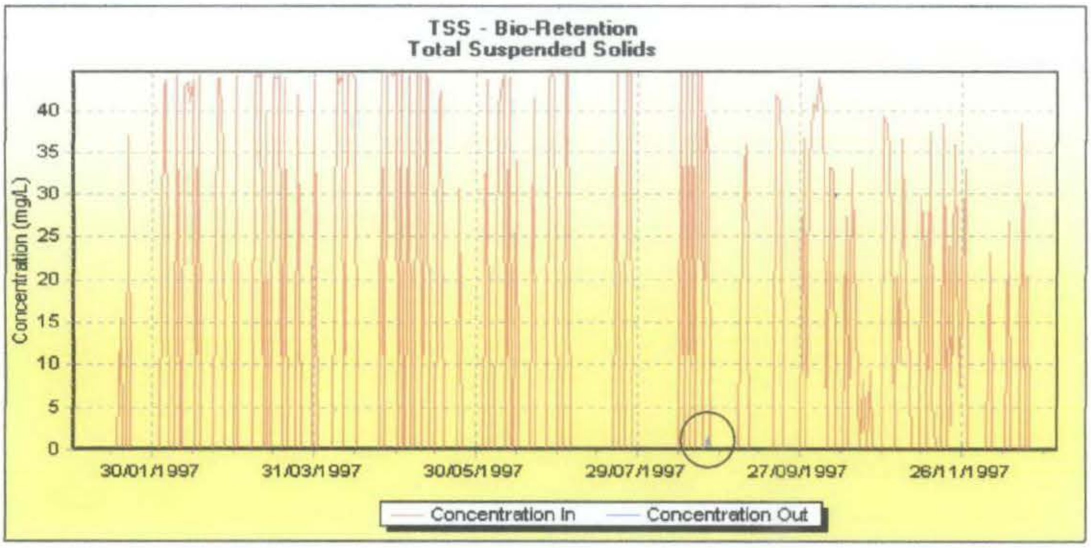

Figure 39: Time-Series Graph of TSS for Sg.Air Putih-after intervention (Dry)

Mean : 6.33×10^{-3} mg/L
Maximum: 1.50 mg/L
Minimum : 0.00 mg/L

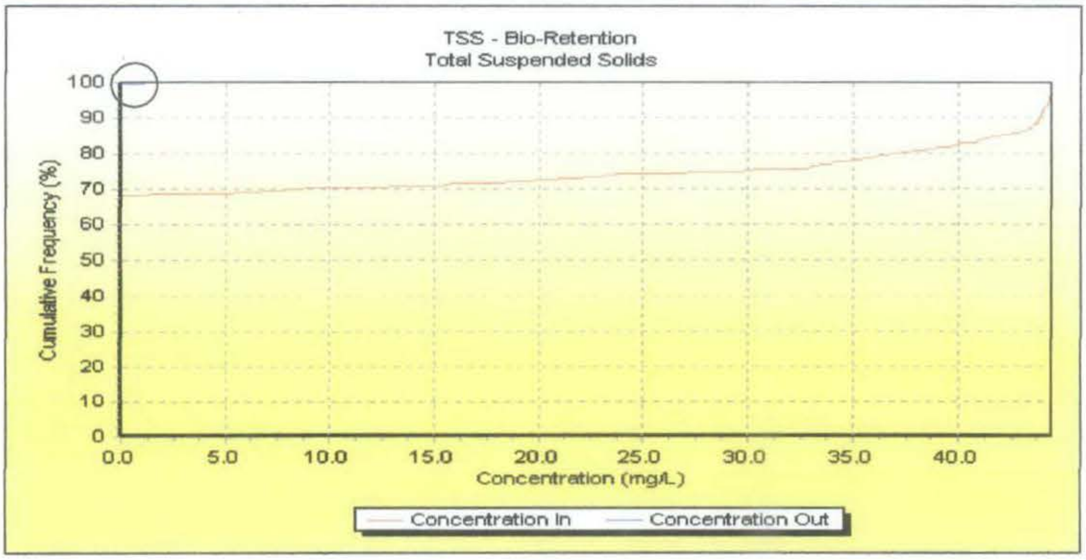

Figure 40: Cumulative Frequency Graph of TSS for Sg.Air Putih-after intervention (Dry)

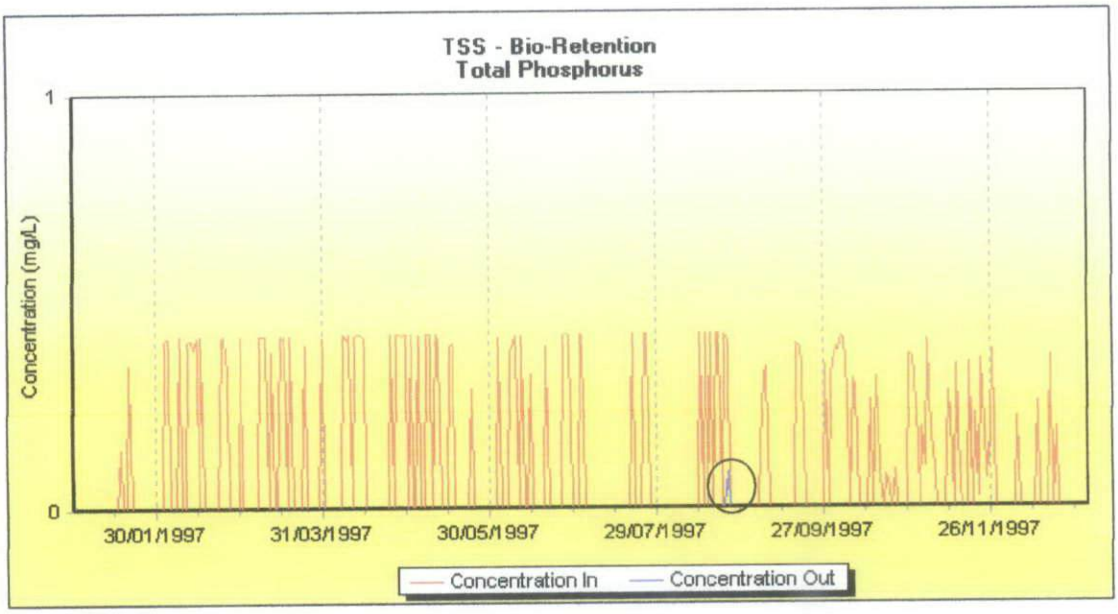

Figure 41: Time-Series Graph of TP for Sg.Air Putih-after intervention (Dry)

Mean : 0.312 x10^{-3} mg/L
Maximum: 86.7 x10^{-3} mg/L
Minimum : 0.00 mg/L

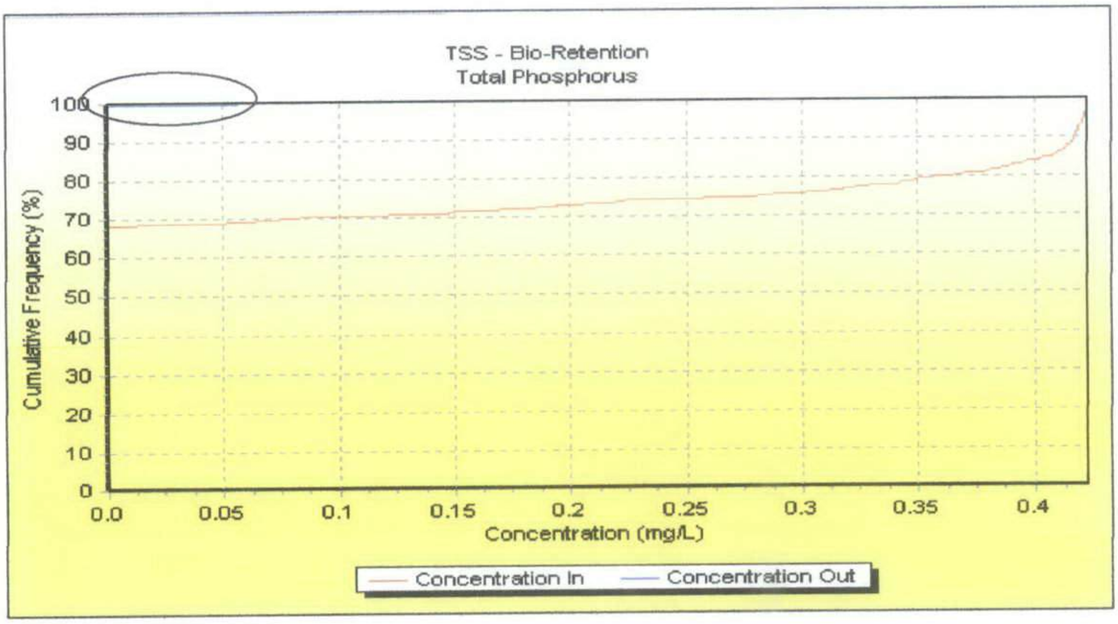

Figure 42: Cumulative Frequency Graph of TP for Sg.Air Putih-after intervention (Dry)

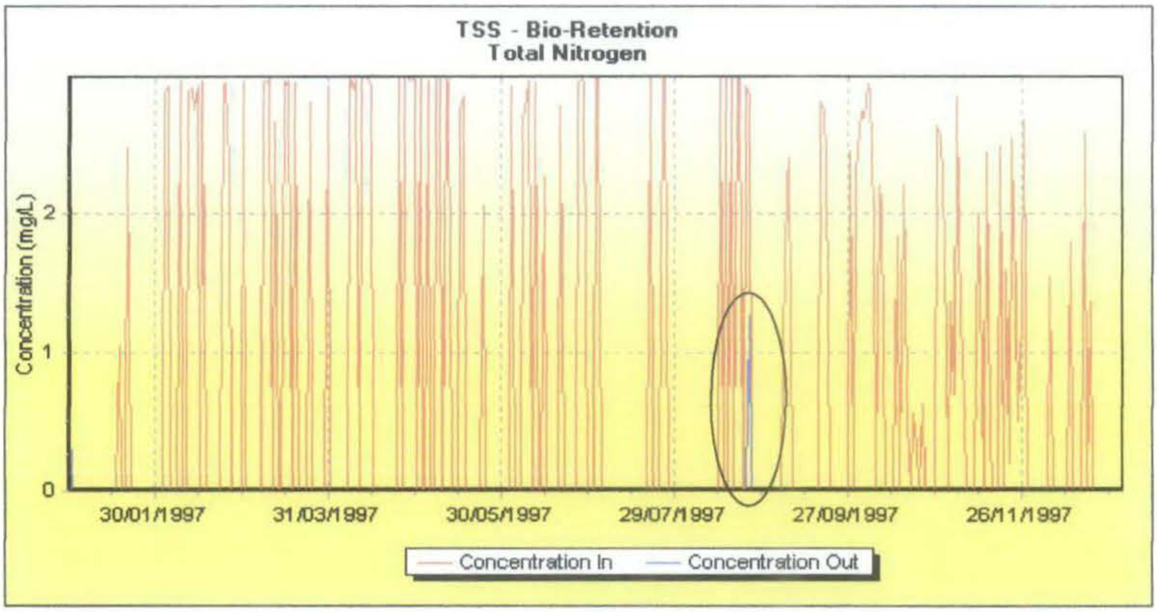

Figure 43: Time-Series Graph of TN for Sg.Air Putih-after intervention (Dry)

Mean : 5.15×10^{-3} mg/L
Maximum : 1.27 mg/L
Minimum : 0.00 mg/L

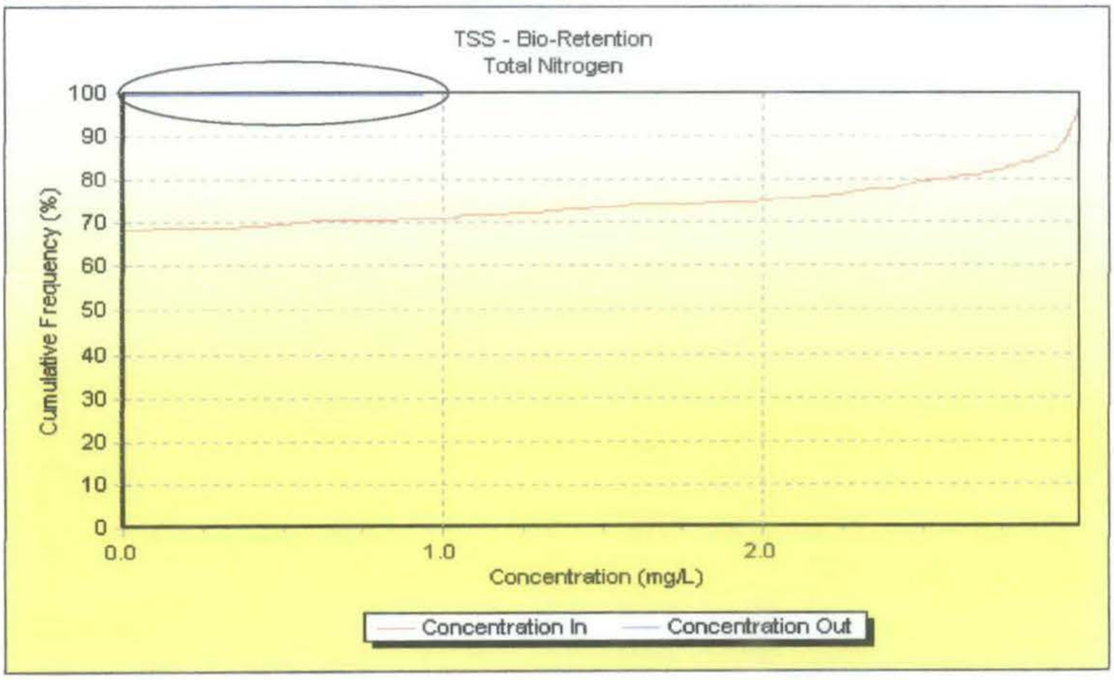

Figure 44: Cumulative Frequency Graph of TN for Sg.Air Putih-after intervention (Dry)

Wet weather flow

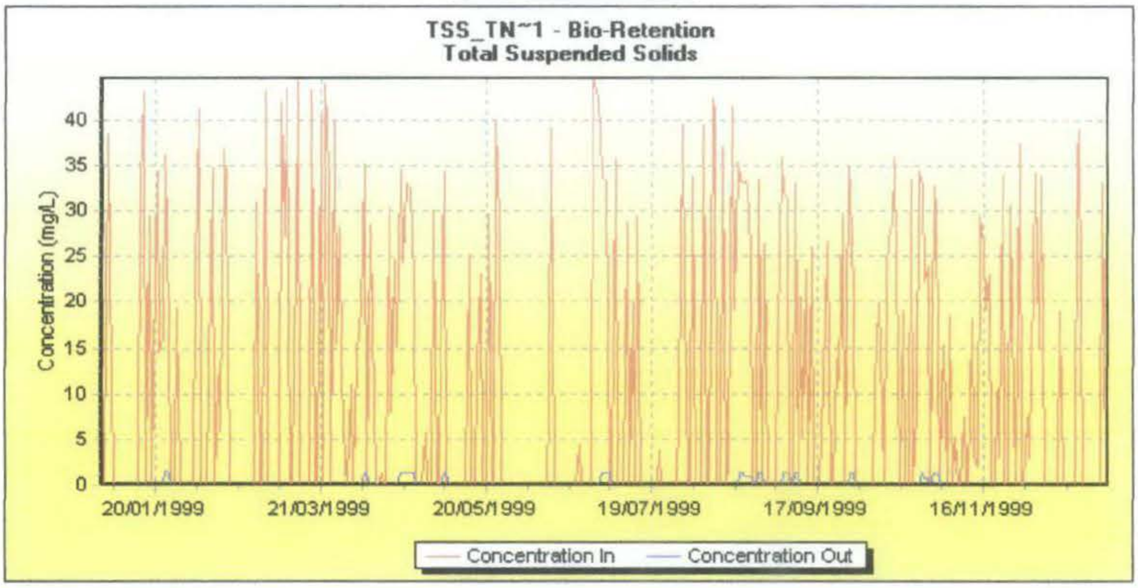

Figure 45: Time-Series Graph of TSS for Sg.Air Putih-after intervention (Wet)

Mean : 0.128 mg/L
Maximum : 1.44 mg/L
Minimum : 0.00 mg/L

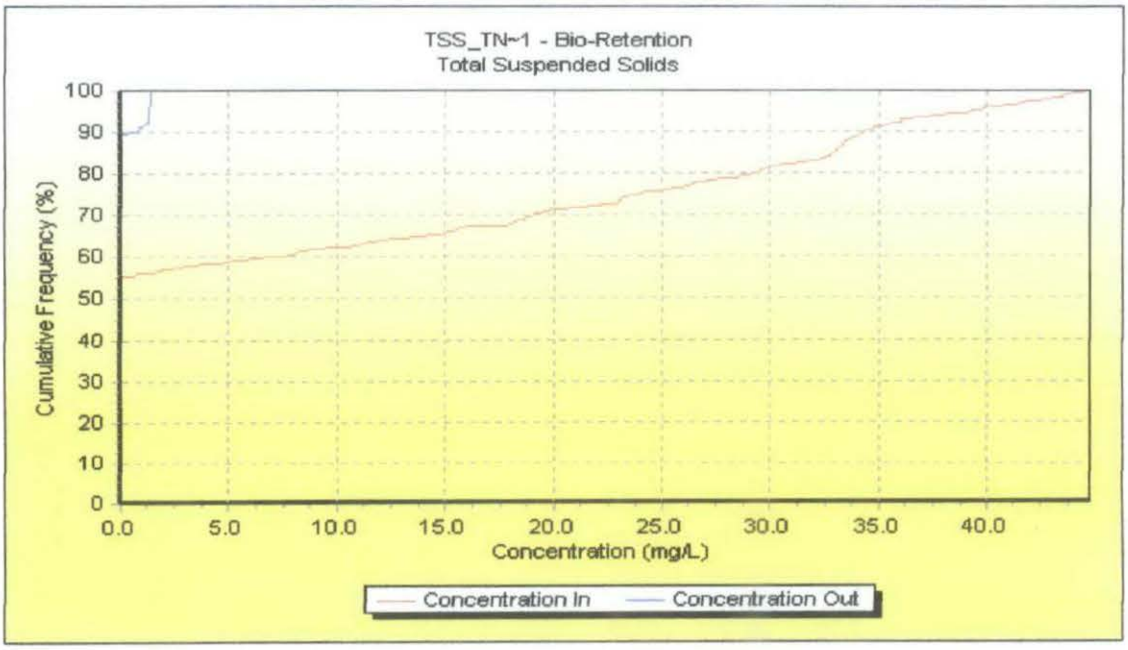

Figure 46: Cumulative Frequency Graph of TSS for Sg.Air Putih -after intervention (Wet)

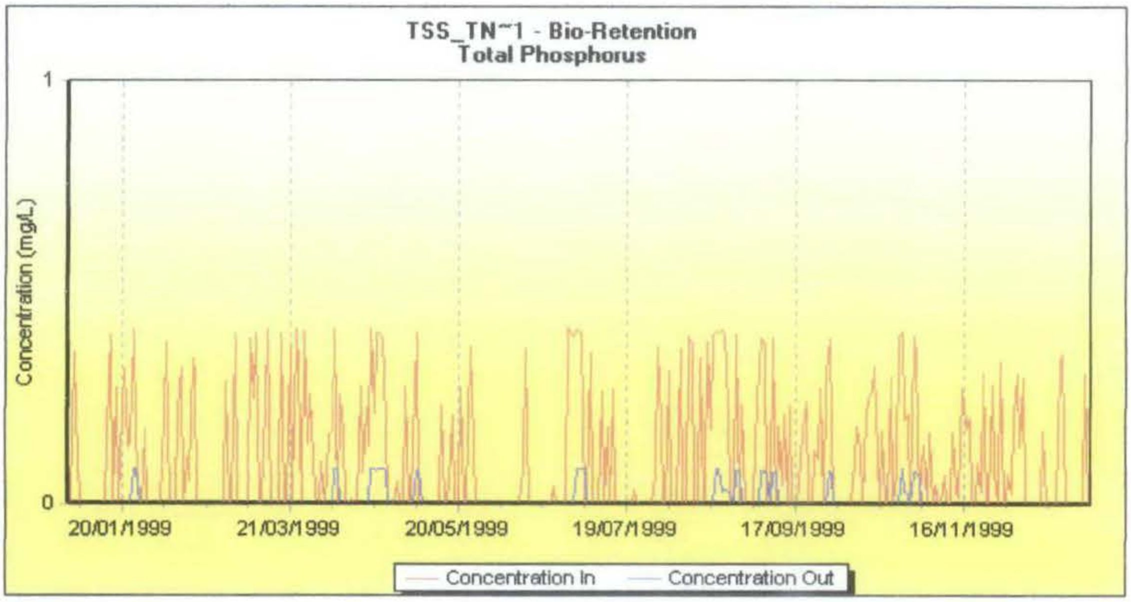

Figure 47: Time-Series Graph of TP for Sg.Air Putih-after intervention (Wet)

Mean : 7.52×10^{-3} mg/L
Maximum : 86.9×10^{-3} mg/L
Minimum : 0.00 mg/L

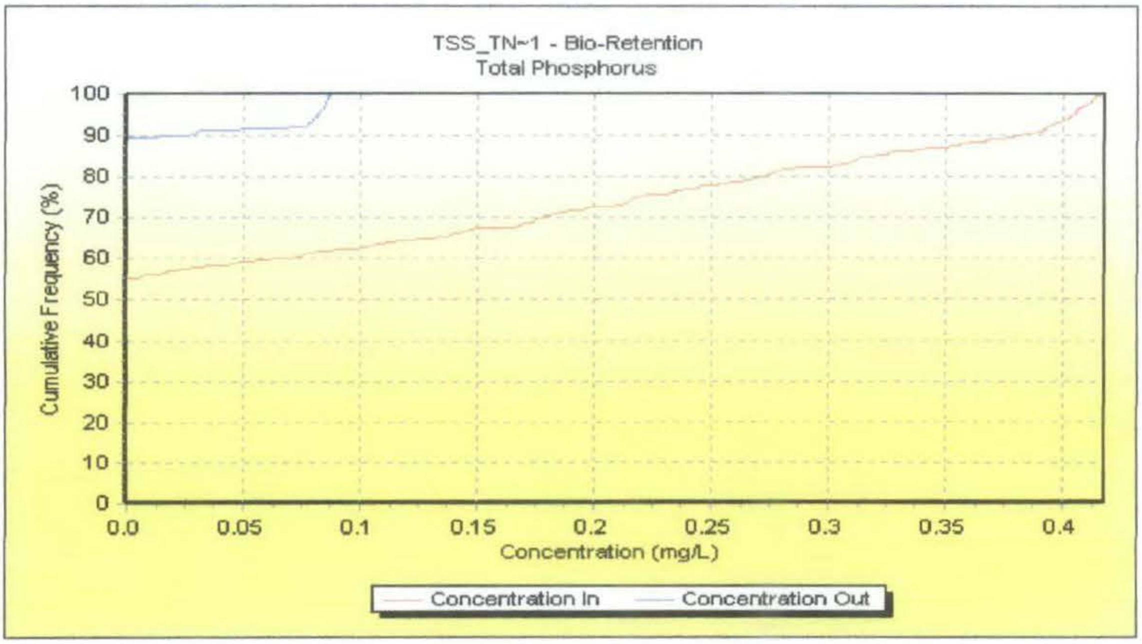

Figure 48: Cumulative Frequency Graph of TP for Sg.Air Putih -after intervention (Wet)

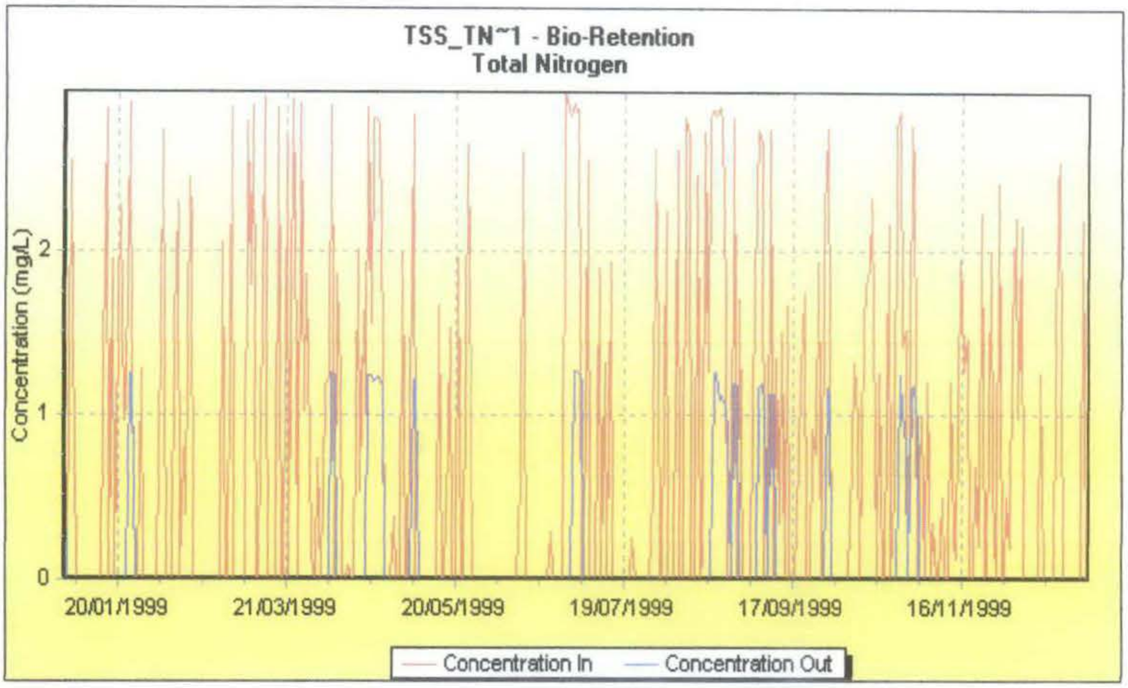

Figure 49: Time-Series Graph of TN for Sg.Air Putih-after intervention (Wet)

Mean : 7.52×10^{-3} mg/L
Maximum : 86.9×10^{-3} mg/L
Minimum : 0.00 mg/L

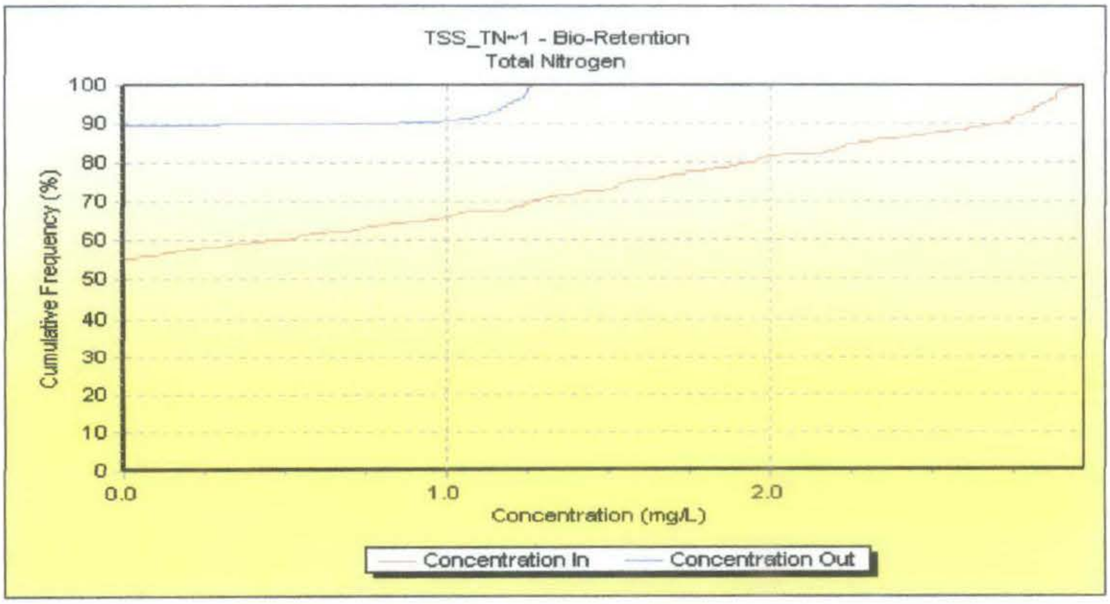

Figure 50: Cumulative Frequency Graph of TN for Sg.Air Putih -after intervention (Wet)

Table 4: The Predicted Results of Sg. Air Putih from MUSIC Software (before intervention)

Concentration (mg/L)	Weather Flow	Mean	Max	Min
TSS	Wet	11.100	44.700	0.000
	Dry	11.400	44.500	0.000
TN	Wet	0.775	2.970	0.000
	Dry	0.768	2.990	0.000
TP	Wet	0.109	0.418	0.000
	Dry	0.109	0.423	0.000

Table 5: The Predicted Results of Sg. Air Putih from MUSIC Software (after intervention)

Concentration (mg/L)	Weather Flow	Mean	Max	Min
TSS	Wet	01.28×10^{-3}	1.440	0.000
	Dry	6.33×10^{-3}	1.500	0.000
TN	Wet	0.12	1.270	0.000
	Dry	5.15×10^{-3}	1.270	0.000
TP	Wet	7.52×10^{-3}	86.9×10^{-3}	0.000
	Dry	0.312×10^{-3}	86.7×10^{-3}	0.000

Table 4 and Table 5 are summarization of the predicted results in MUSIC software before and after intervention. From both tables, the reduction of all parameters TSS, TN and TPP can be predicted accurately.

4.1.3 Laboratory Analysis

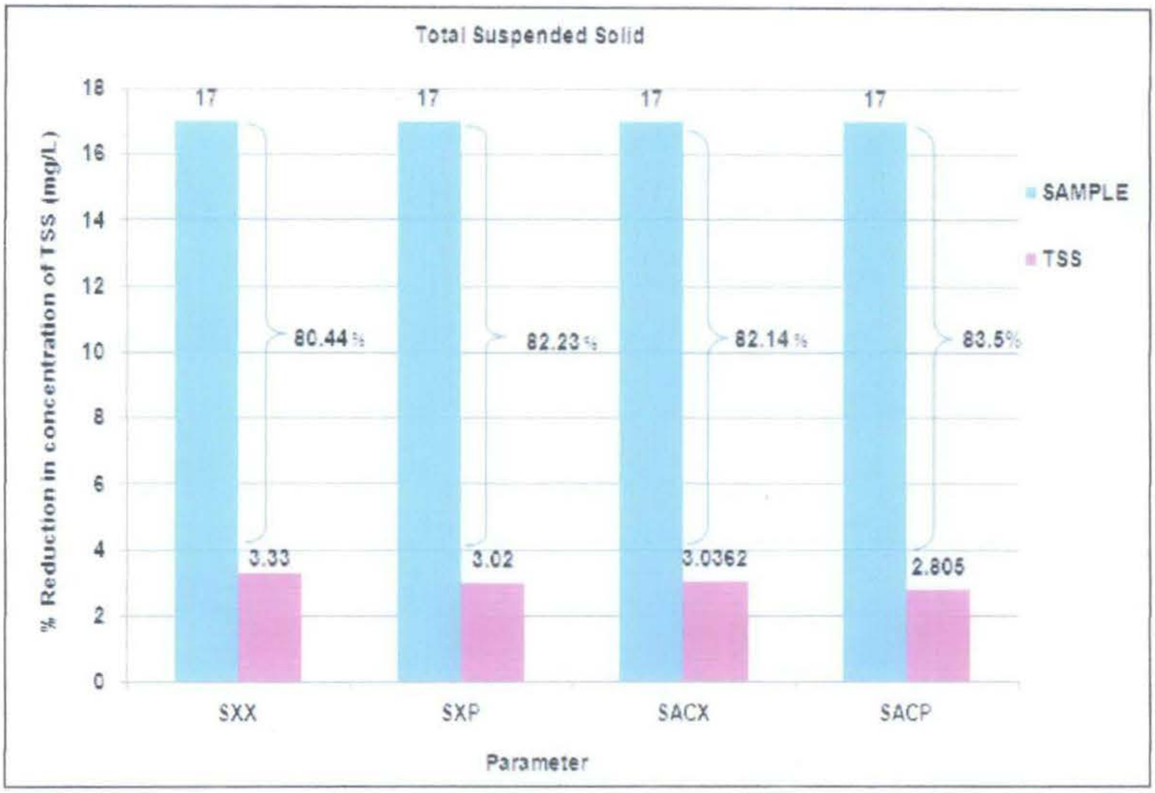

Figure 51: The Percentage Reduction of TSS in Laboratory Model

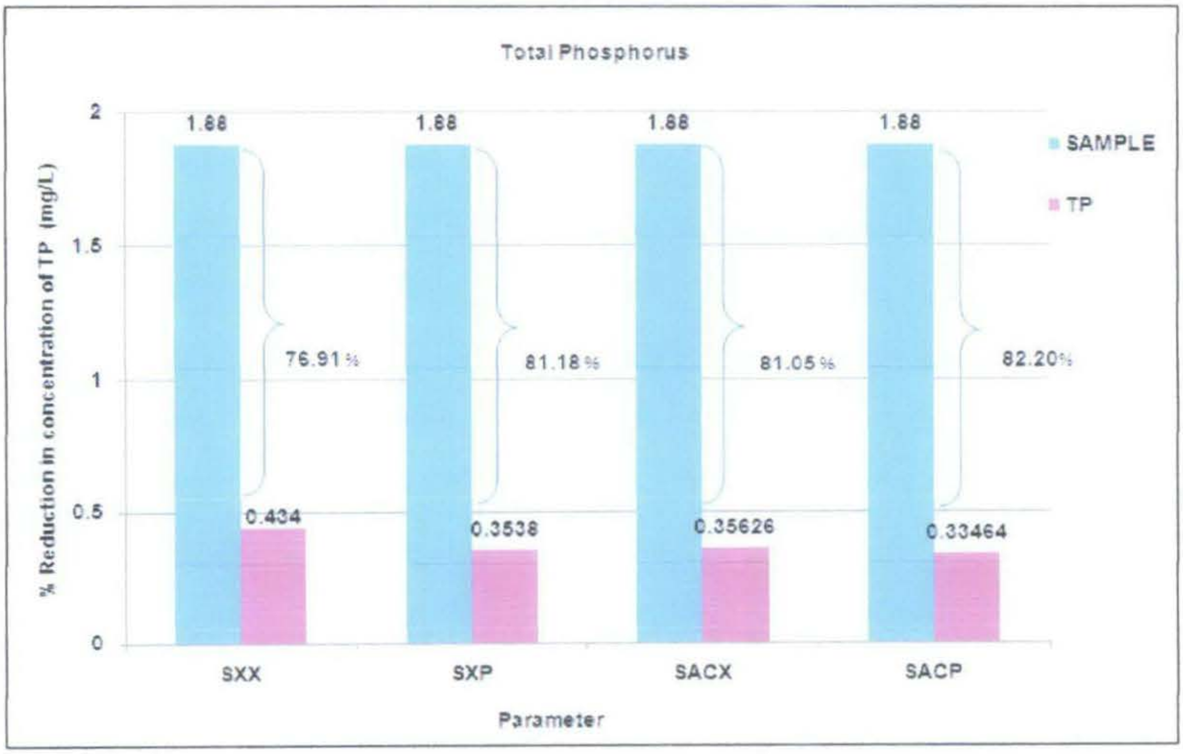

Figure 52: The Percentage Reduction of TP in Laboratory Model

Figure 53: The Percentage Reduction of TN in Laboratory Model

All the graphs above show the concentration of the sample before and after treated by using the physical model of bioretention. The tests have been done by using four different designs of the bioretention;

- SXX – Saturated *without* plant
- SXP – Saturated *with* plant
- SACX – Saturated with activated carbon but *without* plant
- SACP – Saturated with activated carbon and *with* plant

The presence of the plant in the bioretention can reduce more TSS and TP as compared to the bioretention without plant. It is because the plant can trap suspended solid in the surface storage before the influent flow to the filter media. Besides, the plants have the positive effect on TP removal due to the presence of the root system that can trap the phosphorus.

The plant also provides a substrate for biofilm growth within the upper layer of the filter media, which facilitates biological transformation of pollutants (particularly nitrogen) and that is why the biretention with the plant is not suitable in reducing the nitrogen.

The bioretention that have activated carbon gave the lowest in reduction for all parameters. The reason is that the activated carbon is like a filter and the adsorption-desorption capability of activated carbon was incorporated into biological denitrification process with the addition of external carbon source for nitrogen removal in water and wastewater treatment. From that, it is recommended that the activated should be choosing as one of the component for filter media of bioretention.

Then, the result should be analyzed in order to compare the reduction in predicted results from MUSIC with the actual results in the laboratory. The design of bioretention in the laboratory that similar with the design in the MUSIC is the SXP (saturated with plant). So that, the data analysis done between the results of SXP and the predicted results in MUSIC in dry weather flow.

4.1.4 Comparison between actual results (from laboratory) & predicted results (from MUSIC)

	Inflow	Outflow	% Reduction
Flow (ML/yr)	9.02E3	1.97E3	78.2
Total Suspended Solids (kg/yr)	252E3	2.32E3	99.1
Total Phosphorus (kg/yr)	2.86E3	130	95.5
Total Nitrogen (kg/yr)	20.1E3	2.28E3	88.6
Gross Pollutants (kg/yr)	121E3	0.00	100.0

Figure 54: The Percentage Reduction in Predicted Results (from MUSIC)

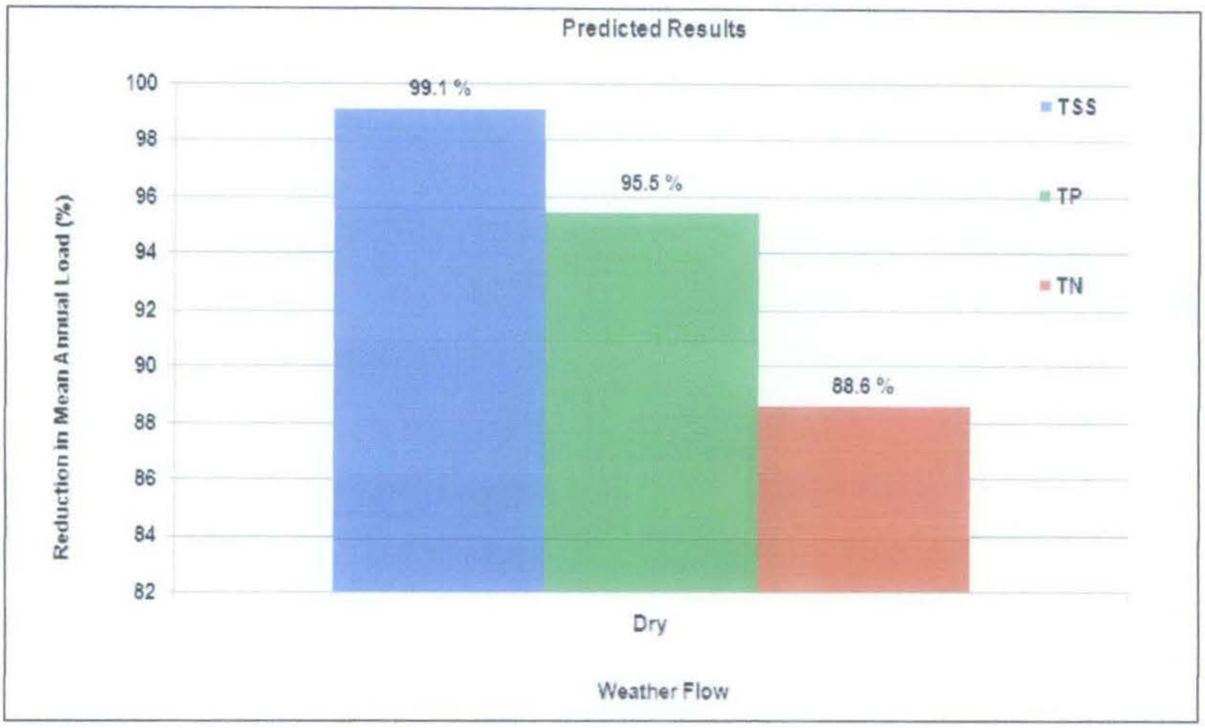

Figure 55: The Graph of Reduction in Predicted Results from MUSIC software

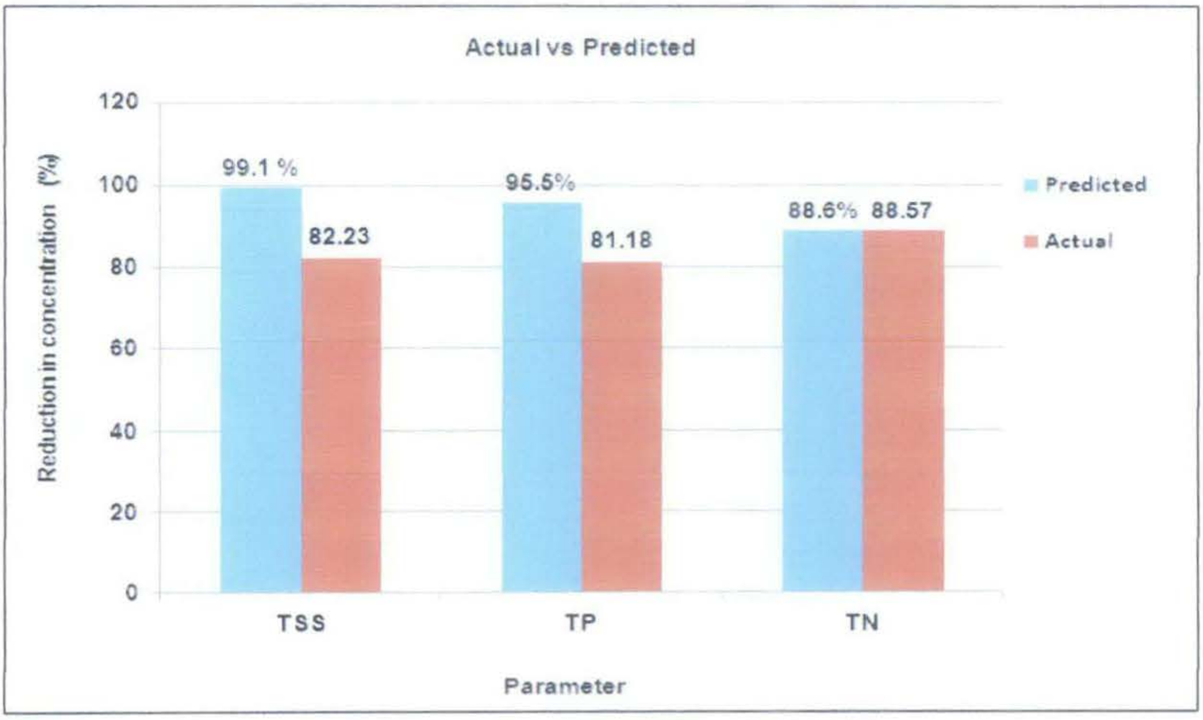

Figure 56: The Comparison between Predicted and Actual Results

Table 6: The Comparison between Predicted & Actual Results

Parameters	Predicted Results (%)	Actual Results (%)
TSS	99.1	82.23
TP	95.5	81.18
TN	88.6	88.57

Table 6 shows the comparison of percentage reduction in concentration of TSS, TP and TN between the predicted and the actual result. The percentage reductions for concentration TN for actual and predicted results are exactly the same. While others parameters have differences around 14%-20 %.

The difference between those results is due to the errors during the laboratory works. Another factor is because the bioretention is not stable enough. Supposedly, the author should let the soil stable for 2 months but in this case the author only stabilizes the bioretention for 5 weeks. That is why there are the differences in the predicted and actual results.

4.2 Properties of Bio-retention in the MUSIC

Representative Seepage Rates:

0 to 0.36 mm/hr for heavy clay
0.36 to 3.6 mm/hr for medium clay
3.6 to 36 mm/hr for sandy clay
36 to 180 mm/hr for sandy loam
180 to 360 mm/hr for sand
360 to 3600 mm/hr for coarse sand

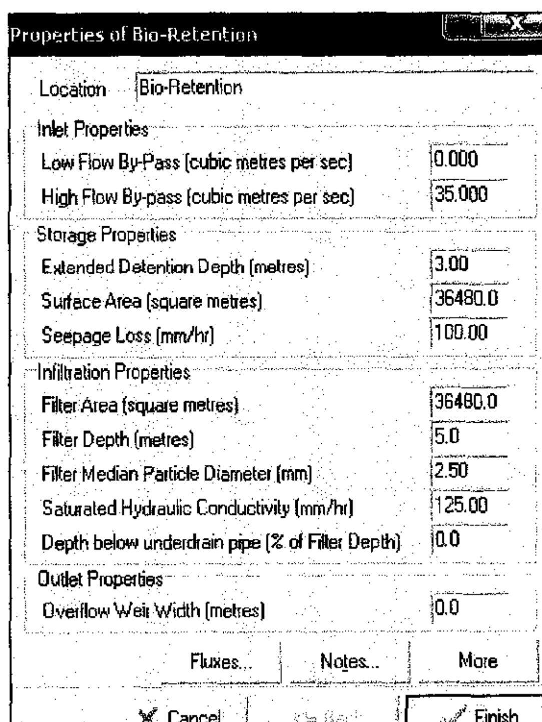

Figure 57: Properties of Bioretention

Table 7: Saturated Hydraulic Conductivity

SOIL TEXTURAL CLASSES & RELATED SATURATED HYDRAULIC CONDUCTIVITY CLASSES					**HYDROTREND VALUES**
Texture	Textural Class	General	Ksat Class	Ksat Rate (µm/sec.)	**Ksat Rate (mm/day)**
Coarse sand	Coarse	Sandy	V. rapid	> 141.14	**> 1219.45**
Sands Loamy sands			Rapid	42.34-141.14	**364.95-1219.45**
Sandy loam ***Fi. san. loam***	***Mod. coarse***	***Loamy***	***Mod. Rapid***	***14.11-42.34***	***121.91-364.95***
v. fi. sa. loam loam silt loam	Medium		Moderate	4.23-14.11	**36.55-121.91**
silt				1.41-4.23	**12.18-36.55**
clay loam sa. cl. loam si. cl. loam	Mod. fine		Mod. slow		
sandy clay silty clay clay	Fine and very fine	Clayey	Slow	0.42-1.41	**3.63-12.18**
Cd horizon Natric horizon, fragipan, ortstein			V. slow or impermeable	0.00-0.42	**0.00-3.**

CHAPTER 5
CONCLUSION

Below are the objectives that had been set at the beginning of the project;

1. To determine the water quality of Sungai Pinang catchment using MUSIC software;
2. To predict the performance of bioretention as a treatment measure (in simulation of MUSIC);
3. To assess the efficiency of bioretention in order to improve the water quality of the river.

For first objective, the water quality for the whole Sg.Pinang and the choosen sub-catchment which is Sg.Air Putih was presented in the result in the form of time-series graph and cumulative frequency graph.

The second objective has been achieved by model simulation with bioretention intervention and those results are known as predicted results using MUSIC software.

The data analysis has been done to ensure that the third objective was achieved. From the data analysis, the results were compares between the predicted results from MUSIC software and the actual results from laboratory.

As a conclusion, the results were comparable and all the objectives had been achieved.

CHAPTER 6
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APPENDIX A

1.1 LABORATORY ANALYSIS

1.2 1.1.1 TOTAL SUSPENDED SOLIDS (TSS)

1.2.1.1 PROCEDURES

1) A 47mm filter disc was placed in the filter holder with the wrinkled surface upward.
2) 100 mL of well-mixed, representative water sample was filtered by applying the vacuum filter to the flask, followed by three separate 10mL washings of deionised water.
3) The vacuum was slowly released from the filtering system and the filter disc was gently removed from the holder. The disc placed on a watch glass. The filtrate (filtered water in flask) was inspected to ensure that proper trapping of solids was accomplished on the disc.
4) Place the watch glass and filter in a drying oven at 103^0C for 1 hour.
5) The watch glass and filter was removed from the oven, and placed on desiccators. It was allowed to cool at room temperature.
6) The disc was removed carefully from the desiccators and weighted to the nearest 0.1mg using an analytical balance.
7) The disc was returned to the watch glass if the mg/L Volatile Non-filterable Residue (VNR) is to be determined. If not, the disc was discarded.
8) The TSS content before and after the application of intervention of wetlands is going to be compared and the percentage reduction will be calculated.

1.2.1.2 CALCULATIONS

To calculate the TSS value;

TSS = (Weight, pan + filter paper after drying) – (Weight, pan + filter paper before drying)

Sample Size (L)

To calculate the percentage reduction:

$$\% \text{ Reduction} = |TSS_{before} - TSS_{after}| \; / \; TSS_{before} \times 100\%$$

1.2.13 HSE ASSESSMENT AND MEASURES

Table 1: HSE Risk Assessment in Handling an Oven in the Laboratory

CONSEQUENCE					PROBABILITY				
Rating	People	Assets (RM)	Environment	Reputation	**A** Never Heard of in industry	**B** Heard of Incident in Industry	**C** Incident Has occurred in Our Company	**D** Happens Several Times Per Year in Company	**E** Happens Several Times Per Year
0	No injury	No Damage	No impact	No impact					
1	Slight injury	Slight damage	Slight impact	Slight impact					
2	Minor injury	Minor damage	Minor impact	Limited impact				Demonstrate ALARP	
3	Minor injury	Local damage	Localized impact	Considerable impact					
4	Single fatality	Major damage	Major impact	Major national		Incorporate Risk Reduction Measures			
5	Multiple fatalities	Extensive damage	Massive impact	Major international				Control or Alternatives	

From this risk assessment, it can be concluded that ALARP must be demonstrated during handling the oven.

In any laboratory works, the following steps must be taken:

- Use appropriate personal protection equipment (PPE).
- Be familiar with first aid kit.
- Use the Standard Operating Procedures and Code of Practice provided.

1.2.2 TOTAL NITROGEN (TN)

1.2.2.1 PROCEDURES

Digestion

1. 10 mL of sample was filled into the digestion tube.
2. H_2SO_4 (98% pure) was added according to the table in application note (20mL).
3. 10 tablets of catalyst were added.
4. Covered in Fume Cupboard, the 'nose' was first closed and the put at the back.
5. The samples were then placed into the digestion unit.
6. The exhaust tube was hooked up to all nose at the back.
7. The Scrubber was switched ON first. NaOH 15% was used in the scrubber unit.
8. The tap water was switched ON to water level mark. Color indicator was added (pink/ bromothymol blue).
9. When scrubber is ON, the digestion unit was switched ON (switched to 10).
    a. Bubbling of air in the scrubber was ensured.
    b. Vacuum was checked if there is any leakage at scrubber.
10. The samples were digested for 30 minutes.
11. After 30 minutes, it was reduced to 5 for 15-20 minutes.
12. Digestion was switched off for cooling 30 minutes.
13. The tap water inlet was switched OFF.
14. All suction tubes were removed for distillation.

Distillation

1. System was switched ON – warmed up for 10 minutes.
    a. H_2O & NaOH – 10 litres were ensured full.
    b. Preheating with empty tube & steam 4 minutes.
2. Tap water was switched ON.
3. The sample was diluted and 50mL of distilled water was added.
4. The sample tube was placed in the distiller.
5. 70 mL of NaOH was added.

6. Distillation was started for 30 minutes.
7. 60 mL of Boric acid was added to trap ammonia (using conical flask).
8. Distiller was stopped and switched OFF.
9. The samples were titrates using 0.25M H_2SO_4 using color indicator.
10. Volume of H_2SO_4 used for pH to 4.65 or color change was determined.

1.2.2.2 CALCULATION

mg $(NH_3\text{-}N)/L$ = (A-B) x 280 / mL sample

where A = H_2SO_4 consumption for sample

B = H_2SO_4 consumption for blank

1.2.3 TOTAL PHOSPHORUS (TP)

1.2.3.1 PROCEDURES

1. The DRB200 Reactor was turned on and preheated to 150°C.
2. The 536 P Total/ AH PV TNT test was selected. The Light Shield in Cell Compartment #2 was installed.
3. A TenSette Pipet was used to add 5.0 mL of sample to a Total and Acid Hydrolyzable Test Vial.
4. A funnel was used to add the contents of one Potassium Persulfate Powder Pillow for Phosphonate to the vial.
5. The vial was capped tightly and was shook to dissolve.
6. The vial was inserted into the DRB200. The protective cover was closed.
7. TIMER>OK was pressed.
8. When the timer expires, the hot vial was carefully removed from the reactor. It was inserted in a test tube rack and cooled to room temperature.
9. A TenSette Pipet was used to add 2mL of 1.54N Sodium Hydroxide Standard Solution to the vial. It was capped and mixed.
10. The outside of the vial was wiped with a damp cloth followed by a dry one.
11. The vial was inserted into the 16mm cell holder.
12. ZERO was pressed. The display showed: 0.00mg/L PO_4^{3-}.
13. A funnel was used to add the contents of one PhosVer 3 Powder Pillow to the vial.
14. It was capped immediately and was shook to mix for 20-30 seconds.
15. The TIMER>OK was pressed. A two-minute reaction period began. The sample was read within 2-8 minutes after the timer expires.
16. After the timer expires, the outside of the vial was wiped with a wet towel, then a dry one. The prepared sample vial was inserted into the 16mm cell holder. READ was pressed. Results are in mg/L PO_4^{3-}.

1.2 DID HYDROLOGICAL PROCEDURE NO 5 CALCULATION

HP5 - RATIONAL METHOD OF FLOOD ESTIMATION FOR RURAL CATCHMENTS IN PENINSULAR MALAYSIA

CATCHMENT SUMMARIES;

1. Location =	Sg. Air Putih	
2. Catchment Latitude & Longitude =		
3. Catchment Area, A =	4.56	sq.km.
4. River Slope (%), S =	8.60	%
5. Length of Main Stream, L =	3.89	km

SOLUTIONS ;

Calculate Critical Storm Duration, Tc (Catchment Time of Concentration);

Tc =	(1.286 x L)/(A^(0.223) x S^(0.263))		- Eqn. 4 from DID HP5 (1989
Tc =	2.03	hours	
Tc =	0.08	days	

Check;

Tc =	(58.5 x L)/((A^0.1)x(S^0.2))		- Bransby-Williams (ARR,19
Tc =	80.22	min.	
Tc =	1.34	hours	
Tc =	0.06	days	

The Tc for the catchment area is about = 0.06

From DID (HP1), find; figure 10

I(100,Tc) = 136.12 mm/hr 182 mm

From (HP5) the curve frequency factor Ct/C10 for different regions, find for relevant region;

C10(Region1) = 0.13

C100 = 0.1645 C100/C10 = 1.27

Compute the estimate of design discharge, QT;

Qt = 0.278 x CT x I x A

Q100 = 28.38 m^3/s

1.3 Construct bioretention model

1.3.1 Design phase:

a) search information about bioretention

b) finalize the material or components for the bioretention

1.3.2 Construction of bioretention phase:

a) The PVC column was cut due to its specific dimension (length is 82 cm)

b) PVC cap was drilled about 9 mm in order to ensure that it is enough to locate the tube inside the hole.

c) The tube also was cut about 1 meter each.

d) The components for bioretention (coarse sand) were collected from the back of building 13.

e) All the components (planting soil, compost, activated carbon and coarse sand) that had been prepared were put into the PVC column based on the design length.

f) The plants were planted at the PVC column that had been fill in with the others components.

Table 2: HSE Assessment during the Journey to Jurutera Perunding Zaaba Sdn. Bhd (Data Gathering)

CONSEQUENCE					PROBABILITY				
Rating	People	Assets (RM)	Environment	Reputation	A Never Heard of in industry	B Heard of Incident in Industry	C Incident Has occurred in Our Company	D Happens Several Times Per Year in Company	E Happens Several Times Per Year
0	No injury	No Damage	No impact	No impact					
1	Slight injury	Slight damage	Slight impact	Slight impact					
2	Minor injury	Minor damage	Minor impact	Limited impact				Demonstrate ALARP	
3	Minor injury	Local damage	Localized impact	Considerable impact					
4	Single fatality	Major damage	Major impact	Major national		Incorporate Risk Reduction Measures			
5	Multiple fatalities	Extensive damage	Massive impact	Major international				Control or Alternatives	

APPENDIX B

Table 1: Land Use Area of Sungai Pinang

DRAIN	Open Area	Forest	Residential	Construction	Urban	Industry	Road & Highway
D1	131.25	3.1	1.03	4.24	0	0	1.703
D2	37.87	3.2	3.48	0	0.39	0.04	2.667
D3	2.06	0	0.09	0.03	0	0	1.383
D4	2.82	0	1.12	0	0.04	0	1.998
D5	2.3	0	0	0	0.15	0	1.062
D6	1.39	0	0.72	0	0	0	0.863
D7	0.99	0	0.49	0	0.07	0	1.189
D8	0	0	1.25	0	0.62	0	1.558
D8-H7	0.29	0	1.51	0	0.54	0	1.396
H7	0.29	0	0.66	0	0.3	0	0.844
H6	0.09	0	0.5	0	0.01	0	0.603
H5	0.56	0	0.09	0	0	0.19	0.954
A3-H5	0.02	0	0.15	0	0.19	0.03	0.54
A3	0.2	0	0.04	0	0.19	0	0.441
A2	0.1	0	2.52	0	0	0	0.55
A2a	62.26	0	6.41	2.3	0.07	0	0.667
A1	347.94	0	3.84	0.08	0	0	0.982
H4	2.17	0	0.13	0	0.03	0	0.603
H3	49.01	0	4.36	0	0.24	0	0.851
H2	0.91	0	0.04	0	0.11	0	0.626
H1	541.3	380.63	0.23	0	0.13	0	0.398
H8	0.8	0	0	0	0.39	0	0.389
H9	0.65	0	0	0	2.98	0	2.317
H10	0	0	0.12	0	0.13	0	0.682
H10-P1	0.64	0	2.11	0	0.98	0	1.85
T9-P1	0.55	0	9.04	0	1.9	0	2.446
T9	0.02	0	3.22	0	0.29	0	0.421
T8	0	0	0.73	0	0.17	0	0.332
T7	0.29	0	0.38	0	0	0	0.597
T6	0.03	0	0.8	0	0	0	0.599
T5	78.28	0	0.36	0	2.38	0	1.2
T4	4.15	0	0.78	0	0	0	0.586
T3	2.98	0	1.08	0	0.06	0	0.889
T2	2.64	0	1.49	0	0	0	0.649
T1	491.57	259.17	2.84	0	1.33	0	1.043
P2	0	0	0	0	0.27	0	0.563
P3	0.41	0	0	0	0.06	0.18	1.059
P4	1.08	0	0.01	0	0.01	0	1.203
P5	1.04	0	0.01	0	0.18	0	0.824
P6	0.08	0	1.27	0	0	0	0.894
P7	0.05	0	0.14	0	0.17	0.8	4.456

Table 2: Value of EMC (Event Mean Concentration)

Parameter	Open Area	Forest	Residential	Construction	Urban	Industry	Road & Highway
AN (mg/l)	0.31	0.25	1.25	1.35	1.76	1.53	1.55
BOD (mg/l)	8	8	10.8	13.5	15	15	14
COD (mg/l)	23.5	15	83	87	92	115	73.5
DO (mg/l)	3.7	3.8	3.2	3.6	3.2	3	3.2
NO2 (mg/l)	0.0017	0.0011	0.0068	0.015	0.0064	0.017	0.0064
NO3 (mg/l)	0.27	0.23	0.57	0.53	0.83	0.79	0.83
TN (mg/l)	2.9	1.2	3.1	6.9	3.5	4.1	3.6
TP (mg/l)	0.42	0.13	0.47	0.35	0.45	0.51	0.34
TSS (mg/l)	29	23	119	250	138	85	103
Total Coliform (MPN/100ml)	1000000	862111	5004530	3054530	4004530	4301579	2000000
Faecal Coliform (MPN/100ml)	70000	67865	62619	54000	59619	88721	72000

Parameter	OA	FOR	RES	CON	URB	IND	RH
TSS	1.462	1.362	2.076	2.398	2.140	1.929	2.013
TN	.462	.079	.491	.839	.544	.613	0.556
TP	-.377	-.886	-.328	-.456	-.347	-.292	-0.469

Table 3: Rainfall Data of Sungai Pinang Catchment Area (Wet) at 1999

Janary	February	March	April	May	June	July	August	September	October	November	December
[illegible]	0	28.9	2.3	19.8	0	79.2	0	0	0	5.3	0
0	0	0	0	0	0	45.6	0	0	0	8.5	2.5
[illegible]	0	0	1.8	0	0	63.9	9.5	6.9	0	0.5	1.5
[illegible]	4.4	0	3.3	5.3	0	0	0	41.7	0	10.8	8.5
0	39.9	0	3.3	96.5	0	0	0	50.9	0	0	22.3
0	0	0	87.4	0.6	0	34.3	0.9	41.2	0	2.8	5
0	0	12.1	0.7	0	0	0	16.6	0	0	0	23.4
0	0.5	2.2	10.8	0	0	0	0	0	4.2	0	0
0	4.5	21.2	5.4	0	0	0	0	70.6	8.3	3.3	0
0	11.2	0	0.5	0	0	15.9	30.9	0	5.3	1.2	0
0	0.7	0	0	0	0	0	23.5	13.2	0.3	0.1	0
0	2	1.9	1.2	0	1.4	7.4	0	2.9	9.3	7.8	0
0	1.4	32.9	0	0	11	0	0	16.1	12.4	1.8	0
[illegible]	12.1	0.5	0	9.9	0	15.5	12.2	1.2	13.9	1.4	6.6
[illegible]	7.7	0	11.9	0	0.9	0	1	19.9	29.2	17.1	0
[illegible]	0	0	2.1	0	0	0	1.1	0.9	4.6	12.6	0
0	0	0	6.8	3.4	0	0	31.5	0	0	7.1	0
[illegible]	0	13	3.3	7	0	0	3.7	0	7.8	8.9	0
0	0	0	102.9	0	0	0	45	5.4	0	0	0
[illegible]	0	0.8	8.3	0	0	0	76.8	9.9	0	0	23.8
[illegible]	0.6	4.6	57.9	10.3	0	0	56.1	18.5	24.3	3.2	36.3
[illegible]	0	0	57.4	0.9	0.6	1.5	119.5	0	1	1.5	0
2	0	16.8	53.5	0	1.1	0	55.6	0	3	21.7	0
[illegible]	0	2.1	10.8	32.6	0	0	13.5	5.9	58.4	1	0
[illegible]	0	0	0	8	0.5	0	0	4.6	106	1.1	0
0	3.9	53.6	0	0.5	0.3	0	0	20.5	11.5	14.9	0
0	0	2.4	0	0.1	0	0	86.6	0	13.8	2.6	0
[illegible]	0	6.7	2.6	0	63.3	0	0	32.8	0.1	0	0
0		2.4	0	0	18.9	1.8	17.9	53.2	68.7	30.3	15.2
0		1.2	0	0	34.6	26.1	0	11.4	28.3	0	0
0		0		0		3.9	0		0.9		0

Table 4: Rainfall Data of Sungai Pinang Catchment Area (Dry) at 1997

Janary	February	March	April	May	June	July	August	September	October	November	December
0	0	0	0.5	0	0	0.5	0	0	4.5	0	0.5
0	0	11	0	5	0	21.5	0	0	9	4	0
0	13	0	0	0	13	12.5	0	0	7	2	0
0	18	0	0	0	0	0	0	0	36.5	59	0
0	0	0	0	1.5	0	0	0	2.5	51	4.5	0
0	0	0	0.5	0	0	0	0	9	7	4.5	10
0	1	0	0	1	3	0.5	0	11.5	1	0	1
0	34.5	0	11	7	5	0	0	0	13	0	0
0	0	10.5	1.5	24	21	0	0	0	12.5	0	0
0	0	6.5	5	0	0	0	0	0	0.5	0	0
0	8.5	12.5	0	15	17	0	0	0	0	12.5	0
0	10.5	0	3.5	29.5	0	0	0	0	0.5	7	0
[illegible]	4	1.5	35	0.5	0	0	0	0	0	0.5	10
0	12	0	7.5	0.5	1.5	0	6.5	0	9	27	0
0	1	0	1.5	0	0	0	1	0	0	2	0
0	23	7	0	7	0	0	6	0	15	1	0
0	0	4	0	13.5	0	0	0	0	6.5	0.5	0
[illegible]	0	6.5	0	0	0.5	0	5	28	2	0	31.5
1	0	0	0	0	0	0	0	16.5	0	33	0
0	0	4	0	0	2.5	0	17	6.5	2	0	4.5
5	0	0	0	0	0	26.5	16	0	1.5	9.5	0
0	1	0	0	0	0.5	0	1	0	0	1.5	0
0	10.5	0.5	0	0	1	1	86	0	2	36.5	0
0	12	0	0	2	0	0	31.5	0	0	9	0
0	1.5	1.5	11	0	1	14	0.5	0	1	3	0.5
0	0	0	0	0	7	40	0.5	0	0	8.5	0
0	0	0	11	1	23	0.5	0	0	0.5	44.5	0
0	0	0	5	0	6.5	0	0	5	23	0	0
0		0	1.5	0	0	0	0	0	20	0	0
0		0	27.5	0	0	0	0	8.5	11.5	0	0
0		2		0		0	0		3		0

Table 5: Evaporation Data for Sungai Pinang Catchment Area

Janary	February	March	April	May	June	July	August	September	October	November	December
4	6	6	4	5	5	5	3.5	4.5	4	4	4
4	3	5	4	5	5	5	3.5	5	3.5	4	4.5
4	5	5	2	5	5	5.5	3	4.5	5	5	3
4	3	5	4	5	5	3.5	3	4	4.5	3	3
4	2	4	4	5	5	4	3	3	6	4	4
5	5	5	4	4	5	2.5	4.5	3.5	4.5	4	4
5	5	2	4	4	5	5	4	4	6	4	3
5	6	4	5	4	5	5	5	5	3	4	3
5	6	5	4	5	6	5	5	5	3	4	4
5	6	5	4	5	5	5	4	5	5.5	3.5	4
5	5	3	5	5	3	5	4	5	4	4.5	4
5	6	4	3	5	2	5	4.5	5.5	4	4	4
5	5	3	5	6	2	3.5	4	5	4	6	3.5
5	5	1	5	6	6	6	5	5	4	5	4
5	4	4	4	5	6	5	4	5	4	4.5	4
5	5	4	5	4	2	4.5	5	6	4	3.5	2
5	6	4	4	4	2	5.5	5	5	4	3	4
6	6	4	5	3	5	6	5	6	5	3.5	4
5	5	4	2.5	5	5	5	5	4.5	4	4	5
5	5	3	3	4	5.5	6	5	5	4	4	3.5
6	6	5	1	4.5	5.5	6	5	5.5	5	4	4
5	5	4	2	4	5	4	4.5	5.5	4	4.5	5
2	5	2	1	5	5	6.5	4.5	5	5	4	4
4	5	3	4	5.5	5	4.5	4	5	4	4	4
4	4	5	5	6	5	4	3	4	4	4.5	5
5	5	5	5	4	5	8	3.5	4	4	4	4
5	5	5	5	5	4	10	3	5.5	6	4	4
3	5	2	5	5	3	6	6	4.5	3	3.5	4
5		4	3	5	10	2	4.5	4	3.5	4	5
5		4	5	4	5	8	5	5	4	4.5	5

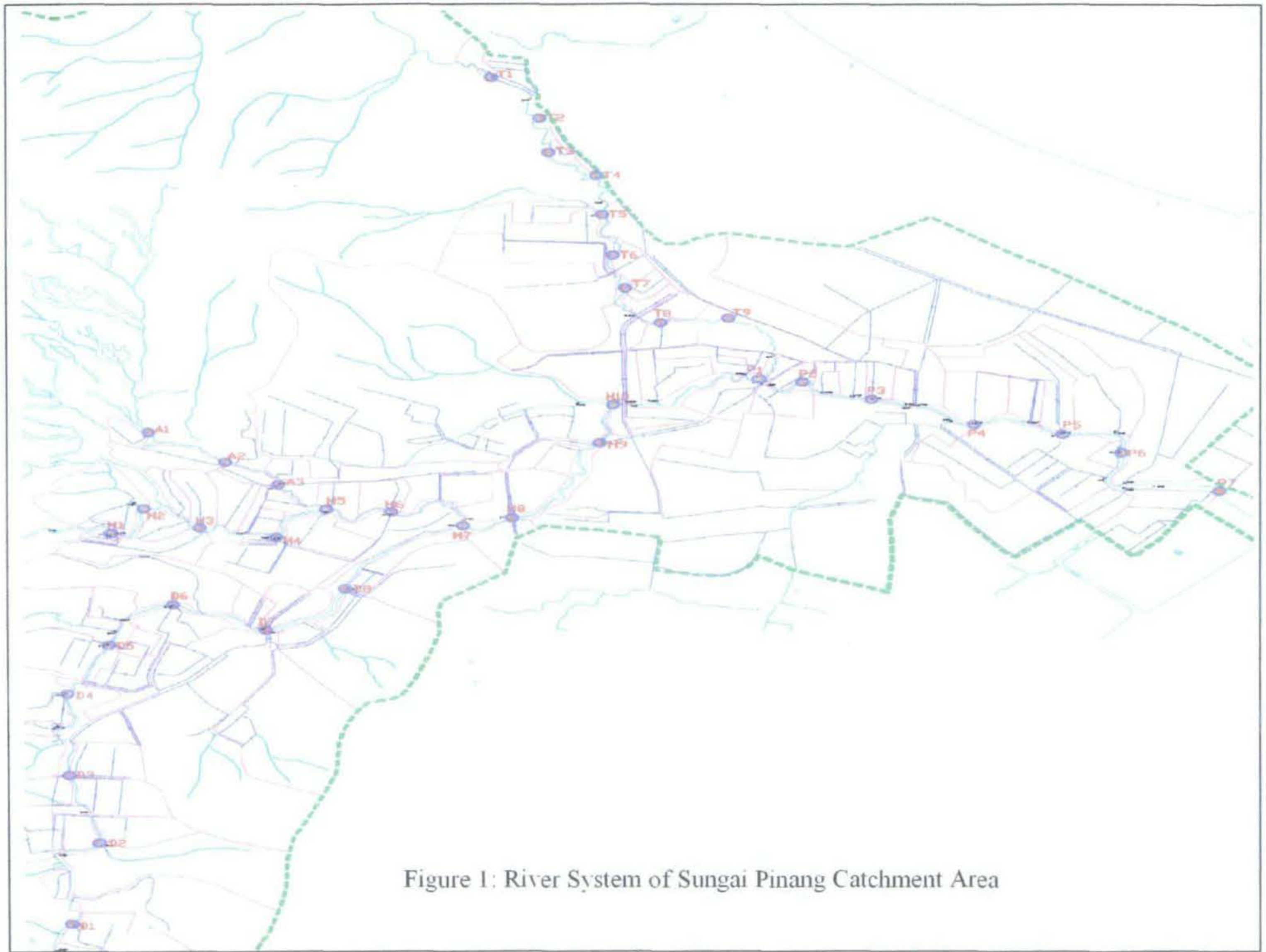

Figure 1: River System of Sungai Pinang Catchment Area

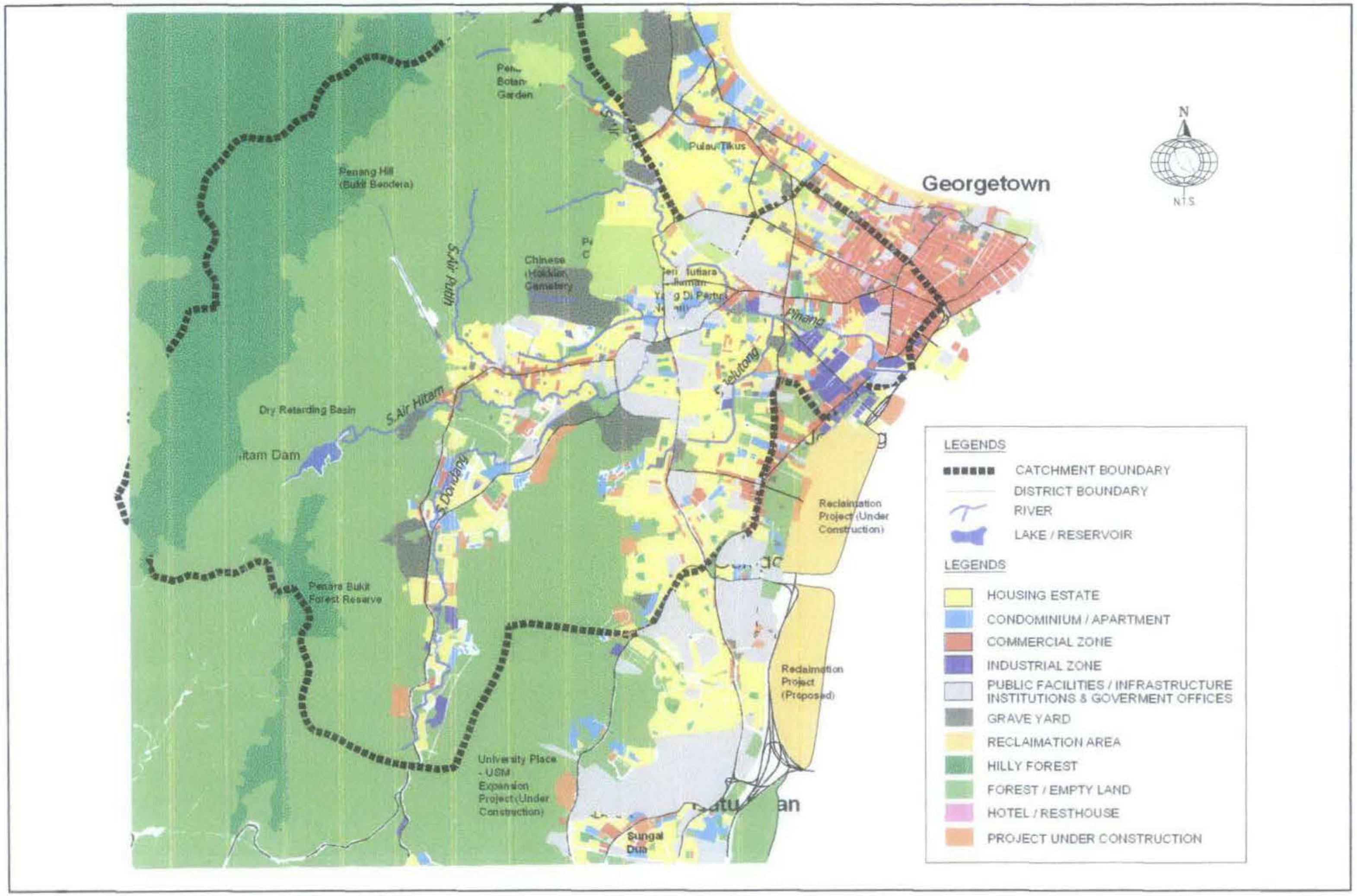

Figure 2: Land use Map of Sungai Pinang Catchment Area

Table 6: Results of TSS in Laboratory

TSS	Before	After			After-before	sample Size (mL)	TSS (mg/L)	TSS ave (mg/L)	% Removal /reduction
		1	2	average					
Water Sample	1.2912			1.2928	0.001600	100	16.00	17.00	
	1.2967			1.2984	0.001700	100	17.00		
	1.2068			1.2086	0.001800	100	18.00		
SXX	1.3201	1.3201	1.3206	1.3204	0.000250	100	2.00	3.33	80.41
	1.2769	1.2769	1.2773	1.2771	0.000200	100	2.00		
	1.3372	1.3378	1.3378	1.3378	0.000600	100	6.00		
SXP	1.2845	1.2849	1.2845	1.2847	0.000200	100	2.06	3.02	82.23
	1.2939	1.2945	1.2941	1.2943	0.000400	100	4.00		
	1.312	1.3131	1.3115	1.3123	0.000300	100	3.00		
SACX	1.3466	1.3479	1.3461	1.3470	0.000375	100	3.75	3.04	82.14
	1.4421	1.4433	1.4415	1.4424	0.000285	100	2.85		
	1.405	1.4059	1.4046	1.4053	0.000251	100	2.51		
SACP	1.4516	1.4524	1.4514	1.4519	0.000322	100	3.22	2.81	83.5
	1.4382	1.4387	1.4382	1.4385	0.000240	100	2.40		

Table 7: Results of TP in Laboratory

	TP (mg/L)	TP ave (mg/L)	% removal
Water Sample	1.890	1.88	
	1.870		
SXP	0.180	0.354	81.18
SXP	0.174		
SXX	0.250	0.434	76.91
SXX	0.184		
SACP	0.050	0.335	82.2
SACP	0.285		
SACX	0.020	0.356	81.05
SACX	0.336		

Table 8: Results of TN in Laboratory

	Remaining (ml)	H2SO4 (ml)	pH	m1	TN	%reduction
Distillation	126	0.1120	4.48			
Water sample	116	0.4620	4.45	3.92	0.70	
SXX	128	0.1188	4.56	0.076	0.01	89.14
SXP	128	0.1190	4.3	0.08	0.01	88.57
SACX	150	0.1178	4.33	0.065	0.01	90.73
SACP	115	0.1189	4.4	0.077	0.01	89

APPENDIX C

FYP 1

NAME: SALIHAH BT SOMBAR @ ABDUL HAMID
ID NO: 6244
TITLE : NPS Pollution Modeling of Sungai Pinang Catchment Area
& Water Improvement by using Bioretention.

TASK	WEEK														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Project Title Submission	■ ●														
Proposal preparation		■	■	■ ●											
Data collection					■	■	■ ●								
Data Analysis								■	■	■ ●					
Model simulation											■	■	■	■ ●	
Design bioretention															■ ●

● Project Title Submission : Submit to coordinator FYP 1
● Proposal preparation : Submit proposal
● Data Collection Print the data
● Data Analysis Print the result
● Model simulation : Print the result

FYP 2

NAME: SALIHAH BT SOMBAR @ ABDUL HAMID
ID NO: 6244
TITLE : NPS Pollution Modeling of Sungai Pinang Catchment Area
& Water Improvement by using Bioretention.

TASK	WEEK														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Construct bioretention model	■	■	■	■	■	■									
Simulation of MUSIC (apply bioretention)						■	■	■							
Laboratory works							■	■	■	■					
Compared the actual model with the simulation of MUSIC									■	■					
Poster presentation										■					
Improvement Work											■	■	■	■	
Final presentation															■

- Construct bioretention model : Ready in laboratory
- Simulation of MUSIC (apply bioretention) : Print the result
- Laboratory works : Print the result
- Poster presentation : Show the poster
- Final presentation : Present the outcome of the overall project