STORMWATER MANAGEMENT BY SECTORAL APPROACH

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UNIVERSITI TEKNOLOGI PETRONAS
JULY 2009

Stormwater Management by Sectoral Approach

by

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DISSERTATION SUBMITTED IN PARTIAL FULFILLMENT OF
THE REQUIREMENTS FOR THE
BACHELOR OF ENGINEERING (HONS)
(CIVIL ENGINEERING)

JULY 2009

Universiti Teknologi Petronas
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CERTIFICATION OF APPROVAL

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A project dissertation submitted to the
Civil Engineering Programme
Universiti Teknologi PETRONAS
In partial fulfillment of the requirements for the
BACHELOR OF ENGINEERING (Hons)
(CIVIL ENGINEERING)

Approved by,

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JULY 2009

CERTIFICATION OF ORIGINALITY

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

....
(HASNUL HANIF HALIM)

ABSTRACT

This report is a brief discussion on the research conducted and basic understanding of the chosen topic, which is Stormwater Management by Sectoral Approach. This study attempts to explore solutions to the stormwater problems which have now been realized that the drastic development dramatically alters the local hydrological cycle and also affect the water quality. This study evaluates the effectiveness of sectoral approach in stormwater management and the best approach to reduce stormwater pollution. In order to understand the effects of stormwater to the environment, five samples from different area in Seri Iskandar were selected and four lab tests were conducted which are BOD Test, COD Test, Turbidity Test and Suspended Solids Test to check for stormwater quality. Runoff quality showed large variations of lab results for each area especially for BOD, COD and Suspended Solids. Further study was done to determine the pollution source for each area and solutions for the pollution were included in this report. In general, the stormwater quality in Seri Iskandar is badly polluted and some of the parameters fall in Class V based on the Malaysian Interim National Water Quality Standards. The COD value for sample one (238mg/L), sample two (136 mg/L), sample four (118mg/L) and sample five (150mg/L) were higher than 100mg/L which mean it falls under class V water. Besides, the BOD value for sample five (26.64mg/L) was higher than 12mg/L and was categorized under class V water. Overall, the outputs of this study give a useful insight into the status of stormwater management practices and effectiveness in Seri Iskandar that will help with the development as well as maintaining clean environment. Although the effect of one property on the quality and quantity of stormwater runoff may seem insignificant, the cumulative impact from hundreds of thousands of yards across the State continues to be destructive to our water quality.

ACKNOWLEDGEMENT

This project, conducted in the Civil Engineering Department of Universiti Teknologi PETRONAS, was done with the help and support of many people whom I would like to thank.

Firstly I would like to praise Allah the Almighty, which have helped and guided me in completing my Final Year Project in partial fulfillment of the requirements for the bachelor of engineering (hons). I would also like to express my sincerest gratitude to my Final Year Project supervisor, AP Dr Nasiman B. Sapari. His continuous motivation and commitment to this project has made it more meaningful and worthwhile. While maintaining his professionalism as a lecturer and supervisor, she also made effort to understand the difficulties and problem which I encountered.

In conducting this study, a lot of manpower was required. The experiment that I've done for this project could not be done successfully without the help and expertise of the laboratory technician of Civil Engineering Department who have been very helpful, unconditionally. I would like to take this opportunity to sincerely thank Mr. Anuar, Mr. Zaaba and Kak Yus.

For the purpose of this project, I also engaged the assistant of other party. Here, I would like to acknowledge the staff of Jabatan Pengairan Dan Saliran Ipoh, Perak. namely En. Suhaimi for his effort and assistance in guiding me throughout my project.

Undertaking this project has been a great challenge, physically and mentally. My friends have been there to provide support and help. I would like to personally convey my appreciation to Suhairi and Asmat and others who have contributed directly or indirectly to the completion of this project.

Last but not least, my deepest appreciation to my father, mother brother and sister for their never-ending, care and patience. I could not have done this without their encouragement and understanding.

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1.1 Background of study

1.1.1 Definition

Stormwater management is everything done within a catchment to remedy existing stormwater problems and to prevent the occurrence of new problems. It involves the development and implementation of a combination of structural and non-structural measures to reconcile the conveyance and storage function of stormwater systems within the space and related needs of an expanding population. It also involves the development and implementation to improve the quality of stormwater runoff prior to its discharge to receiving waters.

Figure 1.1. Stormwater Detention Pond

Over the years, intensive urban development has resulted in a large proportion of the land surface been paved or covered with impervious surfaces, roads and buildings. These situations have contributed to excessive surface runoff volumes. The storm runoffs normally contain all sort of pollutants such as contaminants from atmosphere through rain drops and also accumulated flushes material such as rubbish, dirt, chemicals, fertilizers, pesticides, and other pollutants.

Figure 1.2 shows the different percentage of runoff, infiltration and evapotranspiration between the natural ground and the impervious layer (Adams, 2000).

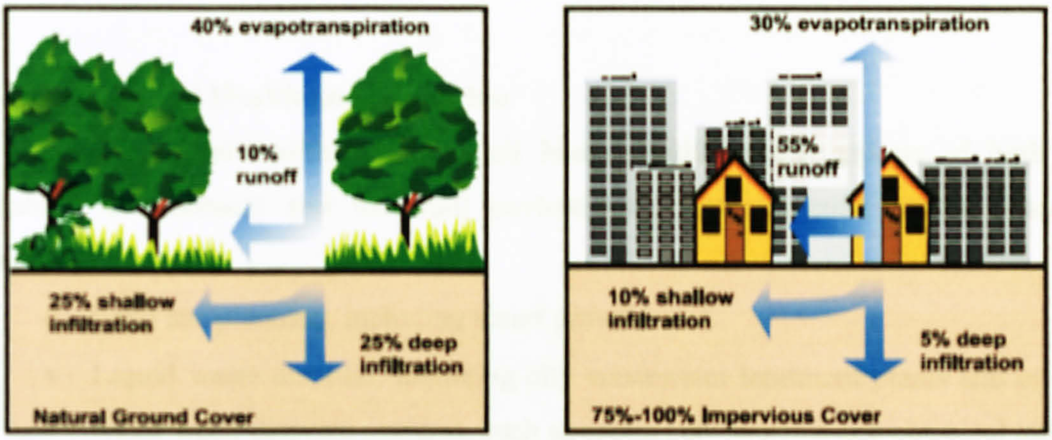


Figure 1.2. Different Conditions between Natural Grounds Cover and Impervious Layer

1.1.2 Strategic Approach

Nowadays, greater awareness of the sensitivity and importance of the natural environment has led to change in the approach to managing the environment by government and communities. The control of both the quantity and quality of urban runoffs is now being seen to be major importance in the management of urban stormwater which involves:

i. Establishment of a storage-oriented approach for controlling runoff quantity from development site.
ii. Establishment of objective which will achieve required levels of floods protection and water quality enhancement.
iii. Establishment of water quality management strategies
iv. Development and implementation of monitoring and surveillance programs to ensure that runoff quantity and water quality being maintained.

1.2 PROBLEM STATEMENTS

Stormwater management has become a concern in government policy due to its importance. The poor stormwater management could lead to a lot of problems such as :

1.2.1 Environmental Health and Sanitation

Environmental health addresses all human-health-related aspects of both the natural environment and the built environment. Environmental health concerns include:

- Land use planning, including smart growth.
- Liquid waste disposal, including city wastewater treatment plants and on-site waste water disposal systems, such as septic tank systems and chemical toilets.
- Recreational water illness prevention, including from swimming pools, spas and ocean and freshwater bathing places.
- Safe drinking water.

1.2.2 Breeding of Vector Due To Water Stagnation

Water stagnation occurs when water stops flowing. Stagnant water can be a major environmental hazard. Water stagnation has become a common problem in Malaysia, making it a good source of mostly mosquito breeding (Figure 1.3), which results in spread of several vector borne diseases like malaria, dengue, chikungunya, etc.

Figure 1.3. Mosquito Larvae in Stagnant Water

1.2.3 Pollution of Water

There are two types of water pollutants exist; point source and nonpoint source. Point sources of pollution occur when harmful substances are emitted directly into a body of water. A nonpoint source delivers pollutants indirectly through environmental changes. An example of this type of water pollution is when fertilizer from a field is carried into a stream by rain, in the form of run-off which in turn affects aquatic life (Figure 1.4). Nonpoint sources are much more difficult to control. Pollution arising from nonpoint sources accounts for a majority of the contaminants in streams and lakes (Bedient, 1995).

Figure 1.4. Polluted River

1.3 OBJECTIVE

The main objective of the project is to study the existing system and management of stormwater and its consequence to the environment as well as to do research to come out with the solutions for better control and better management of stormwater. Correspondently, the project also aims to develop well-rounded civil engineers that have a high awareness and understanding on impact of development, which includes social and environmental responsibilities as an equal to economic goals.

1.4 SCOPE OF STUDY

The scope of this study would be on the analyzing current stormwater management in Seri Iskandar area and evaluating the effectiveness of sectoral approach in stormwater management. For this paper, it would focus on the study of stormwater management in Seri Iskandar, starting from description of the study area. Then the area will be divided into several sectors and the water sample will be collected for water quality analysis. After that, the pollution source will be identified as well as the solutions to those problems. Every research concerning to it will be studied and the results would be included in this paper. The benefits that would be gained at the end of this research would definitely be helpful in order to come out with the best stormwater management to overcome problems such as polluted river, flooding and breeding of vector due to water stagnation.

CHAPTER 2: LITERATURE REVIEW

2.1 EXISTING LAW AND REGULATION IN MALAYSIA

The National Policy on the Environment adopted in 2002 outlines strategies to propel country's growth trends towards sustainable development which embodies the three pillars; economic development, social development and environment protection.

According to the Land Conservation Act, 1960, the full authority on urban drainage falls within the jurisdiction of each State Government. Each State Economic Planning Unit carries out the overall planning co-ordination at the state level. The rest of the responsibilities are mainly delegated to the Local Authorities. This responsibility covers planning, construction, operations and maintenance of the drainage facilities within their areas of jurisdiction. The Local Authority in addition also has the regulatory responsibility on works carried out by others.

Enforcement on stormwater related legislation rests mainly on the Land Administrator and Local Authority as shown in Table 2.1.

Table 2.1. Enforcement Authority Related to Storm water

OFFENCES	ENFORCEMENT AUTHORITY
Land-use violation	Land Administrator /Local Authority
Littering and unauthorised solid waste disposal	Local Authority
Unlicensed blockages and diversions	Land administrator /Local Authority
Effluent discharge violations	Department of Environment / Local Authority
Unauthorised discharge and abstraction	Land administration

Stormwater management essentially deals with issues related to urban drainage and how runoff from urban areas is effectively managed with minimum impact on life and property. Drainage must now be looked at within the context of integrated management of water resources.

In addressing issues related to stormwater management one has to keep in mind laws relating to the following issues:

- water which includes rivers, groundwater, lakes, wetlands, estuaries, coastal waters and other water bodies (collectively referred to as "water sources") as ultimately all drains flow into such water sources;
- land and the development/exploitation of such land;
- drainage;
- municipal administration which is under the authority of the State Authority/local government
- environmental management

(Tsihrintzis & Hamid, 1997).

The Environmental Quality Act, 1974 (EQA), section 25 stated that "no person shall, unless licensed, emit, discharge or deposit any waste into any inland waters in contravention of acceptable conditions." Besides that part viii of the EQA provides the control of activities or nuisance that may pollute any stream, channel, public drain or other water course within the local authority area and local authorities may:

1. prevent littering or depositing of any wastes or filth;
2. prevent any waste being allowed to flow into or the discharge of any liquid or solid;
3. regulate bathing or washing by persons or of animals;
4. prohibit, abate, remove or prevent the occurrence of any nuisance;
5. control the method of cultivation, irrigation and the use of manure or fertilizers;
6. control the keeping of fish
7. generally do all things necessary for or conducive to the safety, health and convenience of the public.

2.2 STORM WATER QUALITY IN MALAYSIA

The state of water quality in Malaysia for the year 2007 is as following. The main river pollutants are domestic sewage, waste from livestock, farms, runoffs from towns, silt from earthworks, leachate from rubbish dumps, runoffs from farms, litter from riverside squatters and mining waste. Of the total of 146 river basin monitored, 80 were deemed clean, 59 slightly polluted and 7 polluted.For marine, it was showed a higher of Escherichia coli, mercury and arsenic level last year than a year before. However, levels of suspended solids, oil and grease, copper, lead, cadmium and chromium dropped (Yusop, Tan, Ujang, Mohamed & Nasir, 2005).

The pollutants commonly found in stormwater runoff and their impacts can be summarized as follows.

2.2.1 Sediment

- Sediment is often viewed as the largest pollutant load associated with storm water runoff in an urban setting. The loadings have been shown to be exceptionally high in the case of construction activity.
- Sediment is associated with numerous impacts in surface waters including increased turbidity, effects on aquatic and benthic habitat and reduction in capacity of impoundments (Figure 2.1).
- A number of other pollutants often attach to, and are carried by, sediment particles.

Figure 2.1. River Carrying Sediment from Construction Area

2.2.2 Nutrients

- The nutrients most often identified in storm water runoff are phosphorus and nitrogen.
- In surface waters, these nutrient loads can lead to heavy algae growth, eutrophication (especially in impoundments) and low dissolved oxygen levels.
- Nutrients enter the urban system in a variety of ways, including landscaping practices (commercial and home), leaks from sanitary sewers and septic systems, and animal wastes.

2.2.3 Organic Matter

- Various forms of organic matter may be carried by storm water in urban areas. Decomposition of this material by organisms in surface waters results in depleted oxygen levels.
- Low levels of dissolved oxygen severely impact water quality and life within surface waters.
- Sources of organic matter include leaking septic systems, garbage, yard waste, etc.

2.2.4 Heavy Metals

- Heavy metals such as copper, lead, zinc, arsenic, chromium and cadmium may be typically found in urban storm water runoff.
- Metals in storm water may be toxic to some aquatic life and may accumulate in aquatic animals.
- Urban sources of metals in storm water may include automobiles, paints, preservatives, motor oil and various urban activities.

2.2.5 Oil and Grease

- Numerous activities in urban areas produce oil, grease, and lubricating agents that are readily transported by storm water.
- The intensity of activities, including vehicle traffic, maintenance and fueling activities, leaks and spills, and manufacturing processes within an urban setting contribute heavily to the level of these pollutants present in adjacent surface waters.

2.3 PROBLEMS ASSOCIATED WITH THE STORMWATER

Malaysia is a growing city with the population expected to increase dramatically in the next 50 years, the careful plan to manage this growth is needed. One area that will need particular attention is how to deal with storm water, to minimize flooding and pollution in the city's streams, underground waters and beaches, and maintain affordable infrastructure (Lee, 1990).

The main problem associated with stormwater is flood. Urbanization, if not properly planned and managed, can dramatically alter the natural hydrology of an area. Increased impervious cover decreases the amount of rainwater that can naturally infiltrate into the soil and increases the volume and rate of storm water runoff. These changes lead to more frequent and severe flooding and potential damage to public and private property.

Besides that, the rate of runoff and stream flow after a storm event also shows dramatic increases under post versus predevelopment conditions. The higher and more rapid peak discharge of runoff and stream flow can overload the capacity of the stream or river, causing downstream flooding and stream bank erosion (Figure 2.2).

Local governments spend a lot of money each year rectifying damage to public and private property caused by uncontrolled stormwater runoff. In heavily developed areas, damage to public and private property occurs during heavy rains. This damage includes road, culvert and water and sewer line washouts, flooded homes and yards, the deposition of sediment and debris on properties and roads, and damage to bridges (Ellis & Hvitved-Jacobsen,1996).

Figure 2.2. Stream Bank Erosion and Fills the Streams with Sediment

Stormwater runoff is also a major source of water pollution. Various pollutants are deposited on surfaces due to man's activities and are washed off during storms into storm drains or directly into streams, rivers and lakes. Pollutant levels are typically much higher in the first inch of runoff commonly referred to as the first flush (Ketchum, Choe & Yu, 2002).

Streams draining urbanized areas have fair to poor water quality due to stormwater runoff and leaking sewer lines. Some reefs along West Malaysia's coast have been contaminated and closed due to stormwater runoff and other pollution sources. Uncontrolled stormwater runoff has many impacts on humans and the environment including:

i. Flooding - Damage to public and private property, including infrastructure (Figure 2.3)
ii. Eroded Stream banks - Sediment clogs waterways, fills lakes, reservoirs
iii. Widened Stream Channels - Loss of valuable property
iv. Aesthetics - Dirty water, trash and debris, foul odors
v. Fish and Aquatic Life - Impairment/destruction
vi. Impaired Recreational Uses - Swimming, fishing, boating, etc.
vii. Threatens Public Health - Contamination of drinking water, fish/shellfish
viii. Threatens Public Safety - Drowning in flood waters
ix. Economic Impacts - Fisheries, shellfish, tourism, recreation related businesses
x. Increased Cost of Water and Wastewater Treatment – Storm water pollution increases raw water treatment costs and reduces the assimilative capacity of water bodies.

Figure 2.3. Flood Causing Damage to Properties

2.4 EXISTING SOLUTIONS TO THE STORMWATER PROBLEMS

Mechanisms for controlling stormwater runoff impacts can be grouped into a couple of categories of activities:

- **Preventative Measures**

  These measures work to reduce the impacts of stormwater runoff through changes in design, operation, or management to minimize or prevent the generation of runoff and the contamination of runoff from pollutants. Preventative measures include land use management practices and source reduction practices. Land use management practices use methods to best plan the way to locate land uses within a jurisdictional area or project site to avoid environmental impacts. Source reduction practices focus on locating the sources of pollutants and implementing design and operational changes that minimize or completely remove these sources. Preventative measures can be very efficient and effective since they are implemented to keep pollutants from ever getting into stormwater.

- **Control Measures**

  These are devices that are put in place to capture stormwater flows and provide pollutant removal through filtering, infiltration, detention, or some related process. These measures may be limited in their ability to efficiently remove some pollutants and may be fairly costly. Control measures also require commitment to long-term operation and maintenance to assure that the measures continue to function properly.

Figure 2.4 and 2.5 show some examples of control measures that have been used to capture stormwater flows.

Figure 2.4. Sand Filters Trap

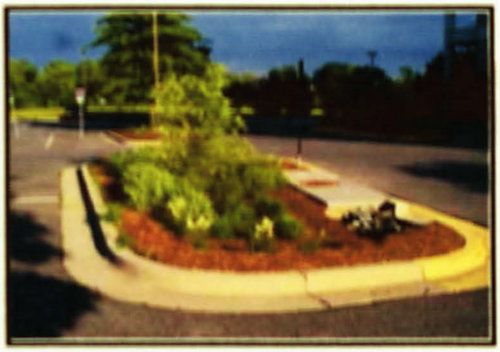


Figure 2.5. Constructed Bioretention Area

Public awareness is an important part of storm water pollutant reduction. Unfortunately not everyone is currently aware that the decisions they make can have an impact on storm water pollution. As an example, some people assume that storm water runoff that enters a storm sewer system is being routed to some type of treatment process before entering our surface waters. The list below is certainly not all inclusive, but it gives an idea of things citizens can do to help control storm water pollution.

- Maintain buffer areas around stream segments to protect stream banks and to provide a mechanism for pollutant removal.
- Minimize impervious areas to reduce runoff.
- Design all new construction to prevent or minimize runoff and storm water pollution – a major component here is planning up front in the design process to consider and manage potential storm water problems.
- Practice "good housekeeping" by keeping areas clean of potentially harmful pollutants. This also may involve changing activities or practices if they have potential impacts.

- Use lawn care practices that protect water quality – minimize the use of fertilizers and pesticides, and when used, do so in a safe manner. When possible incorporate native plant species since they are best adapted to the local growing conditions and tend to be naturally pest resistant.
- Properly use and store household materials and be aware of and make use of local recycling and collection centers to handle household wastes.

(Whipple, Grigg & Gizzard, 1983).

2.5 STORMWATER MANAGEMENT IN OTHER COUNTRY

i. Auckland, New Zealand

Figure 2.6. Logo of Auckland City Council

Auckland City has devices for treating storm water to reduce the level of pollutants. These include:

- catch pits with silt traps
- road sweeping
- litter traps, for example in Oakley Creek
- detention ponds, for example in Waiatarua Basin, which hold storm water for a period, allowing sediments and pollutants to settle, before it is released into the sea
- mechanical filtration systems at Central Park in Penrose.

Auckland City's has a 2005 milestone of removing 27 per cent of the suspended sediments in 70 per cent of storm water catchments. The aim is to protect the city's streams and coastal environments from the gradual build-up of pollutants commonly transported in storm water that can harm freshwater and marine food webs.

Between 2000 and 2003, they protected 190 habitable floors and properties, and a further 100 will be protected by 2005/06 when the Motions Creek project is finished. Completing currently listed projects will see an additional 263 properties protected over the following 5-7 years. The total 20-year expenditure on flood alleviation is predicted to be $256 million (Rimer, Nissen & David, 1978).

CHAPTER 3 : METHODOLOGY

The project will be conducted using the survey research methodology. The flow chart of the methodology is shown in Figure 3.1.

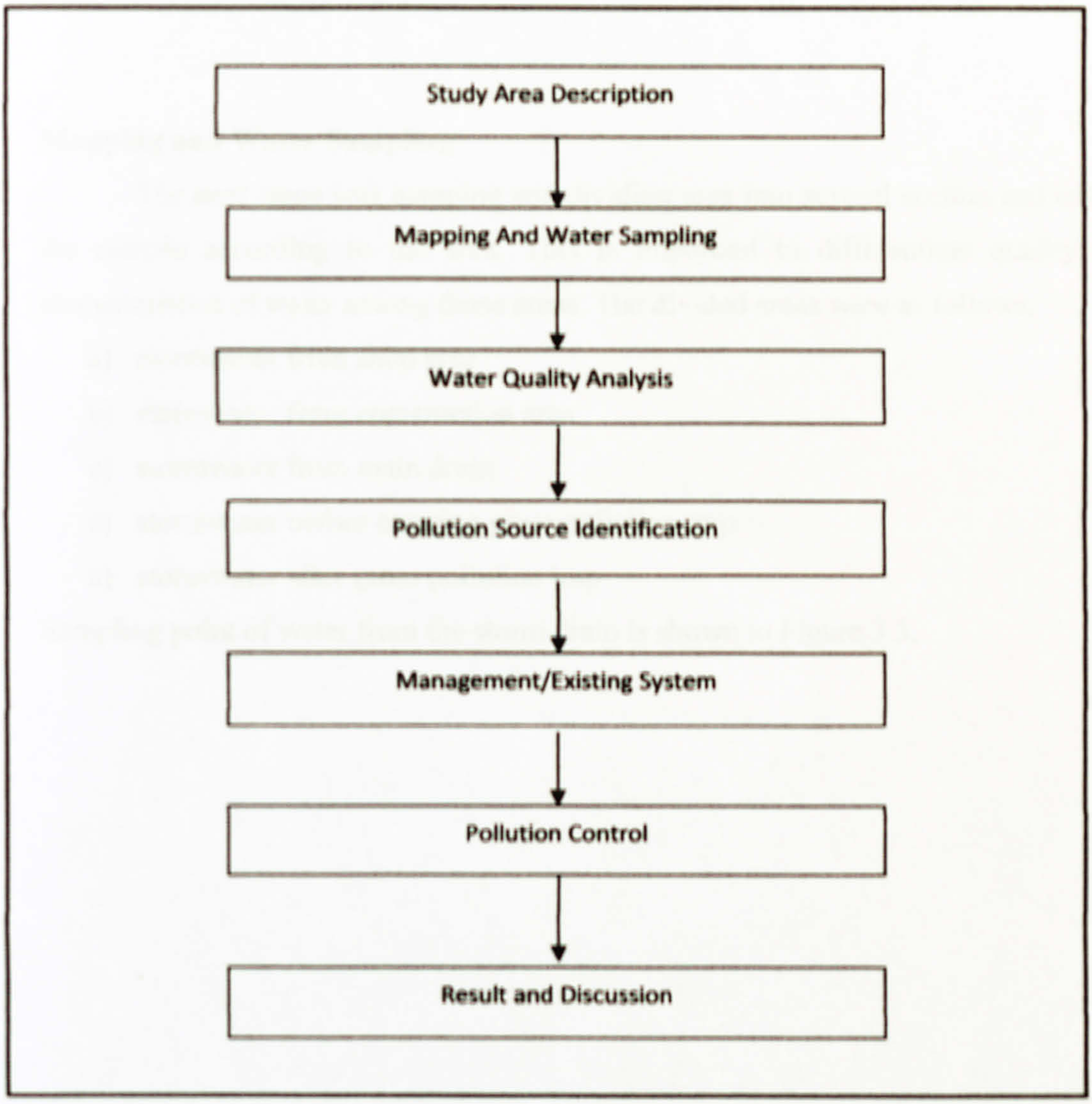


Figure 3.1. Flow Chart of Project Methodology

3.1 Study Area Description

Information and description such as catchment area and rainfall intensity in Seri Iskandar were gathered through study, survey and discussions. The rainfall intensity data were collected from Jabatan Pengairan dan Saliran Ampang. Location of the study area is shown in Figure 3.2.

3.2 Mapping and Water Sampling

The next stage was mapping and dividing area into several section and collect the sample according to the area. This is important to differentiate quality and characteristics of water among those areas. The divided areas were as follows:

a) stormwater from shop area
b) stormwater from construction area
c) stormwater from main drain
d) stormwater before entering gross pollution trap
e) stormwater after gross pollution trap

Sampling point of water from the storm drain is shown in Figure 3.3.

Figure 3.2. Map of Seri Iskandar

Figure 3.3. Sampling Point Of Water from the Storm Drain

From the Figure 3.3, Seri Iskandar area has different sectors which were housing area, shop area and commercial area. These entire sectors produce different type of pollutant that was released to the river. Figure 3.4 shows Gross Pollution Trap at Taman Teknologi, Seri Iskandar and Figure 3.5 show the sampling point after Gross Pollution Trap.

Figure 3.4. Gross Pollution Trap at Taman Teknologi Seri Iskandar

Figure 3.5. Water Sampling Point after Gross Pollution Trap

3.3 Water Quality Analysis

There were four lab test conducted to check for water quality analysis.

3.3.1 BOD test

When organic matter decomposes, it was fed upon by aerobic bacteria. In this process, organic matter was broken down and oxidized (combined with oxygen). Biochemical oxygen demand was a measure of the quantity of oxygen used by these microorganisms in the aerobic oxidation of organic matter. When aquatic plants die, they were fed upon by aerobic bacteria. The input of nutrients into a river, such as nitrates and phosphates, stimulates plant growth. Eventually, more plant growth leads to more plant decay. Nutrients, then, can be a prime contributor to high biochemical oxygen demand in rivers.

3.3.2 COD test

The chemical oxygen demand (COD) test was commonly used to indirectly measure the amount of organic compounds in water. Most applications of COD determine the amount of organic pollutants found in surface water (e.g. lakes and rivers), making COD a useful measure of water quality. It was expressed in milligrams per liter (mg/L), which indicates the mass of oxygen consumed per liter of solution.

3.3.3 Turbidity Test

Turbidity was the cloudiness or haziness of a fluid caused by individual particles (suspended solids) that are generally invisible to the naked eye, similar to smoke in air. The measurement of turbidity was a key test of water quality. Fluids can contain suspended solid matter consisting of particles of many different sizes. While some suspended material will be large enough and heavy enough to settle rapidly to the bottom of the container if a liquid sample was left to stand (the settleable solids), very small particles will settle only very slowly or not at all if the sample was regularly agitated or the particles were colloidal. These small solid particles caused the liquid to appear turbid.

3.3.4 Suspended Solid test

TSS of a water sample was determined by pouring a carefully measured volume of water through a pre-weighed filter of a specified pore size, then weighing the filter again after drying to remove all water. The gain in weight was a dry weight measure of the particulates present in the water sample expressed in units derived or calculated from the volume of water filtered

3.4 Pollution Source Identification

After the water quality analyses were done, the characteristic and the quality of the stormwater were determined. Using this result, the pollutions were identified. Meanwhile, the sources of pollutions were determined on site which mean by field survey.

3.5 Management of Existing System

After that, revisions on the existing system were conducted to identify the problem that lead to pollution. This information was gathered through survey and discussion with local authorities as well as representative from JPS.

3.6 Pollution Control

After the pollution had been identified, the solutions to that pollution or pollution source were determined. Pollution controls were focused into two steps which were water quantity control and water quality control. The approach involves engineering of Best Management Practices (BMP) structures which helps to mitigate and control both the water quantity and quality. For water quantity control the BMPs developed include both dry and wet ponds, wetlands, infiltration systems, filter strips or buffers and porous pavements, swales, soak away sand detention basins

CHAPTER 4 : RESULTS AND DISCUSSION

4.1 Study Area Description

Seri Iskandar area get its name from Sultan of Perak, Sultan Iskandar Shah. The Highness was well known and famous among the people of Perak for his kindness and care of his people. Seri Iskandar has 5 education institutes which are Sekolah Menengah Teknik, Kolej Profesional Mara, Institut Kemahiran Belia, Universiti Teknologi Mara (UiTM) Cawangan Perak and Universiti Teknologi Petronas. Seri Iskandar covers about 2071 ha area .

4.1.1 Rainfall Intensity

Figure 4.1, 4.2 and 4.3 show the monthly rainfall intensity of the nearest study area (about 5 km from study area) for year 2007, 2008 and 2009. Figure 4.4 shows the rainfall and evaporations stations in Perak.

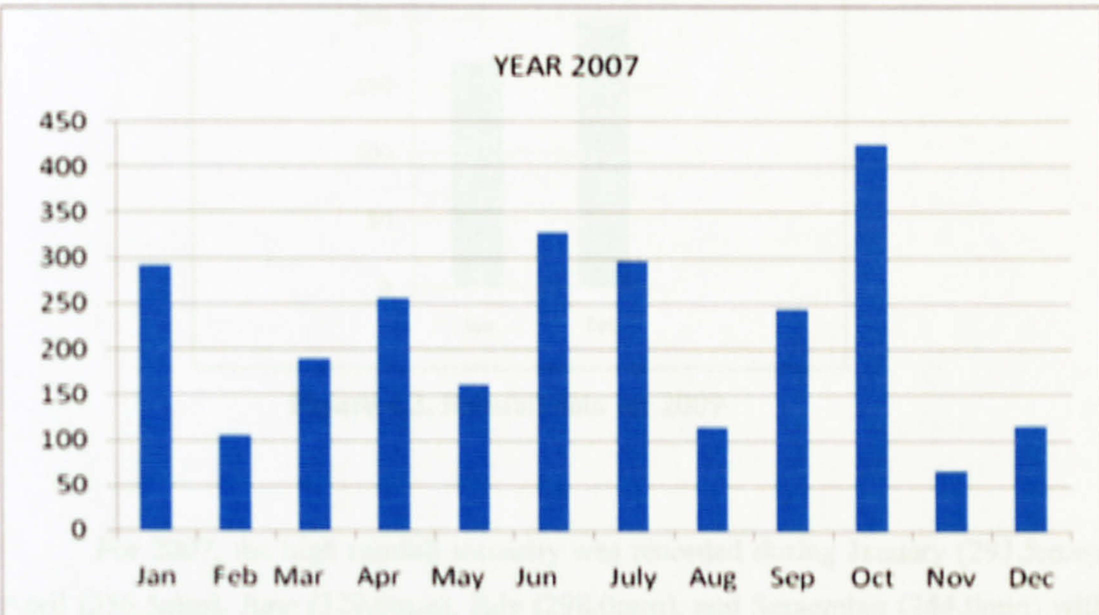


Figure 4.1. Rainfall data for 2007

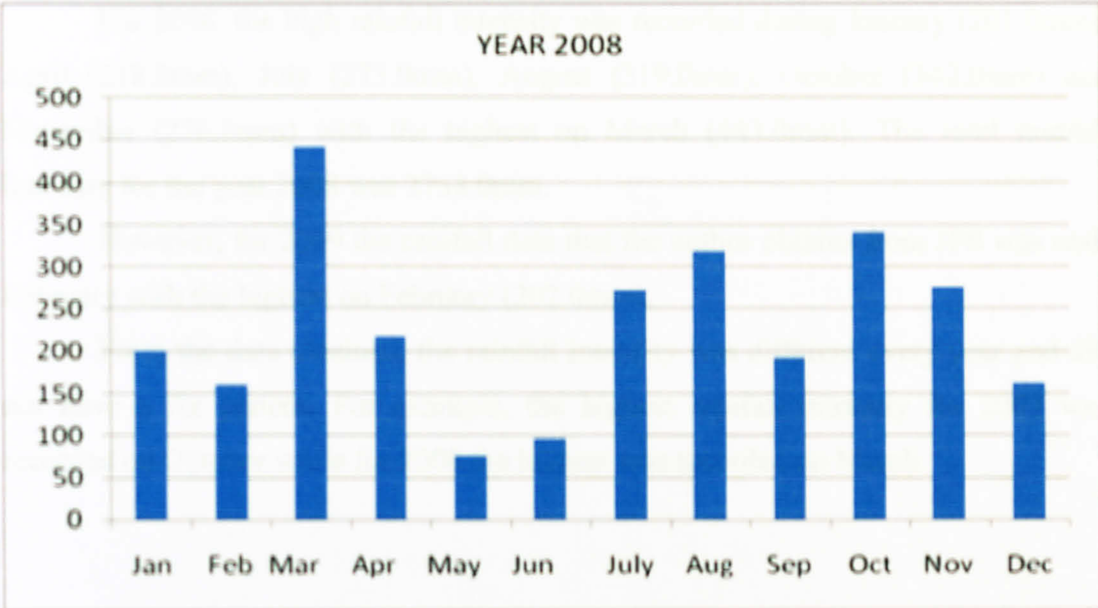


Figure 4.2. Rainfall data for 2008

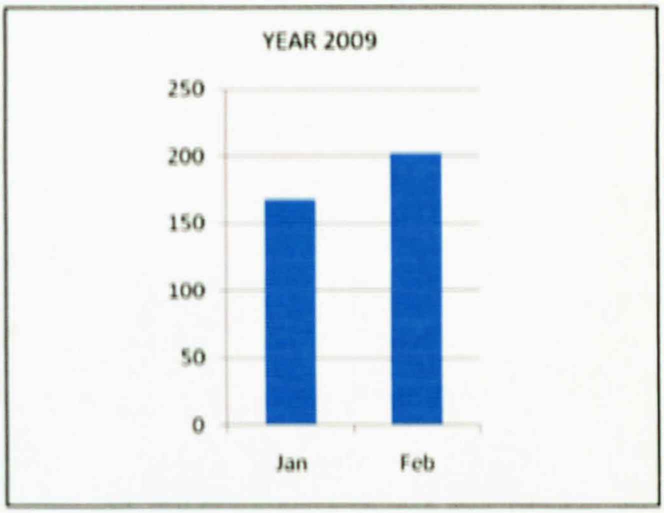


Figure 4.3. Rainfall data for 2009

For 2007, the high rainfall intensity was recorded during January (293.5mm), April (256.5mm), June (329.0mm), July (298.0mm), and September (244.0mm) with the highest on October (426.0mm). The total rainfall intensity for the year 2007 was 2603.0mm.

For 2008, the high rainfall intensity was recorded during January (201.0mm), April (218.0mm), July (273.0mm), August (319.0mm), October (342.0mm) and November (276.0mm) with the highest on March (443.0mm). The total rainfall intensity for the year 2008 was 2758.0mm.

However, for 2009 the rainfall data that the author obtains from JPS was until February with the highest on February (202.0mm).

From the data obtained, the rainfall intensity was different every year and did not have a fix pattern. For example, the highest rainfall intensity for 2007 was recorded on October while for 2008 the highest was recorded on March.

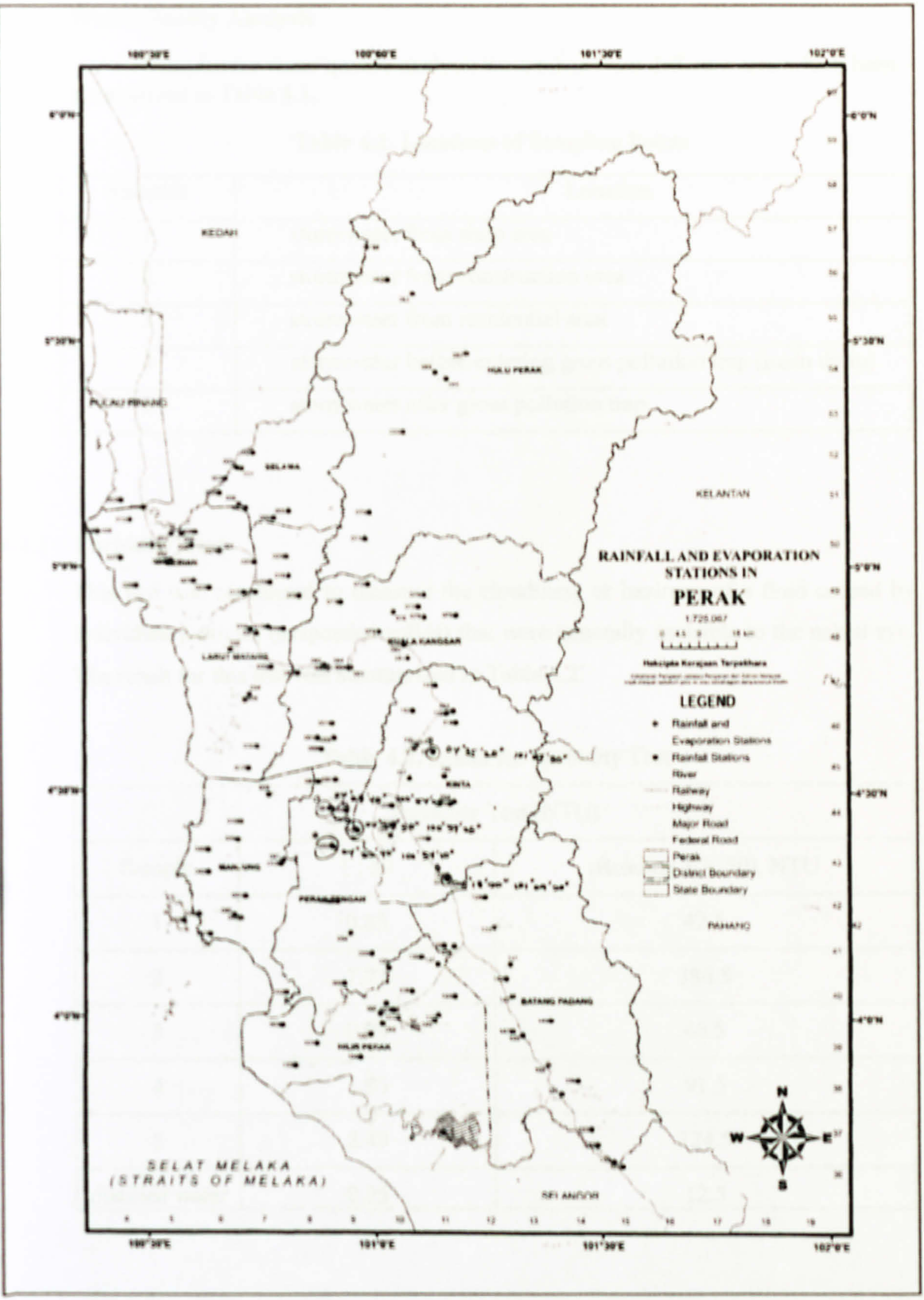


Figure 4.4. Map of Rainfall and Evaporation Stations In Perak

4.2 Water Quality Analysis

Samples for water quality analysis were taken from different area which been summarized in Table 4.1.

Table 4.1. Locations of Sampling Points

Samples	Location
1	stormwater from shop area
2	stormwater from construction area
3	stormwater from residential area
4	stormwater before entering gross pollution trap (main drain)
5	stormwater after gross pollution trap

4.2.1 Turbidity Test

This test was conducted to measure the cloudiness or haziness of a fluid caused by individual particles (suspended solids) that were generally invisible to the naked eye. The result for this test was summarized in Table 4.2.

Table 4.2. Result for Turbidity Test

Turbidity Test (NTU)		
Sample	1 : 50	(Reading 1 X 50), NTU
1	0.85	42.5
2	7.73	386.5
3	0.93	46.5
4	1.83	91.5
5	2.49	124.5
distilled water	0.25	12.5

The experiment was done by diluting the sample according to 1:50 ratio. The results show that sample number 2 has the highest turbidity with 386.5 NTU. The pollutant loading mostly the sediments from the construction area (Figure 4.6) obtained during storm event had caused the turbidity to increase compared to other area. Sample 5 also show a high turbidity value because the effect of stream bank erosion.
Figure 4.5 shows the device to measure turbidity of the sample in NTU unit.

Figure 4.5. Turbidity Meter

Figure 4.6. Construction Area at Seri Iskandar

4.2.2 COD Test

The chemical oxygen demand (COD) analysis was designed to measure the maximum amount of oxygen that was consumed by the organic matter in a sample of water. This was important because when organic polluting matter was discharged to the aquatic environment it will normally take up dissolved oxygen during its subsequent degradation thus reducing the amount of oxygen available for the respiration of fish and other aquatic life. The test was based upon the fact that all organic compounds, with a few exceptions, can be oxidised by the action of strong oxidising agents under acidic conditions. COD value of a sample was always higher than its BOD value. This was due to the fact that the COD test measures both the biologically degradable and biologically non-degradable organic matter. Further, COD test measures the total oxygen equivalents of the organic matter

The advantages of the COD test as compared to the BOD test are:

i. COD results are available much sooner.
ii. The COD test requires fewer manipulations of the sample.
iii. The COD test oxidizes a wider range of chemical compounds.
iv. It can be standardized more easily.

Figures 4.7 and 4.8 show some of the devices use to measure COD in the laboratory.

Figure 4.7. COD digester block

Figure 4.8. COD Test Kit

Table 4.3 represents the COD value of each sample. Samples were brought to the Environmental Laboratory immediately after sampling for water quality analysis.

Table 4.3. Result for COD Test

Sample	Reading (mg/L)
1	238
2	136
3	98
4	118
5	150

From the result that been summarized in table 4.3, we can notice that the highest value of COD was from sample 1 with 238mg/L. Sample 1 was collected from shop area which contain high oil residue. In fact, we can saw directly the oil floating on the water sample (Figure 4.9). Although other samples were collected from the same drain, but the COD values are varies from one place to other. For example, sample 3 was collected from the main drain which combined all the small drain into the larger drain that goes to gross pollution trap. This sample has lower COD value because it contains a lot more water although it comes from the same polluted area.

The major pollutants from urban roadway runoff are TSS and COD. Stormwater runoff from commercial/residential and construction catchments showed high level of COD concentration. Due to high percentages of impervious area, runoff from the Seri Iskandar catchment exhibits high concentration values COD, which suggests that the polluted nature of urban stormwater runoff changes as urbanisation increases.

The main issue here was that the value of COD still quite high after come out from Gross Pollution Trap. This situation was due to the fact that there are vegetation areas around the drain that discharge water from Gross Pollution Trap. It was postulated that there would be high usage of fertilizer for the vegetables. Soil losses and nutrients losses might happen when storms occurred, which would make the stormwater quality have high concentration level of TSS and nutrients.

Figure 4.9. Drain at Shop Area

BOD Test

Biochemical Oxygen Demand, BOD, as it was commonly abbreviated, was one of the most important and useful parameters indicating the organic strength of a stormwater. BOD measurement permits an estimate of the waste strength in terms of the amount of dissolved oxygen required to break down the stormwater. Generally the BOD test was carried out by determining the dissolved oxygen on the stormwater or a diluted mixture at the beginning of the test period, incubating the stormwater mixture at 20°C, and determining the dissolved oxygen at the end of 5 days. The difference in dissolved oxygen between the initial measurement and the fifth day measurement represents the biochemical oxygen demand. Figures 4.10 and 4.11 show some of the devices use to measure BOD in the laboratory.

Figure 4.10. DO Meter

Figure 4.11. Sample of BOD ready for incubation

Table 4.4. Result for BOD Test

Sample	Initial DO	Final DO	BOD (mg/L)
1	9.31	7.69	9.72
2	9.39	8.13	7.56
3	9.4	8.32	6.48
4	8.82	7.52	7.8
5	9.37	4.93	26.64

Most pristine rivers will have a 5-day carbonaceous BOD below 1 mg/L. Moderately polluted rivers may have a BOD value in the range of 2 to 8 mg/L. Municipal sewage that was efficiently treated by a three-stage process would have a value of about 20 mg/L or less. From the result that been summarized in Table 4.4, the highest value of BOD was recorded for sample 5 which the sample was taken after the gross pollution trap. The BOD value from sample 5 is much higher than the standard BOD value for moderate polluted river. The reasons for this high BOD value were because urban runoff carries pet wastes from streets and sidewalks, nutrients from lawn fertilizers, grass clippings and paper from residential areas.

For the other samples, the values of BOD were around 6 to 9 mg/L. These values are still in range for moderate polluted river. This situation caused by phosphate pollution from households. It was discovered that the addition of phosphorous to soaps and detergents made them clean better. Households and businesses were dumping tons and tons of phosphate down the drain. Eventually, much of this nutrient made its way to the watercourses and made the BOD value increase.

Figure 4.12 show the vegetation area around the outlet of Gross Pollution Trap (Figure 4.13) that causes the value of BOD as well as COD to increase. Fertilizers can help plants grow, but when applied in excessive amounts, fertilizers can harm water quality and aquatic ecosystems. Fertilizers are made of nutrients, such as nitrogen and phosphorus. When it rains, these nutrients are carried by stormwater into this nearest Gross Pollution Trap outlet. Too many nutrients in water can cause algae to grow, which uses up the oxygen in the water. Low levels of oxygen in water can hurt aquatic wildlife and even lead to fish kills.

Figure 4.12. Vegetation Area near Gross Pollution Trap

Figure 4.13. The Outlet of Gross Pollution Trap

Total Suspended Solids (TSS)

The composition and concentration of particulate matter in the aquatic environment was affected by the source and pathway of sediment input. These changes can potentially affect the type and quantity of suspended solids input to the environment. Long-term changes in the composition and concentration of suspended solids can have potential cumulative effects on aquatic ecosystems in a multitude of ways. The settleable portion of TSS which was not reported in most storm water studies could settled to the bottom of water bodies and damage invertebrate populations, caused imbalances in stream biota, block spawning gravels, remove dissolved oxygen from the water and reduced the pH of water. The result for total suspended solids test was shown in Table 4.5.

Table 4.5. Result for Total Suspended Solids Test

Sample	Weight of filter + dried residue + pan, (g)	Weight of filter + pan, (g)	Total suspended solids, (mg/L)
1	1.3325	1.3293	32
2	1.3862	1.3729	133
3	1.3577	1.3551	26
4	1.3465	1.3424	41
5	1.4445	1.4331	114

From the table 4.5, highest value of TSS was recorded for sample 2. This situation may be explained by higher concentrations of sediments and high concentration of suspended fines in drains that came from construction area. The high value of TSS for this sample also can be related with high value of turbidity. As shown in figure 4.18, the construction area did not have any detention pond or filter trap to reduce the amount of sediments that discharge directly into the drain. This situation become worse during and after storm event which the runoff will carried away a lot of sediments and can cause clogging. For other samples, the values of TSS were quite low because the sediments and fine particles combined with massive stormwater in drain.

Figure 4.14. Construction Area

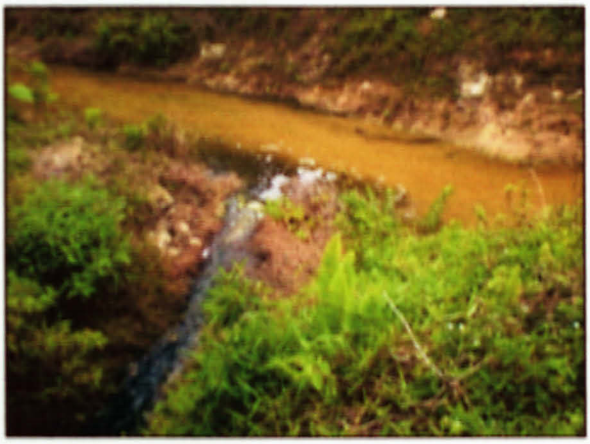
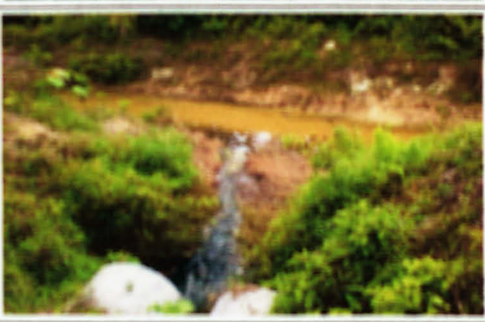


Figure 4.15. Stream Bank Erosion

From Figure 4.14 and 4.15 the sediments mostly soil particles were easily carried away by stormwater into the drain as well as into the river. This situation was terrible because sediment in the water reduces light penetration and affects photosynthesis, the process that allows plants to use light as their source of energy. Besides that soil makes waterways cloudy and can suffocate fish by clogging their gills. In the other hand, the major problem at this area was stream bank erosion. As Figure 4.15 suggest, local soils do not have the necessary strength to resist water erosion and without protective vegetation this situation can lead to extensive erosion. The major effect from erosion was loss of what is often regarded by landholders as the best agricultural land since this area is close to vegetation area.

Pollution Source Identification

Table 4.6. Pollution Source Identification

Source	Description
	• The food stall and workshop discharge their waste directly into the drain • Drain clog with rubbish • High oil residue • Causing high COD value
	• The construction area do not have any detention pond or filter trap • Soil particles been carried away during storm event • Causing high turbidity and high TSS
	• Gross Pollution Trap combined with wetland from sewage treatment plant • Not properly manage • Contain a lot of rubbish
	• Do not have proper irrigation • Dumping of unused fertilizer
	• Do not have proper stream bank management • Increase loading of sediments and suspended solids

Management of Existing System

On 1st April 2009, the author had a meeting with En. Ahmad Suhaimi from Urban Drainage Department, Jabatan Pengairan dan Saliran Ipoh, Perak. The purpose of this meeting was to discuss about the function of JPS in stormwater management, the system that been used to manage stormwater, the impact of stormwater to the environment and the problem associated with stormwater.

The function of JPS is basically can be divided into two which was to control the quantity and quality of the water in the river. Besides that JPS also have the rights to give technical comment to the project that going to be constructing so that they will follow the law to preserve the environment. JPS will monitor the project accordingly from the very beginning until the project had been finished and developer will need to submit several documents such as *Pelan Kawalan Keladak* and *Pelan Jalan Dan Perparitan* time by time during the interval of the project.

According to him, in the context of sediment discharge, for each construction project, they need to monitor their discharge to a certain standard. If they do not achieve the standard, they must construct detention pond to ensure that the water that goes out from construction area contain less sediments.

En. Suhaimi also stated several problems about the stormwater such as causing the flash flood, water pollution, a lot of sediment in the river and causing health problems. Thus the control measures that can be done by developer are to prepare the Gross Pollution Trap for all inlets and transcreen for the outlets. Besides that for all industries and petrol pump, they must have Oil and Grease Trap at all the inlets to prevent oil and grease from entering the river. There are also pollutants in the river cause by plantation but the JPS cannot do anything with it because it is under Jabatan Alam Sekitar.

Most of the standards and references for managing stormwater can be found in the Urban Stormwater Management Manual for Malaysia (MASMA) and all the project shall follow the standard that been stated in this manual.

Pollution Control

After the source of pollution had been identified, the next crucial part was to control pollution from becoming worse. Pollution control can be focused into two steps which were water quantity control and water quality control. The approach involves engineering of Best Management Practices (BMP) structures which helps to mitigate and control both the water quantity and quality.

For water quantity control the BMPs developed include both dry and wet ponds, wetlands, infiltration systems, filter strips or buffers and porous pavements, swales, soak away sand detention basins. The BMPs was designed to be integrated into site plans and become part of landscaping. The key to the design was to have many small scale BMPs throughout the catchment, dispersing runoff rather than concentrating it and keep runoff volume for each individual BMPs small and more manageable and do not overwhelm the ability of system to function.

For water quality control, the pollution was control by adopting a multilevel strategy involving, housekeeping best management practices, source control BMPs and treatment control BMPs. This category aims at keeping stormwater runoff & pollutants at their sources. The example of housekeeping best management practices were summarized in Table 4.7.

Table 4.7. Housekeeping Best Management Practices

Activities	Best Management Practices
Pavement Cleaning	• Sweep parking lots and other paved areas periodically to remove debris. Dispose of debris in the garbage. • If outdoor pavement cleaning with detergent was required, collect wash water and dispose in indoor sinks or drains for discharge to the sanitary sewer.

Litter Control	• Provide an adequate number of trash receptacles for your customers and employees. This helps keep trash from overflowing the receptacles. • Pick up litter and other wastes daily from outside areas including storm drain inlet grates.
Waste Disposal	• Inspect dumpsters and other waste containers periodically. Repair or replace leaky dumpsters and containers. • Cover dumpsters and other waste containers. • Never dispose of waste products in storm drain inlets. • Recycle wastes or dispose properly.
Materials Storage	• Make sure all outdoor storage containers have lids, and that the lids are adequately closed. • Store stockpiled materials inside a building, under a roof, or covered with a tarp to prevent contact with rain.

The main concern in Seri Iskandar area was the construction area that contributed a lot to the pollution. To prevent this situation becoming worse, local authorities need to ensure that developers submit an erosion and sediment control plan before earthworks commence the plan should be posted at the construction site and authorities should periodically visit the site to inspect the control measures and enforce the plan. Besides that, by providing BMPs the TSS can be removed as much as 80% based on Table 4.8.

Table 4.8. Percentage TSS Removal According to BMPs

Acceptable BMPs	TSS Removal Rate, %
Extended Detention Basin	70
Wet Pond	80
Stormwater Wetland	80
Bioretention System	80
Perimeter Sand Filter	80
Surface Sand Filter	80
Enhanced Swale	60
Dry Well	80
Pervious Paving	60
Filter Strip	60

On the other hand, the authorities need to maintain and improve the function of Gross Pollution Trap (Figure 4.16) in Seri Iskandar to ensure that it can intercept trash and debris and the coarser fraction of sediments before being discharge into the river.

Figure 4.16. Gross Pollution Trap in Seri Iskandar

CHAPTER 5 : CONCLUSION AND RECOMMENDATION

From the result and discussion, it was clear that Seri Iskandar stormwater management need to be improved. The lab results show that the stormwater was contributing to the pollution as summarized in Table 5.1.

Table 5.1. Summary of Stormwater Quality Analysis

Sample	Turbidity (NTU)	COD Test (mg/L)	BOD Test (mg/L)	TSS (mg/L)
1	42.5	238	9.72	32
2	386.5	136	7.56	133
3	46.5	98	6.48	26
4	91.5	118	7.8	41
5	124.5	150	26.64	114

Based on the Interim National Water Quality Standard for Malaysia (Appendix 1), the stormwater quality from Seri Iskandar area was severely polluted and some of the test values fall in class V water. Sample 1 which was taken from shop area and sample 2 from construction area have contributed a lot to the stormwater pollution. Thus the quick action needs to be taken to prevent this situation from becoming worse.

The solution provided in this report perhaps could helps to improve the quality of stormwater and the management of pollutants captured by "innovative" BMPs may provide more effective environmental protection because collected pollutants can be more readily removed and managed than trapping systems such as ponds, wetlands and gross pollution traps.

As the demand for water increases and pollution fast depletes water resources, it could be the major threat towards us. For this reason encountering the major problem with right practice is the best means to ensure a sustainable water resources and a cleaner environment.

More intensive stormwater monitoring program is recommended. Preferably, the sampling design must include various storm sizes and be replicated for different land-use types. Consideration on the antecedent conditions of the catchment is also crucial for a better understanding of the pollutant transport mechanism. An important issue to be addressed is the influence of dry weather periods and rainfall intensity on the water quality and pollution loading. Continuous water quality monitoring programmes with reliable rainfall data, though expensive and time consuming, are useful for obtaining reliable data for estimating pollutant loading.

Sampling equipment and protocols must be developed to ensure that consistent representative samples of storm water runoff are collected including the type of samplers, particle size determination, sampling frequency, location and orientation.

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APPENDICES

Appendix 1

Water Quality Criteria
For Freshwater:

Interim National Water Quality Standards for Malaysia (INWQS)

Parameter (mg/l)	Class					
	I	IIA	IIB	III	IV	V
pH	6.5 - 8.5	6.5 - 9	6.5 – 9	5 - 9	5 - 9	-
Salinity (ppt)	0.5	1	-	-	2	-
Conductivity (µS/cm)	1000	1000	-	-	6000	-
Dissolved Oxygen (DO)	7	5 - 7	5 – 7	3 - 5	< 3	< 1
Total Suspended Solids (TSS)	25	50	50	150	300	> 300
BOD_5	1	3	3	6	12	> 12
COD	10	25	25	50	100	> 100
E.Coli (N/100ml)	10	100	400	5000	5000	-
Amm. Nitrogen	0.1	0.3	0.3	0.9	2.7	> 2.7
Oil & Grease	NL	40	No sheen	No sheen	No sheen	No sheen
Mercury (Hg)	NL	0.001	-	0.0001	0.002	> 0.002
Cadmium (Cd)	NL	0.005	-	0.001	0.01	> 0.01
Lead (Pb)	NL	0.05	-	0.01	5	> 5
Chromium (Cr_{3+})	NL	-	-	2.53	-	-
Copper (Cu)	NL	1	-	0.01	0.2	> 0.2
Manganese (Mn)	NL	0.1	-	0.1	0.2	> 0.2
Nickel (Ni)	NL	0.05	-	0.09	-	> 0.2
Zinc (Zn)	NL	5	-	-	2	> 2
Iron (Fe)	NL	0.3	-	1	1	> 1
Phenol (C_6H^5OH)	Absent	10	-	-	-	-

Notes

1. NL: Natural levels
2. Class I: Conservation of the natural environment; minimal treatment required; protection of very sensitive aquatic species.
3. Class IIA: Water supply with conventional treatment; protection of sensitive aquatic species
4. Class IIB: Recreational use with body contact
5. Class III: Water supply with extensive treatment required; water for livestock drinking; moderately tolerant species of aquatic life.
6. Class IV: Water for irrigation.
7. Class V: Water is unsuitable for any of the above uses.

Appendix 2

Milestone for the First Semester of 2-Semester Final Year Project

No.	Detail/ Week	January		February				March					April			
		1	2	3	4	5	6	7		8	9	10	11	12	13	14
1	Selection of Project Topic and discussion with supervisor about the selected project															
2	Preliminary Research Work / Literature Review • Storm water management in other country • Storm water quality in Malaysia • Problem associated with the storm water • Use of storm water in Singapore • Existing law/regulations			1		2										
3	Submission of Preliminary Report															
4	Seminar 1 (optional)						3									
5	Project Work (Sri Iskandar Area) • Dividing area into several section • Collection of sample according to area divided															
6	Poster Presentation										4					
7	Seminar 2 (compulsory)											5				
8	Project work continues • Preparing for lab analysis • Testing the sample • Preparing all the material and plan the procedure for lab in FYP II										6		7			
9	Preparations of Report Final Draft													8		
10	Oral Presentation															

Process

Suggested Milestone :

i. Summary of literature review
ii. Submission of Prelim Report
iii. Power point presentation material
iv. Poster preparation and presentation
v. Map of Sri Iskandar ready with sampling locations
vi. Report on the conditions of existing drainage and infrastructure
vii. Water quality analysis method tested together with some results
viii. *Final report submitted*

TITLE : STORMWATER MANAGEMENT BY SECTORAL APPROACH

Milestone for the Second Semester of 2-Semester Final Year Project

No.	Detail/ Week	July			August				September				October				
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	Study Area Description • Topography • Catchment Area • Population • Rainfall Intensity		1														
2	Mapping • Using GIS Software • Field Survey • Topography Map				2												
3	Water Sampling and Quality Analysis								3								
4	Pollution Source Identification and Pollution Control • Field Survey • Map Location of Different Quality								4								
5	Management and Existing System • Survey • Gathering Information										5						
6	Pollution Control • GPT • Oil Trap • Sandfilter Trap											6					
7	Poster Presentation														7		
8	Preparations of Report Final Draft														8		
9	Submission of Final Report (Soft Bound Dissertation)																9
10	Oral Presentation																

Suggested Milestone :

1. Map and description about study area
2. Topography map
3. Lab analysis
4. Picture of the area and result of field survey
5. Summary of gathered information
6. Example of pollution control
7. Poster preparation and presentation
8. Final report submitted

Appendix 3

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—— NIWA Tideda —— JPS Ampang                              24-APR-2009 16:24
—— PDAY —— VER 1.9
Source is \\Jpshis\databank\Datatideda\Dataneger1\Perak\RFMANUAL.MTD
24 hour periods ending at 8:00:00am each day.
8

Daily totals        Year 2007        site 4409121 LDG. NALLA at TRONOH, PERAK
Rain mm
```

Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
1	?	0.0	46.0	43.0	0.0	0.0	0.0	0.0	48.0	0.0	0.0	6.0	
2	0.0	0.0	0.0	0.0	0.0	52.0	0.0	0.0	56.0	0.0	10.0	0.0	
3	0.0	0.0	0.0	0.0	0.0	37.0	0.0	0.0	4.0	0.0	0.0	0.0	
4	0.0	0.0	0.0	8.0	0.0	45.0	7.0	0.0	1.0	0.0	0.0	0.0	
5	0.0	0.0	1.0	0.0	0.0	6.0	0.0	0.0	0.0	0.0	3.0	0.0	
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.0	0.0	0.0	
7	20.0	0.0	0.0	0.0	0.0	0.0	2.0	0.0	19.0	11.0	3.0	10.0	
8	2.0	0.0	0.0	0.0	0.0	8.0	5.0	0.0	3.0	3.0	6.0	4.0	
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	5.0	0.0	0.0	
10	9.0	0.0	0.0	0.0	14.0	50.0	0.0	0.0	0.0	0.0	0.0	0.0	
11	18.5	0.0	0.0	1.0	5.0	12.0	0.0	0.0	0.0	0.0	5.0	14.0	
12	0.0	0.0	0.0	0.0	0.0	7.0	0.0	0.0	0.0	0.0	0.0	16.0	
13	2.0	8.0	6.0	34.0	18.0	42.0	0.0	0.0	37.0	30.0	6.0	10.0	
14	0.0	47.0	12.0	30.0	23.0	47.0	0.0	0.0	13.0	25.0	0.0	14.0	
15	79.0	0.0	6.0	0.0	5.0	4.0	0.0	0.0	0.0	35.0	3.0	0.0	
16	0.0	0.0	1.0	15.0	0.0	0.0	15.0	14.0	25.0	41.0	0.0	0.0	
17	0.0	0.0	33.0	0.0	0.0	2.0	0.0	49.0	0.0	35.0	0.0	5.0	
18	6.0	0.0	0.0	0.0	0.0	4.0	13.0	0.0	0.0	14.0	0.0	0.0	
19	12.0	0.0	4.0	0.0	0.0	6.0	7.0	0.0	0.0	48.0	0.0	3.0	
20	16.0	24.0	6.0	10.5	16.0	0.0	0.0	5.0	0.0	6.0	20.0	0.0	
21	61.0	0.0	3.0	7.0	0.0	7.0	7.0	7.0	0.0	29.0	10.0	29.0	
22	23.0	0.0	6.0	7.0	9.0	0.0	32.0	14.0	0.0	30.0	1.0	0.0	
23	0.0	10.0	2.0	10.0	0.0	0.0	71.0	0.0	0.0	25.0	0.0	0.0	
24	29.0	3.0	0.0	4.0	32.0	0.0	7.0	0.0	28.0	1.0	0.0	0.0	
25	13.0	1.0	0.0	5.0	20.0	0.0	20.0	25.0	0.0	9.0	0.0	0.0	
26	0.0	0.0	1.0	13.0	19.0	0.0	40.0	0.0	1.0	29.0	0.0	0.0	
27	3.0	0.0	0.0	68.0	0.0	0.0	52.0	1.0	7.0	31.0	0.0	6.0	
28	0.0	12.0	0.0	1.0	0.0	0.0	11.0	0.0	0.0	1.0	0.0	0.0	
29	0.0		28.0	0.0	0.0	0.0	4.0	0.0	0.0	11.0	0.0	0.0	
30	0.0		13.0	0.0	0.0	0.0	5.0	0.0	0.0	0.0	0.0	0.0	
31	0.0		23.0		0.0		0.0	0.0		0.0		0.0	
Min	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tot	293.5	105.0	191.0	256.5	161.0	329.0	298.0	115.0	244.0	426.0	67.0	117.0	2603.0
Max	79.0	47.0	46.0	68.0	32.0	52.0	71.0	49.0	56.0	48.0	20.0	29.0	79.0
NO>0.0	14	7	16	15	10	15	16	7	13	21	10	11	155

Rainfall data for 2007

```
Daily totals        Year 2008        site 4409121 LDG. NALLA at TRONOH, PERAK
Rain mm
```

Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
1	0.0	0.0	4.0	30.0	0.0	0.0	0.0	0.0	0.0	12.0	0.0	0.0	
2	0.0	0.0	10.0	16.0	0.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0	
3	0.0	15.0	2.0	21.0	0.0	3.0	0.0	0.0	112.0	0.0	0.0	0.0	
4	0.0	2.0	21.0	12.0	0.0	25.0	40.0	0.0	3.0	0.0	0.0	0.0	
5	0.0	4.0	0.0	8.0	0.0	5.0	0.0	12.0	0.0	19.0	0.0	14.0	
6	0.0	18.0	45.0	30.0	0.0	10.0	0.0	0.0	23.0	0.0	0.0	6.0	
7	58.0	0.0	3.0	6.0	0.0	10.0	0.0	0.0	0.0	7.0	0.0	2.0	
8	15.0	0.0	3.0	0.0	0.0	0.0	2.0	0.0	0.0	56.0	0.0	33.0	
9	40.0	0.0	22.0	0.0	0.0	14.0	6.0	2.0	6.0	16.0	11.0	0.0	
10	0.0	0.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0	11.0	0.0	0.0	
11	0.0	0.0	3.0	16.0	0.0	8.0	18.0	0.0	33.0	21.0	0.0	0.0	
12	0.0	0.0	43.0	13.0	0.0	0.0	33.0	0.0	1.0	45.0	0.0	0.0	
13	0.0	0.0	56.0	17.0	0.0	0.0	58.0	0.0	0.0	0.0	18.0	5.0	
14	0.0	0.0	0.0	0.0	0.0	0.0	14.0	0.0	0.0	0.0	30.0	0.0	
15	0.0	10.0	0.0	7.0	0.0	0.0	13.0	0.0	0.0	11.0	7.0	30.0	
16	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	35.0	32.0	9.0	
17	0.0	25.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	7.0	0.0	25.0	
18	5.0	10.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	27.0	78.0	0.0	
19	5.0	4.0	19.0	0.0	19.0	3.0	0.0	0.0	0.0	6.0	0.0	8.0	
20	3.0	0.0	16.0	7.0	0.0	2.0	0.0	135.0	0.0	19.0	34.0	0.0	
21	2.0	0.0	0.0	20.0	0.0	0.0	26.0	3.0	0.0	21.0	0.0	0.0	
22	0.0	0.0	35.0	0.0	1.0	0.0	1.0	20.0	0.0	15.0	37.0	0.0	
23	0.0	0.0	28.0	7.0	0.0	4.0	0.0	0.0	0.0	3.0	15.0	0.0	
24	0.0	0.0	30.0	0.0	28.0	2.0	51.0	21.0	0.0	3.0	5.0	0.0	
25	48.0	0.0	14.0	4.0	4.0	0.0	9.0	30.0	0.0	4.0	6.0	0.0	
26	0.0	0.0	37.0	0.0	1.0	0.0	0.0	3.0	0.0	0.0	3.0	0.0	
27	0.0	0.0	41.0	0.0	0.0	0.0	0.0	15.0	0.0	0.0	0.0	0.0	
28	20.0	72.0	0.0	0.0	0.0	0.0	0.0	58.0	0.0	0.0	0.0	0.0	
29	0.0	0.0	0.0	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	19.0	
30	5.0		3.0	0.0	0.0	10.0	0.0	0.0	15.0	4.0	0.0	3.0	
31	0.0		4.0		22.0		0.0	20.0		0.0		8.0	
Min	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tot	201.0	160.0	443.0	218.0	75.0	96.0	273.0	319.0	193.0	342.0	276.0	162.0	2758.0
Max	58.0	72.0	56.0	30.0	28.0	25.0	58.0	135.0	112.0	56.0	78.0	33.0	135.0
NO>0.0	10	9	22	17	6	12	13	11	7	20	12	12	151

Rainfall data for 2008

Daily totals Year 2009 site 4409121 LDG. NALLA at TRONOH, PERAK
Rain mm

Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
1	5.0	0.0	?	?	?	?	?	?	?	?	?	?	
2	2.0	6.0	?	?	?	?	?	?	?	?	?	?	
3	15.0	0.0	?	?	?	?	?	?	?	?	?	?	
4	0.0	0.0	?	?	?	?	?	?	?	?	?	?	
5	3.0	16.0	?	?	?	?	?	?	?	?	?	?	
6	0.0	36.0	?	?	?	?	?	?	?	?	?	?	
7	0.0	5.0	?	?	?	?	?	?	?	?	?	?	
8	0.0	0.0	?	?	?	?	?	?	?	?	?	?	
9	23.0	0.0	?	?	?	?	?	?	?	?	?	?	
10	0.0	0.0	?	?	?	?	?	?	?	?	?	?	
11	0.0	0.0	?	?	?	?	?	?	?	?	?	?	
12	0.0	15.0	?	?	?	?	?	?	?	?	?	?	
13	0.0	0.0	?	?	?	?	?	?	?	?	?	?	
14	10.0	0.0	?	?	?	?	?	?	?	?	?	?	
15	22.0	0.0	?	?	?	?	?	?	?	?	?	?	
16	0.0	0.0	?	?	?	?	?	?	?	?	?	?	
17	0.0	10.0	?	?	?	?	?	?	?	?	?	?	
18	42.0	0.0	?	?	?	?	?	?	?	?	?	?	
19	2.0	15.0	?	?	?	?	?	?	?	?	?	?	
20	0.0	0.0	?	?	?	?	?	?	?	?	?	?	
21	0.0	0.0	?	?	?	?	?	?	?	?	?	?	
22	22.0	20.0	?	?	?	?	?	?	?	?	?	?	
23	0.0	0.0	?	?	?	?	?	?	?	?	?	?	
24	0.0	35.0	?	?	?	?	?	?	?	?	?	?	
25	4.0	35.0	?	?	?	?	?	?	?	?	?	?	
26	0.0	2.0	?	?	?	?	?	?	?	?	?	?	
27	5.0	5.0	?	?	?	?	?	?	?	?	?	?	
28	5.0	2.0	?	?	?	?	?	?	?	?	?	?	
29	0.0		?	?	?	?	?	?	?	?	?	?	
30	0.0		?	?	?	?	?	?	?	?	?	?	
31	8.0		?		?		?	?		?		?	
Min	0.0	0.0	?	?	?	?	?	?	?	?	?	?	0.0
Tot	168.0	202.0	?	?	?	?	?	?	?	?	?	?	370.0
Max	42.0	36.0	?	?	?	?	?	?	?	?	?	?	42.0
NO>0.0	14	13	0	0	0	0	0	0	0	0	0	0	27

End of process

Rainfall data for 2009