Treatment Disposal of Urban Runoff Pollution from Road and Highways

By

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CERTIFICATION OF APPROVAL

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A project dissertation submitted to the
Civil Engineering Programme
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in partial fulfillment of the requirement for the
BACHELOR OF ENGINEERING (Hons)
(CIVIL ENGINEERING)

Approved by,

____
(Ms. Husna BT Takaijudin)

UNIVERSITI TEKNOLOGI PETRONAS
TRONOH, PERAK
January 2011

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 acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

SITI ZAHARAH BT ABU BAKAR

ABSTRACT

Previous management efforts have primarily concentrated on reducing the risk of downstream flooding to protect lives and properties. This is referred to as quality control. Although this approach has proven to be reasonably effective in curtailing flooding problems, it cannot mitigate the adverse impacts urbanization has on stream habitat or increased pollutants export. In order to solve the current problem, a new approach of managing urban runoff called 'control at source' (integrated approach) is being experimented and its implementation in Malaysia is still in early stages. The runoff treatments such as grassed swales, infiltration trenches and wet ponds are looked into as possible treatment to the highway runoff of this project. The methodology of this project will focus on the quality controls of urban runoff. From the preliminary findings, grassed swale is proposed as the treatment for the highway runoff and its efficiency is expected to meet with the standards set up by authorities.

ACKNOWLEDGEMENTS

Praise to God for allowing this project to come to fruition. However, the completion of this project would also be impossible without the patient guidance of my supervisor, Ms. Husna Bt. Takaijudin Despite difficulties in the initial and final stages of the project, I see the project as a success since I have learned many new things during the course of its completion. Lastly, I would also like to express my gratitude to those who had lent their assistance directly and indirectly throughout this project.

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CHAPTER 1
INTRODUCTION

1.1 BACKGROUND OF STUDY

As a developing nation, Malaysia is undergoing rapid urbanization to cater for the country's growth spurt which had transformed the natural landscapes to residential, commercial, industrial and institutional uses. This can have adverse consequences on streams and receiving waters such as an increase in flooding, streambank erosion and pollutant export.

Historically, management efforts have primarily concentrated on reducing the risk of downstream flooding to protect lives and properties. This is referred to as quality control. Although this approach has proven to be reasonably effective in curtailing flooding problems, it cannot mitigate the adverse impacts urbanization has on stream habitat or increased pollutants export.

In order to solve the current problem, a new approach of managing urban runoff called 'control at source' (integrated approach) is being experimented and its implementation in Malaysia is still in early stages.

This study will explore the methods for lessening the impacts of urban runoff from road and highways on the receiving waterbodies.

1.2 PROBLEM STATEMENT

Urbanization has a profound influence on stream quality. In response to the changes made to the original landscape of the area, the hydrology of the stream also experienced changes. The degradation of the environment causes the surrounding area to lose its natural storage capacity and can no longer prevent rainfall from being rapidly converted to runoff. The changes in watershed hydrology as a result of urbanization are illustrated in Figure 1.1(a) and (b).

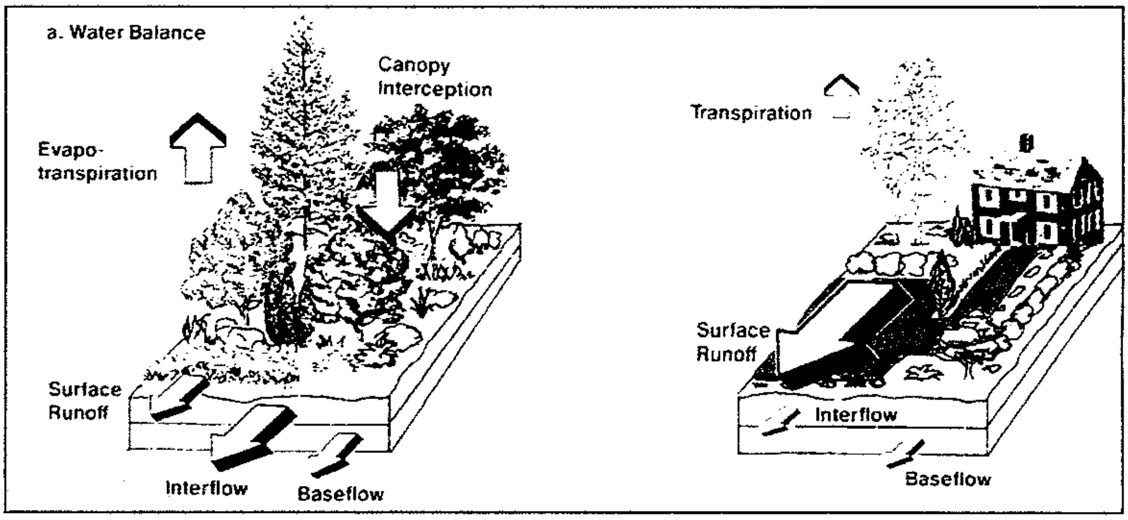


Figure 1.1(a): Comparison between an area before and after urbanization

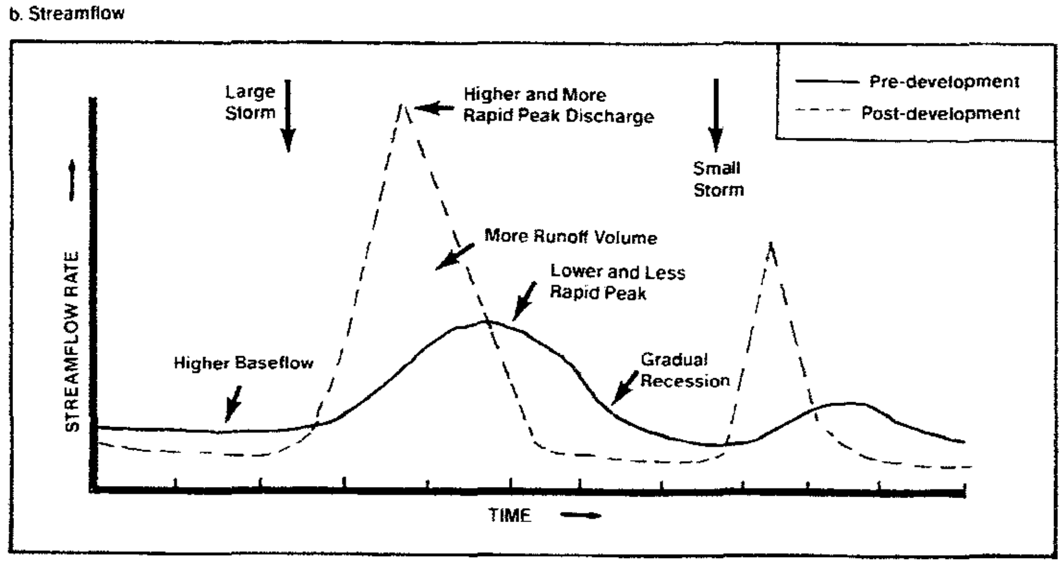


Figure 1.1(b): The series of changes to stream hydrology after urbanization has taken place

Failure to adjust to the new hydrological conditions can has adverse effects such as flooding at the affected area. In Malaysia especially, flooding is always a major concern since it was ranked as the top natural disaster in the country (Natural Disasters in Malaysia, 2004). The familiarity of the pictures of submerged cars and houses, people wading knee-deep in muddy water, and residents sweeping mud and debris out of their flooded homes attest to the regularity and severity of flash floods in the Klang Valley.

Already in 2001, the Selangor Government allocated RM23 million for major flood mitigation, including widening and deepening rivers, building bunds, floodgates and water retention ponds, and raising the level of roads. Apparently, just a week ago before the lash flood occurred at the New Klang Valley Expressway (NKVE) stretch in 2006, the State Government had also approved another RM10 million for the construction of a canal to divert floodwaters.

The massive flood at the NKVE route had affected more than 9,000 residents and about 3,000 homes. The flash flood is believed to have occurred after the Sungai Damansara overflowed its banks following non-stop rain in the afternoon. Often, Km9 of the NKVE gets flooded after downpours. The authority has obtained the cabinet's approval to deepen Sungai Damansara following the incident (New Straits Times, 2006).

Figure 1.2: The picture shows a section of Taman Tun Dr Ismail Jaya in Shah Alam, Selangor, submerged in floodwaters (The Star - Residents rudely awakened by floodwaters, February 27, 2006).

Figure 1.3: Cars submerged in muddy flood waters after a downpour in Kuala Lumpur (The Star - Thousands caught unawares as 2m-high flash floods hit KL).

In March 4, 2009, thousands of motorists were stuck in massive traffic jams for more than two hours after a storm caused flash foods in various parts of the city. According to enforcement officer, the flood waters began to recede after the Smart Tunnel was closed to traffic to enable flood operations.

There is no choice but to do what must be done to minimize preventable flash flooding and to undo the damage that has been done by rapid and uncoordinated urban growth. It is imperative to take the environment into account when planning for development.

Impervious roads made from asphalt and other common building materials have been found to have increased pollutant loads when compared to the runoff from natural areas.

Roads, curbs and gutters are often used for water diversion to prevent flooding; however, these conveyance systems lead to higher pollutant levels and have been found to be harmful to surrounding water ecosystems (Makepeace, 1995; and Wiland, B., and Malina, 1976).

Heavy metals found in highway runoff have also been noted as being a significant problem in waterways because at certain concentrations, zinc and copper are toxic to fish and aquatic micro-invertebrates (Tsihrintiz and Hamid, 1995). Oil and grease originating from automobile usage, as well as improper disposal of petroleum hydrocarbon products, is also toxic to aquatic organisms and affects fish reproduction (Lee and Jones-Lee, 1994).

When considering any possible treatment for stormwater runoff from urban areas, the characteristic of the urban site is an important factor of consideration. In the case of transportation corridors, particulate matter is ubiquitous in the site to numbers of traffic activities produce particulate matter.

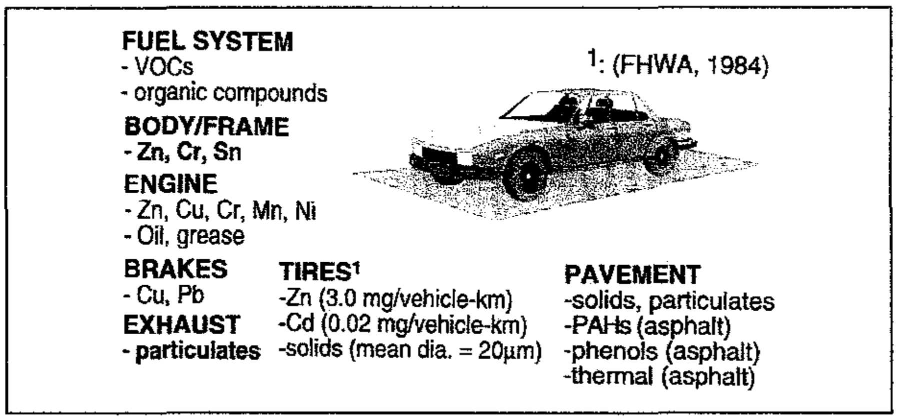


Figure 1.4: Vehicular and pavement sources of constituents generated by traffic activities

A case study was made at an urban Cincinnati to observe the relative contributions of particulate matter. The result is as shown in Figure 1.2 (Field & Sullivan, 2003).

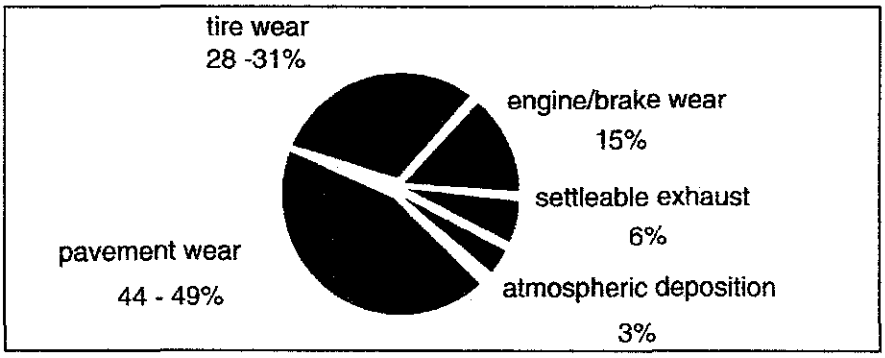


Figure 1.5: Sources of traffic generated particulates for urban Cincinnati transportation land use. For the experimental site in I-75 on Millcreek Expressway with an ADT = 150,000, approximately 13,500 mg/m^2/day of particulate matter was generated in 1995

With respect to brake wear, contributing 15% of the total particulate mass, the relative contribution of selected heavy metals for a typical 130 g brake pad is given in Figure 1.3 (Armstrong, 1994).

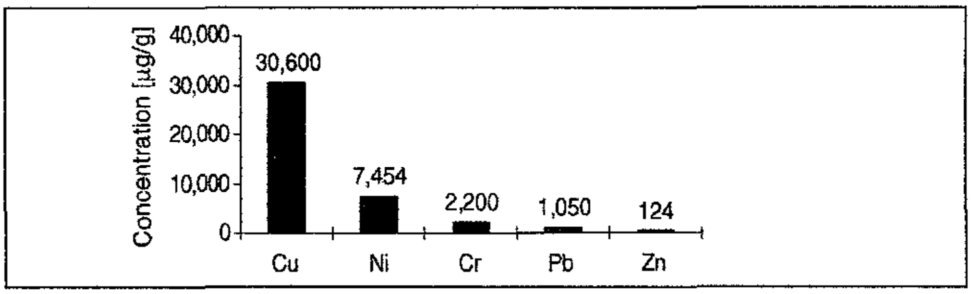


Figure 1.6: Selected heavy metal content of typical 130 g brake pad

A high level of traffic in an urban area is the major sources of anthropogenic pollutants. These traffic characteristics, such as traffic volume (measured as average daily traffic, ADT), vehicular speed, traffic level duration and mix of vehicles and trucks are a primary source.

In urban transportation corridors and roadway environments, heavy metals are primarily caused by the abrasion of metal-containing vehicular parts, which includes the abrasive interaction of tires against pavement and oil and grease leakage. The stormwater from roads contain significantly high levels of zinc, copper, cadmium, lead, chromium and nickel compared to ambient background levels, while as for the heavily travelled roads, zinc, copper, lead and cadmium often exceed U.S. EPA and state EPA surface water discharge criteria on an event basis (Field & Sullivan, 2003).

One of the most important factors which control the accumulation of heavy metals in sediments is the grain-size. Only a few studies discuss the behavior of organic micro-pollutants and the influence of different grain-size fractions. Even within these studies, the lack of standardization in particle fractionation methods aggravates the comparison and generalization of acquired data (Karickho et al., 1979; Readman et al., 1984; Umlauf and Bierl, 1987; Evans et al., 1990; Kukkonen and Landrum, 1996).

Table 1.1: Typical Pollutants Found in Runoff from Roads and Highways

(UEPA, 1997)

POLLUTANT	Source
Particulate	Pavement wear, vehicles, the atmosphere and maintenance activities, snow/ice abrasiveness and sediment disturbance
Rubber	Tire wear
Asbestos	Clutch and brake lining wear (No mineral asbestos has been identified in runoff, however, some break-down products of asbestos have been measured)
Nitrogen and Phosphorus	Atmosphere, roadside fertilizer application and sediments
Lead	Leaded gasoline from auto exhaust, tire wear, lubricating oil and grease, bearing wear and atmospheric fallout
Zinc	Tire wear, motor oil and grease
Iron	Auto body rust, steel highway structures such as bridges and guardrails and moving engine parts
Copper	Metal plating, bearing and bushing wear, moving engine parts, brake lining wear, fungicides and insecticides
Cadmium	Tire wear and insecticide application
Chromium	Metal plating, moving engine parts and brake lining wear
Nickel	Diesel fuel and gasoline, lubricating oil, metal plating, bushing wear, brake lining wear and asphalt paving
Manganese	Moving engine parts
Cyanide	Anti-caking compounds used to keep deicing salt

	granular
Sodium and Calcium	Deicing salts and grease
Chloride	Deicing salts
Sulphates	Roadway beds, fuel and deicing salts
Bromide	Exhaust
Petroleum	Spills, leaks, antifreeze and hydraulic fluids, asphalt surface leachate and blow-by motor lubricants
PCBs and Pesticides	Spraying of highway right-of-ways, atmospheric deposition and PCB catalyst in synthetic tires
Pathogenic bacteria	Soil litter, bird droppings and trucks hauling livestock/stockyard waste

Table 1.1(continued): Typical Pollutants Found in Runoff from Roads and Highways (UEPA, 1997)

Pollutant	Event Mean Concentration for Highway with fewer than 30,000 Vehicles/Day (mg/l)	Event Mean Concentration for Highway with more than 30,000 Vehicles/Day (mg/l)
Total Suspended Solids	41	142
Volatile Suspended Solids	12	39
Total Organic Carbon	8	25
Chemical Oxygen Demand	49	114
Nitrite and Nitrate	0.46	0.76
Total Kjeldahl Nitrogen	0.87	1.83
Phosphate Phosphorus	0.16	0.40
Copper	0.022	0.054
Lead	0.80	0.400
Zinc	0.80	0.329

Table 1.2: Pollution Concentrations in Highway Runoff (Driscoll et. al, 1990)

Particulates or sediment suspended in the runoff can have relatively insoluble substances like heavy metals adhere to them. These substances are then transported to receiving waters where they can become a threat to aquatic life. Many studies have documented the "sink effect" of heavy metal bioaccumulation in stream and lake sediments. Likewise, aquatic life near a highway will, also, show increases in heavy metals.

Airborne particulate matter may be fall to earth where it will become a component of highway runoff during periods of precipitation. Highways can have a deleterious effect on groundwater resources particularly in shallow well areas. Metal concentrations have been measured in elevated levels in shallow well areas which are in proximity to highways and highway stormwater facilities. Nutrients from highway runoff can, also, pose an additional hazard to groundwater resources. However, the distance the well is from the road is an important factor.

From this we can conclude that stormwater from urban and transportation land uses is a complex physicochemical heterogeneous mixtures. This complexity has made treating the urban runoff a very challenging task.

1.3 OBJECTIVES

The objectives of this project are:

- To identify sources and factors affecting highway runoff and its pollutant components.
- To conduct a literature search on the water quality impacts of highway runoff.
- To identify the existing best management practices to ameliorate the water quality impacts.

1.4 SCOPE OF STUDY

The study will consist of a summary of data gathered from secondary sources, evaluation of the data and presentation of findings and recommendations.

Generally, the scope of study will cover the following areas:

- Highway runoff pollutants
- Review past work related to this study
- Design of grassed swale

CHAPTER 2

LITERATURE REVIEW

2.0 RUNOFF TREATMENT

Current directions in Europe, Japan and Australia are typified by nonstructural source control that is designed to prevent initial contamination of the stormwater. In comparison, trends in the United States focus on structural treatment-based or hydraulic controls that attempt to mitigate the effects of already detrimentally impacted stormwater runoff.

2.1 Constructed Wetlands

Recent developments in Malaysia has also shown great interest in the use of natural physical, biological and chemical aquatic processes to treat runoff pollutants. This growing recognition of the natural treatments, have resulted in extensive research efforts and practical applications of these technologies, such as the constructed wetlands (Lariya et al, 2001).

Constructed wetland functions by incorporating natural wetland ability to aid pollutant removal from stormwater. The system is particularly suitable for area with higher groundwater level due to the continuous supply of water necessary to sustain constructed wetland (Urbonas and Strecher, 1996).

The first and biggest constructed wetland in the country was built at Putrajaya, the new Federal Government Administrative Center of Malaysia, covering about 150 hectares and involving 11 million aquatic plants (Lariya et al, 2001). By monitoring the results obtained from the Putrajaya Wetlands, the average water quality index is between 82-92 which is in second category where the status good had been achieved (Selamat, 2001). The Putrajaya Wetlands have shown tremendous ability in removing pollutants in the stormwater runoff, including phosphorous, nitrogen and some heavy metals (PJH, 1996).

The application of constructed wetlands in treating runoff is not foreign overseas, since back in 1980s many studies have suggested that constructed wetlands may improve stormwater runoff quality (Schueler, 1992). From the study conducted by Schueler (1992), based on twenty stormwater wetland sites in United States of America, the long term pollutant rates were found to be 75% for total suspended solids, 45% total phosphorous, 25% total nitrogen, 15% organic carbon, 75% lead and 50% zinc.

Recent research was done in Malaysia, by Mohd Noor et al, (2004) to study the effectiveness of constructed wetland as stormwater treatment by monitoring pollutants in stormwater and suspended sediment of wetland. The observation was focused on pollutant removal efficiency. The water quality was measured based on TSS, BOD and heavy metals. Based on the data collected, the constructed wetland can effectively function as stormwater treatment by the used of appropriate design features and macrophyte plants (Mohd Noor et al, 2004).

Meanwhile Universiti Sains Malaysia (USM) had constructed the miniature version of the wetland in order to improve stormwater quality surrounding the campus area (Lariya et al, 2001). The constructed wetland in the campus area was targeted to achieve water quality objective of the recreational pond so that its water is suitable for body contact recreation and creating a habitat that is conducive for native flora and fauna.

From the study conducted at USM above, it can be concluded that aside from the purpose of improving water quality, the constructed wetland is also designed for multi-functional uses, which includes stormwater treatment, flood control, rain water harvesting, provision of habitat, campus recreation area and wetland research center (Lariya et al, 2001).

Nevertheless, further research needs to be done to identify other factors that contribute to the efficiency of constructed wetland as stormwater treatment device (Mohd Noor et al, 2004).

The large footprint needed to accommodate the construction of the wetland system also has to be factored in for this project. Due to the limited space by the roadside of the designated sites chosen for this project, constructed wetland isn't feasible.

2.2 Grassed Swales

Vegetated grassed swales or biofillers are shallow vegetated channels designed primarily as stormwater conveyance systems with flow depths rarely above the height of vegetation grows within them. There are two types of grassed swales i.e. perimeter swale and ecological swale.

The main pollutant removal mechanisms are by physical filtration through grass and infiltration through the soil, although runoff waters are typically not detained for long enough to remove fine suspended sediments effectively.

From previous studies, ecological swale is considered to be able to control certain peak runoff rates by retarding and impounding stormwater and conveying it downstream at velocities low enough to protect against channel and streambank erosion

(A. Ainan et al, 2004). It is found that the higher frequency of the peak flow causes the stream to cut a deeper and wider channel (Roesner et al, 2001).

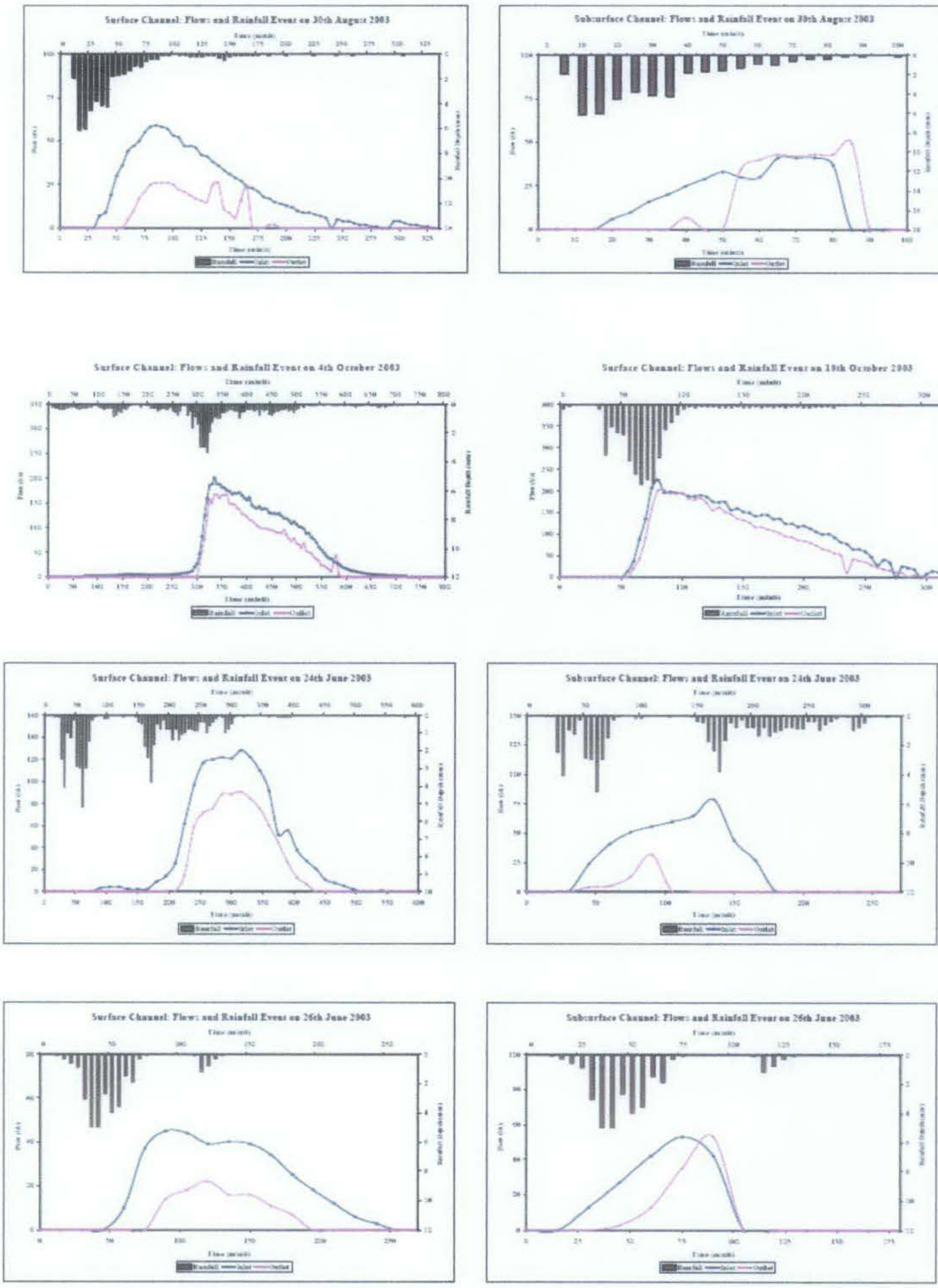
In 2003, data collection was made by Universiti Sains Malaysia (USM) Engineering Campus, to identify percentage reduction of flow volume and peak flow, and lag time between the inflow and outflow for an ecological swale (A. Ainan et al, 2004). The result from the experiment shown that the percentage of volume reduction for the surface channel is between 19.4% to 69.8%, meanwhile the percentage volume reduction for subsurface channel is between 23.7% to 89.2% (A. Ainan et al, 2004). The result is as shown in Table 2.1.

Rain Event (2003)	Rainfall Intensity (mm/hr)	ARI	Location Channel	Peak flow (l/s)		Volume (m^3)		Percentage Reduction (%)	
				(Inlet)	(Outlet)	(Inlet)	(Outlet)	Peak Flow	Volume
24/6	11	3 month	Surface	128	91	418.5	246.6	28.9	41.1
			Subsurface	79	32	134.1	16.2	59.5	87.9
26/6	31.6	6 month	Surface	45	22	105.6	31.2	51.1	70.5
			Subsurface	53	53	53.1	31.2	0	41.2
30/8	14.5	3 month	Surface	59	26	388.8	123.6	55.9	66.6
			Subsurface	41	50	119.1	90.9	0	23.7
8/9	13.8	5 year	Surface	59	26	4043.1	3043.2	55.9	24.1
			Subsurface	70	51	160.2	83.1	27.1	48.1
4/10	6.18	2 year	Surface	201	167	2202.9	1560	16.9	29.2
10/10	33.6	2 year	Surface	226	168	1711.8	1380.3	25.7	19.4
3/11	44.2	1 year	Surface	172	120	1134.6	599.4	30.2	47.2
			Subsurface	41	23	108.9	11.7	43.9	89.2
8/11	9.3	6 month	Surface	115	75	607.8	357.9	34.8	41.1

Table 2.1: Flow attenuation for ecological swale from June to November 2003 (A. Ainan et al, 2004)

From this result, observation can be made that the catchments response time is about 40 minutes, indicating that ecological swales has a capability to delay the flow to downstream site as shown on the inflow and outflow hydrograph in Figure 2.1 (A. Ainan et al, 2004).

Figure 2.1: Inflow and outflow hydrograph for typical rainfall events based on the analysis of attenuation for ecological swale from June to November 2003 (A. Ainan et al, 2004)



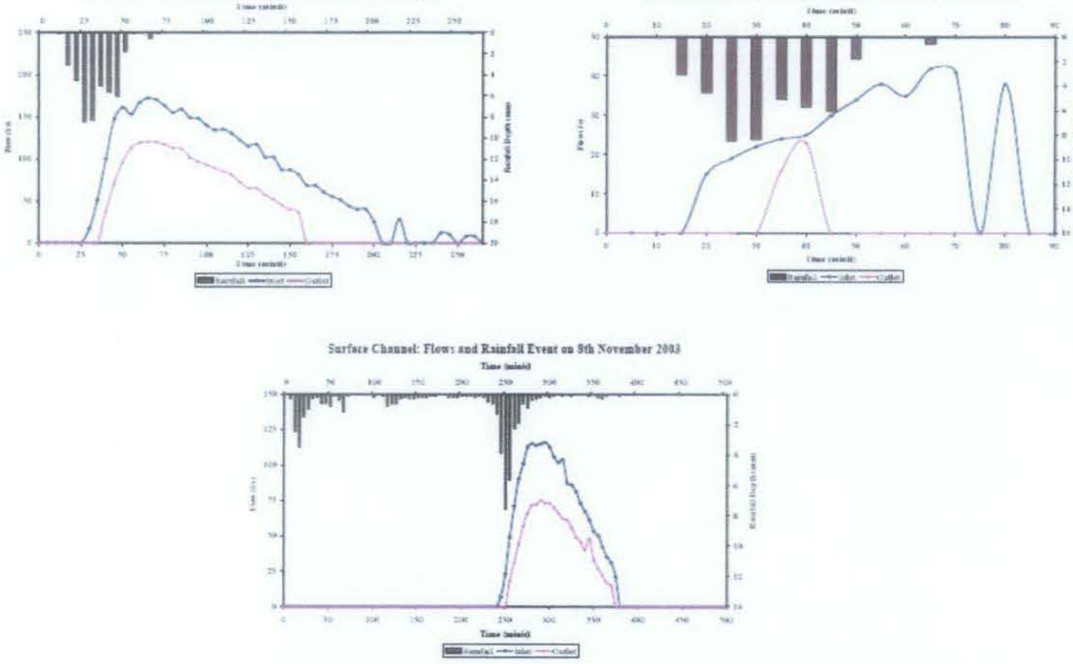


Figure 2.1 (continued): Inflow and outflow hydrograph for typical rainfall events based on the analysis of attenuation for ecological swale from June to November 2003 (A. Ainan et al, 2004)

In a recent design in Germany (Ayub, K. R et al, 2004), stormwater swale is underlain by a gravel infiltration trench with a throttle drain pipe (the so called MR system). The stormwater infiltrating through an active soil is 'pretreated' before entering a gravel trench and drains via a drain pipe discharging into a manhole with a flow throttle. The system shows a good result in removing stormwater pollutants.

A group of researcher from Cooperative Research Center for Catchment Hydrology (CRCCH) further developed the drainage system. The new system is called Bio-filtration and was constructed at a residential area in Australia. The system consists of bio-infiltration systems, constructed wetlands and an ornamental pond.

Amongst suggestions made for future research include assessment of treatment efficiencies of bio-filtration systems with modified parameters (i.e. other forms of swale vegetation, variation in infiltration medium and extended surface ponding) and confirms the significance of insitu graded sand in the adsorption of pollutants (Ayub, K. R et al, 2004).

A study was done to investigate the effectiveness and performance of grassed swales under the tropical climate. Based on the construction of BIOECODS at USM's engineering campus (A. Ainan et al, 2004), several points can be highlighted for the construction of similar drainage systems in other locations:

- Wet swales are not suitable for Malaysia's tropical climate due to mosquito breeding which can be a nuisance. A dry swale is more suitable.
- Individual grassed swales are not enough to treat a very large drainage area of more than 2 ha.
- Grassed swales are not effective in reducing bacteria levels in stormwater runoff. Need further treatment of constructed wetland to enhance the stormwater quality.
- Improper design (e.g. proper slope is not achieved) will reduce the effectiveness of pollutant removal for grassed swales.
- A thick vegetative cover is needed for proper function. Normal grass height should be at least 2 inches above design flow depths.

A stormwater quality monitoring was carried out at the BIOECODS site to measure the capability of the system. The performances of the ecological swales in treating most pollutants showed that there is a reduction of their concentrations from upstream to downstream during the time study (June – October 2003), although it was observed for heavy metals (Pb, Cu and Zn), they do not conform the standards (Ayub et al, 2004).

Considering heavy metals are one of the main pollutants found at road and highway runoff, thus further data is needed to confirm BIOECODS performance.

2.2 Infiltration Trenches

An Infiltration Trench is a "leaky" pipe in a stone filled trench with a level bottom. They are believed to have a good capacity to remove particulate pollutants and a moderate ability to remove soluble pollutants (Field & Sullivan, 2003).

In Japan, as part of flood-prevention method, a law was established in 2003, requiring that infiltration trench is to be built for new road over 1000 m^2 in designated urban river basin (Nakashima S. et al, 2006).

A study was done by Takeshi O. et al (2007) to verify the variation of infiltration capability of trench with time by performing three sprinkling experiments in three consecutive years on a trench constructed in a real highway. From the experimental results, it was presumed that clogging occurred in the trench during the progress, and that infiltration from the trench had no marked impact on the surrounding earth structure. In addition, based on an analysis of the variation of water depth under the real rainfall observed in July 2005, it was also found that this trench could perform effectively for controlling the storm-water runoff, even after a torrential storm.

Despite its high capacity of removing particulate matter, it should be noted that infiltration practices often failed due to clogging. Rather particulate matter should be removed before entering the structure by other means of pretreatment device.

An Infiltration Trench may be preceded by or used in combination with a vegetative filter, grassed Swale, or other vegetative element used to reduce sediment levels from traffic roadways. Design should ensure proper functioning of vegetative system.

Future studies should be focused on the maintenance management and function-recovery techniques for infiltration trench so as to make the application of the infiltration trench come into a wide use.

2.3 Wet Ponds

Wet ponds (a.k.a. stormwater ponds, retention ponds, wet extended detention ponds) are constructed basins that have a permanent pool of water throughout the year (or at least throughout the wet season) and differ from constructed wetlands primarily in having a greater average depth.

Pretreatment incorporates design features that help to settle out coarse sediment particles. Wet ponds are usually paired with a pretreatment sediment forebay which is a requirement in Massachusetts (Massachusetts Department of Environmental Protection, 2008).

Wet ponds are among the most effective stormwater treatment practices at removing stormwater pollutants. A wide range of research is available to estimate the effectiveness of wet ponds.

Table 2.2 provides pollutant removal estimates derived from CWP's National Pollutant Removal Performance Database for Stormwater Treatment Practices:

Table 2.2: Pollutant Removal Efficiency of Stormwater Wet Ponds (Winer, 2000)

Pollutant	Removal Efficiency (%)
TSS	80±27[1]
TP	51±21
TN	33±20
NOx	43±38
Metals	29-73
Bacteria	70±32
1: ± values represent one standard deviation	

A research was done on stormwater pollutant removal by two wet ponds in Bellevue, Washington. One pond was built for flow attenuation and water quality treatment; the other serves only to improve water quality. Pollutant removals varied between a fifth to a half for phosphorus, and greater than half for total suspended solids and most of the analyzed metals. Removal efficiencies were consistently better in the pond designed primarily for water quality.

The California Department of Transportation (Caltrans) has initiated a five-year study in San Diego to examine the benefits, technical feasibility, costs, and operation and maintenance requirements of using a wet pond to treat storm water runoff from an existing freeway. Some of the limitations found:

- Some concern about safety when constructed where there is public access.
- Mosquito and midge breeding is likely to occur in ponds.
- Cannot be placed on steep unstable slopes.
- Need for base flow or supplemental water if water level is to be maintained.
- Require a relatively large footprint

Additional Concerns or unknowns (Charles River Watershed Association, 2008):

- Landscaping, grading and, if required, fencing may be needed to limit access to ensure safety.
- Mosquito breeding can be an issue in wet ponds however this can often be addressed using a composite approach which considers siting and design techniques, water quality issues and biological controls.
- Invasive species can be an issue in wet ponds and may require control measures.
- It is important to provide maintenance access to every vital part of the pond system.

CHAPTER 3
METHODOLOGY

3.1 PROJECT FLOW

The project focuses on both the quantity and quality controls of urban runoff. The procedures involved in this approach for urban runoff from roads and highway are shown in the Figure 3.1.

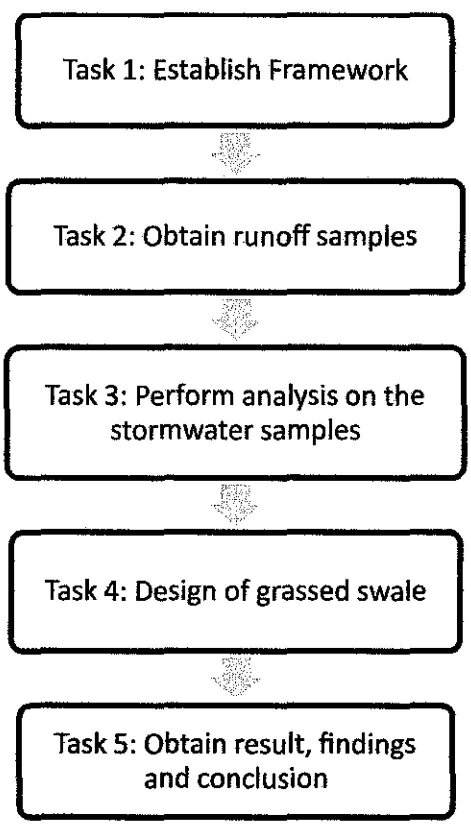


Figure 3.1: Tasks in developing the project

Task 1: Establish Framework

The first task in the project involves establishing the overall framework for the plan and the plan preparation process. This involves establishing:

- The purpose of the project
- The scope of the project
- Resource requirements for the preparation of the project
- Consultation processes with relevant parties

Task 2: Obtain Runoff Samples

Runoff samples are to be taken along the main road of the Ipoh-Lumut Highway. Two points are chosen as the designated points to obtain the runoff samples.

Figure 3.2: Drainage in front of Universiti Teknologi Petronas

Figure 3.3: Drainage along Taman Maju

Task 3: Perform Analysis on the Stormwater Samples

Samples are tested in laboratory using the following parameters set under the National Water Quality Standards for Malaysia:

PARAMETER	UNIT
Ammoniacal Nitrogen	mg/l
Biochemical Oxygen Demand	mg/l
Chemical Oxygen Demand	mg/l
pH	-
Color	TCU
Total Dissolved Solids	mg/l
Temperature	°C
Turbidity	NTU
Oil and Grease	mg/l

Table 3.1: National Water Quality Standards for Malaysia

Task 4: Design of the Grassed Swale

The grassed swale design will further be discussed in part **3.3 Grassed Swale Design** of the chapter.

Task 5: Obtain result, findings and conclusion

From all the results gathered, a conclusion can be made over the effectiveness of the grassed swale method been chosen.

3.2 Water Quality Monitoring

Based on the water quality data obtained from the water sample, the Water Quality Index (WQI) can be determined to classify the current water quality status of the sampling sites.

The water quality data are used to determine the water quality status weather in clean, slightly polluted or polluted category and to classify the rivers in Class I, II, III, IV or V based on WQI and Interim National Water Quality Standards for Malaysia (INWQS) every year (Department of Environment, 2010). WQI is computed based on 6 main parameters:-

- Biochemical Oxygen Demand (BOD)
- Chemical Oxygen Demand (COD)
- Ammoniacal Nitrogen (NH_3N)
- pH
- Dissolved Oxygen (DO)
- Suspended Solids (SS)

The six resulting values are then entered into an established formula to arrive at the WQI score:

$$WQI = 0.22 \times SI\ DO + 0.19 \times SI\ BOD + 0.16 \times SI\ COD + 0.15 \times SI\ AN + 0.15 \times SI\ SS + 0.12 \times SI\ Ph$$

Where SI = sub-index factor, based on the best fit equations for the estimation of the various sub-index values (refer to Appendix for details).

3.3 Grassed Swale Design

3.3.1 General Criteria

- Avoid sharp curves in swale design. If swales are installed prior to or during the site construction phase, they must be free of sediment and reseeded as necessary. Good upstream erosion control must be in place as these swales are designed for modest sediment loads from stable sites.
- Runoff flows should be diverted around swales until grass has become established.
- Erosion control fabric should be installed where flow diversion is not practical. Irrigation is necessary until grass has become established.
- Sod may be used only where proper installation and regular maintenance will occur.

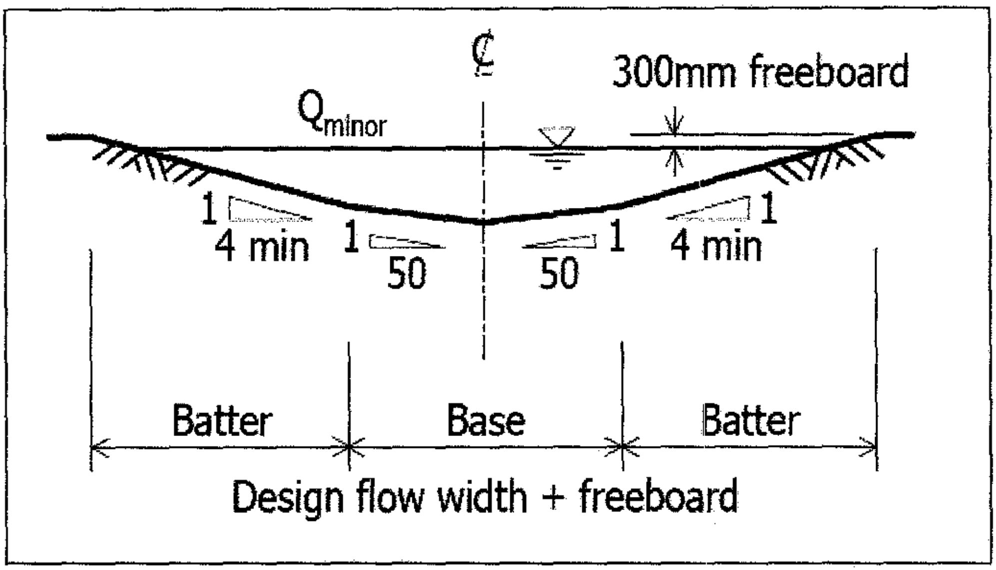


Figure 3.4: Recommended grassed swale cross section (trapezoidal shape)

DESIGN PARAMETER	CRITERIA
Longitudinal slope	2% - 4% < 2% use underlain >4% use drop structure
Maximum water depth	150 mm (water quality)
Manning coefficient of overland flow	0.1 (0.2 if mowed infrequently)
Bed width	0.6 – 3 m
Freeboard height	0.3 m
Minimum hydraulic residence time minutes	2 minutes
Minimum length	60 m
Maximum side slope	3H : 1V 4H : 1V (preferred)
Maximum distance for each drop structure	15 m apart

Table 3.2: Summarized Design Criteria for Biofiltration Swales (Urban Stormwater Management Manual for Malaysia)

3.3.2 Specific Criteria

The specific criteria for the biofiltration swale design are as follows:

- Base the capacity design for biofiltration on the vegetation height equal to the design flow depth and the locally specified water quality design storm of an area. Base the capacity design for flood passage on local agency specifications for flood control.

- Base the design on a trapezoidal cross-section for ease of construction. A parabolic shape will evolve over time. Make side slopes no steeper than 3:1.

- Provide a minimum of 60 m of continuous swale, using a wide-radius curved path, where land is not adequate for a linear swale (avoid sharp bends to reduce erosion or provide for erosion protection). If a shorter length should be used, increase swale cross-sectional area by an amount proportional to the reduction in length below 60 m, in order to obtain the same water residence time.

- Install log or rock check dams approximately every 15m, if longitudinal slope exceeds 4%. Adjust check dam spacing in order not to exceed 4% slope within each channel segment between dams.

- Below the design water depth, install an erosion control blanket, at least 4 inches of topsoil, and the selected biofiltration seed mix. Above the design water line, use an erosion control seed mix with straw mulch or sod.

3.4 The Proposed of Grassed Swale for Future Development

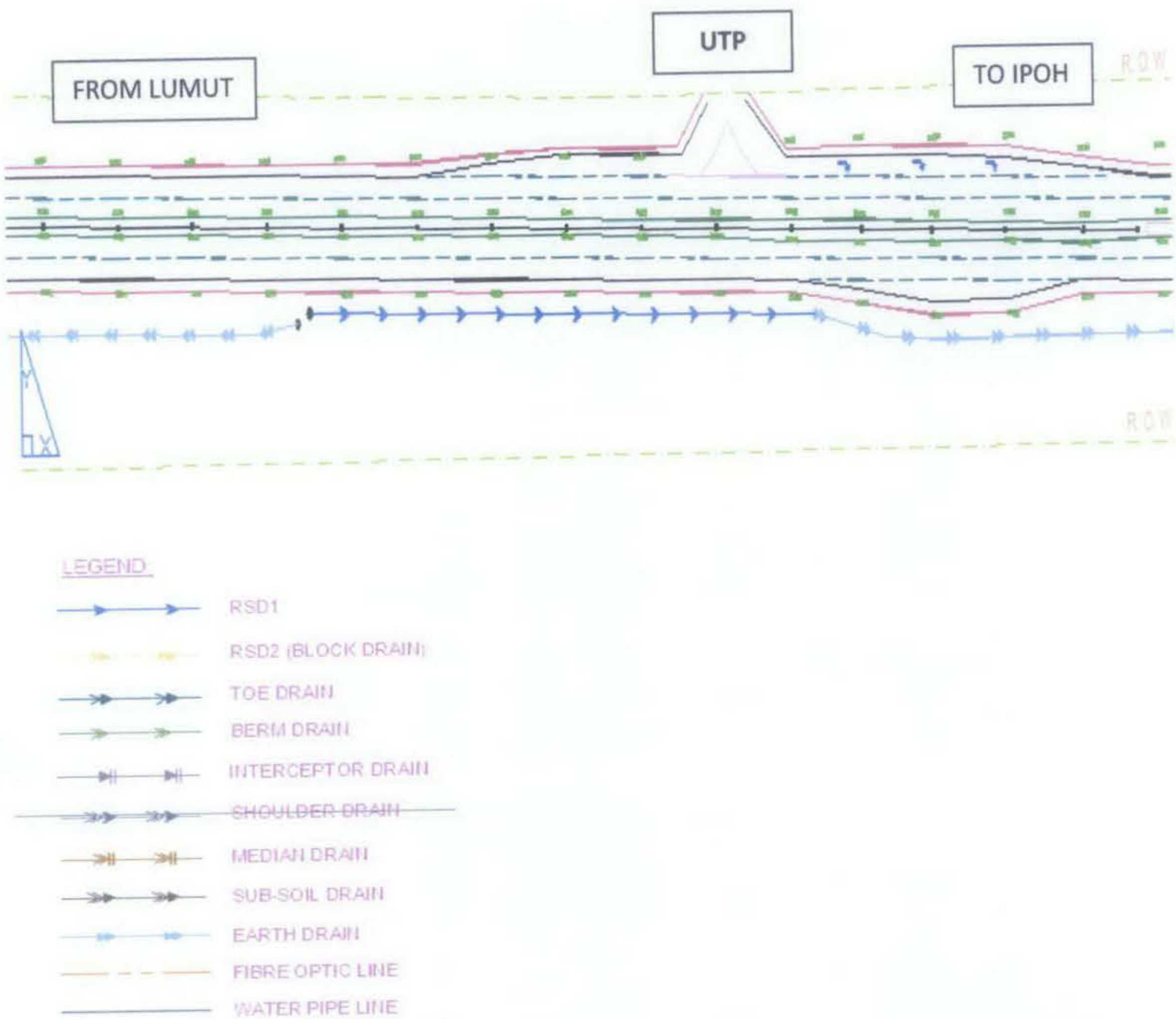


Figure 3.5: The Road Plan for Ipoh – Lumut Highway with the existing drainage

The proposed site is along the Ipoh – Lumut Highway in front of Universiti Teknologi Petronas (UTP). The contribution area is about 8.4 ha. It is a commercial and residential area therefore the quality of the runoff and the effect to the capacity of existing drainage needs to be look into.

The grassed swale technique is proposed for future development in order to tackle these issues. Regarding the advantages of this system, which already been discussed previously, it is suitable to apply this methodology as well as to maintain the environmental quality aspects that need to be taken into account.

1. The grassed swale is chosen because it can be constructed along the road replacing the existing drainage system without causing much damage and cost appropriate.
2. The application of natural vegetation at the proposed site will maintain the environmental quality standard.
3. Due to the steep ground level at the road side, it is feasible to allocate the grassed swale at the proposed area.
4. Due to the development in this area only focused on the commercial and domestic region, the risk of heavy chemical pollutants which commonly from industrial and agriculture runoff become less. Thus the predominant pollutants taken into account are the highway runoff.

CHAPTER 4

RESULTS & DISCUSSION

The samples were to be taken four times from three different points along the Ipoh – Lumut Highway in front of Univeriti Teknologi Petronas (UTP). The samples were taken using the grab samples method.

These samples are then tested in the laboratory to determine its water quality parameters. The details of the site locations and the dates for the samples taken are as follow:

Station	Location
1	UTP Main Gate
2	UTP Bus Stop
3	Taman Maju

Table 4.1: Designated points for the samples to be taken

Day	Date
1	January 26th 2011
2	February 25th 2011
3	Mac 24th 2011
4	April 11th 2011

Table 4.2: Dates of the samples taken

4.1. Chemical Oxygen Demand (COD)

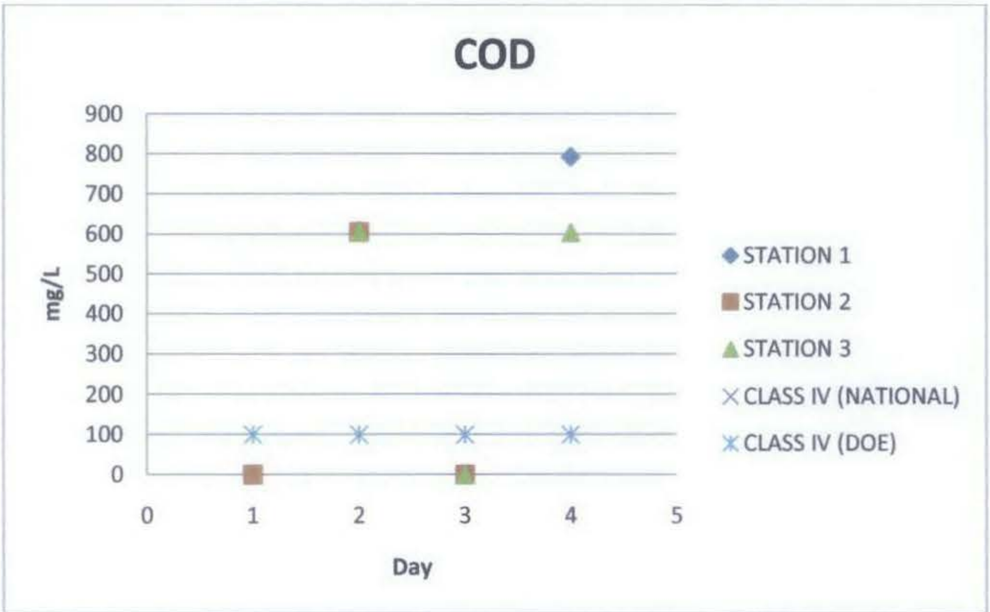


Figure 4.1: COD Test Result

The first 2 days of the COD tests were conducted using high range which resulted in 0 mg/l. For Day 3, low range was used. This time the COD for the samples far exceeded both of the standards because of the high organic compound found in the sample. Day 4 recoded the highest values for COD.

4.2 Turbidity

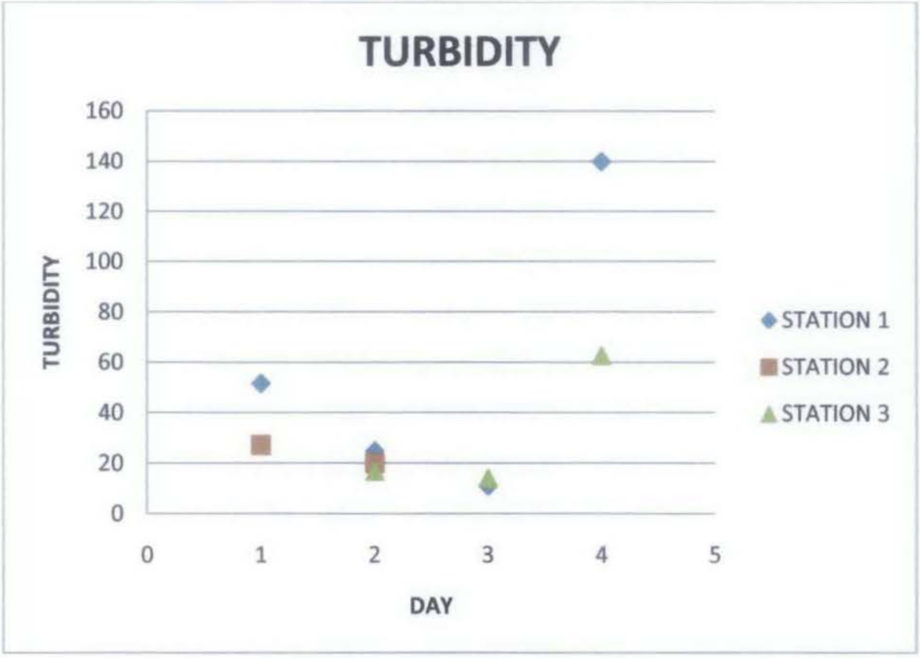


Figure 4.2: Turbidity Test Result

The turbidity is caused by suspended particles from the roads runoff. Most of the pollutants from roads are particulates such as the pavement wear and also from vehicles itself.

4.3 pH and Temperature

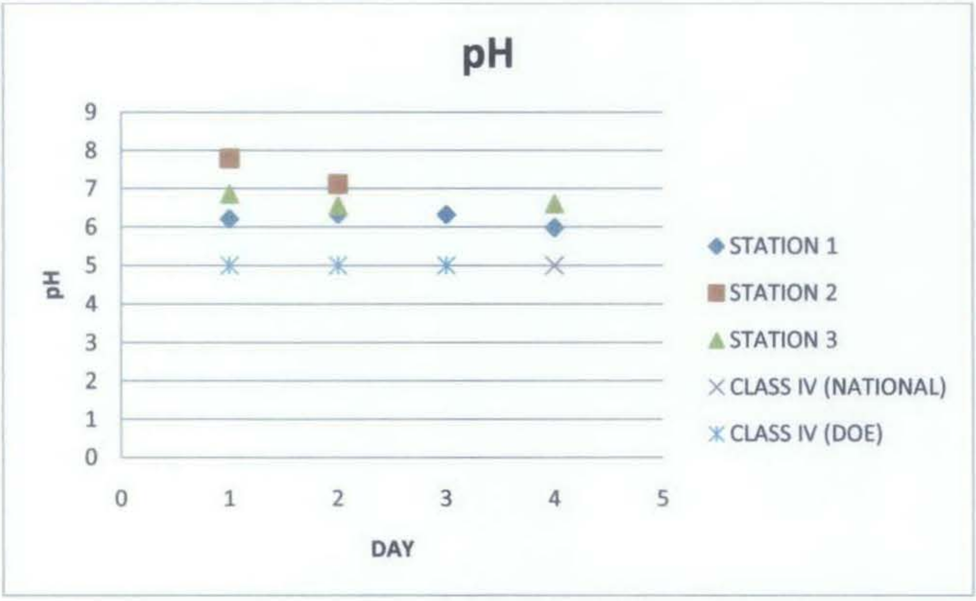


Figure 4.3: pH and Temperature Test Result

The pH test results show that all the stations recorded higher pH than Class IV standards. Station 2 recorded pH around alkali level due to its location at the unoccupied area compared to the other two. Meanwhile, both of the stations 1 and 3 are nearer to residential/campus area, which may contributed to lower pH value.

4.4 Color

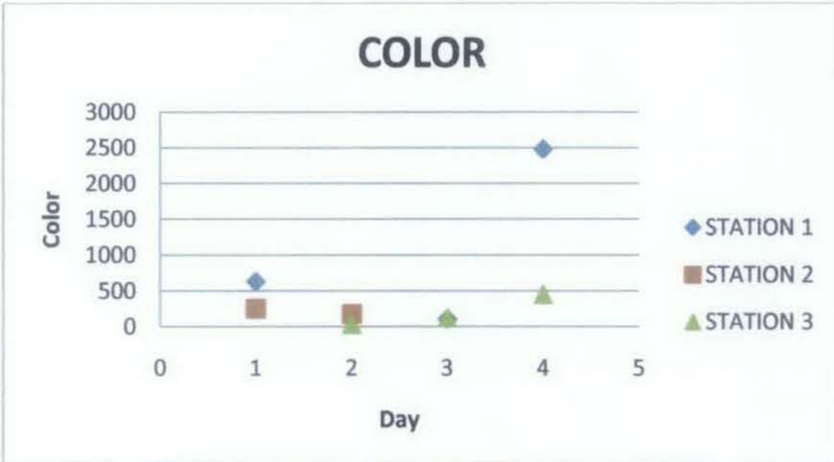


Figure 4.4: Color Test Result

The color test results for all the stations are high. This shows that the water samples contain dissolved organics, minerals and chemicals in the water due to the runoff pollutants.

4.5 Calculating Water Quality Index (WQI)

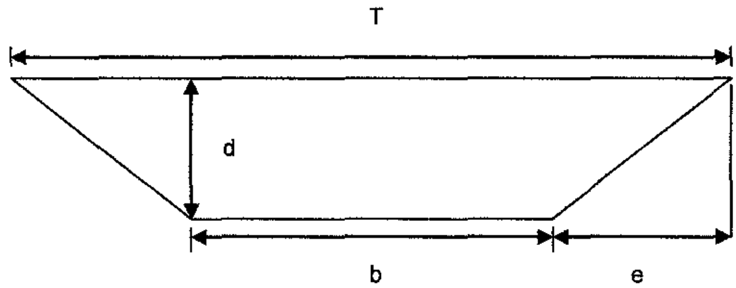
Site	DO%	BOD	COD	SS	pH	NH3-NL
UTP (main gate)	14.49	9.24	792	4.92	5.98	4.39
Taman Maju	12.64	7.29	604	3.508	6.62	2.4

DOSI	BOD SI	COD SI	AN SI	SS SI	pH SI	WQI	CLASS	WQ STATUS
5	64	-32	0	95	91	34	IV	P
4	72	-24	22	95	98	41	IV	P

From the data, the group score is calculated to determine the water quality status and the classifications.

Both of the water qualities of the sites are classified as Class IV based on DOE Water Quality Index Classification, which is the standard for irrigation. The pollution status of the water is polluted. Therefore, the grassed swale runoff treatment proposal is justified.

4.6 Swale Calculation



Trapezoidal Geometry:

Cross section area, $A = By + Zy^2$

Hydraulic radius, $R = R = \frac{A}{B+2y\sqrt{Z^2+1}}$

Top width, $T = B + Zy^2$

From Data:

Total area, $A = 8.4$ ha

Impervious Area, $A_I = 5.6$ ha (category (1) in Design Chart 14.3)

Pervious Area, $A_P = 2.8$ ha (category (7) in Design Chart 14.3)

The following assumptions are made:

Time of concentration, $t_c = 20$ min

The slope of swale, s = 2%

Step 1: <u>Calculate rainfall intensity</u>

$$\ln I = a + b \ln (t_c) + c [\ln (t_c)]^2 + d [\ln (t_c)]^3$$

For Setiawan, 2 year ARI and $t_c = 20$ min

t_c (min)	a	b	c	d	Ln (I)	I (mm/hr)
	5.0790	0.3724	-0.1796	0.0081		
	a	b ln (t_c)	c [ln (t_c)]^2	d [ln (t_c)]^3		
	5.0790	1.1156	-1.6118	0.2178	4.80057	121.58

For Setiawan, 5 year ARI and t_c = 20 min

t_c (min)	a	b	c	d	Ln (I)	I (mm/hr)
	5.2320	0.330	-0.1635	0.0018		
	a	b ln (t_c)	c [ln (t_c)]^2	d [ln (t_c)]^3		
	5.2320	0.9886	-1.4673	0.1828	4.9356	139.16

For Setiawan, 10 year ARI and t_c = 20 min

t_c (min)	a	b	c	d	Ln (I)	I (mm/hr)
	5.5868	0.0964	0.1014	0.0021		
	a	b ln (t_c)	c [ln (t_c)]^2	d [ln (t_c)]^3		
	5.5868	0.2888	-0.91	0.05646	5.0221	151.72

Step 2: <u>Determine the Runoff Coefficient, C and calculate the discharge</u>

Combined Runoff Coefficient, C. = 0.9 x 5.6/8.4 + 0.5 x 2.8/8.4 = 1.18

$$Q_Y = \frac{C\ {}^{y}I_t\ A}{360}$$

ARI (yrs)	${}^{y}I_t$ (mm/hr)	A (ha)	C	Q_y (m^3/s)
2-yrs ARI	121.58	8.4	1.18	3.348 m^3/s
5-yrs ARI	139.16	8.4	1.18	3.832 m^3/s
10-yrs ARI	151.72	8.4	1.18	4.177 m^3/s

Step 3: <u>Determine requirement for swale</u>

Say,

Slope, s_o = 0.03   Side slope, Z = 3

Try,

Overland Manning n = 0.1 (Grass Class D)

Estimate bottom width of the swale;

$$Q = \frac{A\ R^{2/3}\ S^{1/2}}{n}$$

And other equations for trapezoidal swale;

Cross section area, A = By + Zy^2

Hydraulic radius, R = $R = \frac{A}{B+2y\sqrt{Z^2+1}}$

Top width, T = B + Zy^2

Since, $B \gg y$ and $Z \gg 1$, with certain terms are recognized as negligible, the approximate solution for trapezoidal shape is $R \cong y$

Thus;

Bottom width of trapezoidal swale,

$$B \cong \frac{Q_n}{y^{5/3}\, s^{1/2}} - Zy$$

For Q_2 = 1.6795 m^3/s,

B = 43.5 m which is greater than maximum width swale of 3 meter, thus, divide the catchment into 20 parts, such that 10 swale drains/caters runoff from west side and the other 10 swale drains/caters the east side.

Therefore the discharge from individual subcatchment becomes;

Q_2 = 0.08398 m^3/s, and $B \cong 1$ m

Using B = 1 m

A = 0.88 m^2; R = 0.25 m

V_d = Q/A = 0.095 m/s (OK)

Top width, T = B + Zy^2

= 1.5 (use swale top width 2 m)

CHAPTER 5
CONCLUSION

Once the water quantity and quality characteristics of the urban stormwater stream to be treated are determined, treatment mechanism can be selected. Unit operations and process concepts, especially when used in combination will have to be applied to stormwater effectuate in situ or integrated approach treatment.

Grassed swale is proposed as the treatment for the highway runoff of this project. The choice of grassed swale is due to its ability trap particles and pollutants from the highway runoff. This method of stormwater management will be able to ensure that runoff quantity and water quality objectives are being maintained.

From the tests conducted, it is found that the current water quality at the existing drainage is in Class IV based on DOE Water Quality Index Classification. The water quality status is polluted. This shows that the water quality is in the level requiring conventional treatment. Thus, in conclusion, the grassed swale method is the appropriate treatment for the runoff.

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Urban Stormwater Management Manual for Malaysia Volume 12 Source Control BMPs

APPENDIX

APPENDIX A

GANTTCHART for Final Year Project

ACTIVITIES	WEEK														
	1	2	3	4	5	6	7	SEMESTER BREAK	8	9	10	11	12	13	14
Collect Sample 1	■														
Lab Work		■	■	■	■	■	■		■	■	■	■	■		
Progress Report				■	■	■	■		■						
Collect Sample 2						■									
Collect Sample 3										■					
Pre-EDX											■	■			
Collect Sample 4												■			
Draft Report											■	■	■		
Final Report											■	■	■	■	
Preparation for Oral Presentation														■	■

APPENDIX B

WATER QUALITY MONITORING AND CLASSIFICATION

Sub-index Values for WQI Formula

Subindex for DO (in % saturation):

$SIDO = 0$	for x<= 8
$= 100$	or x >= 92
$SIDO = -0.395 + 0.030x^2 - 0.00020x^3$	for 8 < x < 92

Subindex for BOD

$SIBOD = 100.4 - 4.23x$	for x <=5
$SIBOD = 108 * \exp(-0.055x) - 0.1x$	for x > 5

Subindex for AN

$SIAN = 100.5 - 105x$	for x <= 0.3
$SIAN = 94 * \exp(-0.573x) - 5 * \mid x - 2 \mid$	for 0.3 < x < 4
$SIAN = 0$	for x >= 4

Subindex for SS:

$SISS = 97.5 * \exp(-0.00676x) + 0.05x$
for x<= 100
$SISS = 71 * \exp(-0.0061x) - 0.015x$
for 100 < x < 1000
$SISS = 0$
for x >=1000

Subindex for pH

$SIpH = 17.2 - 17.2x + 5.02x^2$
for x < 5.5
$SIpH = -242 + 95.5x - 6.67x^2$
for 5.5 <= x < 7
$SIpH = -181 + 82.4x - 6.05x^2$
for 7 <= x 8.75
$SIpH = 536 - 77.0x + 2.76x^2$
for x >= 8.75

DOE Water Quality Index Classification

PARAMETER	UNIT	CLASS				
		I	II	III	IV	V
Biochemical Oxygen Demand	mg/l	< 1	1 - 3	3 - 6	6 - 12	> 12
Chemical Oxygen Demand	mg/l	< 10	10 - 25	25 - 50	50 - 100	> 100
Ammonical Nitrogen	mg/l	< 0.1	0.1 - 0.3	0.3 - 0.9	0.9 - 2.7	> 2.7
Disolved Oxygen	mg/l	> 7	5 - 7	3 - 5	1 - 3	< 1
pH		> 7	6 - 7	5 - 6	< 5	< 5
Total Suspended Solid	mg/l	< 25	25 - 50	50 - 150	150 - 300	> 300
WQI		>92.7	76.5 - 92.7	51.9 - 76.5	31.0 - 51.9	<31.0

Pollution Status Based (DOE Water Quality Classification based on WQI)

WQI	River Status
0-59	Polluted
60-80	Slightly Polluted
81-100	Clean

WATER QUALITY CLASSES & USES

(NATIONAL WATER QUALITY STANDARDS FOR MALAYSIA)

Class 1	Conservation of natural environment, Water Supply I - practically no treatment necessary, Fishery I - very sensitive aquatic species.
Class IIA	Water supply II - conventional treatment required, Fishery II - sensitive aquatic species.
Class IIB	Recreational use with body contact.
Class III	Water supply III - extensive treatment required, Fishery III - common, of economic value and tolerant species; livestock drinking.
Class IV	Irrigation
Class V	None of the above

APPENDIX C

ANNOVA SINGLE FACTOR

pH

SUMMARY

Groups	Count	Sum	Average	Variance
1	3	18.88	6.293333	0.005233
2	2	14.91	7.455	0.22445
3	2	13.43	6.715	0.04805

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	1.622005	2	0.811002	11.46428	0.022064	6.944272
Within Groups	0.282967	4	0.070742			
Total	1.904971	6				

COD

SUMMARY

Groups	Count	Sum	Average	Variance
1	3	608	202.6667	123221.3
2	3	605	201.6667	122008.3
3	2	606	303	183618

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	15252.54	2	7626.271	0.056568	0.945598	5.786135
Within Groups	674077.3	5	134815.5			
Total	689329.9	7				

TURBIDITY

SUMMARY

Groups	Count	Sum	Average	Variance
1	3	87.4	29.13333	422.1233
2	2	47.2	23.6	25.92
3	2	31.2	15.6	3.92

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	219.8019	2	109.901	0.502929	0.638503	6.94427 2
Within Groups	874.0867	4	218.5217			
Total	1093.889	6				

COLOR

SUMMARY

Groups	Count	Sum	Average	Variance
1	3	911	303.666 7	83177.33
2	2	434	217	2738
3	2	164	82	4232

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	58969.0 5	2	29484.5 2	0.680446	0.556732	6.9442 72
Within Groups	173324. 7	4	43331.1 7			
Total	232293. 7	6				