THE IMPACT OF ROAD CONSTRUCTION ON WATER QUALITY AT KG. SENGKANG, MUKIM GERISEK, MUAR

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**A project report is submitted in partial fulfilment of
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DEDICATION

Dedicated to My Beloved:

Abah

Emak

Along

Angah

Alip

Najwa

Aiman

Zurin

All my sincerely classmates

My dearly fellow friends

and,

A friend who I am wished may be mine.

Syukran 'alaikum.

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~ In the name of Allah, the most Grasious, the most Compassionate ~

Alhamdulillah, the great expression of gratitude to Allah the Almighty for His helps and consents towards the accomplishment of this project.

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May all our good deeds that we have done will be blessed by Allah.

Thank you very much.

ABSTRACT

This study was carried out to assess the water quality of a water body that may be affected directly from road construction project. This study area is along a new proposed route, from Kg. Sengkang Batu 18 to Kg. Teratai, Mukim Gerisek, Muar, Johor Darul Takzim. A total of 12 water samples were collected from 4 stations and sampling was conducted at three different dates, namely on 8th May 2008, 26th July 2008 and 2nd September 2008. In-situ parameters for the water quality study included pH, temperature, and Dissolved Oxygen (DO). Stream flow as well as depth and width of the river were measured on the sampling day. Physical characteristic parameters such as Total Suspended Solids (TSS) were considered in this study. Laboratory analyses were carried out according to the HACH and APHA methods. Results showed that the Dissolved Oxygen (DO) values were very low, except at Station 1 because it is located upstream. This condition indicates that the water was stagnat and move slowly. The impact of these construction activities could result in environmental damage to the adjacent peat swamp by changing the hydrological characteristics, which in the long term could lead to deterioration in the quality of the peat swamp forest ecosystem. Beside that, the increasing traffic flow through this new roadway also contributes to decreasing water quality for this area.

ABSTRAK

Kajian ini dilakukan untuk menilai kualiti air bagi suatu saliran di kawasan ini yang mungkin menerima kesan secara langsung dari projek pembinaan jalan raya. Kawasan kajian adalah di sepanjang laluan yang dicadangkan untuk pembinaan, iaitu dari Kg. Sengkang Batu 18 hingga ke Kg. Teratai, Mukim Gerisek, Muar, Johor Darul Takzim. Jumlah keseluruhan sampel yang dianalisis adalah sebanyak 12, yang diambil dari 4 buah stesen. Pengambilan sampel juga dilakukan sebanyak 3 kali, iaitu pada 8 Mei 2008, 26 Julai 2008 and 2 September 2008. Parameter yang diambil bacaan terus di lokasi persampelan termasuk pH, suhu dan oksigen terlarut. Kadar aliran air, halaju, keluasan dan kedalaman setiap lokasi sampel juga direkod. Parameter fizikal seperti pepejal terampai akan dianalisis di makmal. Analisis di makmal akan mengikut prosedur HACH dan APHA. Hasil analisis menunjukkan nilai oksigen terlarut bagi setiap stesen adalah rendah, kecuali bagi Stesen 1 kerana kedudukannya di kawasan hilir. Ini menunjukkan aliran air yang perlahan dan tidak bergerak seperti di kawasan paya. Kesan dari pembinaan jalan raya ini akan mengakibatkan kemerosotan kualiti alam sekitar, khususnya kepada kawasan paya akibat perubahan ciri-ciri hidrologinya. Untuk jangka masa panjang, ia akan menimbulkan masalah kepada ekosistem paya tersebut. Selain itu, peningkatan bilangan kenderaan yang akan melalui jalan ini, turut menyumbangkan kepada penurunan kualiti air di kawasan ini.

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LIST OF ABBREVIATION

ABBREVIATION		DESCRIPTION
°C	-	Degree Celsius
ADB	-	Asian Development Bank
AN	-	Ammoniacal Nitrogen
BOD	-	Biochemical Oxygen Demand
CFC	-	Chlorofluorocarbons
CO	-	Carbon Monoxide
COD	-	Chemical Oxygen Demand
dB	-	Decibel
DID	-	Department of Irrigation and Drainage
DO	-	Dissolved Oxygen
DOE	-	Department of Environment
EIA	-	Environmental Impact Assessment
EMP	-	Environmental Monitoring Plan
ha	-	Hectare
hr	-	Hour
INWQS	-	Interim National Water Quality Standard
km	-	kilometer
km^2	-	square kilometer
L / l	-	litre
m	-	meter
m^2	-	square meter
m^3	-	cubic meter

mg	-	milligram
MSL	-	Mean Sea Level
NOx	-	Nitrogen Oxides
O&G	-	Oil and Grease
P	-	Phosphorus
PWD	-	Public Works Department
RM	-	Malaysian Ringgit
Temp.	-	Temperature
TSS	-	Total Suspended Solids
WQI	-	Water Quality Index

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CHAPTER 1

INTRODUCTION

1.1 Background Information

Malaysia's road system is among the finest in Asia, which was begun during British colonization, is extensive and covers about 63,445 km. The roads generally are single carriageway with some dual or more carriageways in certain locations with much traffic. In general, roads in Malaysia are primarily bitumen-based macadamized roads. However, a few of the roads have concrete roads too. Apart from these, one also comes across unpaved roads in the countryside, which is fast getting converted to paved roads (Ministry of Transport, 2008).

Road network and accessibility is one of main infrastructure beside clean water supply, gas, electricity, drainage, sewers, telecommunication system and as such. Improving the road network will enhance the efficiency of transportation by reduction of traffic congestions, thus reducing traffic delay. It is also does not only provide benefits in term of transportation, but also largely contribute to the socio-economic development and social integration for the area.

1.2 Problem Statement

The main roads in Malaysia, particularly in big booming towns are under huge pressure and in great need of modernization in order to handle the increased requirements of the national economy. Besides just fixing and paving the roads, widening and straightening of roads and expanding the network is becoming increasingly necessary. This is because the roads can then handle increased traffic, both in terms of goods and public movement together with an increase in the speed of movement.

In general, due to decades of bureaucratic procedural difficulties, the road network has suffered long delays. The related parties have now started examining the situation and taking action to solve this problem. However, there are still other environmental, logistical, and local issues contributing to delay in development of the road infrastructure. For instance, an Environmental Impact Assessment (EIA) need to be prepared in line with the Government's interest in protecting and enhancing the environment. In Malaysia, a list and prescribed activities has been prepared for which an EIA is mandatory under the Environmental Quality (Prescribed Activities) (Environmental Impact Assessment) Order 1987. Some of the lists are the construction of infrastructures, expressway and national highways.

Road projects can be a source of a significant amount of pollution to our nation's environment, particularly to the water. Pollution is generated during road construction, maintenance, and use. Non-point source pollution, or runoff pollution, is created when chemicals, debris, fertilizers, automotive oils, debris from wearing parts, and litter are washed off roadways during rainstorms and carried as runoff to streams, rivers, lakes and swamps.

Storm drain pollution from road construction that involves excavation and grading can cause soil erosion and deposition of sediments in storm drains. During road paving, surfacing, and pavement removal operations, there are numerous opportunities for storm drain pollution from asphalt, saw-cut slurry, or excavated material. By any mean, the development will involve environmental issues, although by just removing the trees. Therefore, there are our responsibilities to focus on the potentially significant adverse impacts from the project that could have on the environment.

1.3 Project Description

Muar District has about 577.84 km, with 179.24 km Federal Roads and 398.60 km State Roads. About 75 percent is paved road. In order to improve the road networks, Malaysia Government intends to make a re-alignment for an existing road from Kg. Sengkang Batu 18 to Kg. Teratai in Muar, Johor Darul Takzim. The purpose of this re-alignment is to enhance road safety and improve road network within Muar District. The proposed project is initiated by Public Works Department Malaysia (PWD), has appointed a consultant which is Juruteras Engineers Sdn. Bhd. to monitor the project while normally, their party will monitor the project by themselves. However, the main turnkey contractor is Innoseven Sdn. Bhd. It has been started on 4th September 2007 and will be completed on 3rd January 2009. Contract period is about 70 weeks, after applying to extend the time period to 18 months (Juruteras Engineers Sdn. Bhd., 2006).

1.4 Aim and Objectives

The aim of the study is "to analyze the change in water quality from road construction project during the construction period," by:

i. Analyzing water quality parameters from existing water body that may affected by on-going road construction;
ii. To analyze the impacts of the road construction to water pollution;
iii. To analyze the minimum Dissolved Oxygen level along a river stretch by using Oxygen Sag Curve;
iv. To estimate the pollutant concentration in water after the project completed by using Mass Balance Analysis; and
v. To suggest best monitoring approach to reduce water pollution and soil erosion due to the project.

1.5 Scope of Study

Scopes of this study including:

i. The boundary of this study is from latitude 102° 41' 18" E to 102° 43' 50" E and longitude 02° 15' 21" N to 02° 16' 10" N.
ii. The considering parameters for this study are pH (Acidity and Alkalinity), Temperature, Dissolved Oxygen (DO), Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Suspended Solid (TSS), Ammoniacal Nitrogen (AN), Phosphorus (P) and Oil and Grease (O&G);
iii. The sampling of water quality is taken at four stations with three times of frequency on different weather conditions (study period is within May 2008 to September 2008);

iv. Water quality parameter will be analyzed based on Water Quality Index (WQI), Interim National Water Quality Standards (INWQS) for Malaysia and Effluent Standard tables; and

v. Oxygen Sag Curve and Mass Balance analyses will be used to analyze the minimum Dissolved Oxygen level along the river and to estimate the pollutant concentration in water after the project completed, respectively.

1.6 Rationale of Study

Based on the aim and objectives, this study is needed to carry out because the road development works will deteriorate the environment particularly the water sources. Basically, the clearing phase such as removing trees and woody vegetation from the road right-of-way; the ground-breaking phase such as excavating and filling the slope to establish the road centerline and approximate grade; the construction phase such as final grade and road drainage installation; and the surfacing phase such as placement and compaction of the roadbed, will decline the water quality by runoff of silt, debris and sedimentation, and also the chemical and nutrient use into the watercourse.

Furthermore, this study can predict and evaluate how far the development will decline the water quality by measuring water quality parameters and analyzing the future decline by using Mass Balance Analysis, based on current water quality.

From the analysis, the study can be a planning tool for preventing environmental problems or at least minimization of pollution, due to the project works. It seeks to avoid costly mistakes in project implementation, either because of the environmental damage or because of modifications that may be required subsequently in order to make the action environmentally acceptable. The study also will detail out the mitigating measures as a remedial action for the project works, to ensure that its project construction will not cause major detrimental impacts on the environment.

1.7 Study Limitation

This study has several limitations, including:

i. The time frame of this project study is quite short, only for about five months,

ii. The most suitable locations for sampling stations can not be made because some of the area can not fully accessible by private vehicle,

iii. The study parameters focus only on WQI parameters, by adding only two more parameters,

iv. Lack of water quality impact reports for road construction projects, particularly in Malaysia, maybe due to this project is an infrastructure or government project, thus sometime do not need to assess the water quality.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The road infrastructure is main catalyst for the development of important key sectors of economy like agriculture, industry, mining, energy, forestry and dairy development. These sectors depend heavily on the development and maintenance of the road network and the efficiency of transportation system. After completing the construction, this segment of road would become a potential road to meet all necessary requirements in contributing to economic growth and national development as the whole (Ministry of Transport, 2008).

2.2 Road Development in Malaysia

The National Expressway, Federal Roads and State Roads form the economic backbone of the country. These have helped development along the route, and many towns have sprung up along major highways. State and Major District Roads constitute the secondary system of road infrastructure of Malaysia. By acting as the link between the rural and urban areas, they contribute significantly to the development of the rural economy and industrial growth of the country.

In Malaysia, the responsible parties to road development are Public Work Department *(Jabatan Kerja Raya)* Malaysia under Ministry of Works *(Kementerian Kerja Raya)* and concessionaires such as Malaysian Highway Authority *(Lembaga Lebuhraya Malaysia)* for expressway. They are responsible to design, create and improve road surface and expand the capabilities to accommodate increasing traffic capacity and heavier loading. Beside these, they also served to prepare transportation infrastructures to manage demand of agriculture development, public services, national defence, and tourism, thus enhance local quality of life. (Public Work Department Malaysia, 2008).

2.3 Road Construction and the Impacts to the Environment

Road projects are generally intended to improve the economic and social welfare of people. Increased road capacity and improved pavements can reduce travel times and lower the costs of vehicle use, while increasing access to markets, jobs, education, and health services and reducing transport costs for both freight and passengers. For all the positive aspects of road projects, they may also have significant negative impacts on nearby communities and the natural environment.

There is a growing awareness that road development has major environmental impacts (World Bank, 1995). Some of the major environmental impacts of road projects include damage to sensitive ecosystems, loss of productive agricultural lands, soil erosion, changes to streams and underground water, and interference with animal and plant life. New roads may induce development in previously undeveloped areas, sometimes significantly affecting sensitive environments and the lifestyles of indigenous people. Roads are agents of change, and can be responsible for both benefits and damage to the existing balance between people and their environment (World Bank, 1997).

Roads bring people, and people bring development. People may also be indirectly affected by projects, through the disruption of livelihood, loss of accustomed travel paths and community linkages, resettlement of large numbers of people, permanent disruption of local economic activities, demographic change, accelerated urbanization, and introduction of disease such as increases in respiratory problems due to air pollution, and injury from road accidents. Consequently, a wide range of environmental impacts result from stressors produced by the construction, maintenance and use of roads. Roads can contribute to air pollution, cause noise and vibrations, affect land use, consume resources, create waste disposal problems, contribute to water pollution, affect hydrology, form barriers to people, wildlife and agriculture, and diminish biodiversity (World Bank, 1997).

2.3.1 Impacts to Water Quality and Hydrology

Roads often bring significant economic and social benefits, but they can also have substantial negative impacts on communities and the natural environment, particularly to water environment.

2.3.1.1 Storm Drain Pollution

Road construction involves excavation and grading which can cause soil erosion and deposition of sediments in storm drains. During road paving, surfacing, and pavement removal operations, there are numerous opportunities for storm drain pollution from asphalt, saw-cut slurry, or excavated material. Extra planning is required to store and dispose of materials properly and guard against pollution of the storm drains and creeks.

Storm water pollution is a serious problem for wildlife dependent on our waterways and for the people who live near polluted streams. Common sources of this pollution are oil, fuel, and fluids from vehicles and heavy equipment; construction debris; landscaping runoff containing pesticides or weed killers; and materials such as motor oil, and paint products that people pour or spill into a street or storm drain. Road construction and traffic operations, if undertaken without a proper understanding of the relationships inherent in environmental function, can be accompanied by serious disruptions to the environment, from which it may take a long time to regain equilibrium. In human terms, this may mean that generations must function in a debilitated environment and suffer many possible associated socio-economic hardships and financial losses (Lorant, 1992).

2.3.1.2 Highway Runoff

The pollutants from road and urban runoff can harm plants and animals when initially released. They often concentrate in sediments, causing future damage. The following water pollution impacts are generally associated with highway runoff (Lorant, 1992):

i. Dissolved oxygen depletion: Generally the biological oxygen demand (BOD) is less than 30 mg/L, based on urban storm water data. High BOD is the consequence of abnormal concentrations of pollutants stimulating algae growth. Excessive algae populations deplete the oxygen available in a body of water for other organisms, harming or killing wildlife.

ii. Nutrients: Urban storm water runoff can contain ammonia and nitrate levels in excess of those recommended by regulatory agencies. Excessive nutrients can create accelerated growth of nuisance aquatic plants in water bodies and lead to oxygen-depleted conditions.

iii. Metals: Metals tend to settle in runoff sediments, where their concentration can be an order of magnitude higher than background sediment levels. Metal concentrations in sediments show a close correlation with traffic volumes. High metal concentrations are very toxic, since these substances bioconcentrate in the food chain.

2.3.1.3 Hydrologic Impacts

Roads and parking lots also alter the normal hydrologic process (Dunne and Leopold, 1978). Rather than percolating into the ground, precipitation washes over the surface into natural or artificial watercourses. The consequences are many, including reduced groundwater recharge, increased surface water runoff volumes and peak flow rates, flooding and erosion, habitat damage, lower dry season flows, increased water management costs and wetland loss. Reduced plant canopy along roads often increases water temperatures, which can harm aquatic wildlife. In many cases, the hydrologic impacts of road and urban runoff are more harmful to receiving waters than the effects of toxic pollutants (Waste Management Group, 1992). These hydrologic impacts are often dispersed and cumulative, with roads and parking lots bearing a portion of the responsibility for the total costs of flooding, flood control and environmental damage.

Motor vehicles, roads and parking facilities are a major source of water pollution and hydrologic disruptions **(Table 2.1).** Water pollution and hydrologic impacts have been widely cited as significant environmental costs (Works Consultancy, 1993; OECD, 1990; Miller and Moffet, 1993; Dunne and Leopold, 1978; Hanson, 1992). Considerable research has been performed on various aspects of these impacts, but few studies have attempted to quantify and monetize their total effect. Loss of wetlands can be considered as hydrologic impact, as well as a land use impact.

Table 2.1: Water pollution and hydrologic impacts of road projects

Water Pollution	Hydrologic Impacts
▪ Crankcase oil drips and disposal ▪ Road de-icing (salt) damage ▪ Roadside herbicides ▪ Leaking underground storage tanks ▪ Air pollution settlement	▪ Increased area of impervious surfaces ▪ Concentrated runoff, causing flooding ▪ Loss of wetlands for water storage ▪ Shoreline modifications ▪ Increased water temperature ▪ Disruption from construction activities along shorelines and waterways, and through water courses and lakes

Sources: Works Consultancy (1993); OECD (1990); Miller and Moffet (1993); Dunne and Leopold (1978) and Hanson (1992).

2.3.1.4 Vehicles and Facilities

Motor vehicles contribute to water pollution through air emissions and wastes that are washed into surface and ground water. Direct automobile water pollutants include petroleum products, tire and brake lining particles, rust and dust. One litre of oil can foul the taste of 4 million litres of drinking water, or make a 0.4 ha slick on surface water. During use, crankcase oil picks up toxic chemicals and heavy metals that harm the environment and human health unless disposed of properly. An estimated 46% of vehicles on the road leak hazardous fluids, including crankcase oil, transmission fluid, hydraulic fluid, brake fluid and antifreeze (Von Zwehl, 1991). The oil spots and rainbow sheens of oil, common in puddles along roads and parking lots, are signs of this problem. Pollutants from vehicles include coarse and fine sediment; vehicle-use related materials including lead, zinc, copper and chromium; and oil, fuels and grease. However, leaded petrol was phased out in January 2002. These pollutants can build up in receiving waterways and contribute to environmental degradation.

Impervious surfaces reduce groundwater recharge, which results in reduced groundwater reserves, lower off-season stream flows and reduced wetland habitats. They also concentrate surface water flows, resulting in damage to riparian (streamside) corridors. Constriction of streams into culverts increases physical barriers to the movement of fish. These impacts impose costs in terms of environmental degradation, storm water management, flood prevention, public water supplies, fisheries and agriculture, recreation, aesthetics and cleanup requirements. Solar heating of paved surfaces and reduced shade-giving vegetation along roadways tends to increase the temperature of storm water runoff (Waste Management Group, 1992). Even a small increase in water temperature can reduce or eliminate sensitive insect and fish species, and tends to increase organisms' sensitivity to toxic metals.

2.3.1.5 Biological Impacts

One experiment has done show severe algae inhibition when exposed to 1, 5 and 10 percent runoff concentrations with very high average daily traffic (ADT) of 185 thousand after two weeks of dry weather. Runoff from 23 000 and 16 000 ADT on rural and suburban highways, preceded by a brief dry period, generally stimulated algal growth (Waste Management Group, 1992). Beside this, pollution from a range of sources may affect fish and aquatic organism, such as:

i. Sedimentation: many freshwater fish species lay eggs on the river bed in areas which provide some shelter from water flow and predators. Sedimentation can smother the eggs and other aquatic flora and fauna, and infilling of gravel beds and deep pools can reduce areas for shelter.
ii. Turbidity: turbid water harms fish by irritating their gills.
iii. Organic matter: organic matter which enters waterways from leaf litter, wastes and general litter is broken down by bacteria and in the process uses up the dissolved oxygen in the water. Low levels of dissolved oxygen may lead to sediment desorption of phosphorous and metals and can lead to stressing of the aquatic community and fish kills.
iv. Acid sulphate soils: fish kills and fish diseases can occur through disturbance and release of acidic runoff from these soils.
v. Oils and heavy metals: these and other pollutants in road runoff can reduce water quality and impact upon the health of aquatic organisms.

2.3.2 Air Pollution

Road transportation produces air emissions directly from road construction and vehicle operation, and indirectly from vehicle manufacture and operation, fuel extraction, production and distribution, and manufacture of construction materials and machinery. The indirect emissions can be a sizable fraction of total vehicle emissions. For example, the energy embodied during manufacturing in an average automobile is 10 to 14 percent of its total lifetime fuel consumption (Warner and Glenys, 1991). Since the energy used in metal production and other industrial processes is primarily fossil-fuel based, embodied emissions are probably significant. Vehicle operating emissions include:

i. Carbon Oxides (monoxide CO and dioxide CO_2),
ii. Volatile Organic Compounds (VOCs), comprising hydrocarbons (HCs) which include methane (CH_4),
iii. Nitrogen Oxides (NOx), which include nitrous oxide (N_2O),
iv. Sulphur Oxides (SOx),
v. Toxic substances,
vi. Dust and finer particulate matter (PM),
vii. Heavy metals, and
viii. Chlorofluorocarbons (CFCs) and other depleters of stratospheric ozone.

These pollutants are emitted from the tailpipe, from the engine and fuel supply system, and from brake linings, clutch plates and tires. The quantity of pollutants emitted by a vehicle depends on its mass, operating conditions, fuel type and fuel formulation, engine type and age, pollution control devices, driver behaviour and level of maintenance. Several of these emissions are greenhouse gases, which contribute to global warming. Vehicle air conditioners and truck refrigeration units contain CFCs, which are greenhouse gases, and ozone-depleting substances, which damage stratospheric ozone when released. Some road construction activities, such as asphalt-mix preparation and lying, generate emissions as diverse as vehicle engines, but in smaller quantities. Local impacts of these emissions during construction may be large. Road construction and usage also produce dust and smaller particles.

2.3.3 Noise and Vibrations

Noise is unwanted sound, which rapidly increases worldwide. Both changes in noise sources and their growth contribute to the worsening situation. Road traffic is one of the most frequent non-occupational sources of noise exposure, together with construction, aircraft operations and rail traffic (Talbott, 1994). With the growth of the load capacity and number of heavy vehicles, concerns about vibration effects on humans and buildings arose, and the measurement methods developed for noise were found useful.

Road construction and vehicle operation cause a variety of noises. Noise originates from engines, tire-road contact and braking, emergency vehicle sirens, vehicle doors and trunks opening and closing, and vehicle radios and horns. Traffic noise is unpleasant and distracting, and can be disturbing to sleep and other activities. It degrades the comfort and well-being of people outdoors and indoors. Consequently, consumers perceive the values of real estate located in noisy environments to be lower than in a quieter environment. Traffic noise can also disturb wildlife.

Noise is typically characterized by the intensity, frequency, periodicity (continuous or intermittent) and duration (acute or chronic) of sound. Noise is measured in decibels (dB) on a logarithmic scale. A 10 dB increase represents a doubling in noise level. Decibels A-weighted (dB(A)) emphasize the frequency sensitivities of human hearing and correlate well with subjective impressions of loudness. Common noise levels are: whisper, 30 dB(A); normal conversation, 50 to 65 dB(A); inside a car with a loud engine, 70 dB(A); average city traffic noise, 80 dB(A); diesel truck, (64 km/h at 15 m distance) 84 dB(A); lawnmower, 85 to 90 dB(A); symphony orchestra or chain saw, 110 dB(A); and shotgun firing, 130 dB(A).

2.3.4 Soil, Erosion and Sedimentation

Erosion from construction sites has the potential to contribute large sediment loads to downstream areas. High turbidity reduces the penetration of light through the water, can impact on feeding and respiration of aquatic fauna and the resulting sedimentation can alter the nature of downstream habitats. Water supplies may be needed during construction for controlling dust and other purposes. Depending on the quantities required and the source of the water, this may have potential impacts on users of the water resource and aquatic fauna and flora.

Acid sulphate soils are the common name given to soils containing iron sulphides. As long as the sulphide soils remain under the water table, oxidation cannot occur and the soils are quite harmless and can remain so indefinitely. When sulphides are exposed to air, oxidation takes place and sulphuric acid is produced, which is toxic to plant and animal life. The acid moves through the soil and acidifies soil, groundwater and surface water. It will strips iron, aluminium and sometimes manganese from the soil and may also in some cases dissolve heavy metals such as cadmium. Thus, it can make the soil so toxic that few plants or only acid tolerant plants can survive. This affects agricultural productivity and natural habitats. Acid leachate can also cause rust coloured stains and slimes. Acid drainage impacts on fish and other organisms and can result in fish kills. Exposure to acidified water also damages fish skin and increases the susceptibility of fish to infection and skin disease. Acidic conditions also damage structures such as bridges and culverts and may lead to increased availability and movement of pollutants (Works Consultancy, 1993).

2.3.5 Operational and Maintenance Use of Road Infrastructure

Storm water pollutants originate from a variety of sources, including, motor vehicles, erosion and surface degradation, adjoining land uses, atmospheric deposition, and miscellaneous surface deposits such as leaf litter. Sources of pollutants in road runoff during operational use include:

i. Vehicle generated pollutants: from fuel emissions or general wear of engine, tyre, brake and other mechanical components. These levels are influenced by traffic type and traffic volumes.
ii. Accidental spills from vehicle accidents.
iii. Pavement and verge materials: wear of pavement materials and wash off of road shoulder and verge materials.
iv. Roadside vegetation and landscape plantings: in urban areas because of the extensive paved and sealed areas, roadside plantings contribute significant leaf litter load to waterways.
v. Litter.

Sources of pollutants in road runoff from maintenance practices such as herbicide use, mowing and road surface cleaning or reparation. Further more, pollutants from other sources which drain to the transport infrastructure network such as atmospheric deposition and runoff from adjoining land uses, buildings, houses, or roads which enters the drainage system. Pollutants that originate from these activities are usually grouped as:

i. Gross pollution and litter (solid matter more than 4 mm diameter),
ii. Sediment and suspended solids,
iii. Nutrients (mainly phosphorus and nitrogen),
iv. Oils and surfactants, and
v. Toxic organic compounds, including herbicides, and trace metals.

2.3.6 Highway Pollutant and the Sources

In summary, **Table 2.2** below shows the potential pollutant from highway and their sources. The pollutants are from the operations of completed project, as well as come from the surrounding area and activities.

Table 2.2: Potential Highway Pollutants and Their Sources

Classification	Contaminant	Source
Heavy Metals	Copper, Iron, Lead, Zinc	Auto fuels (exhaust), brake wear, tire wear, moving engine parts
Inorganic Salts	Sodium, Calcium, Chloride	De-icing salts.
Nutrients	Nitrogen, Phosphorous	Fertilizers, industry emissions, vehicle exhaust.
Organic Compounds	Oxygen Demanding Substances	Domestics, commercial, and industrial wastes; natural decay of organic materials.
Particulates	Dust and dirt "airborne" particles	Atmosphere, highway maintenance, pavement wear, vehicle activity.
Pathogenic Bacteria	Coliform bacteria	Animal transport or grazing in adjacent areas, roadkill.
Petroleum	Road characteristics, vehicle operation	Asphalt surface, oil and other vehicle leaks, spills.
PCB, Pesticides		Atmospheric deposition, synthetic tires, spraying of right-of-ways.
Others	Rubber, Asbestos	Tire wear, clutch and brake wear.

Sources: Gupta, M. K. et al. (1981); Kobrieger, N. P. et al. (1984); Novotny, V. et al. (1981); and Metcalf and Eddy, Inc. (1991).

Table 2.3 and **Table 2.4** below summarize the adverse environment and social impacts from road construction and development.

Table 2.3: Various adverse environmental impacts that may be caused by road development projects on major substantive parameters

Substantive issues	**Environmental impacts**
Soil	▪ Soil erosion and modification of surface relief of borrow zones ▪ Slope failure and mass movements ▪ Sedimentation of roadside drains and water bodies ▪ Loss of productive topsoil in borrow areas ▪ Soil contamination
Water	▪ Modification of flowing surface water in borrow areas causing erosion and siltation ▪ Modification of surface and groundwater during construction and consequent drying and flooding ▪ Water quality degradation by waste materials, and equipment lubricants, fuels and detergents ▪ Sedimentation of surface water bodies
Air	▪ Air quality degradation – caused by dust and vehicle emissions generated through construction activity, construction machinery and vehicular traffic ▪ Adverse impacts on human health, flora and fauna, and on the built environment
Ecosystem	▪ Damage, fragmentation or loss of habitat and biodiversity ▪ Destruction of vegetation ▪ Disappearance of reproduction and food zones for fish, aquatic and migratory birds ▪ Contamination of biota
Landscape	▪ Destruction of natural relief (caused by major cut and fill) ▪ Change in natural drainage patterns ▪ Destruction of vegetation and trees ▪ Deforestation and desertification

Sources: ESCAP (2001).

Table 2.4: Various adverse social impacts that may be caused by road development projects on major substantive parameters

Substantive issues	**Environmental impacts**
Community activities	▪ Split community ▪ Disintegration of social activities ▪ Disruption of traditional modes of transport ▪ Loss of roadside community business ▪ Degradation of roadside environment owing to ribbon development
Displacement and resettlement	▪ Displacement of both private and public institutions and utilities ▪ Displacement of families, businesses and properties ▪ Poor resettlement arrangements for households, properties and utilities ▪ Lack of basic utilities in resettlement areas, leading to decreased well-being of people
Cultural heritage	▪ Damage of sites, structures and remains of archaeological, historical, religious and cultural values ▪ Damage to social values ▪ Degradation of aesthetic values of historical and religious institutions and cultural monuments
Human health and safety	▪ Transmission of diseases ▪ Contamination of local water supplies ▪ Air pollution ▪ Disturbances by noise and vibration ▪ Road accidents owing to poor pavement and shoulder conditions; and obstructions/unsafe conditions ▪ Poor road signs, markings, intersection layout and traffic control system ▪ Poor or inadequate provisions for pedestrians, cyclists and other non-motorized road users

Sources: ESCAP (2001).

2.4 Surface Water Quality Parameters

Water quality (Coulston and Mrak, 1977) is a term used to define the physical, chemical, biological or radiological characteristics by which a particular variety of water may be evaluated to establish its acceptability for various beneficial uses. Water quality is a relative term, referred to as poor, medium or excellent depicting whether the level of contaminants present in the given sample of water is above, at or well below the maximum permissible limits laid down by the regulatory agency. Sources of water supply for public use nowadays are surface or groundwater such as rivers, lakes, streams, aquifers, seawater, reclaimed wastewater and reservoirs.

2.4.1 Principal Categories of Water Pollutants

Water quality under flow condition changes rapidly because it depends on both weather conditions and polluting parameters. This justifies the necessity of monitoring the water quality round the year under different weather conditions. Deterioration in water quality may be attributed to the negligent use of water both by human inhabitation and by various industries. When water becomes unfit for its intended use due to the presence of contaminants, it is considered as polluted. Polluted water acts as a slow poison and adversely affects the ecology and thereby harming the flora and fauna, the natural inhabitant and the entire living world (Saha, Banerjee, and Datta, 2005). **Table 2.5** summarizes common pollutant categories and their sources. Several principal categories of water pollutants that usually used for water quality assessment are:

a. Dissolved oxygen (DO)

DO is an amount of oxygen gas dissolved in a given quantity of water at a given temperature and atmospheric pressure. It is usually expressed as a concentration in parts per million or as a percentage of saturation.

b. Oxygen-demanding Wastes

Substances which consume DO present in water body. The parameters usually used to measure gross amounts of organic matter are as follows:

i. Total Oxygen Demand (TOD): the amount of oxygen required to oxidize organic and inorganic compounds to CO_2 and H_2O in a platinum-catalyzed combustion chamber. The TOD is determined by the loss of oxygen in the nitrogen-carrier gas.

ii. Chemical Oxygen Demand (COD): the amount of oxygen required to oxidize the organic substance by a strong oxidizing chemical (i.e. dichromate). Differs from the BOD test in that COD uses oxygen derived from chemicals, while BOD uses oxygen derived from air dissolved in water.

iii. Biochemical Oxygen Demand (BOD): the amount of oxygen required by microorganisms/bacteria for the oxidation of an organic substance which is biodegradable such as proteins, carbohydrates, fats and oils and biodegradable synthetic organic chemicals in water. The BOD of a wastewater is a characteristic reflecting treatability or stage of decomposition.

c. Pathogens

Pathogen is disease-causing microorganisms such as bacteria, viruses and protozoa.

d. Nutrients

Any element or compound (chemicals) such as phosphorous or nitrogen, that fuels abnormally high organic growth in aquatic ecosystems. It can cause an overabundance of bacteria and algae when high amounts are present, leading to a depletion of oxygen and fish kills. High levels of phosphorous, ammonia, nitrate, nitrite or elemental nitrogen in water are usually caused by agricultural runoff or wastewater treatment plants operation. In natural waters and in wastewaters, phosphorus occurs mostly as dissolved orthophosphates and polyphosphates, and organically bound phosphates

e. Suspended solids

Particles of suspended sediment in water that cause turbidity (Metcalf and Eddy, 1992). It tends to settle at the channel bottom, but upward currents in turbulent flow counteract gravitational settling. Solids in the form of floating debris, grease and oil slicks indicate a highly polluted stream and suspended solids contribute to turbidity and silt load and require sedimentation or filtration for removal.

f. Heavy Metals (toxic metals)

It may cause adverse impacts on human body including nervous system and kidney damage, mutations and tumors. Some heavy metals from road projects are lead and copper.

g. Pesticides

Dichlorodiphenyltrichloroethane (DDT) and Dioxins.

h. Volatile Organic Compounds (VOC)

Vinyl chloride, 1, 2 - dichloroethan, Tetrachloroethylene, Carbon tetrachloride, Trichloroethylene.

Table 2.5: Pollutants and their sources

Common Pollutant Categories							
	BOD	Bacteria	Nutrient	Ammonia	TDS	Acid	Toxic
Point Sources							
Municipal sewage treatment plant	x	x	x	x			x
Industrial facilities	x						
Combined sewer outflows	x	x	x	x	x		x
Non-point Sources							
Agricultural runoff	x	x	x		x		x
Urban runoff	x	x	x		x		x
Construction runoff			x				x
Mining runoff					x	x	x
Septic systems	x	x	x				x

Source: modified from the 1986-305(b) National Report

Other significant physical characteristic is temperature. It is an important criterion as it affects chemical and biological reactions and solubility of gases such as oxygen. For example, high temperatures increase reaction rates and solubility to a certain extent. The pH is the logarithm of the reciprocal (negative log) of the hydrogen ion concentration (hydrogen ion activity) in moles per litre. It is a numeric value that describes the intensity of the acid or basic (alkaline) conditions of a solution. The pH scale is from 0 to 14, with the neutral point at 7.0. Values lower than 7 indicate the presence of acids and greater than 7.0 the presence of alkalis (bases).

Oil and grease also being a significant parameter for the road project assessment. The insoluble organic materials are of concern. Aside from any specific toxic effect due to ingestion of a particular component of the mixture, insoluble organic material can present environmental problems. Insoluble organic materials in effluent create the same problems only on a smaller scale because of the smaller quantities (mg/L to g/L). Even on this smaller scale they can cause death, coating the gill surfaces of fish, amphibians, insects, and other creatures living in water, preventing the transport of oxygen from the water into the animal and interrupting respiration.

The exact details of the isolation process depend on the composition of the organic material. In broad terms, insoluble organic material is composed of oils and greases, surfactants, petroleum hydrocarbons, and a variety of miscellaneous substances from chemical manufacturing and other industrial processes. The term oil is meant to indicate a water insoluble organic material that is a liquid at room temperature. The term grease means a water insoluble organic material that is a solid or semi-solid at room temperature.

2.5 Water Related Regulations and Standards

Road specific environmental and social acts or similar legislation would assign responsibility to an agency for conducting and managing the road-project-related process. In most countries, the road authority is the appropriate agency to be assigned this responsibility. The administrative parties are normally responsible for developing all environmental laws, policy statements, regulations and directives. The environment ministry or authority should also be mandated with the responsibility to incorporate the law into the various phases of road infrastructure development.

2.5.1 Malaysia National Policy on the Environment

National Policy on the Environment which integrates the three elements of sustainable development: economic, social and cultural development and environmental conservation was formulated and approved in 2002. The Policy aims at continued economic, social and cultural progress and enhancement of the quality of life of Malaysians through environmentally sound and sustainable development. It is based on eight inter-related and mutually supporting principles set to harmonise economic development goals with environmental imperatives:

i. Stewardship of the Environment
ii. Conservation of Nature's Vitality and Diversity
iii. Continuous Improvement in the Quality of the Environment
iv. Sustainable Use of Natural Resources
v. Integrated Decision-Making
vi. Role of the Private Sector
vii. Commitment and Accountability
viii. Active Participation in the International Community

In keeping abreast with the country's rapid economic development and to meet with the nation's aspiration for an improved quality of life, the National policy on the Environment serves as an important guide to all stakeholders to ensure that the environment is clean, safe, healthy and productive.

2.5.2 Malaysian Legislations and Regulations for Prevention River Water Pollution

Legislations and Regulations are important to enact for the purposes of prevention, abatement and control of pollution and enhancement of the environment. The legal and institutional frameworks in Malaysia have powers relating to pollution prevention in rivers.

2.5.2.1 Regulations under Environmental Quality Act, 1974 to Control Activities That May Cause Impact to River Water Quality:

i. Environmental Quality (Licensing) Regulations 1977.
ii. Environmental Quality (Prescribed Premises) (Crude Palm Oil) Regulations 1977.
iii. Environmental Quality (Prescribed Premises) (Raw Natural Rubber) Regulations 1978.
iv. Environmental Quality (Sewage and Industrial Effluents) 1979.
v. Environmental Quality (Scheduled Waste) 2005.
vi. Environmental Quality (Prescribed Activities) (Environmental Impact Assessment) Order 1987.
vii. Environmental Quality (Prescribed Premises) (Crude Palm Oil) Order 1977.
viii. Environmental Quality (Prescribed Premises) (Raw Natural Rubber) Order 1978.
ix. Environmental Quality (Prohibition on the Use of Controlled Substance in Soap, Synthetic Detergent and Other Cleaning Agents) Order 1995.
x. Environmental Quality (Prescribed Conveyance) (Scheduled Wastes) Order 2005.

2.5.2.2 List of Acts and Regulations Regarding Water Pollution Control:

i. Local Government Act, 1976 (Act 171).
Section 69 Part VIII: Committing nuisance in streams, etc.

ii. Town And Country Planning Act, 1976 (Act 172).
Part VII: Development Plans.

iii. Fisheries Act, 1985 (Act 317).
Section 38: Power of state Authority and Minister to make the rules concerning turtle's inland fisheries.

iv. Sewerage Services Act, 1993 (Act 508).
Section 19: Industrial effluent or noxious matter not to communicate with public sewer, etc.

v. Land Conservation Act, 1960 (Act 385).
Section 3: Declaration of hill land.

2.5.3 River Water Quality Classification in Malaysia

Water quality data were used to determine the water quality status weather in clean, slightly polluted or polluted category. The classification is a basis for assessment of a water course in relation to pollution categorization. The appraisal of water quality is based on the Water Quality Index (WQI), which is the most commonly used index to denote the quality of river water, and Interim National Water Quality Standards for Malaysia (INWQS).

2.5.3.1 Water Quality Index (WQI)

As with similar systems, WQI relates a group of water quality parameters, i.e., dissolved oxygen, biochemical oxygen demand, chemical oxygen demand, ammoniacal nitrogen, suspended solids and pH, to a common scale and combine them into a single number in accordance with a chosen method or model of computation **(Table 2.6).** The main objective of the WQI system is to provide a preliminary means of assessing a water body for compliance with the standards adopted for five designated classes of beneficial uses. The study extended WQI to the assessment of water quality trends for management purposes, even though it is not specifically intended to be an absolute measure of the degree of pollution or actual water quality. (Refer to **Appendix A** for WQI Sub-Index calculation).

Table 2.6: DOE Water Quality Index Classes

Parameters	**Classes**				
	I	**II**	**III**	**IV**	**V**
Ammoniacal Nitrogen (mg/L)	< 0.1	0.1 - 0.3	0.3 - 0.9	0.9 - 2.7	> 2.7
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
Dissolved Oxygen (mg/L)	> 7	5 - 7	3 - 5	1 - 3	< 1
pH	> 7.0	6.0 - 7.0	5.0 - 6.0	< 5.0	> 5.0
Total Suspended Solids (mg/L)	< 25	25 - 50	50 - 150	150 - 300	> 300
Water Quality Index	**> 92. 7**	**76.5 - 92.7**	**51.9 - 76.5**	**31.0 - 51.9**	**< 31.0**

Source: Department of Environment (2005)

2.5.3.2 Interim National Water Quality Standards for Malaysia

The DOE initiated the development of Receiving Water Quality criteria for Malaysia in 1985 which aimed at developing a water quality management approach for the long term water quality of the nation's water resources. Under INWQS, Malaysian rivers are classified according to the six classes and as described in **Table 2.7**. (Refer to **Appendix B** for INWQS for Malaysia tables).

Table 2.7: River classification according to the water usage

Class	Uses
I	Conservation of natural environment Water supply I - no treatment necessary (except by disinfection of boiling only) Fishery I - very sensitive aquatic species
IIA	Water supply II - conventional treatment required Fishery II - sensitive aquatic species
IIB	Recreational use with body contact
III	Water supply III - extensive treatment required Fishery III - common, of economic value and tolerant species
IV	Irrigation
V	None of the above

Source: Department of Environment (2005)

2.5.3.3 Parameter Limits of Effluent Standard A and B

This standard applies to the industrial and development projects which are located within catchment areas (areas upstream of surface or above sub-surface water supply intakes, for the purpose of human consumption including drinking). (Refer to

Appendix C for Parameter Limits of Effluent of Standards A and B). Standard B is the standard for the quality of industrial and sewage effluents discharged into rivers and not used for water supply. Standard A of the schedule is used for discharge to rivers used for water supply. Moreover – since these standards are for effluents – the standards for diluted effluent in the river should be much higher – as it is assumed that effluent is diluted in the river water and so the levels detected in the river are significantly lower. The effluent quality of any discharge from a sewage treatment process to an inland water (that is, other than one having an ocean outlet) shall meet the minimum requirements of the Environmental Quality Act 1974 and the limits set down by the Environmental Quality (Sewage Industrial Effluent Regulations, 1979 (Amendment 2000) [Regulations 8(1), 8(2), 8(3)].

2.5.4 Environmental Regulations in the United States

These regulations are to compare with the Malaysian regulations since the case study is adopted from U.S. water quality assessment. The Clean Water Act is the primary federal law in the United States governing water pollution. Commonly abbreviated as the CWA, the act established the symbolic goals of eliminating releases to water of high amounts of toxic substances, eliminating additional water pollution by 1985, and ensuring that surface waters would meet standards necessary for human sports and recreation by 1983.

The principal body of law currently in effect is based on the Federal Water Pollution Control Amendments of 1972, which significantly expanded and strengthened earlier legislation. Major amendments were enacted in the Clean Water Act of 1977 enacted by the 95th United States Congress and the Water Quality Act of 1987 enacted by the 100th United States Congress.

2.5.4.1 Environmental Law Statutes and Regulations

i. Clean Air Act
ii. Clear Water Act - U.S. Code, Title 33, Chapter 26 (also known as Water Pollution Prevention and Control)
iii. Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) - U.S. Code, Title 42, Chapter 103
iv. Conservation - U.S. Code, Title 16
v. Development of Energy Soruces - U.S. Code, Title 42, Chapter 73
vi. Endangered Species - U.S. Code, Title 22, 2151q
vii. Environmental and Natural Resources - U.S. Code Title 22
viii. Environmental Taxes - U.S. Code, Title 26, Chapter 38
ix. Hazardous Materials Transportation Act - OEPA Summary
x. Insecticides and Environmental Pesticide Control - U.S. Code, Title 7, Chapter 6
xi. International Biological Program - U.S. Code, Title 22, 274a
xii. National Drinking Water Regulations - U.S. Code, Title 42, 300g-1
xiii. National Environmental Policy - U.S. Code, Title 42, Chapter 55
xiv. National Environmental Policy Act - U.S. Department of Energy
xv. Noise Pollution - U.S. Code, Title 42, Chapter 65
xvi. Ocean Dumping - U.S. Code, Title 33, Chapter 27
xvii. Oil Pollution - U.S. Code, Title 33, Chapter 40
xviii. Prevention from Pollution from Ships - U.S. Code, Title 33, Chapter 33
xix. Protection Of Environment - Code of Federal Regulations, Title 40

2.6 Water Quality Modelling

Water quality models simulate the fate of pollutants and the state of selected water quality variables in water bodies. They incorporate a variety of physical, chemical, and biological processes that control the transport and transformation of these variables. Water quality models are driven by hydrodynamics, point and non-point source loadings, and key environmental forcing functions, such as temperature, solar radiation, wind speed, pH, and light attenuation coefficients. Some water quality models focus on particular problem contexts, such as dissolved oxygen depletion or organic chemical fate. Other models are more general, and can be used to simulate different water quality problems. Every model has their own strengths, limitations, and data requirements prior to application.

2.6.1 Oxygen Sag Model

A major aspect of water quality management involves the modelling of water quality changes in rivers and streams subject to both natural and anthropogenic inputs of oxygen demanding wastes. The development of water quality models involves the application of materials balances and reaction kinetic expressions to describe the response of the physical system. One of the earliest mathematical water quality models is called Streeter-Phelps model and is used to predict the oxygen deficit in a river resulting from the discharge of a waste.

The DO sag equation can be used to find the concentration at any point downstream of a waste discharge as long as we know the travel time to that point, which is easy to calculate if the stream velocity is known. The Streeter-Phelps equation accurately models the amount of DO in a stream after wastewater is discharge into it. This model follows the pollutant downstream as it travels at the stream velocity. When a pollutant is introduced into a water source, the DO typically decreases to a minimum before gradually recovering to the saturation level. The plot of the DO as a function of time is called the DO sag curve (Master, 1998).

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The Streeter-Phelps **(Figure 2.1)** oxygen sag model relates the rate of change of the oxygen deficit with distance to the respective spatial rates of deoxygenation (Equation 2.1) and reoxygenation (Equation 2.2). Deoxygenation is caused by microbial decomposition of organic wastes, while reaeration is oxygen dissolved into river.

$$\therefore \text{ Rate of deoxygenation} = k_d L_t = k_d L_0 e^{-kdt} \quad \text{.. } \mathbf{(2.1)}$$

$$\therefore \text{ Rate of reaeration} = k_r D \quad \text{.. } \mathbf{(2.2)}$$

Where k_d = deoxygenation rate constant, day^{-1},

L_t = BOD remaining after time t, after the wastes enter the river (mg/L),

L_0 = ultimate BOD at the point of discharge (mg/L)

k_r = reaeration rate constant, day $^{-1}$,

D = dissolved oxygen deficit = DO_s - DO

DO_s = saturated value of dissolved oxygen

DO = actual dissolved oxygen at a given location downstream

The reaeration constant, k_r, is much dependent on the particular conditions in the river **(Table 2.8).** Many attempts have been made empirically to relate key stream parameters to the reaeration constant. One of the most commonly used formulations being the following (Equation 2.3) (O'Connor and Dobbins, 1958):

$$\therefore \; k_r = \frac{3.9\,u^{\frac{1}{2}}}{H^{\frac{3}{2}}} \quad \text{.. } \mathbf{(2.3)}$$

Where k_r = reaeration coefficient at 20°C (day^{-1})

u = average stream velocity (m/s)

H = average stream depth (m)

Table 2.8: Typical reaeration constants for various water bodies

Water body	**Range of k_r at 20°C (day^{-1})**
Small ponds and backwaters	0.10 - 0.23
Sluggish streams and large lakes	0.23 - 0.35
Large streams of low velocity	0.35 - 0.46
Large streams of normal velocity	0.46 - 0.69
Swift streams	0.69 - 1.15
Rapids and waterfalls	> 1.15

Source: Tchobanoglous and Schroeder (1985).

The deoxygenation caused by microbial decomposition of wastes and oxygenation by reaeration are competing process that are simultaneously removing and adding oxygen to a stream. Combining the two equations (Equation 2.1 and 2.2) yields the following expression for the rate of increase of the oxygen deficit:

Rate of increase of the Oxygen Deficit = Rate of Deoxygenation - Rate of Reaeration

$$\therefore \ \frac{dD}{dt} = k_d L_0 e^{-k_d t} - k_r D \, , \qquad \text{(2.4)}$$

which has the solution:

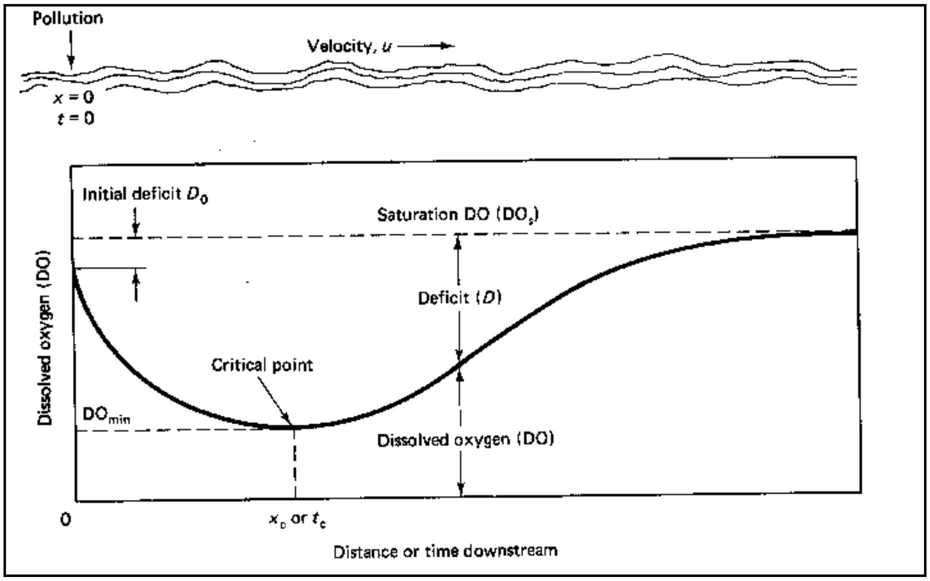
$$\therefore \ D = \frac{k_d L_0}{k_r - k_d}\left(e^{-k_d t} - e^{-k_r t}\right) + D_0 e^{-k_r t} \, , \qquad \text{(2.5)}$$

or:

$$\therefore \ D = \frac{k_d L_0}{k_r - k_d}\left(e^{-k_d \frac{x}{u}} - e^{-k_r \frac{x}{u}}\right) + D_0 e^{-k_r \frac{x}{u}} \qquad \text{(2.6)}$$

Critical point occurs when $\frac{dD}{dt} = 0$ .... **(2.7)**

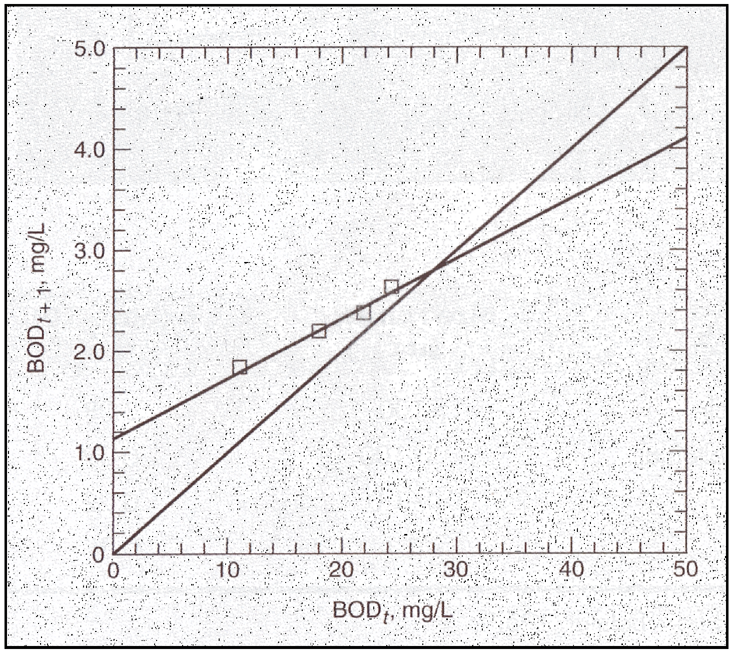
$$\therefore \ t_c = \frac{1}{k_r - k_d} \ln\left\{\frac{k_r}{k_d}\left[1 - \frac{D_0 (k_r - k_d)}{k_d L_0}\right]\right\} \qquad \text{(2.8)}$$



Source: Streeter and Phelps (1925)

Figure 2.1: Streeter-Phelps oxygen-sag curve

The value of k is needed if the BOD_5 is used to obtain UBOD, the ultimate BOD. The usual procedure followed when these values are unknown is to determine k_1 and UBOD from a series of BOD measurements. These are several ways of determining k_1 and UBOD from the results of a series of BOD measurements, including the method of least squares, the rapid ratio method (Sheehy, 1960) and the Fujimoto Method (Fujimoto, 1961). By using Fujimoto method, the k_1 value and UBOD will be determine by preparing an arithmetic plot of BOD_{t+1} versus BOD_t and on the same plot, draw a line with a slope of 1 **(Figure 2.2).** The value at the intersection of the two lines corresponds the ultimate BOD (UBOD) (Metcalf and Eddy, Inc., 2004).



Source: Fujimoto (1961).

Figure 2.2: Arithmetic plot to fine UBOD

2.6.2 Mass Balance Model

A mass balance (also called a material balance) is an application of conservation of mass to the analysis of physical systems. By accounting for material entering and leaving a system, mass flows can be identified which might have been unknown, or difficult to measure without this technique. The exact conservation law used in the analysis of the system depends on the context of the problem but all revolve around mass conservation, i.e. that matter cannot disappear or be created spontaneously. Mass balances are used widely in engineering and environmental analyses. For example mass balance theory is used to design chemical reactors, analyse alternative processes to produce chemicals as well as in pollution dispersion models and other models of physical systems.

A basic principle of stream water quality models is the conservation of mass. Thus, a very fundamental concern with the existing approach is the fact that using BOD as a state variable intrinsically means that mass balances cannot be closed because BOD is ill defined and does not account for all biodegradable organic matter. Rather than being a unique material, BOD is the result of a bioassay measurement, the yield of which changes with the type of substrate consumed. Hence, the amount of substrate consumed and biomass produced, and the rates of those processes, can vary significantly. Existing models, with a single BOD substance and decay rate, cannot account for these variations (Masters, 1998).

$\therefore$ Input rate = Output rate + Decay rate ……….............................. **(2.9)**

$\therefore$ Decay rate = KCV

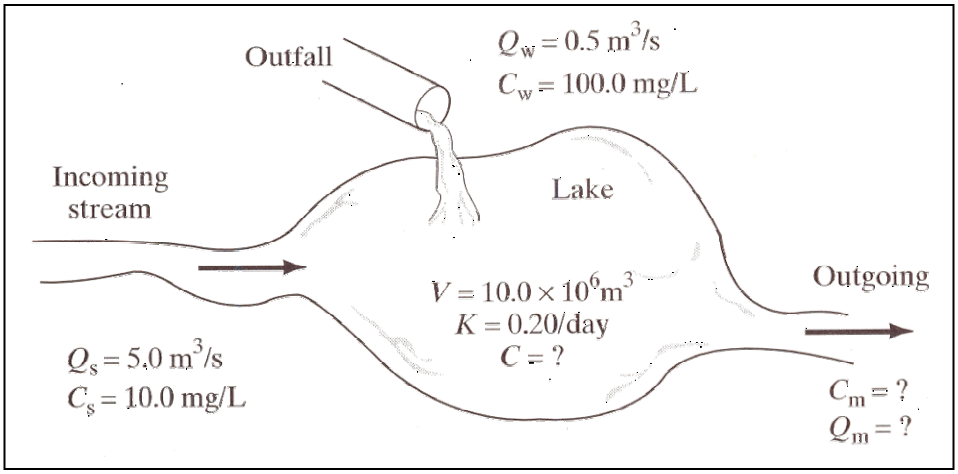
Where K = reaction rate coefficient with dimensions of time ($time^{-1}$)

C = pollutant concentration

V = volume

Therefore, Input rate = Output rate + KCV ……….............................. **(2.10)**

The uniqueness of the model calibration is also an issue given that there are parameters that can counteract such that several sets of parameter values lead to the same modeling results. For example, the BOD decay coefficient, K_1, and the reaeration coefficient, K_2, can be adjusted to compensate for each other such that multiple acceptable calibration combinations typically are possible. Similarly, Li (1962) has shown that a distributed inflow from nonpoint sources may mimic the effect of altered reaeration and degradation rates. His analytical solutions for a uniformly distributed inflow of constant BOD showed this inflow term to be mathematically indistinguishable from changes in the reaeration and BOD decay rates. Mass-balance approach commonly uses for water-quality degradation assessments because it is easily applied, requires few data, and provides a quantitative basis for land-use planning decisions.



Source: Master (1998)

Figure 2.3: An example of steady state system with non-conservative pollutants

Implicit in (Equation 2.10) is the assumption that the concentration *C* is uniform through-out the volume, *V*. This complete mixing assumption is common in the analysis of chemical tanks, called reactors (Masters, 1998).

2.7 Previous Studies on Water Quality Assessment of Road Project

Urban creeks and lakes can be important habitats for a variety of aquatic life, as well as an aesthetic resource to communities. A key component of this resource is the quality of water in these waterbodies. Studies below are devoted to a review of water quality problems in urban creeks and lakes associated with storm water runoff and other urban sources of pollutants. A discussion is presented of the characteristics of urban storm water runoff as they may impact the water quality-beneficial uses of urban creeks and lakes. Below are two case studies from U.S. and Nigeria. These studies adopted since there is not much and completed data and study from Malaysia and other Asean countries.

2.7.1 Previous Studies in United States

In many areas, urban stormwater runoff occurs into a relatively small urban creek, which in turn discharges to a larger waterbody within or outside of the urban area. In some areas, urban creeks discharge to urban lakes, where the primary water entering the lake is urban stormwater drainage. Urban creeks and lakes are waters of the US, which means that US EPA water quality criteria/state water quality standards are applicable to urban creek and lake water, including the application of the US EPA worst-case-based national water quality criteria for protection of aquatic life propagation.

Presented below is an updated overview discussion of the water quality problems in urban creeks and lakes. Consideration is given DO, nutrients/excessive fertilization, PAHs, oil and grease, and suspended sediment and turbidity. The data gained in studies of the creeks and sloughs associated with the city of Stockton, California. The CWP (2003) report is an expansion/update of earlier work by Schueler (1994) on the impact of urbanization (paving) of an area on the waterbodies receiving the runoff from the area. This report provides summaries of several reviews on the characteristics of urban stormwater runoff.

CWP (2003) reported that the BOD_5 event mean concentrations in urban stormwater runoff in about a dozen cities located across the US ranged from 11 to 112 mg/L. While urban stormwater runoff can have appreciable concentrations of BOD_5, ordinarily little of this BOD would be exerted in the urban creek, because of the relatively short time typically associated with urban creek flow through the urban area during a stormwater runoff event and the slow rate of exertion of the biochemical oxygen demand. Typically, about five days is required for about 75 percent of the BOD to be exerted. Therefore, the oxygen demand associated with the urban runoff is likely manifested in waterbodies downstream of the City.

Lee and Jones-Lee (2003b) and Lee (2003b) have presented the results of studies of the dissolved oxygen content of several of these creeks/sloughs (city of Stockton, California) following stormwater runoff events. A stormwater runoff event in November 2002, and another in August 2003, which were the first major runoff events of the summer/fall, led to large fish kills in half a dozen or so of these waterbodies. Measurements by the Delta Keeper (2002) of dissolved oxygen in the waterbodies just prior to, during and following the runoff event showed that the DO prior to the event was adequate for maintenance of aquatic life – i.e., above about 5 mg/L. Shortly after initiation of the event, the DO in some of the waterbodies dropped to less than 1 mg/L. It stayed depressed for several days.

Urban stormwater runoff contains elevated concentrations of various nutrients (nitrogen and phosphorus compounds) that can lead to excessive fertilization of urban creeks, lakes and downstream waterbodies. Nutrients, especially nitrate, in addition to being derived from stormwater runoff, can also be present in groundwater flow to urban creeks and lakes. This can be an important source of nitrate. CWP (2003) reported event mean total nitrogen concentrations in urban stormwater runoff in about a dozen municipalities across the US ranging from 1.7 to 4.6 mg/L, and total phosphorus ranging from about 0.3 to about 0.8 mg/L, with soluble P ranging from 0.04 to about 0.5 mg/L P. These concentrations, if in algal available forms, could readily lead to excessive growths of aquatic plants. CWP (2003) has provided some information on sources and source areas of nutrients, providing information on the total nitrogen and total phosphorus concentrations in runoff from various types of urban land use, including commercial parking lots, streets, rooftops, residential lawns, etc.

Many urban stormwater runoff monitoring programs include the measurement of COD. According to CWP (2003), the mean of the event mean concentrations for COD in urban stormwater runoff ranges from about 53 to about 66 mg/L.

There are a number of organic compounds that are of potential concern in urban stormwater runoff that are not pesticides or organochlorine bioaccumulatable chemicals. These include oil and grease, PAHs, etc. CWP (2003) provides a summary of information on hydrocarbons, PAHs and oil and grease in urban stormwater runoff. Some of the PAHs are human carcinogens and are toxic to aquatic life. CWP (2003) reported mean event mean PAH concentrations in stormwater runoff of about 3 to 13 μg/L. CWP (2003) also reported oil and grease mean event mean concentrations in stormwater runoff ranging from about 2 to 13 mg/L. Within the oil and grease fraction and TOC present in urban stormwater runoff can be thousands of unregulated organic chemicals that are a threat to be toxic to aquatic life and/or to bioaccumulate in edible aquatic life to be a threat to higher trophic-level organisms, including humans. For example, Silva (2003) of the Santa Clara Valley Water District has reported that flares used at highway accidents, after burning, can still contaminate 726,000 gallons of drinking water with perchlorate above the California Department of Health Services action level of 4 μg/L.

If the urban creek watershed has areas of new construction and/or if the urban creek watershed and the creek have readily erodible soils, there can be significant increases in suspended solids/turbidity in the creek during runoff events. CWP (2003) reported mean event mean concentrations in stormwater runoff for TSS ranging from 78 to 174 mg/L. The TSS impacts the turbidity of the stream water. CWP (2003) reported mean event mean concentrations for turbidity of 53 NTU.

2.7.2 Previous Study in Borno State, Nigeria

Prior to embarking on any major project, activity or development in Nigeria, it is mandatory that the proponent carries out a study to ascertain the likely impacts, adverse and / or beneficial and the extent of these impacts on the physical, biological and human socio-economic environment. Throughout all stages of the project from its planning phase to operational and decommissioning phases the proponent shall ensure that all identified adverse impacts addressed in different stages of the project.

The Federal Ministry of Works (FMW) proposes to embark on the development of new road project within the Borno State. This is part of Federal Government's efforts at opening up the area given its place as one of the main contributor to the economy of the country. Borno is home to companies involved in the exploration and exploitation of mineral resources for domestic and commercial purposes. It is now proposed by the FMW to construct a road that would cover Project area road with paved shoulders and strengthening the existing one by overlays / rehabilitation / reconstruction, and same goes to the existing cross-drainage structures on the route. New cross-drainage structures would be provided on the new one carriageway.

This project traverses Local Government Areas viz: Askira / Project area Local Government, Borno State. It lies between latitudes 302220 E and 268001 E and between longitudes 1157159 N and 1191258 N. The route is on a dry savanna terrain of light mangroves, bush and especially but gradually yielding to encroachment by human activity. Agriculture is mainly subsistence farming, and driving forms the main occupation of the people. The topography of the area is relatively flat, and it is characterized by sandy clayey topsoil, and savanna vegetation.

In addition to strengthening the existing carriageway, the project would improve the geometric deficiencies including the improvement of any intersection encountered. The proposed improvement aims at enhancing the riding quality, improving journey speed and reducing congestion of traffic on the highway. It is proposed to provide service roads, proper drainage, grade-separation, road furniture, utilities and amenities wherever required. The project highway passes through 5 major towns and 15 village settlements.

The road is designed in accordance with the all relevant engineering standards and specification enumerated in the document 'Engineering Design' of the Project area Road Project belonging to the Federal Ministry of Works. It is proposed to be a two-lane (2 x 3.5m) bituminous carriageway, with paved and unpaved shoulders and strengthening the existing road by overlays / rehabilitation / reconstruction. In addition to strengthening the existing carriageway, the project would improve the geometric deficiencies including the improvement of any intersection encountered. To minimize the adverse impacts on the various settlements and to minimize the land and structure acquisition, realignments have been proposed.

The quality of the surface water in places like Project area, Askira and Mbalala is of great concern, since the local inhabitants sometimes depend on the river water for domestic use. The gross organic pollution loads of the samples were generally low to moderate. Water samples indicate sign of good aeration. Below is the summary of the water quality for this road project.

Table 2.9: Surface Water Physicochemical Characteristics

Characteristics	**BH - 3**	**SW - 1**	**SW - 5**	**SW - 10**
pH	6.3	7.5	7.44	7.43
Temperature	30	29.5	28.7	28.6
TSS	31	53	**60**	56
Dissolved Oxygen	6.6	8.9	6.3	6.5
BOD	**14**	6.84	5.66	3.99
COD	13.65	**36**	34	28
Oil and Grease	< 0.05	8.38	5.82	3.76
Sulphate	11.06	4.22	4.18	4.69
Phosphate	0.07	1.4	1.28	1.77

Sources: Borno State Local Government (2005).

Note: the results above are taken for highest value of BOD, COD and TSS

CHAPTER 3

RESEARCH METHODOLOGY

3.1 Introduction

This chapter covers all aspects of the study, from the beginning to the end of it. It will include several stages of study. The base of the study is to gather the secondary data, and continue by gathering the primary data, or sample collection. Sampling, data collection and analysis for the parameters were done in accordance with recommended procedures and practices for environmental data collection and analysis in Malaysia.

3.2 Preliminary Research and Secondary Data Collection

This research will be done with five stages which are early research, literature review, data collection and field study, data analysis and modelling, conclusion and recommendation stage. At this stage, reading and early revision about research scopes will be done from relating writing sources. The information will be used to form research question, aim and objectives. Preliminary research is important to get a clearly picture about the research.

Data collection from secondary sources will involve the reference on printed and unprinted report from *Majlis Daerah Muar* (MDM) (now is *Majlis Daerah Ledang*) and *Majlis Perbandaran Muar* (MPM). Reference is made on Muar District Local Plan (2002-2015) and other related reports. Other important secondary data is Topographic Map (Scale 1: 50, 000) and other supporting secondary sources to this research also being used. In literature review, further understanding about research scopes will be done. This literature review will be focus to these aspects of road construction and its impacts to water quality. All data are collected from books, reports and journals, researches that are related to the study aspects.

3.3 Data Collection and Field Study (Primary Data Collection)

This study needs information to do the analysis and to support the recommendations which will be formed in the end of this study. This data collection will be done based on two stages which are primary and secondary data collection. This primary data collection will be done through field works which are observation and sampling. This is to get baseline water quality to represent the water bodies including river and swamp area that may be affected by road construction project by testing the selected parameters.