INTEGRATION OF THE RIVER ECOSYSTEM ATTRIBUTES FOR RIVER HEALTH ASSESSMENT

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DEDICATIONS

I dedicate this research work to my mother *Mek Kepiat a/p Chau Chan* and my late father *Eh Rak s/o Cha Bok* for bringing me up, guiding me in the right path and equipping me with knowledge and soft skills.

To my beloved wife *Mek Keperum a/p Eh Pelian* for the sacrifices and indefatigable support she gave all the years

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ABSTRACT

Currently in Malaysia, only physical and chemical components are used as an indicator for river health monitoring and rehabilitation programme. These attributes were used for many years as a basis and reference in rehabilitating rivers in Malaysia and none of them was proven to be successful. Therefore, the aim of this study is to integrate the river ecosystem attributes for the purpose of river health assessment in Malaysia by using benthic macroinvertebrate as the main biological indicator. This study was conducted in Sungai Mengkibol, Sungai Madek and Sungai Dengar in Johor. There were a total of five sampling sites, three for impact stations and two as reference stations, including one highland station. The **s**ampling was conducted six times during November 2008 to June 2010. Surber Net measuring 500 micron mesh size combined with a rectangular quadrate of 30 cm x 30 cm (0.09 m^2) were used to sample the benthic macro-invertebrate. Biodiversity Indices was also analyzed. For water quality, six in-situ parameters were measured namely temperature, conductivity, dissolved oxygen (DO), pH, turbidity and salinity using a multi parameter probe as well as a single parameter probe. Meanwhile, field survey form was used to assess river habitat namely river riparian compositions, canopy cover and large woody debris. In addition, Pebble Count Method was used to measure substrate compositions and Valeport ‘Braystoke’ Model 001 Flow Meter was used to gauge the river. Based on the results obtained from the study, it can be suggested that ephemeroptera, plecoptera, and trichoptera index (EPT) taxa could be used as biological indicator for preliminary river health assessment. However, for the detail assessment, physicochemical water quality, river discharge, channel deformation, substrate compositions, riparian and canopy cover and large woody debris need to be evaluated and integrated.

ABSTRAK

Buat masa ini di Malaysia hanya komponen fizikal dan kimia sahaja digunakan sebagai penunjuk untuk pemantauan kesihatan sungai dan program pemuliharaan sungai. Ciri-ciri ini telah digunakan bertahun-tahun sebagai asas dan rujukan dalam memulihkan sungai di Malaysia dan setakat ini tidak ada satu pun sungai telah terbukti berjaya dipulihkan. Oleh itu, tujuan kajian ini adalah untuk mengintegrasikan ciri-ciri ekosistem sungai bagi tujuan penilaian kesihatan sungai di Malaysia dengan menggunakan *makro-invertebrata bentik* sebagai petunjuk biologi utama. Kajian ini telah dijalankan di Sungai Mengkibol, Sungai Madek dan Sungai Dengar di negeri Johor. Terdapat lima tapak persampelan dengan tiga tapak untuk stesen impak, dua tapak untuk stesen rujukan termasuk stesen tanah tinggi di dalam kawasan kajian. Persampelan telah dijalankan sebanyak enam kali bermula dari November 2008 sehingga Jun 2010. *Surber net* yang bersaiz 500 micron dengan kuadrat segi empat bersaiz 30 cm x 30 cm telah digunakan untuk persampelan *makro-inverterbrata bentik*. Indeks Biodiversiti telah dianalisis. Enam parameter *in-situ* telah dicerap bagi kualiti air iaitu suhu, kekonduksian, oksigen terlarut, pH, kekeruhan dan kemasinan menggunakan *multi parameter probe* dan *single parameter probe*. Sementara itu, borang kaji selidik lapangan telah digunakan untuk menilai dan merekodkan habitat sungai iaitu komposisi dan penutup riparian sungai, penutup kanopi dan serpihan kayu. Sebagai tambahan, Kaedah Pengiraan Kerikil telah digunakan untuk mencerap komposisi substrat sungai dan *Valeport 'Braystoke' Model 001 Flow Meter* telah digunakan untuk mencerap luahan sungai. Berdasarkan kepada keputusan yang diperolehi dicadangkan bahawa taksa *ephemeroptera, plecoptera,* dan *trichoptera index (EPT)* boleh digunakan sebagai penunjuk biologi untuk menilai kesihatan awal sungai. Walau bagaimanapun, bagi penilaian secara terperinci, semua komponen yang terlibat seperti kualiti fizikal dan kimia sungai, luahan sungai, perubahan dasar sungai, komposisi substrat sungai, riparian, penutup kanopi dan serpihan kayu dalam sungai hendaklah dinilai dan dintegrasikan.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

WQI	-	Water Quality Index
INWQS	-	Interim National Water Quality Standards for Malaysia
EPT	-	Ephemeroptera, Plecoptera and Trichoptera
LWD	-	Large Woody Debris
DOE	-	Department of Environment
NTU	-	Nephelometric Turbidity Unit
NPK	-	Nitrogen, Phosphorus and Potassium
USEPA	-	United States Environmental Protection Agency
PNMAP	-	Pacific Northwest Aquatic Monitoring Partnership
BOD	-	Biochemical Oxygen Demand
COD	-	Chemical Oxygen Demand
DO	-	Dissolved Oxygen
NH_3-N	-	Ammoniacal Nitrogen
SS	-	Suspended Solids
CBOD	-	Carbonaceous Biochemical Oxygen Demand
$K_2Cr_2O_7$	-	Potassium Dichromate
H_2SO_4	-	Sulfuric Acid
TS	-	Total Solids
TDS	-	Total Dissolved Solids
H^+	-	Hydrogen ions
H_3O^+	-	Hydronium ions
OH^-	-	Hydroxide ions
Fe	-	Ferum
Al	-	Aluminium
Mn	-	Manganese
NO_3-N	-	Nitrate Nitrogen
NH_4-N	-	Ammonium Nitrogen

PO_4-P	-	Orthophosphate
AN	-	Ammoniacal Nitrogen
YSI	-	Yellow Springs Instrumentations
APHA	-	Standard Methods for the Examination of Water and Wastewater
CREAS	-	Christchurch River Environment Assessment Survey

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Background

Water is the basic element of life; without it life would be difficult to sustain. The usage for water increases as population grows until the demand for clean water sometimes exceeds the supply or availability. Although the quantity of water on earth is the same all the time due to the hydrological cycle but the quality of the water that is available has drastically changed over time. Every time we utilize water, we somehow alter the condition of the water in many ways than one. Every watershed is affected by what takes place on the land or, in other words, land use changes. Once used, water flows out as quickly as it comes and this water will go down the drain and into our river systems. This cycle will go on continuously until at some stage all the clean water will disappear if nothing is done to minimize the impact to our river systems.

In Peninsular Malaysia, there are more than 100 rivers and more than 50 river systems in Sabah and Sarawak (River Basin Initiative Portal, 2011). As in many parts of the world, water from rivers and streams in Malaysia is used extensively for domestic needs, agriculture, aquaculture, industry and hydroelectric power as well as provide recreational use. Rivers are important as they support the nation’s economic development, social and cultural needs, religious beliefs and the natural environment (Kavanagh, 2002). River with clean water body and the riparian area in its vicinity would be able to support diverse and delicately balanced natural aquatic ecosystems.

There is considerable public concern about river water quality in Malaysia and this has arisen over the last few decades as rivers play important roles in our daily life as well as to other living organisms. In addition, rivers also have very fragile ecosystem (Md. Pauzi *et al.,* 2000). Unfortunately, clean fresh water is becoming scarce. This is due to various kinds of land development activities which have taken a toll on our riverine habitats, the very systems that provide sustenance to our socio-economic well-being and to the natural inhabitants of our forests and aquatic environment (Fatimah and Zakaria, 2005). Hence, a few river rehabilitation project were proposed but the success rate is very low or almost none. Based on information obtained from official sources of the Department of Drainage and Irrigation Malaysia (DID), there were five rivers identified by the government for rehabilitation or restoration programme in Malaysia. Among the rivers were Sungai Pinang in Penang, Sungai Melaka in Malacca, Sungai Tebrau, Skudai and Segget in Johore. Total budget spent for the whole programme was RM 1.09 billion where RM 30 million was spent to rehabilitate Sungai Pinang, another RM 160 million for Sungai Melaka and RM 900 million for Sungai Tebrau, Skudai dan Segget. Activities involved in those river rehabilitation programmes were river beautification, desiltation, channel straightening, riverbank concreting and rubbish trap for rubbish collection. All the rehabilitation approaches was based on physicochemical water quality of the river.

The failure was believed to be due to the wrong assessment tools used by the various authorities and inappropriate rehabilitation approaches as well as the wrong interpretation made and no clear understanding of the river rehabilitation concept. Understanding and interpretation of what river rehabilitation entail among authorities is crucial in determining the success of the programme because if the interpretation is incorrect at the initial stage, all the related implementation works that follow will not meet the desired target. When the local authorities who are responsible for river rehabilitation programme interpret and misunderstand the concept, this then is a manifestation of the failure on the part of the system of governance. The whole operation is not laid on the right track. Furthermore, the stakeholders (or the consumers) who assumed that they were supplied with clean and healthy river water simply accept whatever quality that was provided due to lack of knowledge. The end result is the wrong concept adopted in river rehabilitation in the country is further strengthened in its implementation because when the authorities undertake the programme no enforcement or checking is done. In the wrongly execution of the river rehabilitation programmes at least five approaches are normally adopted namely desiltation, riverbank straightening, riverbank concreting, rubbish trapping and riverbank beautification. Desilting for example is just dredging all the silt at the river bottom and the waste dumped elsewhere. Such callous dumping of silt in unapproved sites actually contribute to soil and ground water pollution in that location which may then pollute the other river systems instead of enhancing the physicochemical properties of the river. In channel or riverbank straightening all river meanders are removed or altered making them straight as they act as rubbish or silt traps and impede water flow. Based on the hydrology concept, the faster the river flow the greater is river erosion, thus the straightened channel will contribute to increase river flow resulting in increase river erosion. When the silt and debris is accumulated over time the river become shallow and would require desilting. This process will occur endlessly and large sums of money will have to be put aside annually for rehabilitation work. Already straightening river channel is environmentally unsound in terms of its impact to the river but by concreting the riverbank the authorities further worsen the situation. Concreting the river will further increase the velocity of river flow. The noble approach of river bank beautification in which the natural canopy and riparian vegetation is removed to allow planting of ornamental plants as replacements is a misleading exercise. Natural canopy basically perform its function as shelter and help to cool the water all the time for aquatic life to thrive, while the riparian vegetation act to control siltation or pollution run-off which will help to regulate the water quality and health of the river. The other misleading approach by the authorities in rehabilitation is the provision or erection of rubbish traps along the river systems to trap rubbish and garbage dumped in by nearby residents or those debris and the like brought downstream during rainy days. The volume of rubbish will naturally increase over time if the authorities continue to ignore the source of the problem and merely erecting barriers or traps is not really solving the problem. All these approaches adopted by the authorities were merely to tackle the problem of pollution as and when it arises or for river beautification and for aesthetic purposes.

In order to achieve the goals of river rehabilitation, identification of the characteristics of a healthy ecosystem will be the main component to study. When talking about a healthy ecosystem in river rehabilitation process, it is not only observing the water quality of the river alone but also the river ecosystems as well. Changes of river quality as well as its ecosystem depend very much on land use activities in the catchment areas. Various pollutants in a catchment area will determine river water quality as well as the nature of the river ecosystem itself. A healthy river is said to be that which favours aquatic life in the river.

River basin ecosystem such as streams, rivers, lakes, ponds, wetlands and estuaries are the lung of the environment because they provide homes for wildlife; aquatic animals and plants; water supplies for homes and industries; and places of recreation. In addition, rivers reflect the health of the surrounding land because they are the collection point for runoff flowing from all around. Therefore, the ultimate goal of river monitoring is to improve and sustain the health of its ecosystem for the benefit of living organisms.

Good physicochemical quality of river water does not ensure the health of aquatic life in the rivers and clean water itself is not a sufficient indicator for the health of the rivers. The presence of a healthy living aquatic species in the rivers is the key reference for river rehabilitation. In order to determine the health of the river not only must the physical and chemical qualities of the health of the river be taken into account but also the biological aspects. Biological monitoring is an essential element needed to assess the environmental health of aquatic ecosystems. Biological organisms are diagnostic when determining the health of aquatic ecosystems and they can be measured quantitatively. Ecologically, the concept of niche space provides the theoretical framework for understanding the importance of biological monitoring to any evaluation of environmental health. The organisms that inhabit aquatic ecosystems are the fundamental sensors that respond to any stress affecting that system. The health of an aquatic ecosystem is reflected in the health of the organisms that inhabit it. Any stress imposed on an aquatic ecosystem manifests its impact on the biological organisms living within that ecosystem (Loeb, 1990). Benthic macroinvertebrates are good bio-indicators, since they are very sensitive to changes in their habitat. In polluted water, the tolerant species will survive in abundance but the sensitive species will perish. Under normal clean water condition, more species were found to survive, unlike in polluted water condition where only one or two species can survive but with a higher density (Rahim, 1994).

The changes of macro benthic populations is not only influenced by the physical and chemical quality of the rivers but also by catchment characterisations such as the catchment covers, hydraulic and hydrology parameters, river bank conditions, river covers and river riparian vegetation. The changes of catchment characteristics are normally due to the disturbance of the catchment areas due to development or anthropogenic activities. This becomes worse if the disturbances have been carried out in the wrong manner without any proper control measures. It is not that easy to use a biological parameter as an indicator to assess river water quality or health. The assessments are unlike physical and chemical parameters, since biological changes specifically with macroinvertebrate benthic species are influenced by various factors. Nevertheless, the main factors are definitely the physical and chemical water qualities while the other factors include the physical habitat quality and river morphology. Furthermore, Thompson (2005) validated and highlighted that it is important from a biological perspective to not only calculate indices and spatially represent water quality data, but to incorporate more detailed physical habitat quality parameters into biological geo-databases. Results in the form of universal index are not going to help in portraying the real status of pollution. The numbers or indices indicate only differences between stations over distance or time. They enable one to compare upstream with downstream or one place in different years or seasons (Hynes, 1990). Works by Braccia and Voshell Jr. (2006) demonstrates the importance of quantitative sampling through time when research goals are to identify relationships between macroinvertebrates and environmental factors.

1.2 Problem Statement

The great concern with river water quality in Malaysia has arisen over the last few decades as rivers play important roles in our daily life as well as to other living organisms. In addition, rivers also have very fragile ecosystem. Unfortunately, clean fresh water is becoming scarce. A few river rehabilitation projects were proposed and some of the rivers are under rehabilitation process. For example, Sungai Klang in Kuala Lumpur and Selangor, Sungai Skudai and Sungai Segget in Johor and a few other rivers in the country which are classified as polluted rivers. Sungai Klang has been in the rehabilitation programme for more than 10 years but there is still no improvement in terms of quality as well as the health of the river. River rehabilitation programme in Malaysia is considered a failure due to the reason that the rehabilitation programme here are normally based on physical rehabilitation alone and do not incorporate other component especially biological. The Malaysia Water Quality Index (WQI) and National Water Quality Standard for Malaysia (NWQS) was used to indicate the river water quality as well as used as an indicator for river rehabilitation programmes and unfortunately, until today none of the programmes have succeeded. Apart from that, the understanding and interpretation of the term "river rehabilitation" among the locals as well as the authorities were also one of the reasons which contributed to the failure of river rehabilitation programme in Malaysia. The common folks always assume that rehabilitation is none other but beautification of the riverbanks where its natural riparian zone is unceremoniously removed and replaced with exotic ornamental plants or creation of mini gardens along the river. On the other hand, the authorities understanding on river rehabilitation is a little different, nonetheless, it does not make any different in terms of the actual work carried out. The authorities tend to interpret river rehabilitation as channel straightening, riverbank concreting, riverbank beautification, rubbish trapping and desilting where a huge sum of money is set aside annually for the physical clean-up of the rivers without really improving their physicochemical quality. Such short-sighted approaches aren't bringing back the natural state of the river systems with untainted water quality and rich with aquatic life usually referred to as healthy rivers. The true meaning of clean rivers is actually rivers with clear water, chemical free and with abundance of aquatic life or in other words healthy rivers. Therefore, to ensure that the implementation of the rehabilitation programme is successful, biological component (benthic macroinvertebrate) is one of the mandatory attribute which are needed to be assessed and integrated with few other attributes. This is because by assessing individual component either biological or physico-chemical water quality without integrating all the necessary ecosystem attributes, the true health of a river cannot be identified. On top of that, the polluted river cannot be rehabilitated effectively due to incomplete data or information available while in addition the correction measures adopted may not fit the problem. At present there are no studies which have been done to correlate and integrate all the river ecosystem attributes either locally or internationally. Most of the study already attempted was either focused on biological monitoring (McBridge, 1985; Rosenberg and Resh, 1993) or if the river ecosystem attributes have been considered, they were not comprehensive and at the same time did not show or provided proof for the correlation between one attribute to another.

1.3 Goal

The purpose of this study is to integrate the river ecosystem attributes for the purpose of river health assessment in Malaysia by using benthic macroinvertebrate as the main biological indicator.

1.4 Objectives

The objectives of the proposed study are:

1.4.1 To determine river discharge, riverbed changes, substrate composition and physicochemical characteristics for rivers from three different land uses.

1.4.2 To calculate biological diversity index and the ephemeroptera, plecoptera, and trichoptera index (EPT Index) for rivers from three different land uses.

1.4.3 To describe and identify the habitat characteristics as well as characterize benthic macroinvertebrate assemblages.

1.4.4 To determine the correlation of all the river ecosystem attributes and integrating them.

1.5 Scope of the Study

The boundary of the study is within Sungai Endau catchment area where three tributaries with three sub-catchment areas were selected for the study (**Figure 1.1**). These three sub-catchments and tributaries represented four types of land use namely agriculture, logging, urban area, undisturbed (pristine) area. The main criteria for sites selection is the land use cover. The sub-catchments that were selected for the purpose of this study are those catchments with at least 90% of the total area covered by a single type of land use. Sungai Mengkibol sub-catchments were selected to represent urban area, Sungai Madek sub-catchments for logging activities, Sungai Dengar sub-catchments downstream part for agricultural activities, middle part which are located at the foot of Gunung Berlumut as background station or reference station. The study area involves inland area including river banks as well as water body in those particular sub-catchment areas. The selected study sites were only streams that are perennial and wadeable.

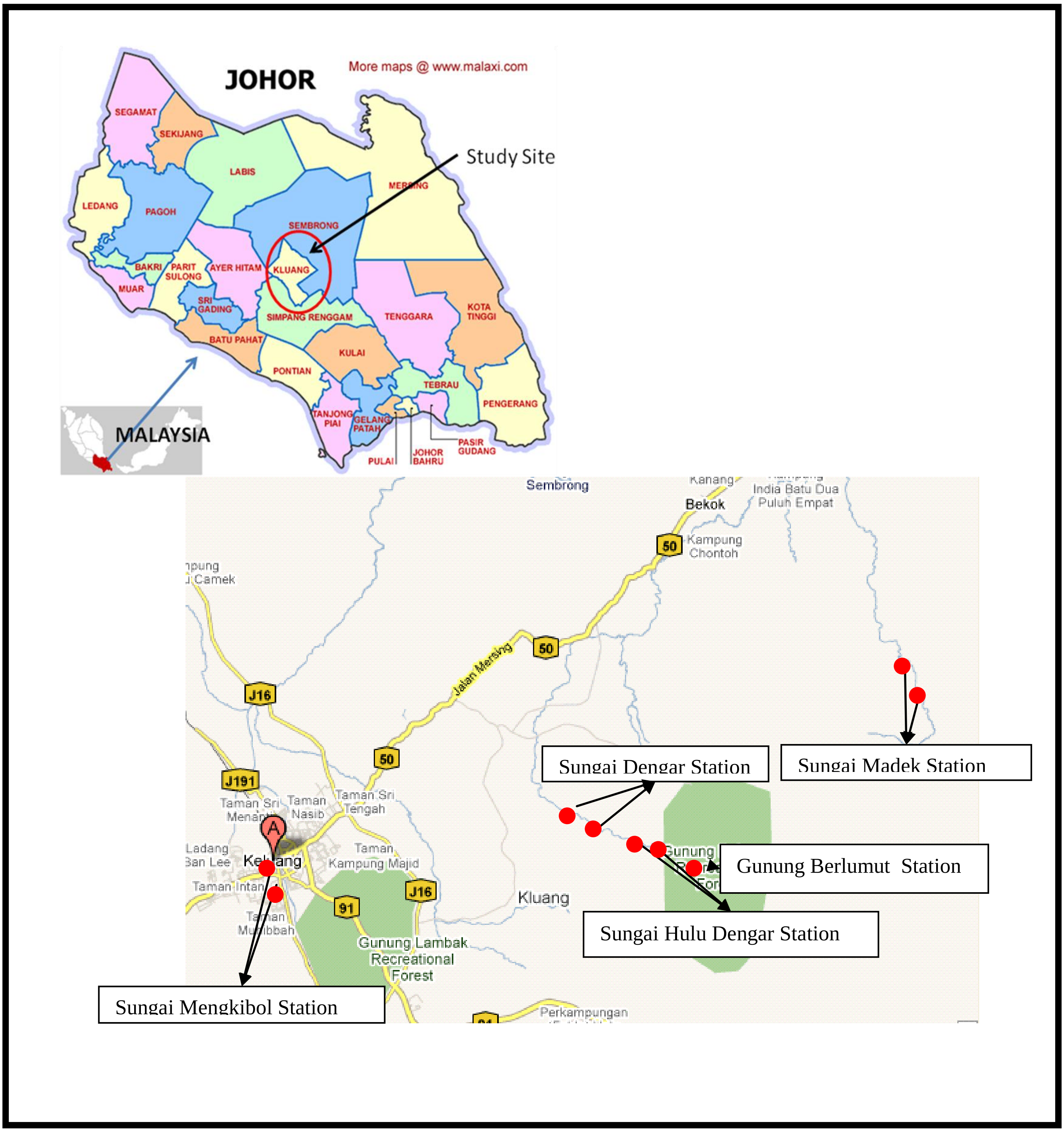

Figure 1.1: Study Area and Sampling Station (Source: Google Map)

Table 1.1: Flow for the proposed study

1. Site selection	Selection of suitable rivers which fits the purposes of the study.
2. Background information of rivers	The hydraulic information and the dimensions of the rivers would be collected as one of the steps in this study.
3. Water quality	The water quality of the river where the benthos sampling station is located will be measured through *in-situ* measurements and also taking water samples for laboratory analyses.
4. Hydraulic and hydrology	Hydraulic parameters and river dimensions will be measured and assessed.
5. Habitat	Habitat at the benthos sampling stations will be assessed using site survey forms, including pebble counts.
6. Benthic macroinvertebrates	Samplings of benthic macroinvertebrates.
7. Laboratory	River water quality samples will be preserved upon sampling before being brought back to laboratory for analyses. Benthos samples will then be brought to laboratory for identification purposes.
8. Results summary	All the results, field measurements and field surveys as well as laboratory results will be summarized and keyed in the computer.
9. Data analysis	The results will then be processed.
10. Index calculations	Abundance, taxa richness, diversity index, Evenness index will be calculated based on available indices such as Pielou Index, Shannon-Wiener Index, EPT Index, etc.
11. Conclusions	Conclusions will be drawn from the results obtained from both.
12. Thesis preparation and presentations	The final outcome will be analyzed and compiled in a form of a thesis and will be presented to the examination panel, and where appropriate at seminars, forums and workshops, and also as articles in journals.

Table 1.1 shows the flow of the proposed study, where the study will be initiated by site selection to select the rivers which meet the criteria and will be followed by actual sampling on site. The actual sampling on site will include river morphology assessment, water quality sampling, benthic macroinvertebrates sampling as well as habitat assessment. The next step would be the laboratory analysis and identification of samples of river water and those of benthic macroinvertebrates and followed by summarizing the results. It will then be followed by analyzing the data obtained for determining the biodiversity index, water quality index, habitat characteristics, river discharge, river substrate compositions

and calculations of Large Woody Debris density. Finally, the research project would be concluded by making informed conclusions and drawing some recommendations as to the how some ecosystem tools can be integrated for use when assessing the health of our river system.

1.6 Significance of the Study

The success of river rehabilitation and management programme depends very much on the definition of river rehabilitation as well as the tools that will be used as water quality assessment (river health assessment). Governmental department who are responsible to take care of the river as well as the ordinary folks, use to interpret river rehabilitation as physical clean-ups of rivers such as desiltation, but rightly river rehabilitation means engaging in some activity to turn the river to become healthy and living. Healthy rivers means clean river with original ecosystems remaining intact such as ensuring the natural riparian, sufficient canopy cover, original banks, original substrates with minimum erosion and sedimentation, river meanders, original river flows and discharges, presence of aquatic plants as well as aquatic life are as it is. The use of sampling and monitoring tools are very important in river rehabilitation work or river health monitoring because these tools will ensure the success of a rehabilitation programme turning a polluted river into healthy one and not allowing an existing unpolluted river to deteriorate over time. Currently in Malaysia, the tools that are in use to determine the water quality include Water Quality Index (WQI) and National Water Quality Standards for Malaysia (NWQS).

Biologists and environmentalists, meanwhile, had a different view of what a healthy river should be and began concentrating on biological characteristics such as diversity, richness, evenness, dominance, ephermeroptera, plecoptera and trichoptera (EPT) Index in the river. However, these groups of researchers were only looking at the biological components present in the river without correlating these parameters on how they impact on the river ecosystem. On the flip side of this, the biodiversity group was interested in surveys merely to determine the compositions of terrestrial plants at the riparian zone, aquatic plants in the river, the percentage of canopy cover, the length and number of meanders and presence of large woody debris (LWD) in the river. The river engineering group, on the other hand, was pre-occupied in identifying the types of river bank, changes of river bed, width and depth of river and discharge of river. All of these interested parties, each with their areas of specializations, are interrelated in many ways. A single assessment tool will never be appropriate to resolve the problem of river health as a whole. The changes of catchment areas has led to the changes of river morphology, hydrology, river habitat which will then lead to deterioration of the physical and chemical quality of water and these changes in water quality and river bank ecosystems will then lead to the deterioration of aquatic life.

For a successful river rehabilitation work to be carried out and ensuring it to remain healthy thereafter will require the integration of all the physical, chemical and biological components for ecosystem assessment when determining the health of a given river. In this study, the presence of benthic macroinvertebrates was used as the bio-indicator as this organism can be considered the most important component in the aquatic food chain. It is a source of food for bigger aquatic life especially fish. Benthos are good indicators of watershed health because they live in water for all or most of their life, stay in areas suitable for their survival, are easy to collect, different in their tolerance level to the amount and types of pollution, easy to identify, often live for more than one year, have limited mobility, and are integrators of environmental condition.

Presently, there is a dearth of information on how to integrate all the available assessment tools on ascertaining river ecosystem health. Many of the previous studies concentrated on bioassessments with the objectives of identifying aquatic species, especially those of benthic macroinvertebrates in certain rivers with different physicochemical qualities but were not related to land use, physical habitat, river morphology and substrate composition of the river (Lim, 1987; Sarmini, 1988; Azrina *et al.*, 2006 and Juahir *et al.*, 2009).

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