UNIVERSITI PUTRA MALAYSIA

GIS-BASED NON POINT SOURCE POLLUTION MODELLING OF SG. SELANGOR BASIN

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By

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To my dearest parents and brother.

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfillment of the requirement for the degree of Master of Science

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Non Point Source (NPS) pollution is a diffuse pollution and regarded as one of the major pollution affecting the quality of water. It is yet to be taken into consideration in managing the water quality of river basin in Malaysia. Geographic Information System (GIS) is used to study the pollution since the sources and the spread involved spatial characteristic. Sg. Selangor basin has been chosen as the study area. Assessment of NPS pollution was conducted based on three parameters namely Biochemical Oxygen Demand (BOD), Total Nitrogen (TN) and Suspended Solids (SS). Runoff and land use are considered as the major factors contributing to the NPS pollution since NPS pollution travels through land area before reaching the stream network. The generated runoff was based on rainfall data and runoff coefficient. Stream network generation will be produced from digitized topographic maps where threshold values were tested. Expected Mean Concentration (EMC) values, associated with land use were extracted from literatures and research works and used to estimate the loading of pollutants in that

area. Data from two sampling stations operated by the Department of Environment, i.e. 3517605 (upstream) and 3516604 (downstream) were to determine the level of NPS pollution. Annual accumulation of NPS pollutions were determined where the cumulative loadings of pollutants were compared with the computed observed values at the two sampling stations. Results for BOD showed that the differences of computed observed values exceeded generated values by 50.1% at the upstream station and by 9.2% at the downstream station. For SS, there is a 38.9% difference at upstream and 38.6% differences at downstream. However, there was a wide variation in TN results with 67.2% differences in upstream and -39.1% in downstream. These variations are mainly due to limitations that are related to theoretical EMC values.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia
sebagai memenuhi keperluan untuk ijazah Master Sains

PEMODELAN PENCEMARAN BUKAN PUNCA TITIK DI LEMBANGAN SUNGAI SELANGOR BERPANDUKAN GIS

Oleh

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Ogos 2002

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Pencemaran bukan punca titik (NPS) adalah satu pencemaran berbaur dan dianggap sebagai salah satu pencemaran utama yang memberi kesan kepada kualiti air. Ianya masih belum lagi diambil kira dalam menguruskan kualiti air bagi lembangan sungai di Malaysia. Sistem Maklumat Geografi (GIS) telah digunakan dalam kajian ini untuk mengkaji pencemaran ini kerana ciri-ciri pencemar yang melibatkan ruangan. Lembangan Sg. Selangor telah dipilih sebagai kawasan kajian. Penilaian terhadap pencemaran NPS telah dijalankan di mana tiga parameter telah digunakan iaitu Keperluan Biokimia Oksigen (BOD), Jumlah Nitrogen (TN) dan Pepejal Terapung (SS). Air larian dan guna tanah dianggap sebagai faktor-faktor utama yang menyumbang kepada pencemaran NPS kerana pencemaran NPS melalui kawasan tanah sebelum sampai ke sungai. Penghasilan air larian adalah berdasarkan data air hujan dan pekali air larian. Penghasilan jaringan sungai daripada pendigitan peta-peta topografi dilakukan dengan menguji nilai-nilai ambang. Nilai Jangkaan Min Kepekatan (EMC) yang

dikaitkan dengan guna tanah diambil dari kajian literatur dan hasil penyelidikan digunakan untuk menganggar kemasukan beban pencemaran di kawasan kajian. Data dari dua stesen pencerapan yang diperolehi dari Jabatan Alam Sekitar iaitu 3517605 (hulu sungai) dan 3516604 (hilir sungai) digunakan sebagai titik penentu untuk pencemaran NPS. Pengumpulan tahunan bagi pencemaran NPS ditentukan dengan membandingkan bebanan pencemaran dengan kiraan data pencerapan pada dua stesen pencerapan tersebut. Keputusan untuk BOD menunjukkan kiraan data pencerapan melebihi nilai yang dihasilkan sebanyak 50.1% di stesen hulu sungai dan sebanyak 9.2% di stesen hilir sungai. Bagi SS, perbezaan sebanyak 38.9% terdapat hulu sungai dan sebanyak 38.6% di hilir sungai. Namun begitu, terdapat jurang yang besar dalam keputusan TN dengan 67.2% di hulu sungai dan -39.1% di hilir sungai. Perbezaan ini adalah disebabkan oleh kelemahan-kelemahan yang kebanyakannya berkaitan dengan nilai EMC digunakan yang berujukan bahan.

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LIST OF ABBREVIATIONS

AGNPS	Agricultural Non Point Source
ANSWERS	Areal Non Point Source Watershed Environment Response Simulation
BMP	Best Management Practices
COD	Chemical Oxygen Demand
CREAMS	Chemicals, Runoff, and Erosion from Agricultural Management Systems
DEM	Digital Elevation Model
DID	Drainage and Irrigation Department
DOA	Department of Agriculture
DOE	Department of Environment
EIA	Environmental Impact Assessment
EMC	Expected Mean Concentration
EPA	Environmental Protection Agency
GIS	Geographic Information System
GLEAMS	Groundwater Loading Effects of Agricultural Management Systems
HSPF	Hydrological Simulation Program-FORTRAN
NPS	Non Point Source
SWAT	Soil Water Assessment Tool
TIN	Triangulated Irregular Network
USLE	Universal Soil Loss Equation

CHAPTER I

INTRODUCTION

1.1 Introduction

Water resources especially freshwater are very important and precious to human being. Availability of freshwater resources can be obtained from groundwater or surface water such as rivers, lakes or ponds. Rivers in Malaysia are considered as the main water supply for its population and economic usage. The upstream river water can be used for hydropower generation and water-based recreation and downstream river water can be used for irrigation, municipal uses and waste dilution (Uzir, 1993). In Malaysia, the main usage of water (in 1996) is for irrigation (9.0 billion m^3), domestic and industrial water supply (2.6 billion m^3) and for hydropower generation (1590 MW) while the minor usage includes breeding and cleaning for fisheries and livestock (Neo, 1996).

Freshwater, which is the key component of the Earth's hydrosphere, is needed for all aspects of life. However the scarcity, gradual deterioration and aggravated pollution of freshwater resources in many world regions are becoming increasingly apparent (Thompson and Hollis, 1997). Managing the water resources to mitigate the pollution level in the rivers requires incorporation of all relevant technical and non-

technical considerations. This can be seen in the river basin management in many developing countries including Malaysia, which is at present carried out by a number of organizations with minimal coordination among them (Nyon, 1999). Hence, integrated river basin management needs to be implemented to provide a sustainable development.

Depleting freshwater resources especially from the rivers are mainly due to pollution from non point source. Non point source pollution is caused by runoff water from rainfall that results in soil surface erosion. The sediment may end up in river or lakes or ponds before flowing towards the sea. It is often difficult to detect the exact location where it happens.

In the process of achieving sustainable development, advances in computer technology have provided useful tool in working towards the goal. Information from various agencies needs to be compiled and gathered to formulate a proper planning. Geographic Information Systems (GIS) is one of the tools that can be used to solve problems which are related to environment such as non point source pollution. It can provide database management, tools, visualization, simulation and assessment models. It also supplies open and unclouded information to generate dependence and a collaboration among all parties involved in river basin management (Nyon, 1999).

1.2 Non Point Source Pollution in Malaysia

Malaysia, as a developing country, has undergone very rapid development with subsequent population growth, urbanization, expansion of agriculture, mining and logging activities, and industrialization. These changes have caused complex environmental problems and the most affected natural resource is water (Yeo, 1999). Due to the rising concern over the degradation of river water quality in Malaysia, monitoring of water quality in Malaysia was conducted by the Department of Environment since 1970s. From 1995, Alam Sekitar Malaysia Sdn Bhd took over the monitoring to continue the effort of maintaining the river water quality (ASMA, 2000).

In Malaysia, emphasis has been put on point source pollution because this pollution causes great impacts on the ecosystem. Controlling of point source pollution is also much easier as "polluter-pay-principle" is applicable. As for non point source pollution, it is still new in terms of number of studies that have been conducted. Therefore, it is difficult to acquire comprehensive information regarding the pollution as this kind of studies need long term. In the past, studies (Loh, 1999; Yeo, 1999) have been done on river water quality that is related to land use activities. Indirectly, this is also related to non point source pollution as the land use is one of its main parameters.

1.3 Problem Statement

As its name implies, non point source pollution is not easily monitored at the point of origin and contaminants are not generally traceable to an exact source. It usually occurs sporadically, and is often correlated with climatic events. Most of the

contribution to water quality degradation is due to non point source, which appears to be equal or exceed those from point sources, often by substantial margin (Hall, 1975). Even the best intentions to have multi-million ringgit water clean up programme would not be a success without the understanding of non point source pollution. This requires the relevant parties to reconsider for a better management plan.

Non point source pollution is produced by the transport by runoff of constituents from diffuse sources on the land to streams (Olivera, 1995). According to Huber (1993), land use has a strong influence only on the amount of runoff (volume of water per unit time), while its effect on the runoff concentration (mass of pollutant per unit volume of water) is less important. Still, land use affects the pollutant load (mass of pollutant per unit time) when the runoff increased. Many methods that have been produced in modelling non point source pollution according to the land use that involved. For examples, the AGNPS model is used for agricultural areas, the USLE method is used for measuring soil loss or erosion, GLEAMS method used for groundwater loading effects from agriculture management systems and etc. Due to the difficulty of obtaining accurate data in the required amount to generate pollutographs (concentration-time plots) or loadographs (mass-time plots), non-point source pollution is commonly represented by the Event Mean Concentration. In this study, Expected Mean Concentration (EMC) was used to represent Event Mean Concentration as it is taken from literature-based and the concentration was to be expected as it is. This method was used as it requires only pollutants concentration parameters based on land use category. In Malaysia, there are no local EMC values available at the moment to be used in

modelling non point source pollution. However, EMC values have been recommended by DID to be used in estimating pollutant loading in river basin. Hence, the hypothesis of this study is EMC is applicable in estimating loading of pollutants.

Modelling of a river basin can be achieved when the right model been applied and there are enough basic data and correct parameters used. With data such as contour, spot height, rainfall and etc., these data can be interpolated and manipulated using GIS to do modelling. Parameters such as the runoff coefficients and EMC values will affects the model that been produced using GIS. As GIS is able to analyse and display the results of the processing, the effects of the parameters used in modelling can be seen. In Malaysia, GIS is yet to be applied in this area as GIS application in this field has not been fully utilized.

1.4 Objectives of the Study

With the current management of river basin in Malaysia where only point source is taken into consideration, there is a pressing need to study the non point source pollution to complete the overall view of the river water quality. GIS will be used as a modelling tool in assessing non point source pollution. The objectives of this study are:-

a) to find the most suitable grid cell resolution to generate stream network.

b) to assess the runoff generated from land use and rainfall parameters.

c) to assess the efficiency of non point source pollution modelling using Expected Mean Concentration (EMC) method.

1.5 Overview of the Thesis

The first chapter highlights the introduction of non point source pollution and the objective of the study. Literature review of the non point source pollution models and the use of GIS in non point source pollution modelling were mentioned in Chapter II. Chapter III describe the methodology of the study to produce the accumulation of non point source pollution. Description on the study area and the data used will also be mentioned in this chapter. The results and analysis of the process are covered in Chapter IV. The discussion of the results and the limitations of the study will also be mentioned in Chapter IV. Finally, conclusion and recommendations on the study are given in Chapter V.

CHAPTER II

LITERATURE REVIEW

2.1 Definition of Non Point Source (NPS) Pollution

Non point source (NPS) water pollution can be defined as a diffuse input of substances into receiving water that negatively impacts the water's beneficial uses. These substances include, but are not limited to, sediments, nutrients, bacteria, oxygen-demanding materials, heavy metals, and trace organics (Reinelt et al., 1988). The Environmental Protection Agency (EPA) defines the NPS pollution as caused by rainfall or snowmelt moving over and through the ground (EPA, 1997). As the runoff moves, it picks up and carries away natural and human-made pollutants, finally depositing them into lakes, rivers, wetlands, coastal waters, and even our underground sources of drinking water. These pollutants include:

- Excess fertilizers, herbicides, and insecticides from agricultural lands and residential areas;
- Oil, grease, and toxic chemicals from urban runoff and energy production;
- Sediment from improperly managed construction sites, crop and forest lands, and eroding stream banks;

- Salt from irrigation practices and acid drainage from abandoned mines;
- Bacteria and nutrients from livestock, pet wastes, and faulty septic systems;

Assessment of NPS pollutants is a complex; multidisciplinary environmental problems that encompasses physical and chemical processes that occur across disparate spatial and temporal scales. Moreover, NPS pollutants are spread over large areas in relatively low concentrations, and their detrimental environmental health-related effects are chronic rather than acute. Nevertheless, they are of greater environmental concern than point source pollutants because they are ubiquitious and the task of cleanup is costly and nearly impossible to accomplish (Loague et al., 1998).

Some criteria had been developed by Churchill (1975) which described NPS pollution as follows:-

i. NPSs enter the receiving waters in a diffuse manner.
ii. They are intermittent.
iii. The pollutants arise over an extensive area of land and are in transit over land before they enter navigable waters.
iv. NPS pollutants generally cannot be monitored readily at their point of origin and are not always traceable to their exact source.
v. Their prevention or control must be directed at a site-specific management or conservation practice.
vi. Compliance monitoring for NPSs is conducted on land rather than on water.