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UNIVERSITI PUTRA MALAYSIA

APPLICATION OF GEOGRAPHICAL INFORMATION SYSTEM IN ASSESSING WATER QUALITY IN THE KUANTAN RIVER WATERSHED, MALAYSIA

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By

NGEOW KIN VOON

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirement for the Degree of Master Science.

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To family and friends who make a difference.

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the Degree of Master of Science

APPLICATION OF GEOGRAPHICAL INFORMATION SYSTEM IN ASSESSING WATER QUALITY IN THE KUANTAN RIVER WATERSHED, MALAYSIA

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NGEOW KIN VOON

September 2008

Chairman: Mohammad Firuz Ramli, PhD

Faculty : Environmental Studies

Malaysia has gradually entered its fast pace economic development era following the implementation of the 20 years economy policy in the late 1970s. Due to the rapid urban development, a comprehensive river water quality assessment is required to cope with the dramatic increment of undesirable materials and residues introduced into the river system. A river water quality assessment focusing on suspended solids, sediment, total phosphorus and total nitrogen had been undertaken in Kuantan river watershed. The aim of the study is to determine the pollutant loads and concentration for non-point source pollution while determining the applicability of the geographic information system (GIS) for the water quality study in the Kuantan river watershed. The research involves hydrological and water quality data from the Department of Irrigation and Drainage (DID) and Department of Environment (DOE), topographical digital map from the Department of Land and Survey (JUPEM), and

landuse information from the Department of Agriculture (DOA), were loaded onto the geographical information system to represent the variation of pollutant loads emitted from series of non-point pollution sources. Validation works were conducted by comparing between the predicted results and measured results from GIS simulation as well as DID and DOE records for streamflow and water quality data. The validation results for the streamflow in Kuantan river watershed for the year 2005 has a correlation value of r^2 = 0.5944 for mean flow condition (p <0.05). The validation results for the pollutant concentration showed the highest correlation values for suspended solids, sediments, total phosphorus and total nitrogen were r^2 = 0.6043 in March 2005, r^2 = 0.9642 in March 2005, r^2 = 0.5806 in July 2005 and r^2 = 0.5882 in March 2005, respectively. The lowest correlation values for suspended solids, sediments, total phosphorus and total nitrogen were r^2 = 0.1988 in July 2005, r^2 = 0.3322 in May 2005, r^2 = 0.2341 in January 2005 and r^2 = 0.0449 in January 2005 (p <0.05), respectively. Based on the simulation results, the applicability of the GIS is suitable for the water quality study in the Kuantan river watersheds due to moderate correlation values. The existing results have shown that standard GIS functions could be adapted for data manipulations and solving complex water quality problems.

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

PENGGUNAAN SISTEM MAKLUMAT GEOGRAFI UNTUK MENILAI KUALITI AIR DI LEMBANGAN SUNGAI KUANTAN, MALAYSIA

Oleh

NGEOW KIN VOON

September 2008

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Malaysia telah mengalami era pembangunan ekonomi yang pesat sejak pelaksanaan dasar ekonomi selama 20 tahun dalam lewat 1970-an. Penilaian kualiti air sungai diperlukan untuk mengatasi pertambahan bahan pencemar yang dibuang ke dalam sungai disebabkan oleh pembangunan. Penilaian kualiti air merangkumi pepejal terampai, mendakan, jumlah fosfurus dan jumlah nitrogen dijalankan di lembangan Sungai Kuantan. Objektif kajian ini bertujuan untuk mengangarkan muatan beban bahan pencemar dan kepekatan nilai pencemar untuk pencemaran tidak berpunca serta mengetahui keberkesanan penggunaan sistem maklumat geografi (GIS) di lembangan Sg Kuantan. Kajian ini melibatkan data hidrologi dan kualiti air daripada Jabatan Pengairan dan Saliran (JPS) dan Jabatan Alam Sekitar (JAS), peta digital Pahang daripada Jabatan Ukur dan Pemetaan Malaysia (JUPEM), maklumat gunatanah daripada Jabatan Pertanian Malaysia (JPM) untuk diintegrasikan ke dalam sistem maklumat geografi bagi mewakili aliran muatan beban bahan pencemar

daripada sumber pencemaran sungai. Kesahihan data telah dijalankan dengan membandingkan keputusan secara ramalan dan secara pengukuran daripada simulasi sistem maklumat geografi dan rekod data JPS serta JAS untuk aliran sungai dan kualiti air. Hasil daripada keputusan kesahihan bagi aliran sungai di lembangan Sg Kuantan semasa tahun 2005 menunjukan nilai korelasi r^2 = 0.5944 bagi mean keadaan aliran tersebut (p < 0.05). Keputusan kesahihan bagi kepekatan pencemar yang menunjukan nilai korelasi tertinggi bagi pepejal terampai, mendakan, jumlah fosfurus and jumlah nitrogen masing – masing adalah r^2 = 0.6043 semasa Mac 2005, r^2 = 0.9642 semasa Mac 2005, r^2 = 0.5806 semasa Julai 2005 dan r^2 = 0.5882 semasa Mac 2005. Nilai korelasi yang terendah bagi pepejal terampai, mendakan, jumlah fosfurus dan jumlah nitrogen adalah r^2 = 0.1988 semasa Julai 2005, r^2 = 0.2126 semasa Julai 2005, r^2 = 0.3322 semasa Mei 2005, r^2 = 0.2341 semasa Januari 2005 serta r^2 = 0.0449 semasa Januari 2005 (p < 0.05). Berdasarkan keputusan simulasi, penggunaan sistem maklumat geografi menunjukan keberkesanan untuk penilaian kualiti air di lembangan Sg Kuantan disebabkan oleh nilai korelasi yang memadai. Keputusan telah menunjukan fungsi GIS dapat digunakan dalam penilaian data dan menyelesaikan masalah kualiti air yang rumit.

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I certify that an Examination Committee has met on 16 September 2008 to conduct the final examination of Ngeow Kin Voon on his Master of Science thesis entitled "Application of Geographical Information System in Assessing Water Quality in the Kuantan River Watershed, Malaysia" in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The Committee recommends that the student be awarded the Master of Science.

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DECLARATION

I hereby declare that the thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UPM or other institutions.

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NGEOW KIN VOON

Date:

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

AGNPS	Agricultural Non-Point Source Pollution
ANSWERS	Aerial Non-Point Watershed Environment Response Simulation
DEM	Digital Elevation Model
ERDAS	Earth Resources Data Analysis Support System
ESRI	Environment System Research Institute
GLEAMS	USDA Groundwater Loading Effects of Agricultural Management Systems
GRASS	Geographic Resources Analysis Support System
GWRAPPS	GIS-Based Water Resources and Agricultural Permitting and Planning System
JUPEM	Department of Survey and Mapping Malaysia
RE	River Ecosystem Classification System
RQO	River Quality Objectives
RSO	Rectified Skew Orthomorphic
SOLUS	Sustainable Option for Land Use
SS	Suspended Solids
TIN	Triangulated Irregular Network
TN	Total Nitrogen
TP	Total Phosphorus
USEPA	United States Environmental Protection Agency

CHAPTER I

INTRODUCTION

1.1 INTRODUCTION

This chapter presents the objectives, limitation and outline of the study for the application of GIS on assessing the water quality status in Kuantan river watershed.

1.2 BACKGROUND STUDY

Water is a scarce and fading resource, and its management can have an impact on the flow and the water quality of the rivers and streams (Prat and Munne, 2000). In many cases, shortages or water stress could be experienced in the more developed regions of the country. This would probably be caused by the uneven temporal and spatial distribution of rainfall and water resources which would result in fluctuating river flows over a wide range of volume. One major concern is the effect of anthropogenic activities on the aesthetics, economic viability, safety and health. Economic losses attributable to environmental degradation include the damage to vegetation and crops and the subsequent effect on livestock. Many rivers and streams in the developing countries are heavily polluted due to anthropogenic activities, such as industrial and sewage discharges (Jonnalagadda and Mhere, 2001).

The water resources are under threat mainly by increase of human activities who has harvest more of natural resources than the environment can replenishes itself (Buck

et al., 2004). In Malaysia, as in many parts of the world, the river system has historically been used to dispose of waste products of industry and municipalities. Pressure on the river system ability to assimilate the waste products increased with the rapid development of the watershed. In many events, this ability has been overcome and the rivers are very polluted. Sufficient amount of clean water is needed and expected as the rivers have limited natural self cleansing ability (Darken, 2002). A quantified water quality criteria need to be classified as it will represents overall quality of water bodies (Ahmad *et al.*, 2001).

Geographical information system (GIS) has become important tools for inventory and monitor natural resources (Setiawan, 2001). The availability of GIS and remote sensing techniques has allowed researchers to quantify river water quality at different scales (Olsson, 1987; Leipnik *et al.*, 1993; Buck *et al.*, 2004). GIS has been widely adopted for the use with hydraulic and hydrologic computer models providing functions for environmental simulation, impact assessment, and remedial planning for river water quality (Peccola *et al.*, 1996; Tsanis and Boyle, 2001; Satti and Jacob, 2004).

The capability of GIS to handle spatial data derived from remote sensing, ground surveys, or interpolation of point measurements offers new opportunities for hydrologic and water quality modelling (Schumann *et al.*, 2000; Gyllenhammer and Gumbricht, 2004). Raster-based GIS technology had been applied in assessing non-point and point pollution sources such as pollutant loads, monitoring and management (Hession and Shanholz, 1988).

1.3 SIGNIFICANCE OF STUDY

A research approach places emphasis on application of GIS for assessing water quality in watershed area. This study uses a fine mesh of cells laid over the land to determine the pollutant loads and runoff derived from each cells. By tracing the flow water from cell to cell, the movement of pollution over the land areas and within the selected stream network were simulated. In addition, the study allows for the estimation values for non-point source pollutant loads.

The study showed the association of selected pollutant concentrations with landuses in a watershed which has been structured to provide spatial analysis in water quality studies. The study had presented the estimated pollutant loads and concentration to determine the non-point source pollution while tracing the impacts of these pollutants as the non-point sources pollution within the Kuantan river watershed.

The study had reviewed water quality status within the Kuantan river watershed based on the updated water quality information from databank collected from the relevant agencies and other studies.

This study would elucidate in better understanding of the water resources and would be able to assist in decision-making by utilising GIS. The significance of this study is to find out a better solution for quick assessment and applicability of GIS on river water quality on watershed scale.

1.4 STUDY LIMITATION

There are several limitations within the scope of the study. Firstly, only average annual assessments are performed, thus the runoff and pollutant loads are considered as the steady state parameters within any year.

Secondly, pollutant loads from the local runoff is assumed to be directly related to landuse in this region and is not considered to vary from event to event or within areas of similar landuses (Saunder and Maidment, 1996). In particular, a single average estimated pollutant concentration is assigned to all agricultural landuses instead of considering unique concentrations for different crops, soil types, or activities.

The third limitation is that there is very little measured data available on stormwater pollutant loads in Malaysia. In Malaysia, datasets such as event mean concentration (EMC) were not readily exploited and utilised for pollutant loads calculation within the network of rivers and streams in Malaysia (Department of Irrigation and Drainage, 2004).

Another limitation of this study is that concentration values were assumed to be zero, if the value was below the detection limit. This would underestimate the total concentration values of the stormwater pollutants within the Kuantan river watershed.

1.5 STATEMENT OF PROBLEMS

Non-point source pollutant is becoming major issues and problems towards the river system as the point of origin and contaminants are not generally traceable to exact source (Wranic *et al*., 1994). This type of pollutions can be nutrients, sediments, toxic substances and other materials. Due to its importance, non-point source studies have received a worldwide attention among earth and environmental scientist. The utilisation of GIS to investigate non-point source pollution may require extensive knowledge of terrain, soil, landuse and management practices within the river basin. Nevertheless, they are of greater concern than point source pollutants because they are ubiquitious and the task of cleanup is costly and nearly impossible to accomplish.

A complete solution to improve water quality and prevent pollution problems accrue from non-point sources has not actually met in the study area. Nevertheless, various regulatory agencies, individual, community and consultancy groups are involved in planning, decision-making and managing the development along the river corridor of Sg Kuantan. To date, no standard approach or water quality management has been collectively adopted by participating agencies, since each has individual respective areas suitability and limitation of application. New GIS techniques and computer simulation hold significant promise for improving water quality prediction system. The GIS mapping has become more precise prediction tool as most of the information are obtained from the water monitoring stations operated by governmental authorities such as DOE and DID around the Kuantan river watershed.

1.6 AIMS OF STUDY

The study is aimed to study the pollutant loads and concentration in the Kuantan river system because of the rapid development and intense population growth within the watershed area. Hence, this research has been undertaken with the following objectives summarised as follows:

(a) To determine the pollutant loads for non-point source in the Kuantan river system

(b) To derive pollutant concentration from the pollutant loads in the Kuantan river system

(c) To determine the applicability of the GIS for the water quality study