



UNIVERSITI PUTRA MALAYSIA

**EVALUATION OF DRASTIC AND GEOGRAPIDC INFORMATION
SYSTEM AS A TOOL IN DETERMINING THE GROUNDWATER
QUALITY VULNERABILITY OF KUALA LANGAT AQUIFER**

HII CHING POON

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SYSTEM AS A TOOL IN DETERMINING THE GROUNDWATER
QUALITY VULNERABILITY OF KUALA LANGAT AQUIFER**

By

HII CHING POON

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

April 2002



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

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This thesis describes the results of a ground water pollution potential modeling, which examined the entire Kuala Langat aquifer using GIS. The pollution potential model implemented within GIS is known as DRASTIC, a model, which was developed by the U.S. Environmental Protection Agency in 1985. In compiling a groundwater vulnerability map of Kuala Langat, it was decided to use the widely known DRASTIC methodology that includes Depth to groundwater, Recharge due to rainfall, Aquifer media, Soil media, Topography, Impact of the vadose zone, and Conductivity (hydraulic).

Although not designed for a GIS, this model represents a classic spatial analysis approach for which GIS have become known. This thesis outlines the techniques used in compiling the data sets for those factors that influence the susceptibility of groundwater contamination over Kuala Langat and the techniques involved in



manipulating and displaying these data in a GIS. The different techniques employed in the gathering and calculations of the different information sets required by the DRASTIC model to describe the groundwater vulnerability are presented in detail. The final output, which is in the form of a color paper map, will be useful in presenting the concept of groundwater vulnerability and groundwater protection to the layman. Results show that DPPI ranges from 80 to 165 giving 90% of the entire area as moderate vulnerable. However the south and east portion of Kuala Langat pose much more pollution potential than other area. Pesticide DPPI ranges from 114 to 166 with higher numbers representing higher pollution potential, indicating that moderate pesticide pollution potential occurs through out the entire Kuala Langat aquifer. The Pesticide DRASTIC Pollution Potential Index of Kuala Langat is higher than DRASTIC Pollution Potential Index (DPPI) of Kuala Langat. From these findings, it can be concluded that the potential source of pollution in the area derived from agricultural activities.



Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia Sebagai memenuhi keperluan untuk Ijazah Master Sains

**PENILAIAN DRASTIC DAN SYSTEM MAKLUMAT GEOGRAFI SEBAGAI
ALAT PENENTUAN KEBOLEHCEMARAN KUALITI AIR TANAH DI
KUALA LANGAT**

Oleh

HII CHING POON

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Pengerusi : Profesor Madya Dr. Salim Said

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Tesis ini mengajikan kebolehcemaran tanah air berteraskan teknologi System Maklumat Geografi ke atas Kuala Langat. Model DRASTIC yang dibangunkan oleh Agensi Pemeliharaan Alam Sekitar Amerika Syarikat pada tahun 1985.

Namun Model DRASTIC bukan dibagunkan khas untuk diamplicasi dengan teknologi System Maklumat Geografi, kesamaan kedua-dua system dari segi analisis ruangan telah menggalakan percantuman kedua-dua system tersebut. tesis ini juga menerangkan teknik yang digunakan untuk mengumpul, menyusun, dan mempamerkan data-data yang diperlukan dalam penentuan kebolehcemaran tanah air di Kuala Langat dengan terperinci. Contoh pengiraan yang ringkas dan jelas bagi set data yang berlainan juga tercatat dalam kertas ini. Keputusan akhir telah dihasilkan dalam bentuk peta berwarna yang sesuai bagi menerangkan konsep kebolehcemaran tanah air dan pemeliharaan kepada golongan yang kurang mahir dalam bidang tanah air. Keputusan menunjukkan

indeks kebolehcemaran tanah air berjulat antara 80 hingga 165 yang menunjukkan 90% daripada seluruh kawasan Kuala Langat adalah berada dalam tahap kebolehcemaran yang sederhana. Manakala, kawasan selatan dan timur Kuala Langat adalah lebih tinggi tahap kebolehcemaran berbanding dengan kawasan lain dalam Kuala Langat. Indeks kebolehcemaran racun serangga tanah air untuk Kuala Langat berjulat antara 114 hingga 166 yang menunjukkan sederhana tahap kebolehcemaran terhadap racun serangga. Indeks kebolehcemaran racun serangga tanah air adalah lebih tinggi berbanding dengan indeks kebolehcemaran tanah air untuk keseluruhan Kuala Langat. Keputusan menunjukkan unsur yang berpotensi dalam pencemaran dalam kawasan tersebut adalah berpunca daripada aktiviti-aktiviti pertanian.

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I certify that an Examination Committee met on 25th April 2002 to conduct the final examination of Hii Ching Poon on his Master of Science thesis entitled "Evaluation of DRASTIC and Geographic Information System as a Tool in Determining the Groundwater Quality Vulnerability of Kuala Langat Aquifer" in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulation 1981. The committee recommends that the candidate be awarded the relevant degree. Members of the Committees be as follows:

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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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LIST OF ABBREVIATIONS

AET	Actual Evapotranspiration
CGIM	Customized Groundwater Information Management
CPU	Central Processing Unit
DPPI	DRASTIC Pollution Potential Index
DRASTIC	A standardized system for evaluating groundwater pollution potential protection by EPA
EPA	Environmental Protection Agency
GIS	Geographic Information System
IDW	Inverse Distance Weighting
IRLS	Infrared Line Scan
ISA	Inland Swamp Association
JICA	Japan International Cooperation Agency
JUPEM	Survey and Mapping Department of Malaysia
LS	Limestone
MUN	Munchong Soil Series
NRCS	Natural Resources Conservation Service
PI	Percolation Index
SCS	Soil Conservation Service



SDG	Serdang Soil Series
SDG-MUN	Serdang Munchong Association
SH	Shale
SS	Sandstone
SLAR	Side-looking air borne radar
SLR-BRH	Selangor Briah Association
US EPA	Environmental Protection Agency of United State



CHAPTER I

INTRODUCTION

Groundwater has been used in Asia since ancient times, for instance, in Central Asia where no other sources of water supply are permanently available. In China, wells hundreds of meters deep are drilled by using bamboo rods more than 400 years ago. Large-scale groundwater projects have been developed since World War II. Thousands of tube wells have been introduced to the Indian subcontinent – Pakistan, India and Bangladesh. Despite a doubling of population, development of groundwater has helped to avoid famines, which plagued China and India in the earlier part of the last century.

Nevertheless, the huge leaps forward in groundwater prospection, assessment and development are endangered groundwater prospect ion. In some overcrowded islands of the Maldives in the Indian Ocean, scarce resources are prey to pollution, exhaustion and seawater intrusion. Bangkok and Shanghai are the two major metropolitans areas, which encountered “ subsidence phenomenon” (Foster et al, 1994). Additionally, the uses of fertilizers and pesticides in modern agricultural development programmes, and industrial development, threatens groundwater quality.

With the continuous rapid growth of the country, the water resources in several places of Malaysia appear to be inadequate or even unavailable. States with Small River basins and low rainfall such as Perlis, Pulau Pinang and Melaka have the least water resources.



Kedah and Kelantan face water shortages during the dry season to meet the peak irrigation demands of their large paddy areas, which consume a considerable proportion of their available water resource. The Klang valley already face water shortage problems resulting from the rapidly increasing population and industrial activities. The Southern Johor region such as Johor Bahru and Sg. Lingi and Sg. Sepang of Negeri Sembilan will also have the similar problems. In Sarawak, the estuaries of the rivers are all affected by saline intrusion causing shortage of fresh water resources during dry seasons. Groundwater storage potential has been estimated to be 63 billion m³ for Peninsular Malaysia, 14 billion m³ for Sabah and 22 billion m³ for Sarawak. Safe yield of groundwater has been estimated to be 5.7 billion m³/yr for peninsular Malaysia, 2.2 billion m³/yr for Sarawak (Lim T.K, 1982). The industrial use of groundwater is estimated to be about 35 percent – 40 percent, and is concentrated largely in Selangor where privately owned tubewells are installed in many of the large factories in the Kuala Lumpur and Petaling Jaya areas. According to Geological survey Department Malaysia, there is no major problems related to groundwater extraction have so far been encountered, except for the case of land subsidence as a result of mine dewatering. However, with increasing abstraction rates, problems related to seawater intrusion and groundwater pollution are anticipated.



Statement of Problem

Based on the National Water Resources Study by Japan International Cooperation Agency (2000) and Malaysia government department (JPS), only 3% of the total water use of Malaysia's fresh water resources originates from underground sources. Since the groundwater is difficult to put to use than the water flowing in rivers or residing in a nearby lake. There is a lack of groundwater development in Malaysia. One of the factors that lead to the problem is misconception that groundwater use is not sustainable and harmful. There are no existing documents that can assist planners, managers and administrators in the task of evaluating the relative vulnerability of areas to groundwater contamination from various sources of pollution. Unlike surface water resources, the groundwater resources are not only underutilized but also have not been sufficiently mapped, and additional work is required.

A standardized system is needed for evaluating pollution potential and to display it on maps for the purpose of relative evaluation. DRASTIC was developed in 1987 by the United States Environmental Protection Agency (EPA) as a method for assessing ground-water pollution potential (Aller et al., 1987). The main goal of the development of DRASTIC was to produce a standardized methodology that would give results suitable for screening regions with respect to ground-water protection, monitoring, and clean-up efforts. The method uses hydrogeologic settings as the basic mapping units. For each setting, seven parameters are evaluated: Depth to water, net Recharge, Aquifer media, Soil media, Topography, Impact of the vadose zone, and hydraulic Conductivity.

The capitalized initials in this list give the DRASTIC acronym. Pesticide DRASTIC model is similar to DRASTIC model. The procedure for generating the pesticide DRASTIC map was identical to that described above for the generic DRASTIC map. The only difference was in the weights used for some of the parameters. There is an important need to evaluate the vulnerability of aquifer systems in Malaysia. This research investigates this issue with respect to the Kuala Langat aquifer system as a case study.

For the purpose of relative evaluation and mapping, a system that incorporates numerical ratings and hydrogeologic settings, which influence the vulnerability of that setting to groundwater pollution, need to be developed by using Geographic Information System (GIS). GIS is able to display and combine many layers of spatial data into differing formats so that results may be more easily interpreted by the user.

Objectives of the Study

In view of the issues and problems discussed, the aim of this study is to produce pollution potential maps for Kuala Langat aquifer system using DRASTIC model, Pesticide DRASTIC model and GIS.

The specific objectives are:

1. To obtain static water level information from generated static water level maps.
2. To apply the DRASTIC model to evaluate the vulnerability of Kuala Langat aquifer systems using GIS.
3. To compare the DRASTIC model with Pesticide DRASTIC model as applied to the Kuala Langat aquifer.

CHAPTER II

LITERATURE REVIEW

Geographic Information System

A geographic information system (GIS) is a computer-based tool for mapping and analyzing things that exist and events that happen on earth. GIS technology integrates common database operations such as query and statistical analysis with the unique visualization and geographic analysis benefits offered by maps. These abilities distinguish GIS from other information systems and make it valuable to a wide range of public and private enterprises for explaining events, predicting outcomes, and planning strategies. The ultimate goal of a GIS is to support decision making in, for example, natural resource and environment management, urban and regional planning, and any other activities, which have a spatial context. Implementation of GIS technology is often a complicated task, which involves careful planning, selection of computer hardware and GIS software, and resolving many organizational issues and problems.

GIS is a mapping environment where individual coverages, or themes, can be displayed or removed depending on the intended application. Each coverage is linked to an attribute table so that information is available on the individual features, or records, of the theme. For instance, an applicable coverage for a petroleum refinery is the on-site storage tanks. For each tank,



there might be data available on what products are currently stored there and what products have been stored there in the past. Besides this obvious data-mapping advantage, GIS also has the ability to query specific information about a theme. So in the example above, all the tanks that store gasoline could be identified. Geographic Information Systems are predominantly used for mapping and visual display, but analysis and modeling functions are increasingly being explored.

Three separate data models can be supported by GIS, namely: (1) vector data, (2) raster data, and (3) triangulated irregular networks (TINs). Vector data includes feature representation with points, lines, or polygons. For example, the monitoring wells for a site could be mapped as a point data source. Example line features include rivers, roads, and boundaries. Some polygon feature examples are buildings, lakes, and watersheds. While vector data are the most common format, other data sets are better represented with grids, where each cell in the grid has a particular value. This type of format is referred to as raster data and is effective for representing elevations and concentrations. Triangulated irregular networks are the final type of data model and are particularly useful for surface representation and three-dimensional mapping. TINs are constructed by connecting a group of points, such as surveyed elevations. The lines that connect these points form triangles, and since each point in the TIN has an associated value, each triangle in the model (i.e., continuous surface of planar triangles) is sloped. This allows for powerful visualization capabilities with a three-dimensional viewer. The most common method of connecting points to form a



TIN model is Delauney triangulation, which maximizes the minimum interior angles of the triangles formed, thereby avoiding long and thin triangles (Jones, *et. al.*, 1990).

Any one of the commercially available GIS software packages can be used in the research. However, this research has utilized the Environmental Systems Research Institute, Inc. (ESRI) products: ArcView GIS Version 3.1 and ARC/INFO Version 7.2.1. These software packages have been chosen based on their ease of use and worldwide availability. ArcView's graphical interface allows a user to display spatial data, build maps, query datasets, create charts, and perform calculations. ARC/INFO is a more powerful set of programs that is useful for data editing and analysis. ARC/INFO has more functionality than ArcView but is also more expensive. For purposes of developing groundwater quality vulnerability map, ArcView is the most effective software tool. Its analytical capabilities have improved significantly over the past few years, and unless otherwise noted, all the methods discussed in this document can be performed with ArcView. One of the advantages of a GIS such as ArcView is its ability to connect with many different applications in a C-based environment. C-based environment comprised of five components such as maps, databases, spreadsheet, models and GIS. Each component is a tool for information processing. Maps can be used to convey geographic features and relationships along with the results of a data analysis. Databases can be used to store physical and chemical data along with geologic and hydrogeologic information. Example spreadsheet uses include concentration data analysis and simple transport



algorithms while models utilize sophisticated transport simulations in order to characterize chemical attenuation and migration in the environment. These information-processing tools can be either internal or external to the GIS application. External programs are often dynamically linked to the GIS application so that when information is updated in one location, it is updated throughout the system. The ability to utilize this type of approach has only recently become available with the release of more cost-effective personal computers and more integrated software applications.

GIS and Cartography

The previous studies of using GIS for cartographic purposes involves constructing a database of appropriate coverages and then overlaying these coverages for decision-making applications, such as planning and management. The cartography (i.e., maps of a study area) displays important characteristics of an area and how these characteristics might be related. These characteristics play an important role in describing information about sources and receptors. The modeling then provides the mechanism to analyze how chemicals migrate and attenuate from a source to a receptor.

Because of GIS's spatial storage and display capabilities, numerous examples exist of using maps for making environmental decisions. *Managing Natural Resources with GIS* (Lang, 1998) provides a good overview of some environmental mapping case studies. These studies involve using GIS in the all

