



UNIVERSITI PUTRA MALAYSIA

**APPLICATION OF SWAT HYDROLOGICAL MODEL WITH GIS
INTERFACE TO UPPER BERNAM RIVER BASIN**

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FK 2001 26

**APPLICATION OF SWAT HYDROLOGICAL MODEL WITH GIS
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By

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**Thesis Submitted in Fulfilment of the Requirement for the
Degree of Master of Science in the Faculty of Engineering
Universiti Putra Malaysia**

March 2001



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

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Faculty : Engineering

Rising concern over the degradation of the environment due to rapid land development in recent years has created a need for watershed modeling. The Upper Bernam River Basin in South Perak and North Selangor, Malaysia was chosen for this study. This study was carried to evaluate the effectiveness of a GIS interface physically based hydrologic model (SWAT) in predicting surface runoff and sediment load from a basin scale watershed. The effects of land use changes on runoff and sediment loading rate were also studied.

The data required for this study is the topographical, hydrometeorological, soil, and the land use data. All of them are integrated in a GIS in tabular, vector and grid formats. The land use data in this study were derived from Landsat TM images. These images were enhanced and classified using a combination of different classification strategies.



The classified land use maps compares reasonably well with the map showing broad vegetation types of the river basin with an accuracy of 95%.

Due to recent rapid land use changes, the model was run in a short term basis. The results from model application and statistical analysis show that SWAT generally does a good job in predicting both runoff flow and sediment load with a an average gap of 22% and 34% respectively between observed and predicted results. The exception is for those days with very heavy rainfall (> 35 mm/day), SWAT seriously overestimated runoff.

Results from historical data, trend analysis, and calculated runoff rate and sediment loading rate due to open area have also shown the close relationship between surface runoff, sediment load and open area downstream of the upper river basin. It is found that the average increment of sediment loading rate for the study area ranges from 1.47 to 2.06 tonnes per millimeter of rainfall for each kilometer-square increase of open areas.



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

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Kesedaran tentang ancaman pembangunan tanah yang pesat terhadap alam sekitar di Malaysia beberapa tahun ini mencetuskan keperluan pemodelan lembangan sungai. Hulu Lembah Bernam yang berada di Selatan Perak dan Utara Selangor, Malaysia telah dipilih untuk kajian ini. Kajian ini telah dijalankan untuk menguji keberkesanan satu model hidrologi yang berteraskan GIS untuk menganggar aliran permukaan dan endapan dari sebuah lembangan tadahan air. Kesan guna tanah terhadap aliran permukaan dan endapan juga telah dikaji.

Data yang diperlukan untuk kajian ini ialah data yang berkenaan dengan topografi, hidrocuaca, tanah, dan data guna tanah, dimana semua data tersebut telah diintegrasikan dalam satu pangkalan data GIS dalam bentuk jadual, vektor, dan grid. Data guna tanah yang digunakan dalam projek ini adalah diperolehi daripada imej Landsat TM. Imej tersebut telah diperbaiki dan dikelaskan dengan menggunakan satu kombinasi strategik

klasifikasi yang berlainan. Hasil peta guna tanah yang dikelaskan adalah baik setelah dibandingkan dengan peta yang menunjukkan jenis tumbuhan umum di lembangan tersebut dengan satu ketepatan 95%.

Disebabkan perubahan guna tanah yang kerap, permodelan telah dijalankan untuk satu tempoh yang singkat. Keputusan daripada penggunaan model dan analisis statistik menunjukkan bahawa SWAT secara umumnya adalah baik untuk mengangar kedua-duanya aliran permukaan dan endapan dengan satu jurang 22% dan 34% masing-masing di antara data data yang dipunggut dan data data yang dianggar, kecuali untuk hari-hari yang mempunyai hujan lebat (> 35 mm/day), SWAT telah lebih anggar aliran permukaan dengan serius.

Hasil dari data yang lepas, tren analisis, kadar aliran permukaan dan kadar endapan terhadap kawasan terbuka yang dikira juga telah menunjukkan perhubungan yang rapat di antara aliran permukaan, endapan, dan kawasan terbuka di bahagian hilir lembangan sungai tersebut. Adalah ditemui bahawa untuk setiap kilometer persegi pertambahan dalam kawasan terbuka, kadar endapan purata telah bertambah sebanyak 1.47 hingga 2.06 ton per milimeter air hujan.

ACKNOWLEDGEMENTS

With a deep sense of gratitude the author would like to acknowledge his project supervisory team Associate Professor Ir. Dr. Mohd. Amin Mohd. Soom, Assoc. Prof. Kwok Chee Yan and Dr. Abdul Rashid Mohamed Shariff for their invaluable guidance, constructive suggestions and encouragement throughout the duration of this project.

Sincere thanks are extended to Dr. Lim Jit Sai and Mr. Rao of the Department of Agriculture Malaysia for providing the unpublished detailed soil data and land use maps of study area. Thanks are also extended to the staff of Hydrology Branch of Drainage and Irrigation Department, the staff of Malaysian Meteorological Services, and the staff of Malaysian Centre for Remote Sensing (MACRES) for providing related hydrometeorological and satellite data used in this study. Special thanks are for Prof. Nancy Sammons (USDA, ARS-Temple) and Prof. Mauro Diluzio (Texas A&M University, TAES-Temple) for their valuable reading materials and technical assistantship (model updating and error checking) in watershed modeling.

Lastly, the author would like to express his sincere appreciation to his family for their undying love, patience, encouragement and supports during the course of study.



TABLE OF CONTENTS

		Page
ABSTRACT		ii
ABSTRAK		iv
ACKNOWLEDGEMENTS		vi
APPROVAL SHEETS		vii
DECLARATION FORM		ix
LIST OF TABLES		xiii
LIST OF FIGURES		xiv
LIST OF ABBREVIATIONS		xvii
CHAPTER		
I	INTRODUCTION	1
	Statement of Problem	2
	Objectives of the Study	3
II	LITERATURE REVIEW	4
	Geographical Information System (GIS)	4
	Concept of GIS	4
	The Benefits and Advantages of Using GIS	6
	ArcView – 3D Analyst and Spatial Analyst	6
	Remote Sensing	7
	Advantages of Using Remote Sensing	9
	Thematic Mapper (TM) image	10
	Watershed Model	13
	Model Selection	14
	Overview of SWAT	15
	Model Theory	15
	Land Phase of The Hydrologic Cycle	17
	Erosion	21
	Routing Phase of The Hydrologic Cycle	22
	SWAT – ArcView Interface	25
III	METHODOLOGY	27
	Description of Study Area	27
	Topography	30
	General Geology and Soil	30
	Land Uses/Land Covers	31



	Climate	31
	Water Quality	32
	Data Acquisition	32
	Data Processing and Management	34
	SWAT Project Development	38
	Model Calibration and Simulation	39
	Methods for Analyzing Results	40
	Theil's Technique	40
	Correlation Analysis	41
	Overall Procedure	42
IV	RESULTS AND DISCUSSION	44
	GIS Output	44
	Digital Map	44
	Grid Maps	47
	ArcView Database Tables	50
	Raster Outputs	55
	Feature Extraction	55
	Enhancement	55
	Land Use Identification	58
	Land Use Classification	58
	Supervised Classification	58
	SWAT Databases and Data Estimation	70
	SWAT Database – User Soils	70
	SWAT Database – User Weather Station	72
	SWAT Database – Land Cover/Plant Growth	73
	Historical Data Analyses	75
	Rainfall-Runoff Ratio and Basin Water Balance	75
	Relation Between Discharge and Sediment	78
	SWAT Project	83
	Model Results and Discussion	89
	Statistical Analyses	100
	Effect of Land Use Changes on Streamflow and Sediment Load	101
V	CONCLUSIONS AND RECOMMENDATIONS	104
	Summary	104
	Conclusions	105
	Recommendations	106



BIBLIOGRAPHY	107
APPENDICES	114
BIODATA OF THE AUTHOR	122



LIST OF TABLES

Table	Page
2.1 Characteristic of Landsat Thematic Mapper (TM) Data	12
2.2 Advantages and limitations of model reviewed	14
3.1 Background of the river basin	28
3.2 Types of data and their sources	33
3.3 Categorization of model application results using correlation analysis	42
4.1 ArcView database tables and their functions	52
4.2 Water balance calculation for the Upper Bernam Basin	76
4.3 Subbasins delineated, coverage area, and main reach draining each subbasin	85
4.4 Land use information derived from Landsat TM images	89
4.5 Observed and calibrated results of the Upper Bernam Basin for year 1998	91
4.6 Observed and predicted results of the Upper Bernam Basin for year 1993	94
4.7 Observed and predicted results of the Upper Bernam Basin for year 1995	97
4.8 Statistical analyses of modeling results for the Upper Bernam Basin	101
4.9 Relationship between open area and streamflow rate for the month the satellite imageries were taken	101
4.10 Relationship between open area and sediment loading rate for the month the satellite imageries were taken	102



LIST OF FIGURES

Figure		Page
2.1	Spatial data	5
2.2	Relative reflectance of typical ground cover types as a function of wave length	11
2.3	Land phase of the hydrologic cycle	16
2.4	ArcView View menu and tool bars	25
2.5	SWAT Watershed View menu and tool bars	25
3.1	Map showing location of study area.....	29
3.2	Sequence of Landsat TM image processing	35
3.3	Data management using WDMUtil	37
3.4	SWAT databases	37
3.5	Customized Watershed menu in ArcView interface for SWAT project development	38
3.6	Schematic diagram showing overall procedure of the study	43
4.1	Topographic relief of the Upper Bernam Basin	45
4.2	Top view of Triangulated Irregular Network (TIN) representing the project area	46
4.3	Digital Elevation Model (DEM) for the Upper Bernam Basin	48
4.4	Grid map representing soil types of the Upper Bernam Basin	49
4.5	Classified Land use grid map derived from Landsat TM image (Date: 28/1/98)	51
4.6	Samples of location tables and look up tables	53
4.7	Samples of data tables.....	54



4.8	Landsat TM Image before enhancement	56
4.9	Landsat TM image after enhancement	57
4.10	Land use identification based on Landsat TM image band 4, 5 and 3	59
4.11	Signature selection	60
4.12	Recode classes	61
4.13	Classified land use map derived from Landsat image	
4.13a	derived from Landsat image (Date:	63
4.13b	derived from Landsat image (Date:	64
4.13c	derived from Landsat image (Date:	65
4.14	Sampling points for classified raster image accuracy assessment	67
4.15	Reference values for generated sampling points	68
4.16	Classification accuracy assessment report	69
4.17	SWAT database - User Soils	71
4.18	SWAT database - User Weather stations	73
4.19	Average annual rainfall from representative stations and runoff for the Upper Bernam Basin upstream of SKC Bridge gauging station	77
4.20	Average annual runoff/rainfall ratio for the Upper Bernam Basin upstream of SKC Bridge gauging station	77
4.21	Sedimentation rate at SKC Bridge station	81
4.22	Sedimentation rate at SKC Bridge station plotted by month of the year	82
4.23	Watershed, subbasins and stream definition	84
4.24	Subbasins delineation	86
4.25	Land use/soil combination used to create multiple HRUs for each subbasin	87



4.26	Weather and river monitoring stations available in the project area ...	88
4.27	Comparison of rainfall, streamflow and sediment load of the Upper Bernam Basin for year 1998	92
4.28	Mass curve of stream flow and sediment load of the Upper Bernam Basin for year 1998	93
4.29	Comparison of rainfall, streamflow and sediment load of the Upper Bernam Basin for year 1993	95
4.30	Mass curve of stream flow and sediment load of the Upper Bernam Basin for year 1993	96
4.31	Comparison of rainfall, streamflow and sediment load of the Upper Bernam Basin for year 1995	98
4.32	Mass curve of stream flow and sediment load of the Upper Bernam Basin for year 1995	99



LIST OF ABBREVIATIONS

ρ	Correlation coefficient
3D	3 Dimensional
ADP	Average daily precipitation in month
ALB	Moist soil albedo
AWC	Available water capacity of soil layer
BARE	4 digit land use class – bare land
BD	Moist bulk density of soil layer
C	USLE crop management factor
CH_D	Average depth of main channel
CH_K	Effective hydraulic conductivity in tributary channel alluvium
CH_L	Length of main channel
CH_N	Manning’s “n” value for the tributary channel
CH_W	Average width of tributary channels
CLAY	Clay content of soil layer
CN2	SCS curve number for moisture condition II
CO2	Carbon dioxide concentration
COEF	Skew coefficient of daily precipitation in month
DEWPT	Average dew point temperature in month
FRSE	4 digit land use class – forest
GPS	Global Positioning System
HHMX	Maximum 0.5 hour rainfall in month for the years with available data
HRU	Hydrologic Response Unit
HRU_FR	Fraction of total watershed area contained in HRU
HWQ	Hydrologic and water quality
HYDGRP	Soil Hydrologic group.
K	Saturated hydraulic conductivity of soil layer



OILP	4 digit land use class – oil palm
OV_N	Manning’s “n” value for overland flow
Pcp98FTU	daily precipitation for 1998 recorded at station Felda Trolak Utara
Pcp98LTL	Daily precipitation for 1998 recorded at station Ladang Trolak
Pcp98LKY	Daily precipitation for 1998 recorded at station Ladang Ketoyang
Pcp98PTM	Daily precipitation for 1998 recorded at station Pekan Tanjung Malim
PCPD	Average number of days of precipitation in month
PRB_D	Probability of wet day following dry day in month
PRB_W	Probability of wet day following wet day in month
RUBB	4 digit land use class – rubber
SAND	Sand content of soil layer
SCRB	4 digit land use class – scrub
SCS	Soil Conservation Service
SDP	Standard deviation for daily precipitation in month
Sg	Sungai / river
SILT	Silt content of soil layer
SLOPE	Average slope steepness
SLSOIL	Slope length for lateral subsurface flow
SLSUBBSN	Average slope length
SOL	Average daily solar radiation for month
tmp98tmx	Daily maximum temperature recorded for year 1998
tmp98tmn	Daily minimum temperature recorded for year 1998
TMPCVT	Coefficient of variation for the average temperature for month
TMPMX	Average maximum air temperature for month
TMPMN	Average minimum air temperature for month
TIN	Triangulated Irregular Network
U	Theil’s coefficient
URBN	4 digit land use class – urban area
USLEK	USLE equation soil erodibility (K) factor



WATR	4 digit land use class – water body
WDMUtil	Watershed Data Management Utility
WIND_AV	Average wind speed in month
Z	Depth of a certain soil horizon / layer



CHAPTER 1

INTRODUCTION

In recent years, growth, urbanization, expansion of agriculture, logging activities, and industrialization. These changes have caused complex environmental problems and the most affected natural resource is water.

Rising concern over the degradation of the environment, such as our river water quality, has resulted in an increase in research on the identification and study of environmental problems. The rapid rise in the volume and quantity of data collected, and massive changes in technical capability have facilitated the development of Geographical Information System (GIS) and remote sensing to handle the diversity of information involved.

Inherent in the solution of the above problem and many environmental problems is the need to bring together dispersed data sets. The complexity and size of these databases make the requirement for application of GIS and remote sensing technology all the more necessary. The advantage of holding all the information together is to allow searches and queries to be made on a combination of information so that effective formulation and implementation of any strategies, policies and plans which are highly dependent on accurate, comprehensive and timely information can be achieved.

Statement of the Problem

In the study of watershed problems, it has been found that most of the distributed/physically based hydrologic and water quality (HWQ) model from developed countries are not suitable for local use due to different atmospheric conditions and availability of data. Another fact is that most of those models are too complex and thus, too difficult to use or not user friendly. In addition, very few of them are applicable to basin scale study. Knowing these, a simple GIS interface physically based and computationally efficient distributed model has been chosen for evaluation. By confirming the effectiveness of the selected model in the tropical watershed management, it provides an alternative to potential users such as hydrologists, environmentalists, policy makers and etc.

Through data overlaying technique, classified remote sensing data has been applied in this study. Necessary data set representing hydrology, weather, soil, elevation and surface characteristic were integrated in a GIS in tabular, vector and grid formats. By bringing key data and analytical components together “under one roof”, it is hoped that the problems of lack of integration, limited coordination, and time-intensive execution typical of the more traditional assessment tools can be overcome. Similar studies in the future will become easier in terms of time, effort and cost saving to acquire and manage temporal as well as spatial data.

With the ability of a selected model to predict or generate simulated rainfall, stream flow and water quality from a river basin, these provide quantitative means to test alternatives and controls before expensive measures are implemented. These also enable effective planning and decision making of any development of pollution control strategies, plan or policy for better water management of a humid tropical river basin.

It is envisaged that the database generated and the water quality output of the simulation as well as maps, charts, or tables generated can be used to advance the knowledge on the existing environment during the study period. This is to allow comparison with the present or future situation of the river basin and also allow a continual trend analysis for any further similar studies.

Objectives of the Study

In view of the issues and problems discussed above, this study aims to evaluate the effectiveness of a GIS interface physically based hydrologic and water quality (HWQ) model in predicting daily stream flow and water quality from a tropical river basin.

The specific objectives:

1. To carry out a preliminary research into combining remote sensing data, GIS a watershed model for hydrologic evaluation purposes;
2. To evaluate the effectiveness of selected model in a river basin using remote sensing data and GIS-derived inputs.

CHAPTER II

LITERATURE REVIEW

Geographical Information System (GIS)

GIS in the general context of the environmental applications can be defined as a computer-assisted and integrated environment for geographical data creation, storage and retrieval, management, manipulation, analysis and display (Norlin Jaafar, 1997). It is able to provide effective and efficient functions for handling large spatial database and aids data inventory, management, problem solving and decision making.

Concept of GIS

According to Holdstock (1998), one of the world's leading GIS software vendors organizes data in such a way that they can be envisioned as digital layers or coverages of information. Each coverage is registered to the same common map base; each has a distinct type of feature such as points, polylines or polygons.

data and attribute data. A coverage represents a single theme, such as land-use (polygon), soils type (polygon), rivers (line), roads (line), and buildings (point) as shown in Figure 2.1.

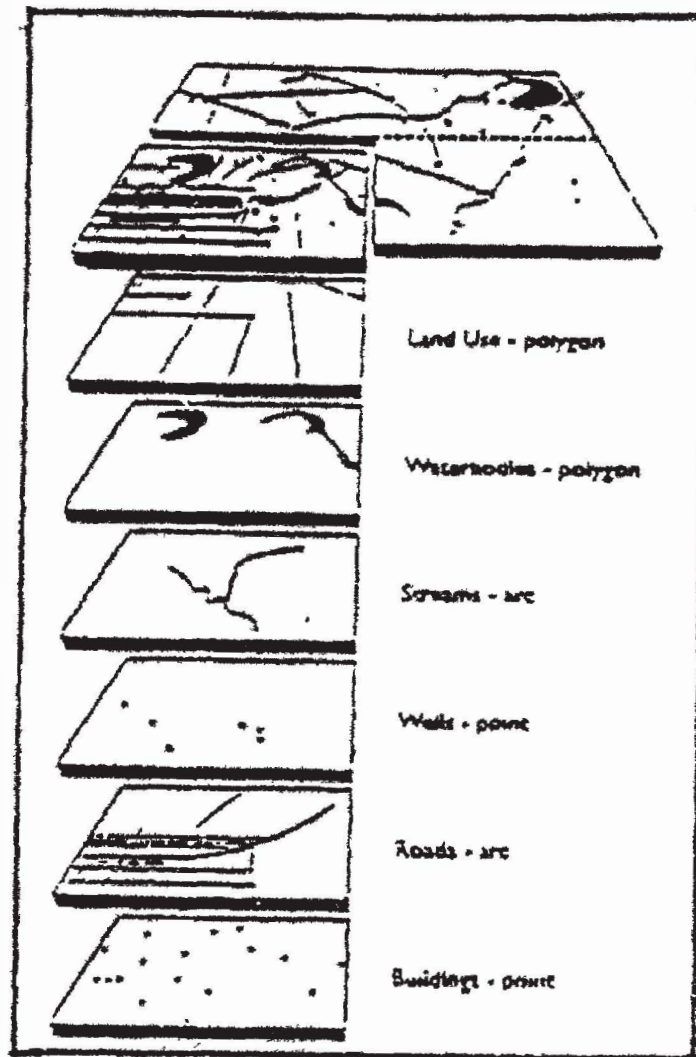


Figure 2.1: Spatial Data

(Source:

Transportation Research and Education (ITRE), North Carolina State University)