

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

**PREDICTION OF TOTAL SUSPENDED SEDIMENTS  
IN PENANG WATERS  
USING REMOTE SENSING**

**By**

**TAN SEK AUN**

**July 2004**

**Chairman : Associate Professor Shattri Bin Mansor, Ph.D.**

**Faculty : Engineering**

Total suspended sediments (TSS) are one of the main causes of pollution in the country's coastal areas. Land-based loaded and seabed re-suspension are two main sources of TSS in coastal and estuary areas. In this study, remote sensing techniques were used to predict TSS concentrations.

Landsat-5 TM satellite imagery was used simultaneously with ground-truth data collected on 27<sup>th</sup> May 2000 in the Penang Straits. Various image processing steps such as geometric correction, radiometric correction and atmospheric correction were carried out in this study. Initially, digital number (DN) of imagery was corrected and converted into reflectance values for algorithm development. Subsequently

combinations of various radiometric correction methods were used in this study to reduce the errors from various sources prior to statistical analysis. Data generated from corrected satellite imagery and TSS concentrations measured from field sampling were compared and tested using statistical analysis. Only the best-fit algorithm developed in this study was selected to predict the TSS concentrations from satellite imagery. Out of the six algorithms derived, Algorithm 6 showed the best correlation with the ground-truth data ( $R^2$  value of 0.9755 and RMSE value of 4.0107).

The developed algorithm was then applied to predict the TSS concentrations on historical Landsat imagery acquired on 1<sup>st</sup> February 1993. The historical satellite image was normalized and converted to reflectance for the biophysical study. Besides the derived algorithm, models suggested by other researchers were tested in this study. However, the Algorithm 6 showed the best results in predicting TSS concentration for the Penang waters. The predicted TSS concentrations distribution maps were generated and compared with the GIS platform.

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

**PENGANGGARAN ENDAPAN TERAMPAI KESELURUHAN  
DI SEKITAR PERAIRAN PULAU PINANG  
DENGAN PENDERIAAN JARAK JAUH**

**Oleh**

**TAN SEK AUN**

**Julai 2004**

**Pengerusi : Profesor Madya Shattri Bin Mansor, Ph.D.**

**Fakulti : Kejuruteraan**

Endapan terampai keseluruhan (*total suspended sediments* atau *TSS*) merupakan salah satu punca pencemaran yang sering ditemui di alam marin di negara ini. Penghasilan endapan terampai keseluruhan dari darat dan dasar laut adalah dua sumber utama di kawasan laut dan muara. Dalam kajian ini, teknik penderiaan jarak jauh telah digunakan untuk menganggar kepekatan kandungan endapan terampai keseluruhan.

Imej satelit Landsat-5 TM digunakan serentak dengan data kajian lapangan yang telah dijalankan pada 27hb. Mei 2000 di perairan negeri Pulau Pinang dalam kajian ini. Pelbagai langkah pemprosesan data seperti pembetulan geometri, pembetulan radiometrik dan pembetulan atmosfera telah dilakukan ke atas imej satelit itu. Nombor digital (*digital*

*number* atau *DN*) telah diperbetulkan dan ditukarkan nilainya menjadi *reflectance* untuk pembentukan algoritma. Kombinasi pelbagai cara pembetulan radiometrik telah digunakan dalam kajian ini untuk mengurangkan ralat yang terhasil daripada pelbagai sumber sebelum analisis statistik dijalankan.

Data daripada hasil pemprosesan imej satelit dan kerja lapangan telah dibandingkan serta dianalisis secara statistik. Hanya algoritma yang terbaik sahaja dipilih dan digunakan untuk meramal kepekatan endapan terampai keseluruhan daripada imej satelit. Daripada enam algoritma yang dihasilkan, Algoritma ke-6 menunjukkan korelasi yang paling tinggi dengan data yang dikumpulkan semasa kerja lapangan (nilai  $R^2$  mencatatkan 0.9755 and nilai RMSE mencatatkan 4.0107).

Algoritma yang terhasil itu kemudiannya digunakan untuk meramal kepekatan endapan terampai keseluruhan dari imej satelit Landsat yang diperolehi pada 1hb. Februari 1993. Imej tersebut seterusnya diselaraskan dan ditukar nilai pada *reflectance* untuk kajian biofizikal. Selain daripada algoritma yang dihasilkan, model yang dicadangkan oleh penyelidik lain turut dikaji dalam kajian ini. Bagaimanapun, Algoritma 6 menunjukkan keputusan yang terbaik untuk meramal kepekatan endapan terampai keseluruhan di perairan negeri Pulau Pinang. Peta-peta ramalan kepekatan TSS dihasilkan dan dibandingkan dengan teknik GIS.

## ACKNOWLEDGEMENTS

I would like to express my deepest appreciation to my supervisors , Assoc. Prof. Dr. Shattri Mansor, Prof. Dr. Mohd. Ibrahim Mohamad and Dr. Muhamad Radzali Mispan for their invaluable guidance, constructive criticisms and encouragement as well as the financial support throughout the period of the study.

I would also like to thank the Malacca Straits Research and Development Centre (MASDEC), Malaysian Centre for Remote Sensing (MACRES), Japanese International Cooperation Agency (JICA), Malaysian Meteorological Services (MMS) and Fisheries Research Institute (FRI) Batu Maung, Penang for their contributions of facilities and materials in this study.

Special thanks are also dedicated to my beloved family and friends for their valuable assistance, patience, support and encouragement.

I certify that an Examination Committee met on 9<sup>th</sup> July 2004 to conduct the final examination of Tan Sek Aun on his Master Degree thesis entitled “Total Suspended Sediments Prediction of The Penang Waters Using Remote Sensing Technique” in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1980. The Committee recommends that the candidate be awarded the relevant degree. Members of the Examination Committee are as follows:

**Azlan Abdul Aziz, MSc.**  
Faculty of Engineering  
Universiti Putra Malaysia  
(Chairman)

**Shattri Bin Mansor, Ph.D.**  
Associate Professor  
Faculty of Engineering  
Universiti Putra Malaysia  
(Member)

**Mohd. Ibrahim Hj Mohd, Ph.D.**  
Professor  
Faculty of Science and Environmental Studies  
Universiti Putra Malaysia  
(Member)

**Muhamad Radzali Mispan, Ph.D.**  
Strategic, Environment and Natural Resources Research Centre (SENR)  
MARDI, G.P.O. Box 12301  
50774, Kuala Lumpur, Malaysia  
(Member)

---

**GULAM RUSUL RAHMAT ALI, Ph.D.**  
Professor/Deputy Dean  
School of Graduate Studies  
Universiti Putra Malaysia

Date:

This thesis submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirements for the degree of Master of Science. The members of the Supervisory Committee as follows:

**Shattri Bin Mansor, Ph.D.**

Associate Professor

Faculty of Engineering  
Universiti Putra Malaysia  
(Member)

**Mohd. Ibrahim Hj Mohd, Ph.D.**

Professor

Faculty of Science and Environmental Studies  
Universiti Putra Malaysia  
(Member)

**Muhamad Radzali Mispan, Ph.D.**

Strategic, Environment and Natural Resources Research Centre (SENR)  
MARDI, G.P.O. Box 12301  
50774, Kuala Lumpur, Malaysia  
(Member)

---

**AINI IDERIS, Ph.D.**

Professor/Dean  
School of Graduate Studies  
Universiti Putra Malaysia

Date:

## **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.

TAN SEK AUN

---

Date:



# TABLE OF CONTENTS

	Page
<b>DEDICATION</b>	<b>ii</b>
<b>ABSTRACT</b>	<b>iii</b>
<b>ABSTRAK</b>	<b>v</b>
<b>ACKNOWLEDGEMENTS</b>	<b>vii</b>
<b>APPROVAL</b>	<b>viii</b>
<b>DECLARATION</b>	<b>x</b>
<b>LIST OF TABLES</b>	<b>xiii</b>
<b>LIST OF FIGURES</b>	<b>xiv</b>
<b>LIST OF ABBREVIATIONS</b>	<b>xviii</b>

## **CHAPTER** **INTRODUCTION**

1.1	Background Study	1
1.2	Statement of Problems	3
1.3	Objective	7
1.4	Scope of Project	7

## **LITERATURE REVIEW**

Remote Sensing	9
Landsat-5 TM	11
Total Suspended Sediments	15
Application of Remote Sensing on Total Suspended Sediments Study	25
Existing Empirical Models	28
2.5.1 Existing Empirical Models From Other Areas	28
2.5.2 Local Existing Empirical Models	32

## **METHODOLOGY**

The Straits of Malacca	34
Study Area – Penang’s Coastal Areas	35
Materials	36
3.2.1 Water Quality Data	36
3.2.2 Remote Sensing Data	43
Image Processing Methodology	44
3.3.1 Geometric Correction	44
3.3.2 Radiometric Correction	46
3.3.3 Multi-date Image Normalization	53
3.3.4 Algorithms Development	55

## **RESULTS AND DISCUSSIONS**

Results of The Study	57
4.1.1 Historical Data	57
4.1.2 Site Measured Data	61
4.1.3 Geometric Correction	67

4.1.4	Radiometric Correction	72
4.1.5	Image Normalization	76
4.1.6	Algorithms Development	80
4.1.7	Comparison of Developed Algorithm 6 and Existing Empirical Models from other Areas	98
	Comparison of Developed Algorithm 6 and Local Existing Empirical Models	105
4.1.9	TSS Prediction Maps for Different Years	112

## **CONCLUSION AND RECOMMENDATION**

Conclusion	119
Recommendations	124

## **REFERENCES**

**125**

## **APPENDICES**

**130**

## **BIODATA OF THE AUTHOR**

139