UNIVERSITI PUTRA MALAYSIA

JANAM
OIL SPILL DETECTION AND CONTINGENCY PLANNING USING RADAR IMAGERY AND GIS

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By

HAMID ASSILZADEH

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirement for the Degree of Doctor of Philosophy

April 2002

DEDICATION

To my dear family, my parents, brothers and sisters who have been my source of inspiration, wisdom and strength through the most difficult times of my life. I dedicate also this thesis to my lovely country mates who are the symbol of resistance.

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Doctor of Philosophy

OIL SPILL DETECTION AND CONTINGENCY PLANNING USING RADAR IMAGERY AND GIS

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HAMID ASSILZADEH

March 2002

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

Faculty: Engineering

Shipping casualties often resulted in serious accidental spills as experienced in the Straits of Malacca in the past decade. Operational remote sensing and geographic information system (GIS) are important tools for oil spill research and development activities. The use of remote sensing and GIS has been making important contributions to environmental monitoring, modeling and management. The combined use of remotely sensed images and GIS data has received considerable interest in recent years to protect human life, and reduce the environmental consequences of both spills and cleanup efforts. It is necessary to identify vulnerable coastal locations before a spill happens, and promptly perform removal actions when an oil spill occurs, so that the protection priorities can be established and clean-up strategies recognized. In this project an oil spill contingency plan has been created for the Straits of Malacca in three steps as follow: (a) SAR data such as RADARSAT has been used to detect and map oil spills pattern on the Malaysian coastal waters. Information on detection, exact position and size of the oil spill can be identified by

remote sensing in SAR images and then plotted on maps in GIS and a priority of the combat efforts and means according to the identified coastal sensitive areas can be carried out; (b) environmental sensitivity index (ESI) map; suggested to provide spill response teams with information about shoreline sensitivity and ranking based on vulnerability of the spill area. This map can show resources at risk in the event of an oil or hazardous substance spill; (c) Prediction of oil spill trajectory, using main seasonal surface currents and surface drift produced by winds. Hypothetical spill trajectories have been simulated for each of the potential launch areas across the entrance of the straits of Malacca. These simulations assumed more than hundred spills occurring in each seasons of the year from each launched area. A successful combating operation to a marine oil spill is dependent on a rapid response from the time the oil spill is reported until it has been fully combated. In order to optimize the decision support capability of the surveillance system for oil spill contingency planning, GIS database have been integrated with the detection tool. An automatic oil spill detection tool was established and information on the exact position and size of the oil spill is then visualized in GIS environment. The system offer opportunities for integration of oil drift forecast models by prediction of wind and current influence on the oil spill for risk assessment using EASI program in PCI software.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

PENGESAN TUMPAHAN MINYAK DAN PERANCANGAN KONTIGENSI MENGGUNAKAN IMEJ RADAR DAN GIS

Oleh

HAMID ASSILZADEH

March 2002

Pengerusi: Profesor Madaya Shattri Bin Mansor, Ph.D.

Fakulti: Kejuruteraan

Sektor perkapalan sering menyebabkan kemalangan yang serius sebagaimana yang dialami di Selat Melaka dalam dekad yang lepas. Sistem Penderian Jauh dan GIS merupakan alat yang penting dalam aktiviti penyelidikan dan pembangunan untuk kajian tumpahan minyak. Penggunaan sistem penderian jauh dan GIS telah memberikan sumbangan yang besar dalam pemantauan, pengurusan dan permodelan alam sekitar. Kombinasi penggunaan data dari imej penderian jauh dan GIS telah mendapat perhatian sejak kebelakangan ini dalam melindungi kehidupan manusia dan juga dalam mengurangkan kesan alam sekitar akibat daripada tumpahan minyak dan langkah pembersihan. Untuk tujuan ini, adalah perlu untuk mengenalpasti kawasan pinggir pantai yang terdedah kepada tumpahan minyak dan dengan ini usaha yang serta merta dapat dilakukan untuk mengatasi hal ini apabila ianya berlaku. Dengan ini strategi perlindungan dan langkah pembersihan dapat dikenalpasti. Untuk memenuhi keperluan di Selat Melaka, pelan kontigensi tumpahan minyak telah direkacipta di dalam tiga langakah seperti berikut: (a) Data

SAR contohnya RADARSAT telah digunakan untuk mengesan dan memetakan corak tumpahan minyak di perairan Malaysia. Maklumat tentang pengesanan, posisi yang sebenar dan saiz tumpahan minyak boleh dikenalpasti dengan menggunakan teknik penderian jauh dalam imej SAR dan kemudiannya diplotkan ke dalam peta menggunakan GIS. Dengan ini langkah pencegahan bagi kawasan pinggir pantai yang terdedah dapat dikenalpasti; (b) Peta indeks kepekaan Persekitaran (ESI) dıcadangkan bagi memberikan maklumat tentang kepekaan dan tahap garis pinggir pantai berdasarkan kepada kawasan yang terdedah kepada tumpahan minyak kepada pasukan yang bertindakbalas . Peta ini boleh menunjukkan sumber yang berisiko semasa kejadian tumpahan minyak atau bencana yang berkaitan dengannya; (c) Jangkaan trajektori tumpahan minyak menggunakan keadaan permukaan musim utama dan pergerakan di atas permukaan yang dihasilkan oleh angin; Hipotesis trajektori tumpahan minyak telah disimulasikan untuk setiap kawasan perlancaran yang berpotensi merentasi Selat Melaka. Di dalam mengoptimunkan keupayaan sokongan membuat keputusan bagi sistem pemantauan untuk perancangan kontigensi tumpahan minyak, pangkalan data GIS telah diintergrasikan dengan peralatan pengesanan. Simulasi ini mengandaikan lebih daripada ratusan tumpahan yang wujud bagi setiap musim untuk setiap tahun bagi kawasan yang dilancarkan. Operasi yang berjaya bagi tumpahan di lautan ini bergantung kepada tindak balas yang kerap dari masa tumpahan minyak dilaporkan sehinggalah ianya diatasi sepenuhnya. Untuk tujuan mengoptimakan keupayaan sokongan keputusan untuk sistem pengesanan bagi pelan kontigensi tumpahan minyak, pangkalan data GIS telah diintegrasikan dengan alat pengesan. Alat pengesan automatik tumpahan minyak telah dikenal pasti dan maklumat posisi sebenar dan saiz tumpahan minyak kemudiannya divisualkan dalam persekitaran GIS. Sistem ini menawarkan satu keupayaan untuk mengintegrasi model ramalan hanyutan minyak dengan membuat jangkaan pengaruh angin dan semasa ke atas tumpahan minyak untuk penilaian risiko dengan menggunakan program EASI yang terdapat dalam perisian PCI.

ACKNOWLEDGEMENTS

I am most indebted and grateful to Associate Professor Dr. Shattri Bin Mansor, Ph.D. who has guided and supported me along the way and given me a lot of constructive comments, advice, and ideas, and finally for his kind friendship. He is certainly the person who is responsible for the successful completion of this study.

I would like to extend my gratitude to the members of my Supervisory Committee, Prof. Dr. Mohd. Ibrahim Hj Mohd, and Dr. Abdul Rashid Mohamed Shariff for their advice, kind and constant support, encouragement and omnipresence at all my difficulties. My appreciation also goes to Mr. Ahmad Rodzi Mahmud for his interest and guidance in my project.

This research was made possible through the financial support of the Ministry of Science, Technology and Environment, Malaysia (IRPA grant), which is highly appreciated. I would like to acknowledge support from Department of Environment (DOE), Malaysia Meteorological Service Department (MMS), Malaysia Center of Remote Sensing (MACRES), for various aspects of the project to make it successful.

Special thanks to my friends for all their patience, kind help and morale support. Many thanks to Ali Mashinchian and his wife Lisa Pourlak, Dr. Peyman Roostaeian and Javad Khadem Sameni, Wong Tai Hong, Nor Aizam Binti Adnan and all my other friends who contributed so much indirectly towards this achievement. Special thanks to Laura Sanchez my best friend.

I certify that an Examination Committee on 26th Appril 2002 to conduct the final examination of Hamid Assilzadeh on his Doctor of Philosophy thesis entitled "Application of remote sensing and geographic information system for oil spill contingency planning in the Straits of Malacca" in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Putra Malaysia (Higher Degree) Regulations 1981. The Committee recommends that the candidate be awarded the relevant degree. Members of the Examination Committee are as follows:

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DECLARATION

I hereby declare that the thesis is based on my original work except for quotations and citation, 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.

Hamid Assilzadeh

Date:

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LIST OF ABBREVIATIONS

APC:	Antenna Pattern Correction
ASA:	Applied Science Associates
ASEAN:	Association of South East Asian Nations
CASI:	Compact Airborne spectrographic Imager sensor
CCRS:	Canada Center for Remote Sensing
CCRS:	Canadian Center for Remote Sensing
DBIC:	Database Input Channel
DBOC:	Database Output Channel
DN:	Digital Number
DOE:	Department of Environment
DSS:	Decision Support System
EASI:	Engineering Analysis and Scientific Interface
ESI:	Environmental Sensitivity Index
FLI:	Flourescence Line Imager
GCP:	Ground Control Point
GEMS:	Marine Department of Environmental Management System in USA
GIS:	Geographical information system
GLCM:	Gray level co-occurrence matrix
IAS:	Image Analysis System
LDIAS:	Landsat Digital Image Analysis System
LEAF:	Laser Environmental airborne fluorosensor
MEIS II:	Multi-spectral Electro-optical Imaging Scanner sensor

MOSIS:	Marine Oil Spill Information System
Nbr:	Neighbor pixel
NLOOK:	Number of Looks
NOCC:	National Oil Spill Control Committee
NRDA:	Natural Resource Damage Assessment Model
Oil SCAN:	Oil Spill Contingency and Navigation System
OSC:	On Scene Commander
OSPAR:	Oil Spill Preparedness and Response in Asia
PACE:	Picture Analysis, Correction, and Enhancement
PMI:	Programmable Multi-spectral Imager
PMR:	Power-to-mean ratio
Ref:	Reference pixel
RPI	Research Planning Institute
SAR:	Synthetic Aperture Radar
SARBETA:	PCI function generates a radar brightness
SARGEO:	PCI function creates a geocoded SAR image
SCAL:	Gray Level Scaling program in PCI
SI:	Spill Impact
SIS:	Spatial Information System
SLAR:	Side-looking Airborne Radar
TEX:	PCI function produces several output based on texture analysis
WQ:	Water Quality

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Malaysian coastal and marine environment contain many species, habitats and other resources that could be severely affected by oil pollution. The most sensitive areas are coastal areas where oil can strand on the foreshore. The Straits of Malacca is located west of Peninsular Malaysia and it is an important and unique water body. A unique, tropical estuarine environment, rich in renewable and non-renewable natural resources characterizes the Malacca Strait. For the local communities, the Straits host a large marine fishery sector and numerous aquaculture and mariculture ventures. At a national level, the three littoral states rely greatly either on the production of rich natural resources or on trades/shipping business associated with the Straits. Finally, the importance of the Straits to international users is reflected in the high tonnage of goods carried through the Straits.

The Malacca Straits is considered highly vulnerable to pollution risk due to increased maritime activities and rapid industrial developments along the coastal areas causing deterioration of the marine and coastal ecosystems. The most important risk is that associated with possible oil spills from tankers crossing the Straits of Malacca. There are several reports since 1975 on the number and extent of these oil spills in the Straits of

Malacca (Calow, 1997). According to these records the southwestern coast of Johor state up to Melaka are areas at highest risk. This area is vulnerable due to presence of different kinds of environmental reservoirs, natural resources and anthropogenic activities. Managing and reducing pollution risks in the Straits will require concerted efforts among users and bordering littoral states. Such efforts were initiated by GEF/UNDP/IMO Regional Program for the Prevention and Management of Marine Pollution in the East Asian Seas, including Environmental Profile (1997) and Initial Risk Assessment (1997), prepared by Professor Peter Calow and Dr. Valery E. Forbes.

On the other hand, development of space technology in Malaysia was driven initially by its effort to use space remote sensing technology for natural resources and environmental management in 1990s. Despite having a short history in space technology, Malaysia has already made significant impacts towards achieving selected capabilities in this technology - through the launching of MEASAT-1 communication satellite in 1997. In the ground segment, Malaysia is currently implementing a project to acquire a satellite remote sensing ground receiving station to facilitate real-time reception of high-resolution data to meet the national need for a more effective environmental monitoring and natural resources management. These include monitoring of forest fires that lead to recent serious haze problem, illegal forest logging, and oil spill in the surrounding waters. In the field of oil spill detection, and environmental impact assessment, this technology has already been widely utilized.