BASIN MODELLING USING GIS

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CIVIL ENGINEERING

UNIVERSITI TEKNOLOGI PETRONAS

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Basin Modelling Using GIS

By

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Dissertation submitted in partial fulfilment of
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CERTIFICATION OF APPROVAL

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Approved by,

(A.P. Dr. Abdul Nasir bin Matori)

UNIVERSITI TEKNOLOGI PETRONAS
TRONOH, PERAK
June 2010

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, thah the original work is my own except as specified in the references and acknowledgements, and that the original work contained herien have not been undertaken or done by unspecified soirces or persons.

AHMAD SAFUAN BIN AHMAD HUSNI

ABSTRACT

The aim of this projet is to locate potential hydrocarbons area by overlaying the elements of hydrocarbons accumulation simultaneously in GIS software. It is not reliable to locate a potential hydrocarbon reserves based on a single data of an element only in a single time. The elements which include source rocks, migration routes, reservoir rocks, traps and seals are needed to be assessed simultaneously to reduce error in locating potential hydrocarbons area that will contribute to the petroleum exploration risk. In completion of this project, several procedures had been implemented. It includes GIS software familiarization, data gathering, GIS database development, conduct anlaysis and discussion of the results. Finally, the results are obtained. The discussions of the results are based on the relationship between the elements of hydrocarbons accumulation.

ACKNOWLEDEMENT

In the name of Allah, the Most Gracious, the Most Merciful. Praise to Him the Almighty, that in His will given strength, I managed to complete this Final Year Project.

I would like to express my appreciation to my supervisor, Assc. Prof. Dr. Abdul Nasir bin Matori, whose continuous help, support and guidance had played an important role in the completion of this project.

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TABLE OF CONTENTS

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

1. INTRODUCTION

1.1 Background of Study

1.1.1 What is Geographic Information System (GIS)?

Geographic Information System (GIS) is a technological field that incorporates geographical features with tabular data in order to map, analyze, and assess real-world problem [1]. GIS is the merging of cartography and database technology [2]. GIS systems are utilised in cartography, remote sensing, land surveying, photogrammetry, geography, urban planning, emergency management, navigation, and localized search engines. GIS is a system that has limitations that may be use for which a specific GIS is developed. In general, the term describes any information system that integrates, stores, edits, analyzes, shares, and displays geographic information [2]. In another word, GIS applications are tools that allow users to create interactive queries, analyze spatial information, edit data, maps, and present the results of all these operations. A GIS helps user answer questions and solve problems by looking at the respective data in a way that is quickly understood and easily shared [3].

1.1.2 What is Basin (reservoir) and Prospect?

Basin (reservoir) is a region in where there is accumulation of hydrocarbons contained in porous or fractured rock formations [4]. The naturally occurring hydrocarbons are trapped by overlying rock formations with lower permeability [4].

Prospect is a potential trap which geologists believe may contain hydrocarbons [5]. A sufficient amount of geological, structural and seismic investigation must first be completed to prove as a prospect. Five elements have to be present for a prospect to work and if any of them does not present, hydrocarbons will not be accumulate.

Elements for a prospect to work and hydrocarbons accumulation are:

1. Source rocks
2. Migration routes
3. Reservoir rocks
4. Seals
5. Traps

Conditions that must be fulfilled for accumulation of hydrocarbons are:

1. There must be an organic-rich source rock to generate hydrocarbons.
2. The source rock must have been heated sufficiently to yield its hydrocarbons.
3. There must be a reservoir to contain the expelled hydrocarbons. The reservoir must have porosity to contain the hydrocarbons and permeability to permit fluid flow.
4. The reservoir must be sealed by an impermeable cap rock to prevent the upward escape of petroleum to the earth's surface.
5. Source, reservoir and seal must be arranged in such a way as to trap the hydrocarbons.

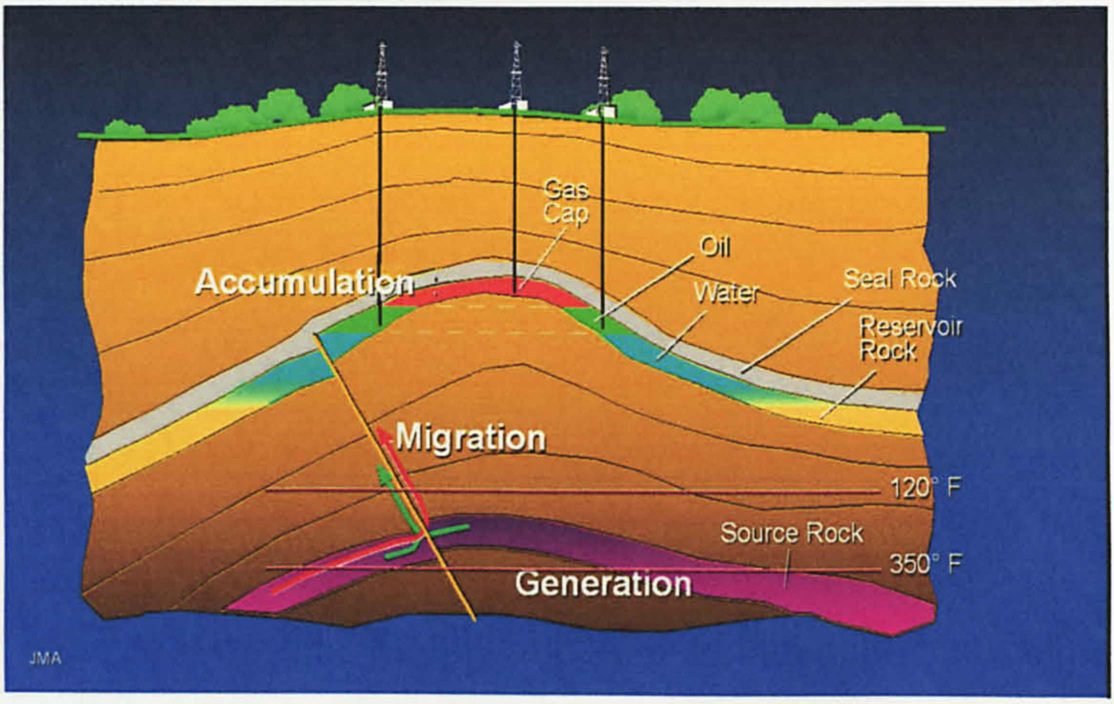

Figure 1.1: Illustration of Hydrocarbons Accumulation

Source: http://faroq.files.wordpress.com/2009/06/petroleum-system.jpg

1.1.3 What is Basin Modelling?

Basin modelling is analysis of formation and evaluation of sedimentary basins and evaluation of potential hydrocarbon reserves [6]. Basin modeling also can be defined as the process of using either proprietary or commercially available software to assess charge risk by integrating diverse geological and engineering data types into a model of hydrocarbons accumulation in an area being explored. It is commonly applied by a group of geological disciplines. It can be used to analyse the formation and evaluation of sedimentary basins, often but not exclusively to aid evaluation of potential hydrocarbon reserves.

1.2 Problem Statement

At present, it is feasible to make a lot of predictions on the hydrocarbon potential of an area during the initial stages of exploration. In this stage, oil and gas companies such as PETRONAS, Shell and ExxonMobil have spend millions of dollars. In order to maximize the return of the significant investment, the petroleum exploration risk must be reduced. There are several risks that must be addressed prior to locate a potential hydrocarbon area; source rocks, migration routes, reservoir rocks, traps and seals. All of these elements must be in-place for an exploration to be successful. Assessing the source rocks, migration routes, reservoir rocks, traps and seals are routine tasks of oil and gas companies in exploration stage. So it is essential for the companies to do basin modelling on a routine basis. It is less efficient to locate a potential hydrocarbon reserves based on a single data of an element only (e.g. source rocks data, reservoir rocks data, seals data or traps data) in a single time. These elements need to be assessed simultaneously to reduce error in locating potential hydrocarbon area which will contribute to the petroleum exploration risk.

1.3 Objective

The objective of basin modelling using Geographic Information System (GIS) particularly as the interactive tool is:

- To locate potential hydrocarbons area by overlaying the elements of hydrocarbons accumulation simultaneously in GIS software.

1.4 Scope of Study

In order to complete this project, Angsi Oilfield of Peninsular Malaysia Offshore (PMO) has been selected as the location of study. Angsi Oilfield is situated in Malay Basin which is located at South China Sea.

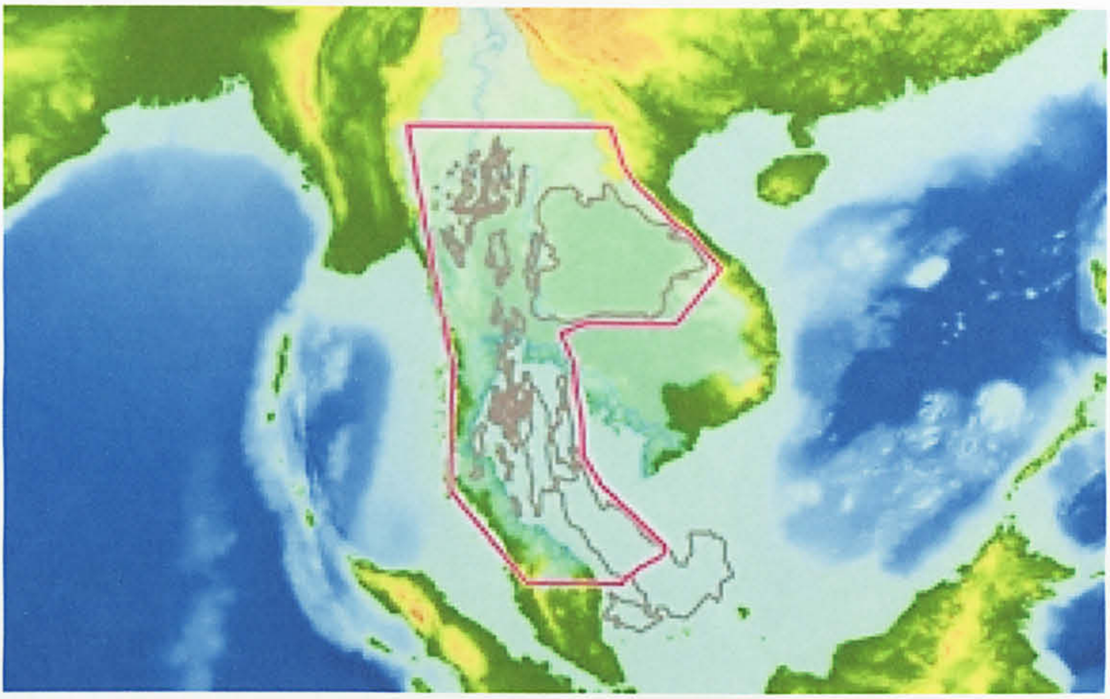

Figure 1.2: Location of Malay Basin

Source: http://www.getech.com/interpretation/indochina.htm

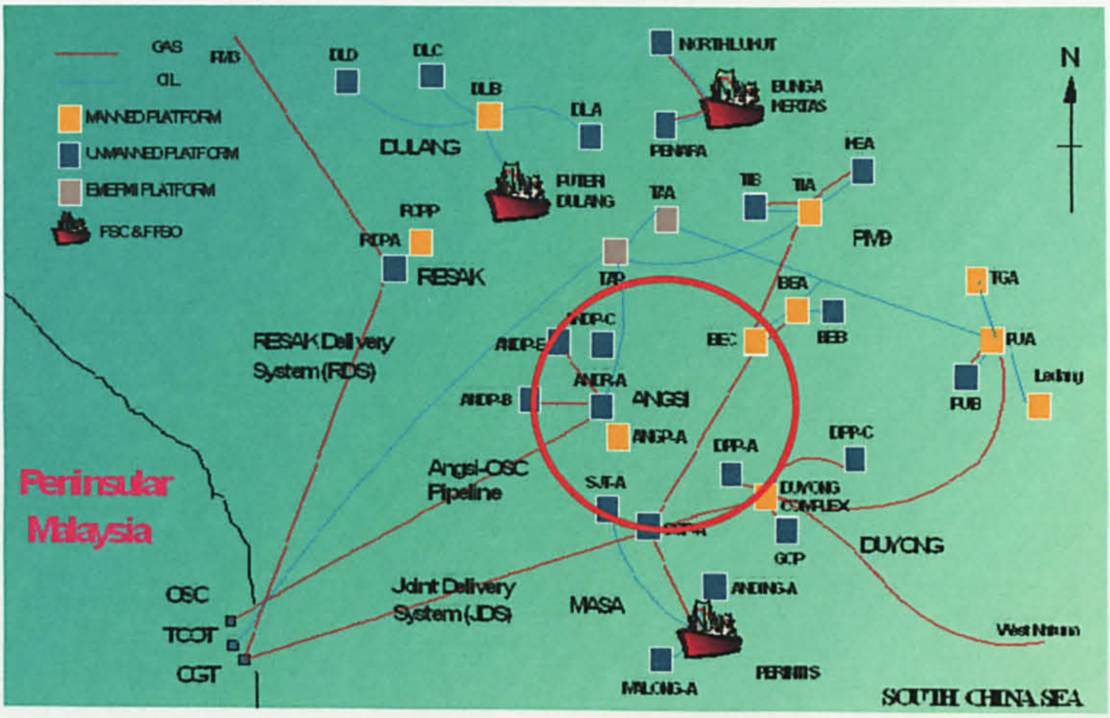

Figure 1.3: Location of Angsi Oilfield

CHAPTER 2

LITERATURE REVIEW

2. LITERATURE REVIEW

2.1 Geographic Information System (GIS)

Geographic Information System (GIS) is a broadly used software system for storing, managing, analyzing, and visual expressing geographic information (Goodchild, 1991). GIS's influential spatial analysis functions have made it find wider and wider application in the field of petroleum exploration, including analysis of sedimentary environments, simulation of hydrocarbon migration and accumulation, paleao-tectonic evolution study and three-dimensional reconstruction of oil and gas-bearing basin, resource evaluation, and reservoir classification, etc. (Li et al., 1998; Ramos-Scharro´ n et al., 2007; Hua et al., 2006; Sawunyama et al., 2006; Paulus, 2000; Hood et al., 2000; Day et al., 2000; Yero-Batista et al., 2002; Grace, 2001; Liu et al., 2003a, b). However, application modules provided by general GIS software are often inadequate. To develop the capability of a general GIS, second development is usually necessary to allow expert's knowledge in some special field to be embedded inside. The complexity of the hydrocarbon migration mechanism determines that the migration pathways are unable to be modelled with common functions offered by general GIS software. In this study, a GIS-based method is presented to simulate the pathways of secondary hydrocarbon migration, in which geologic mechanisms of hydrocarbon migration and accumulation are integrated with special analysis functions of GIS.

2.3 Petroleum System

Once generated, hydrocarbon will usually migrate a certain distance until it arrives at a proper site, i.e., the so-called 'trap', and accumulates there. Two stages of migration are defined in petroleum geology: one is the primary migration, which is understood as the emigration of hydrocarbons from the source rock (clay or shale) into permeable carrier beds (generally sands or carbonate), the other is the secondary migration, which is referred to as the subsequent movement of oil and gas within permeable carrier beds or reservoirs. Secondary migration is mainly driven by difference between buoyancy and capillary pressure (Selley, 1998). In the scale of a basin, a carrier bed can be regarded as approximately homogeneous, and hydrocarbons within it migrate along the directions of the maximum driving force. Thus the hydrocarbons expelled from the source rocks will be migrated up-dip along directions perpendicular to the strike of a carrier bed, and this makes the modelling of secondary migration route possible (Catalan et al., 1992; England et al., 1987).

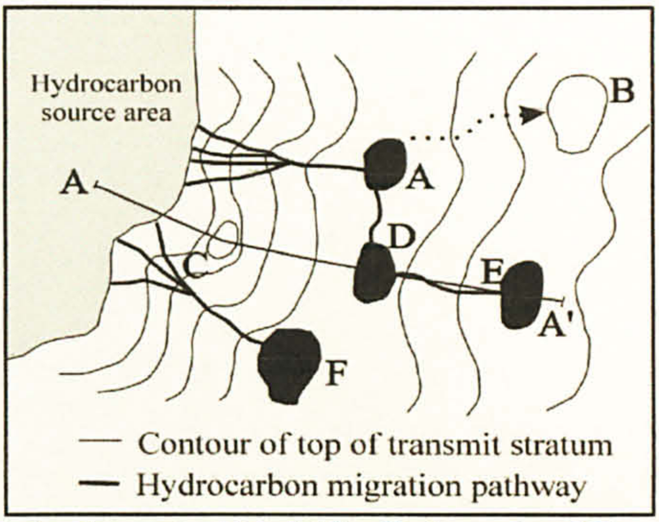

Figure 2.1: Geologic Conceptual Model for Hydrocarbon Migration (Hao et al., 2002).

Considering Figure 2.1 as an example, the hydrocarbon-generation depression or source area is located at the upper-left corner, and the reservoirs and traps are situated in the middle and right parts of the figure. When the hydrocarbons are generated and expelled from the source area on the upper-left corner, the secondary migration commences. If poor potentiality of hydrocarbon generation exists in the source area and only a small amount of hydrocarbons is generated, the hydrocarbons expelled from the source area will not be enough to fill up the traps adjoining to the source area, for example, traps A and F in Figure 2.1 and the hydrocarbon migration process will terminate at traps A and F. If the amount of hydrocarbons expelled is more than enough to fill up the adjacent traps (A and F in Figure 2.1), the excessive hydrocarbons will continue to migrate upwards by taking other pathways within the carrier bed until arriving at a new trap, for example, from trap A to trap D along path A–D or even Trap E along path A–D–E. Generally, structural ridges at the top of a carrier bed are regarded as advantageous paths for secondary hydrocarbon migration (Hindle, 1997), and the excessive hydrocarbons are likely to make a long distance migration along the structural ridges before their final accumulation at a suitable trap (Li, 2006; Hao et al., 2002).

2.2 Basin Modelling

Basin modelling is an important approach for exploration and development geologists to understand hydrocarbon migration processes. In recent years, many authors have attempted to simulate the history of hydrocarbon migration and accumulation from different aspects and by different methods (Ungerer et al., 1984, 1988, 1990; Hindle, 1997; Hantschel et al., 2000; Wu et al., 2001; Shi and Zhang, 2004). Ungerer et al. (1984, 1988, 1990) presented an integrated two-dimensional basin simulation model in which heat transfer, fluid flow, hydrocarbon generation and migration were involved. Hindle (1997) simulated hydrocarbon migration pathways using three-dimensional ray tracing techniques. Hantschel et al. (2000) made a research on modeling of petroleum migration using finite element analysis and ray tracing methods. Wen and Hao (2001) simulated the pathway and process of hydrocarbon migration and accumulation in Liaohe oilfield, northeast China, using artificial intelligence and visual reality techniques. Using artificial neural network method, Wu et al. (2001) made a qualitative research on hydrocarbon migration and accumulation process in the Zhusan Depression on the northern margin of the South China Sea. These researches have greatly advanced the study of hydrocarbon migration.

CHAPTER 3

METHODOLOGY

3. METHODOLOGY

3.1 Project Procedure and Methodology

Figure 3.1 shows the summarization of the project procedure and methodology that had been implemented in the project timeframe. This project was based on the research and development which some method of basin modelling had been studied and another method of basin modelling by using GIS tools is to be proposed.

In the early development stage, research in several topics was done to get deep understanding about the project. This includes the petroleum systems and petroleum reservoir modelling. The purpose of petroleum systems research is to understand how the hydrocarbons are produced and to know the elements that need to be present for hydrocarbons to be produced. The purpose for doing research about petroleum reservoir modelling is to know the concept that can be applied in this project.

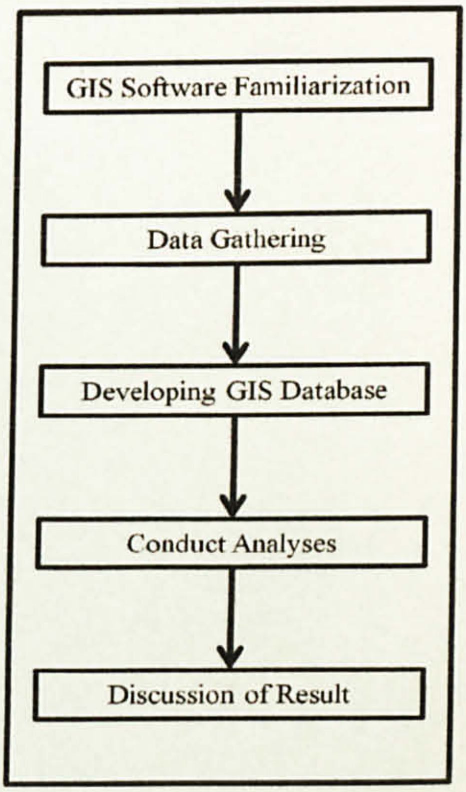

Figure 3.1: Project Methodology

3.1.1 GIS Software Familiarization

The familiarization of GIS software is essential as it will contribute a lot throughout the project. The GIS software which was been using is ArcView GIS 3.2a. An initiative is taken in order to familiarize with the software as this software was never been taught in any courses in UTP Civil Engineering Curriculum Structure. In acquiring some ideas on how to run the software, several journals and manuals were reviewed. Tutorial sessions from the project supervisor, Assoc. Prof. Dr. Abdul Nasir Matori, was also conducted in familiarizing the software.

ArcView GIS 3.2a by ESRI was been used throughout the project. ArcView is powerful software that provides for visualizing, querying, exploring, and analyzing data geographically. ArcView encompasses a wide variety of operations which work as a powerful GIS tool that can display information, read spatial and tabular information from a variety of data formats, access external databases, produce thematic maps, perform spatial queries, connect spatial information to database attributes and provide several analytical tools. The operations which have conducted are:

i. Showing the geographic distribution of data
ii. Querying GIS data
iii. Overlaying different layers
iv. Doing a complex analysis

3.1.2 Data Gathering

The Angsi Oilfield spatial data of source rocks, migration routes, reservoir rocks, traps and seals are requested from Petroleum Management Unit (PMU) of PETRONAS. Unfortunately, PMU only managed to deliver the Angsi Oilfield raster data except the migration routes. Hence, the raster data are needed to be digitized in order for the project to continue.

3.1.2.1 Assumptions Made

After several discussions with the project supervisor and due to unavailability of data, the migration routes data will not be considered at all. This is because the migration routes are not possible to be translated in terms of drawing as it cannot be viewed physically. So it is assumed that migration routes are towards the traps.

3.1.3 GIS Database Development

The Angsi Oilfield raster data which are received from PMU need to be digitized. Subsequently, the raster data of source rocks, reservoir rocks, traps and seals are required to be drawn as Computer Aided Drafting (CAD) files format by using AutoCAD 2004. The CAD files format has to be converted to the GIS shapefiles format which is required in the software as all the maps were drawn using AutoCAD 2004. The maps were drawn in a scale of 1:10000 (1 AutoCAD unit = 1 m). Consequently, the GIS shapefiles format data need to be entered and arranged properly in to the GIS software. The entered data are to be input into layers. All of the layers are need to be overlaid together in the software.

3.1.3.1 Converting CAD files to GIS shapefiles

After the map data of source rocks, migration routes, reservoir rocks, traps and seals had been drawn as CAD files format (.dwg) using AutoCAD 2004, it was saved as .dxf. Next, the data is opened by using the GIS software. Finally, the data is converted to .shp by clicking on the tab Theme > Convert to Shapfile.

Figure 3.2 illustrates how CAD files can be converted to GIS shapefiles.

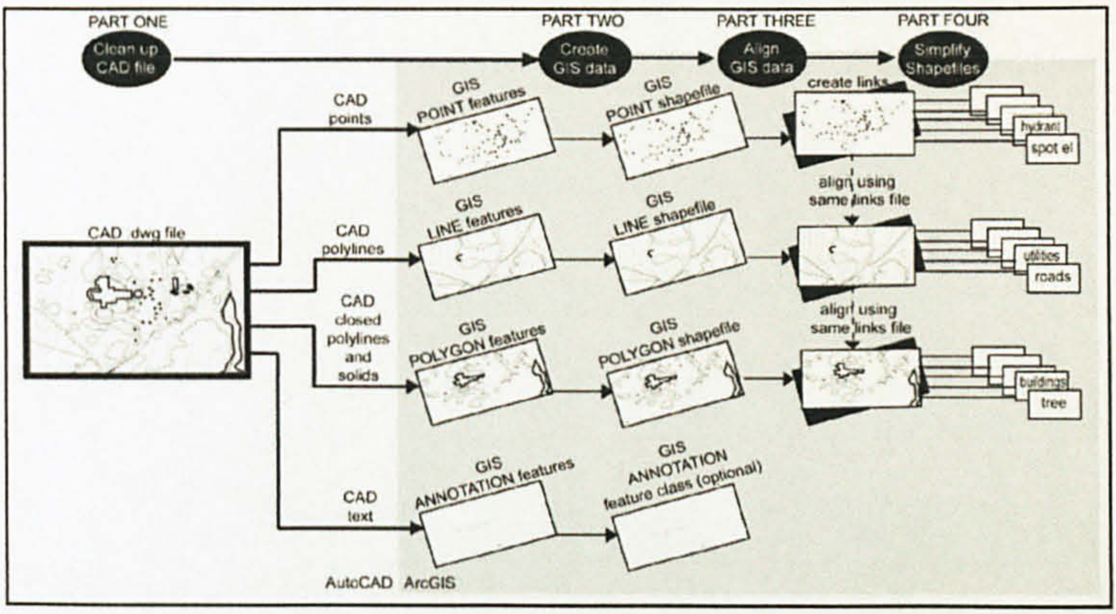

Figure 3.2: Flow Chart of How .dwg Converts to .shp

3.1.3.2 Layering

All the drawings in CAD files format (.dwg) that have been converted into GIS shapefiles format (.shp) were arranged into layers that will followed by conducting the analysis.

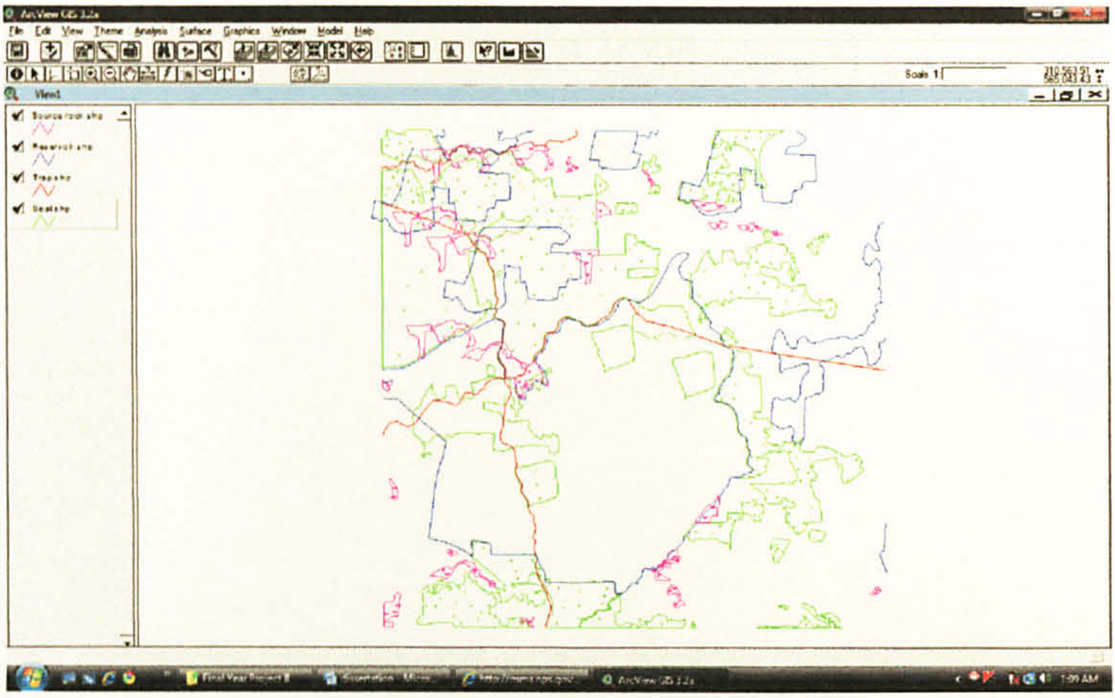

Figure 3.3: Layers of Angsi Oilfield Source Rocks, Reservoir Rocks, Traps and Seals data

3.1.4 Conduct Analysis

Analysis of the Angsi Oilfield data layers was conducted in order to locate the potential hydrocarbons area. The data are overlaid with different arrangement as it will give the best result in finding the potential hydrocarbons area. The area that fulfilled the conditions for hydrocarbons accumulation is expected to contain hydrocarbons.

3.1.5 Discussion of Results

Results of the analysis were discussed after conducting analysis of the data. The relationship between the data has contributed in the analysis. Finally, the conclusion was made solely based on the discussions.

CHAPTER 4

RESULTS AND DISCUSSION

4. RESULTS AND DISCUSSION

4.1 Results

The data of source rocks, reservoir rocks, seal rocks and traps are fully needed in order to locate hydrocarbons. All of data need to be overlaid and the intersect region will be much anticipate to contain hydrocarbons.

Below are the results so far which consist of Angsi Oilfield data of source rocks, reservoir rocks, seal rocks and traps.

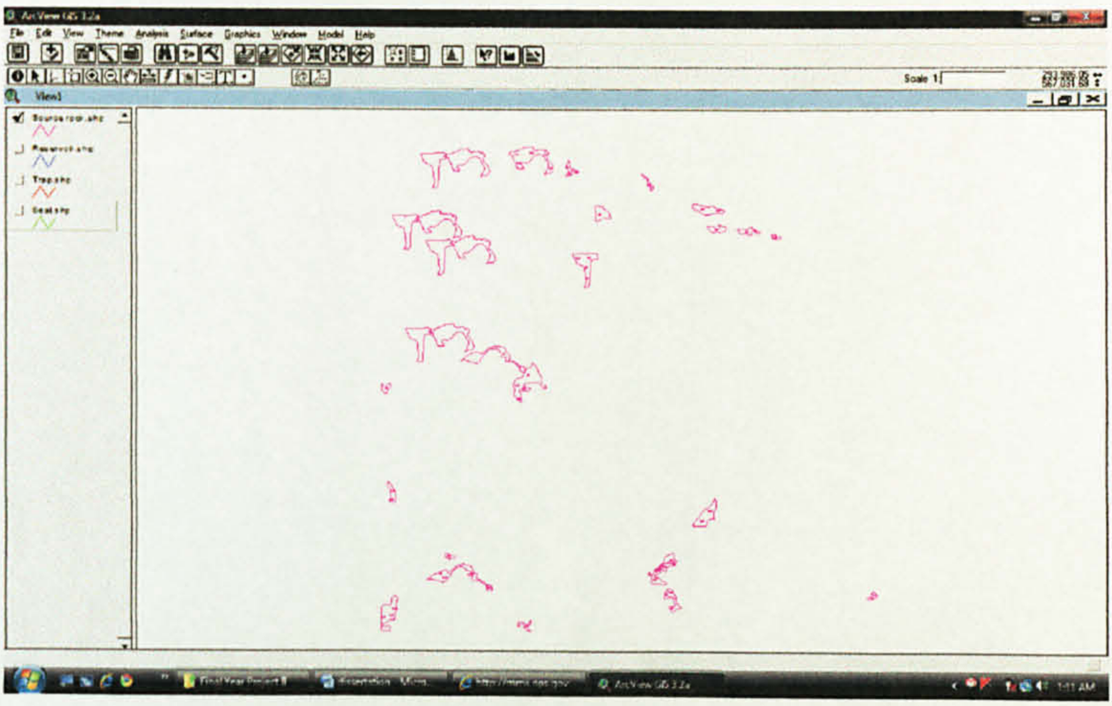

Figure 4.1: Data of Source Rocks

Figure 4.2: Data of Reservoir Rocks

Figure 4.3: Data of Seals

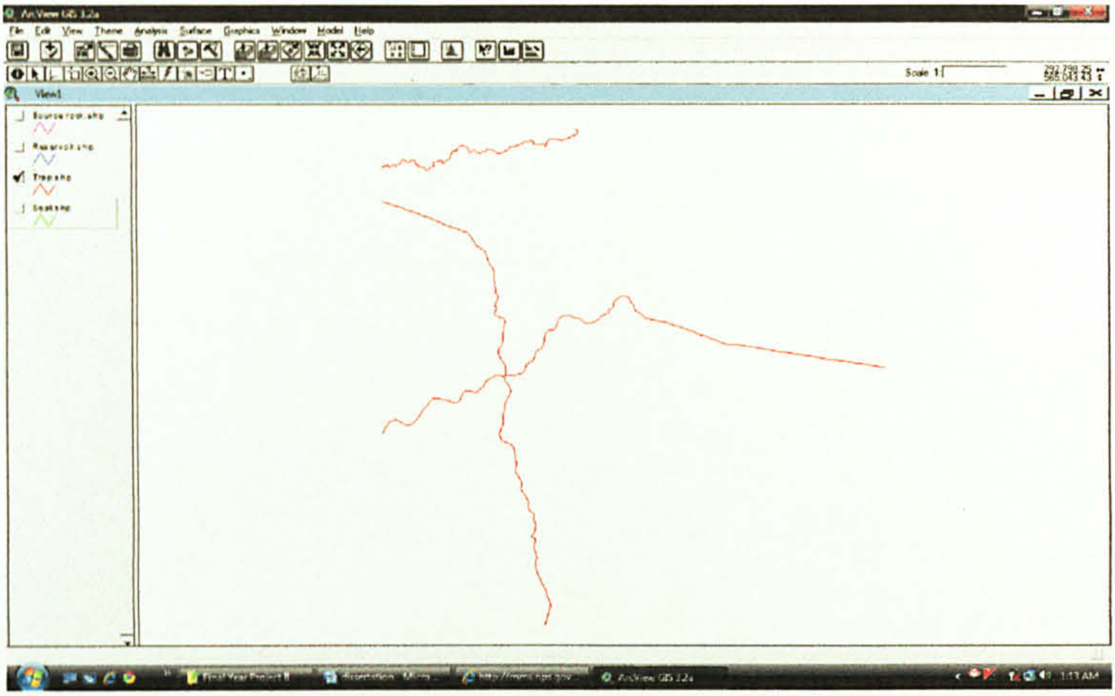

Figure 4.4: Data of Traps

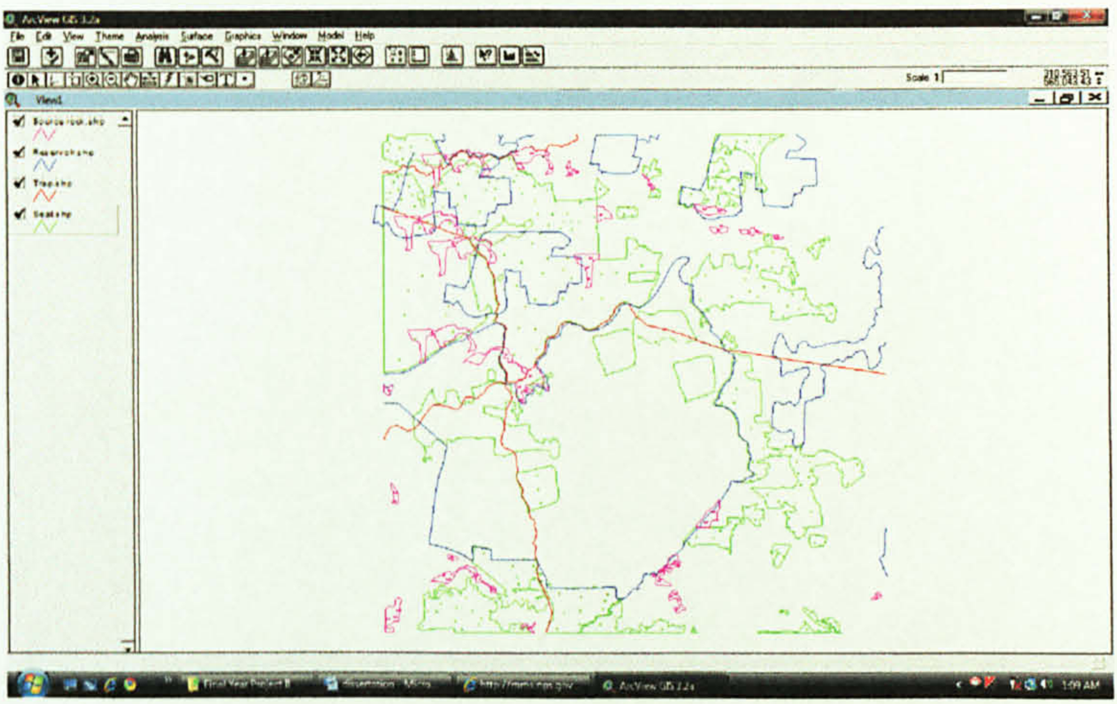

Figure 4.5: Data of Source Rocks, Reservoir Rocks, Seals and Traps are overlaid

4.2 Discussion

4.2.1 Relationship between Source Rocks and Traps

The hydrocarbons that have been expelled by the source rocks are contained in the reservoir rocks. Before it can be contained, the hydrocarbons are needed to be trapped. The hydrocarbons are buoyant and have to be trapped within a structural or stratigraphic trap.

Based on the intersection of source rocks data and traps data, several areas have been identified. Figure 4.6 shows the intersectional areas which are dubbed to contain hydrocarbons.

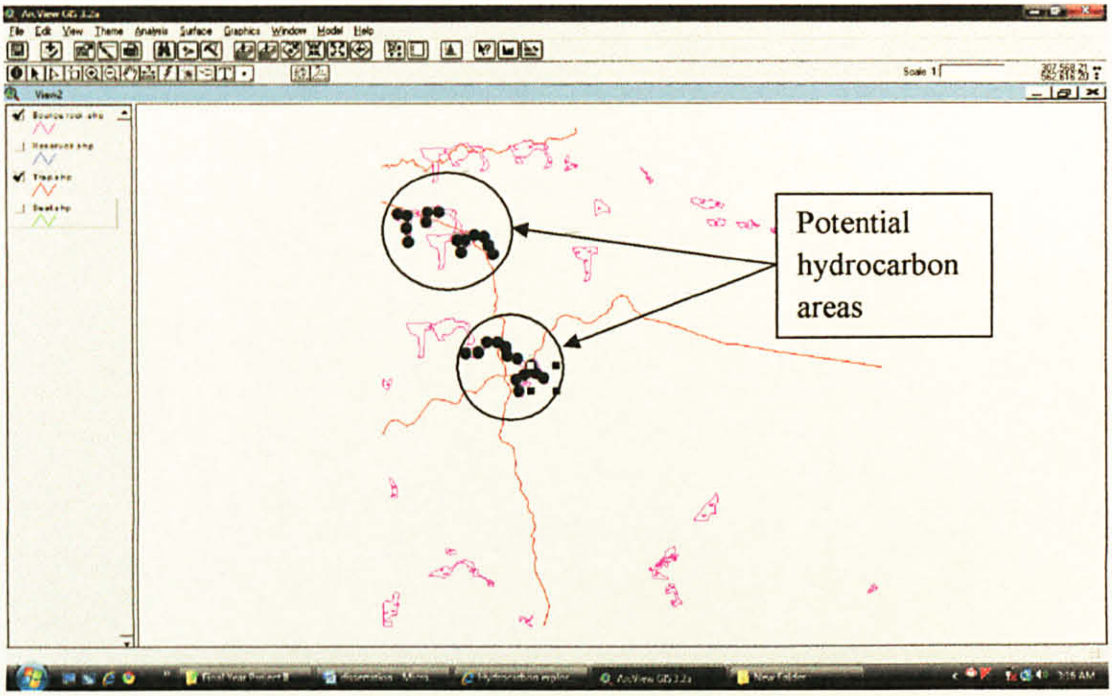

Figure 4.6: Data of Source Rocks Overlaid With Data of Traps

4.2.2 Relationship between Source Rocks, Traps and Reservoir Rocks

The hydrocarbons are contained in reservoir rocks. The reservoir rocks have the porosity and permeability for the hydrocarbons which had been expelled by the source rocks to migrate into the reservoir rocks.

Several areas have been identified to contain potential hydrocarbons. It was based on the intersection of the source rocks and reservoir rocks. It was assumed that the intersectional areas have the possibility for containing hydrocarbons. The intersectional areas can be viewed in Figure 4.7.

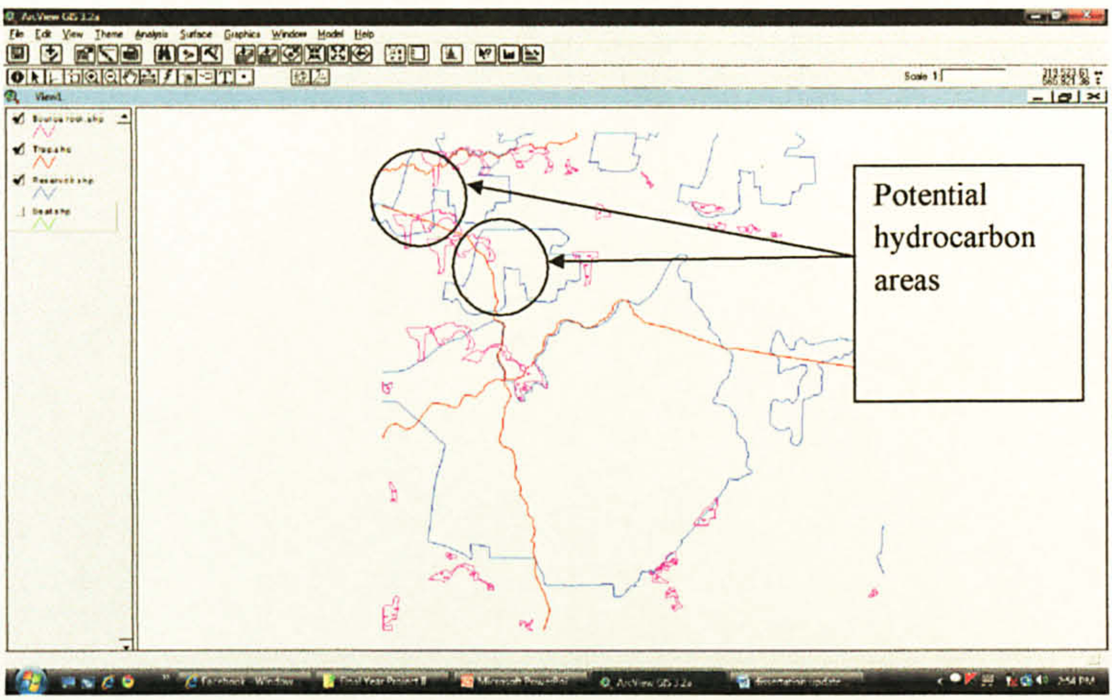

Figure 4.7: Data of Source Rocks Overlaid With Data of Traps and Reservoir Rocks

4.2.3 Relationship between Source Rocks, Traps, Reservoir Rocks and Seals

The highest possibility for areas to contain hydrocarbons can be found when the data of source rocks, reservoir rocks, traps and seals are overlaid together. The areas should have a right amount of source rocks to generate hydrocarbons, reservoir rocks to contain the hydrocarbons, traps for hydrocarbons to be trapped in the reservoir rocks and seals that prevent the hydrocarbons from escaping to the surface. Figure 4.8 shows the areas that have the highest possibility to contain potential hydrocarbons.

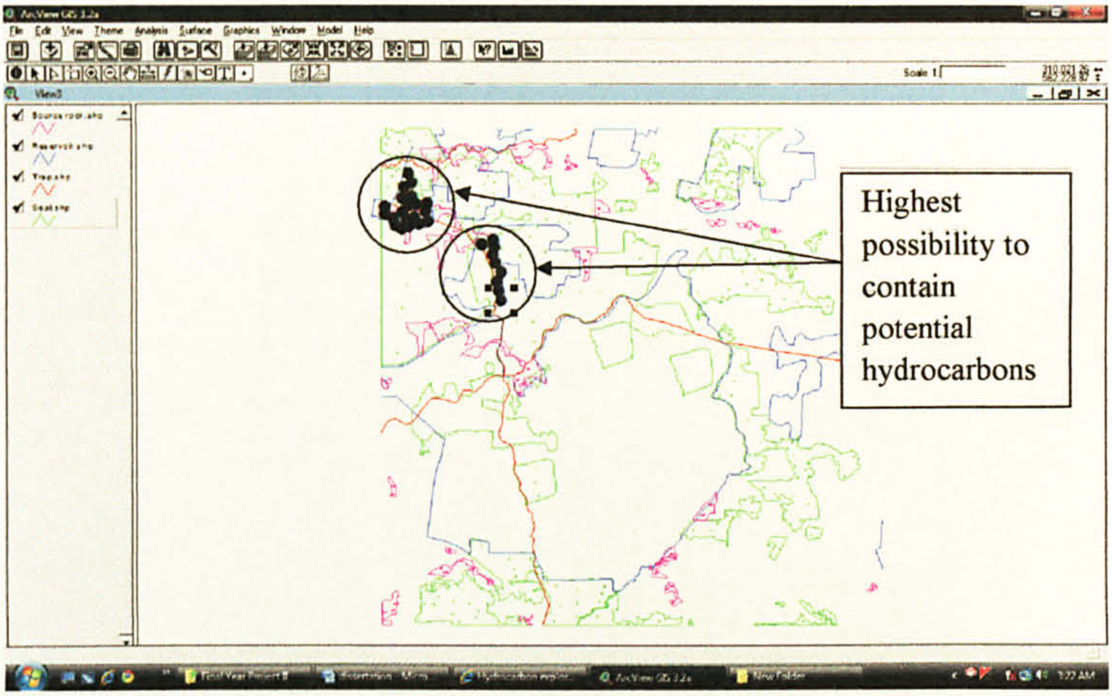

Figure 4.8: Data Source Rocks, Traps, Reservoir Rocks and Seals are overlaid together

CHAPTER 5

ECONOMIC BENEFITS

5. ECONOMIC BENEFITS

GIS benefits organizations in almost every industry. There is a growing awareness of the economic and strategic value of GIS, in part because of more standards-based technology and greater awareness of the benefits demonstrated by GIS users. The benefits of GIS generally can be described into three basic categories:

5.1 Cost savings resulting from greater efficiency

These are associated either with carrying out the objective or improvements in the objective itself. The greater the efficiency of GIS usage in the project will boost the cost savings.

5.2 Better decision making

This typically has to do with making better decisions about location. Common examples include zoning, planning, conservation, natural resource extraction, etc. People are beginning to realize that making the correct decision about a location is strategic to the success of an organization.

5.3 Better geographic information recordkeeping

Many organizations have a main responsibility of maintaining authoritative records about the status and change of geography. Cultural geography examples are zoning, population census, land ownership, and administrative boundaries. Physical geography examples include source rocks inventories, traps inventories, environmental measurements and a whole host of geographic accountings. GIS provides a reliable framework for managing these types of systems with full transaction support and reporting tools. These systems are conceptually similar to other information systems in that they deal with data management and transactions, as well as standardized reporting (e.g., maps) of changing information.

CHAPTER 6

CONCLUSION AND RECOMMENDATION

6. CONCLUSION AND RECOMMENDATION

6.1 Conclusion

It can be concluded that the project has achieved the objective. The objective has been set to locate potential hydrocarbons area by overlaying the elements of hydrocarbons accumulation simultaneously in the software. The methodology that has been used which includes GIS software familiarization, data gathering, developing GIS database, conduct analysis and discussion of result are really important in achieving the objective.

6.2 Recommendation

There are several recommendations can be made for future expansion of the project. These recommendations have the potential to be successful in achieving much kind of objectives and purposes. The recommendations are as follow:

- The data that have been used in the project do not have the attribute of elevations. If the elevations attribute are present, the volume of potential hydrocarbons can be estimated.
- Newer version of GIS software would provide more extension of GIS software. So analysis of data will be easier and efficient. It also will give more detailed analysis and further research on any particular project.

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[4] website refer to http://en.wikipedia.org/wiki/Petroleum_reservoir

[5] website refer to http://en.wikipedia.org/wiki/Hydrocarbon_exploration

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APPENDICES

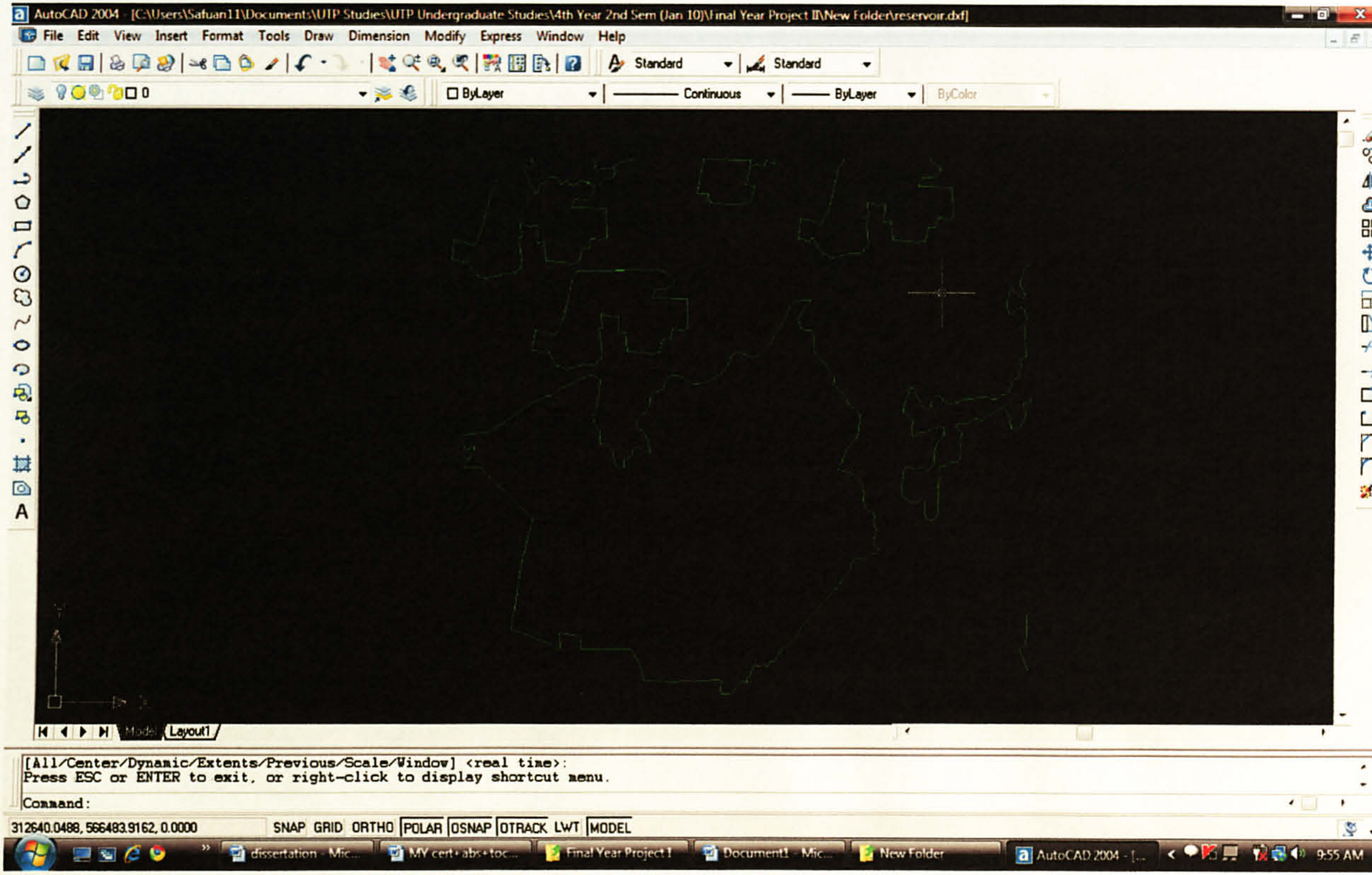
Appendix 1: Gantt Chart for Final Year Project 1

No.	Details/Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Selection of Project Topic														
	Proposal Topic														
	Confirmation of topic selection														
2	Preliminary Research Work														
	Literature Review														
	Familiarize with GIS software														
3	Submission of preliminary report			X											
4	Literature Review														
	Familiarize with GIS software														
5	Submission of Progress Report							X							
6	Literature Review														
	Familiarize with GIS software														
8	Submission of Interim Report													X	
9	Oral Presentation														X

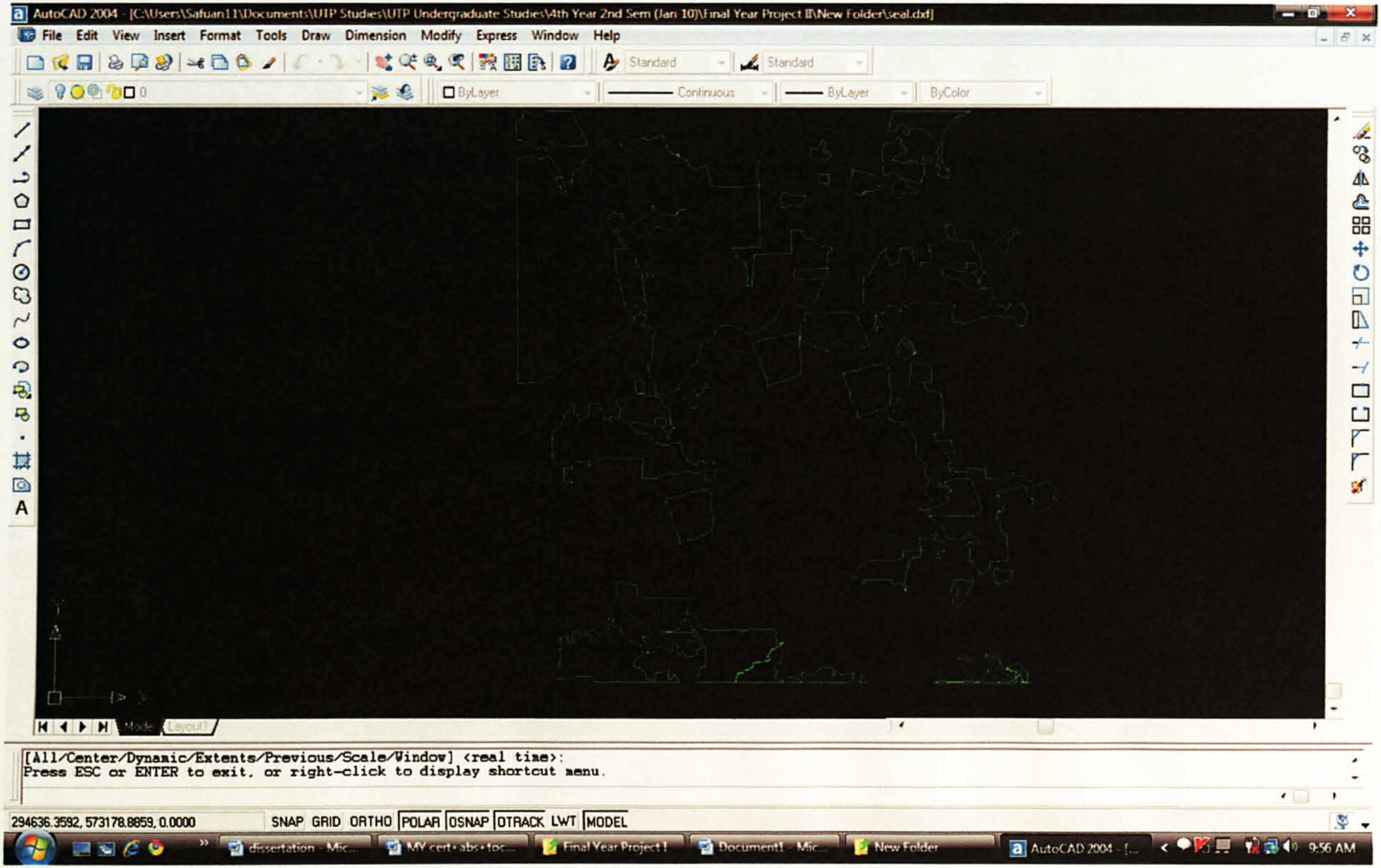
Appendix 2: Gantt Chart for Final Year Project 2

No.	Details/Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	19
1	Familiarize with GIS software															
	Data Gathering															
2	Submission of Progress Report 2								X							
3	Familiarize with GIS software															
	Data Gathering															
	Develop GIS Database															
	Conduct Analysis															
4	Submission of Dissertation Final Draft														X	
5	Oral Presentation															X

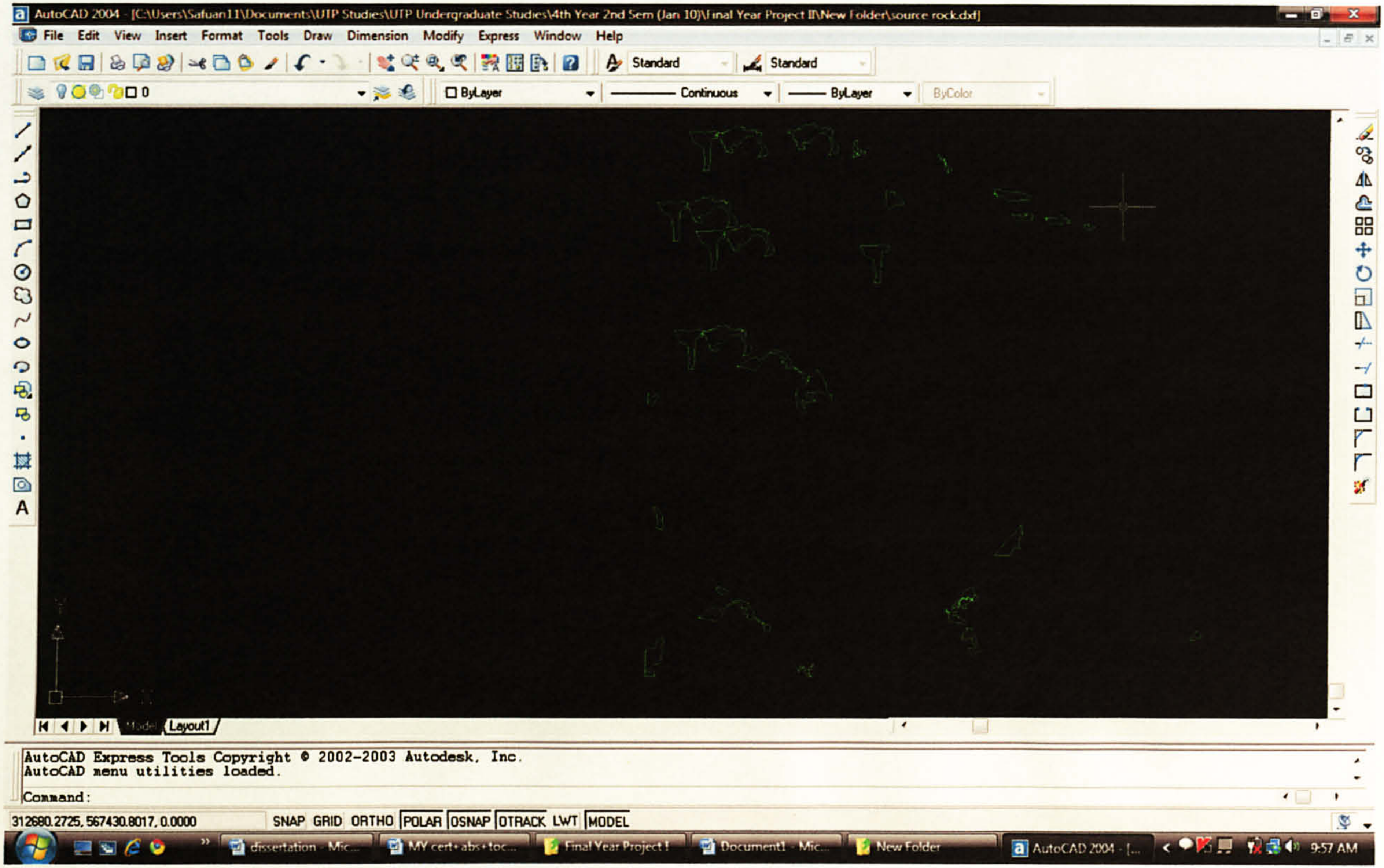
APPENDIX 3: AutoCAD Drawing of Reservoir Rocks Data



APPENDIX 4: AutoCAD Drawing of Seals Data



APPENDIX 5: AutoCAD Drawing of Source Rocks Data



APPENDIX 6: AutoCAD Drawing of Traps Data