CHAPTER I
INTRODUCTION

1.1 General Statement

Environmental problems associated with lake and its watershed area continues to be a cause of concern in Thailand and other developing countries. Currently, researchers and policy makers rely on the result of environmental analysis more and more on the use computer models (e.g., Dietz, 2000). The GIS model plays a large role also in managing and making decisions concerning natural resources exploitation. Models provide insight into how human and natural actions affect the environmental quality in a watershed. Additional modeling tools and efforts trace how those effects transfer through the ecosystems, economies, and human health. This research applied such an effective tool to develop conceptual models for evaluating heavy metals concentration and distribution, and sediment transportation in Songkhla Lake, from part of one of the most important watersheds in the southern Thailand.

Songkhla Lake area has faced the environmental problems due to the fast growing and uncontrolled development. Apart from human-induced environmental problems, one of the natural problems being occurred in the Songkhla Lake is the lake shallowness (PCD, 2005). The sedimentation rate of Songkhla Lake was reported about 6-7 mm per year (Chittrakarn et al., 1997), while the depth becomes shallower to about 1-2 m (DMR, 2005). The rate of sedimentation, if correct, is believed to be faster accumulation than the natural process. Both natural and human-induced environmental problems become a major concern for the Thai government in order to manage the area for transportation network and industrial center.

Basically, the goal of the Geographic Information System (GIS) is to allow a modeler to visualize the changes of landscape and produce resultant input values for the individual application. Building appropriate GIS technique to be a useful tool for conducting a watershed analysis is a complex task. Analysis that accounts in a various

scale from the state of human modifications to the entire watershed minimally requires combination of analytical models from the fields of geology, hydrology, ecology, and economics. Thus, the main purpose of this research is to apply GIS technique capable for integrating those diverse fields of study. The models focus explicitly on potential changes in land use, in the form of placement of new neighborhoods and developments, as perturbations on the landscape.

This research stems in part from a project of investigation on mineral resource and management in Songkhla-Lake Basin conducted in 2005-2006 by the National Research Center, Chulalongkorn University. Many efforts have been made previously to link GIS with environmental models in this area. However, due to the limitation of data accessible, several gaps in analytical process together with the use of GIS technique remained exist for further discussion. Those gaps include;

a) Lack of methods for selecting and obtaining appropriate spatial data;
b) Absence of procedures for enhancing and customizing spatial data sets for use in models; and
c) Lack of information on how to handle differences in spatial and temporal resolution among models and the GIS.

1.2 Objectives

To fill the gaps mentioned earlier, the objectives of this research are designed to:

1. Collect and enhance spatial data for using in a watershed and lake environment with clear rationales for selection of specific data sets;
2. Determine and model the rate of sedimentation and soil erosion and also the distribution of heavy metals into the Songkhla Lake watershed environment using the GIS application; and
3. Identify the "source areas" and transportation of heavy metal contaminants.

1.3 Hypothesis

If the Songkhla Lake becomes shallow, then the plan if required to excavate the lake sediments to deeper its bottom whether sediments in the Songkhla Lake are

contaminated or not, is the issue of debate for a long time. If so, then the source areas must be identified and environmental protection plan should be conducted in the early day. If not, then some spaces are required for the soil/sediment deeps. Recycles of the dig-out sediments must be investigated. For all these matters concerned, it is anticipated that GIS can be a main tools for manipulating and analyzing all the available data gathered from several concerned agencies.

1.4 Scopes of the Study

The research area (Figure 1.1) is located in the eastern part of southern Thailand peninsular. The Songkhla Lake covers an area of 3 provinces, including Nakorn Si Thammarat, Pattalung, and Songkhla. Specifically, the study area is located in the middle part of Songkhla Lake and its catchment area mostly covering entire Pattalung province. The area comprises approximately 1,400 square kilometers, geographically defined as 3 subcatchment areas namely; Tha Chiat, Pa Bon and Pru Por subcatchment areas. The coordinates of the study area are extended approximately from 7'31°N 99'56°E in the northwestern edge and 7'6°N 105'25°E in the southeastern edge in the Universal Transverse Mercator projection with 47 North Zone (UTM 47N) in WGS84 ellipsoid. The study area is about 58 km long and 43.5 km wide. The upstream rims are bounded by the steep slopes with maximum altitude of about 1400 m in the western part of the area, down to the gentler slopes, then flat terrain, and end up by the coastline of the Songkhla Lake at the altitude of 0 m above mean sea level in the eastern part. The sub-catchment configuration lies in west-east trending.

The research work focuses also on analysis in heavy metals concentration as well as sediment erosion and deposition by integrating several existing data, including remote sensing data, topographic configurations, types of landforms, pattern of catchment area, land use pattern, geology, drainage pattern and density, soil types, rainfall record, rate of sedimentation and age dating data. All of these data are firstly needed to be restored, manipulated, analyzed, and presented in GIS formats. Analyses of soil erosion and heavy metals distribution were done by software ARCGIS version 8.3.

ARCGIS 8.3© and Rockwork2004©; they are major tools to analyze sedimentary correlation and identify heavy metals distribution in lake environment.

It is important to note here that the "source area" of the heavy metals mentioned in this research means (1) the area where heavy metals exist and (2) the area that the main action from both of human activities and natural environmental impacts can be identified.

Since, many data set selected from various sources are involved in this research, normalization of these data are firstly needed. To do this, all the data sets were divided into primary and secondary sources. Secondary data set includes reports of regional and detailed geology, hydrology, and meteorology mainly provided by Department of Mineral Resources (DMR), Land Development Department (LDD), and Thailand Meteorological Department (TMD), respectively. Primary data sets include basically field data such as core logging, radiocarbon dating, and chemical analyses.

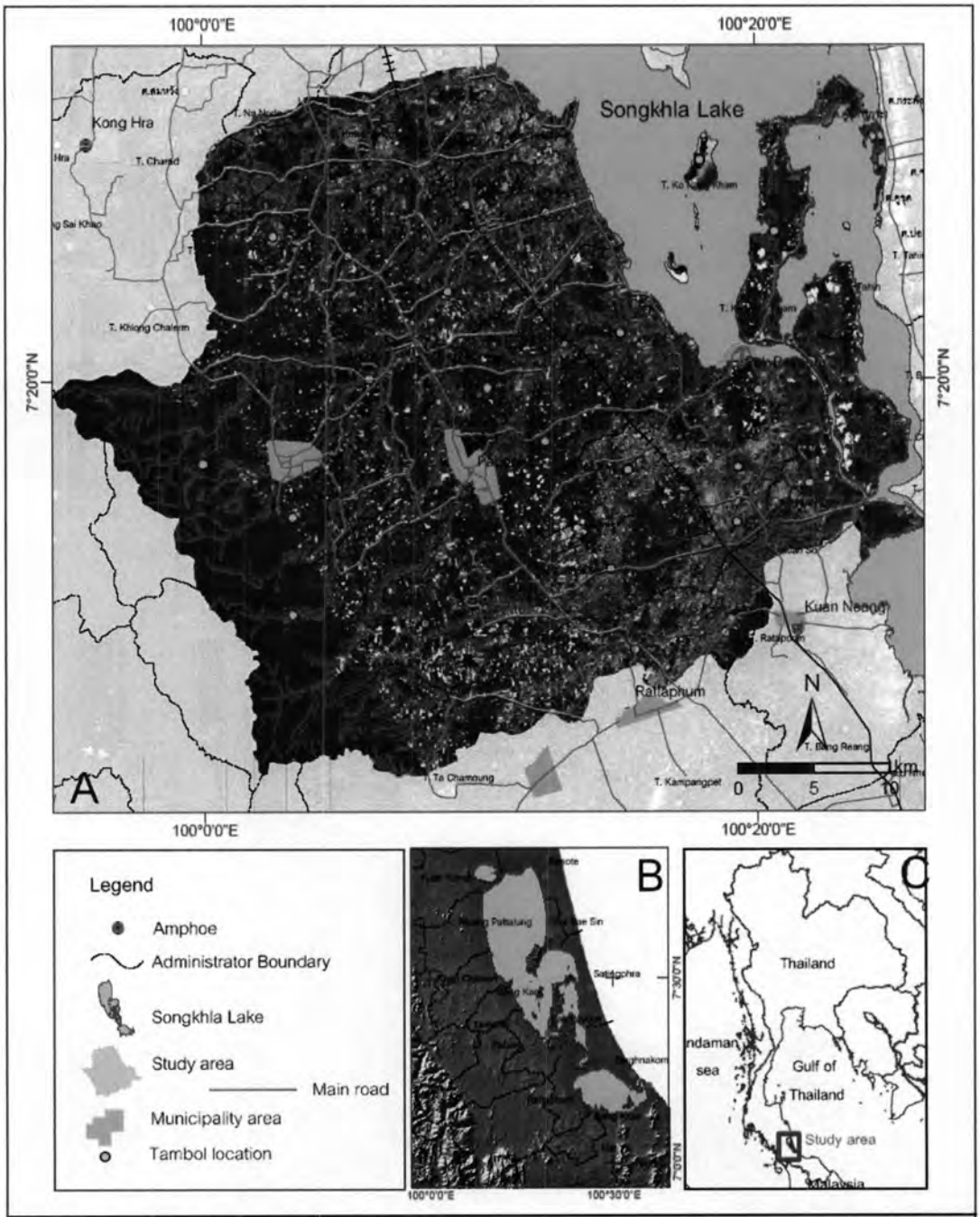
1.5 Expected Results

The expected outputs of this research consist of:

- Rate of sedimentation and heavy metal accumulation in the middle part of Songkhla Lake.
- Three dimension models and maps represent the level of heavy metal concentrations of the lake sediment in the focused area.
- Maps representing the rates of soil erosion and sediment transportation into the lake and those involving concentrations and source areas of heavy metals in the catchment.

As this research applied and integrated data set from many sources, results are expected to provide reliable information for environmental planners and decision-makers able to apply the most adequate and understandable information for a more effective planning with appropriate strategies to reduce, migrate and prevent the heavy

metal and sediment load supplying into the Songkhla Lake. In addition, evaluation of short-term and long-term risk, that may be repeatedly occurred in this area as well as in other areas where exhibit similar geographic conditions, would also be carried out.



Sources: Royal Thai Survey Division (2003)

Figure 1.1 The study area : Middle part of Songkhla Lake Catchment Area (A), Songkhla Lake Region (B), Index map (C)

1.6 Research Methodology

To accomplish the aims of this thesis, six sequential investigation steps are designed as present in Figure 1.2. Each of which is described below.

1.6.1 Literature Survey

Main purpose of this step is to collect and review general information and previous works related to this thesis research. Subsequently, they lead to construction of conceptual frameworks of this study. Main interest of the data search is focused on sources and transportation of heavy metals, lake sediment and heavy metal depositions, soil erosion, and Geographic Information System (GIS) application to lake and watershed management. The conceptual frameworks and methodology designed for this research are described in the next steps.

1.6.2 Data Collection and Manipulation

From the previous step, the research framework is constructed; consequently, data required for the whole study are known. Then, this step of the study is to collect and manipulate data into the appropriate format preparing for analyses in the next steps. GIS is applied initially within this working step and throughout the entire study. This step can be separated into 4 parts including data acquisition, field investigation, database design and data manipulation.

- *Data acquisition:* data and information required from reviewing in section 1.6.1 are acquired in this step. They include aerial photographs (1:50,000), satellite images (Landsat TM), topographic map, geologic map, land use map, soil map and lake bathymetric map. This procedure is carried out to understand geographic conditions, geologic setting and land use pattern in the study area. These data are provided by many sources and set in different scales; therefore, all of data have to be integrated, uniformed, verify and enhanced in the next steps.

- *Field investigation:* This step is aimed initially to understand and recognize the limitation of the study area. In addition, some information observed in the filed can be used to verify some data collection and prepare further working plan. Moreover, field investigation is additionally taken place to survey and define the physical conditions, geographic features, soil and lake characteristics that may cause soil erosion in the catchment area and sedimentation in the lake. The results consequently conduct ground truth for inspection, verification and analysis of the data collection.

- In addition, detailed soil survey is also carried out along the lowland area. Soil samples are then systematically collected in specific soil types covering the study area. The results from this survey are used as characteristics of the eroded soils and then taken for detailed study in laboratory. Rates of soil erosion are therefore estimated using this information in cooperation with other criteria.

- *Database design:* is procedure to collect and arrange data into suitable pattern for further easily analysis and interpretation. All of the data are patterned in Geodatabase field using ArcGIS software. Data sets are eventually grouped into 15 categories including:

1. Administrative, 2. Aerial photo, 3. Bathymetry,
4. Climate, 5. Drillholes 6. Geochem,
7. Geology, 8. Infrastructure, 9. Lake,
10. Landuse, 11. Polluted area, 12. Soil and landform
13. Topography, 14. Tourist attraction, and 15. Stream and catchment area.

The geodatabase is a collection of geographic datasets of various types used in ArcGIS. It can be managed in either a file folder or a relational database.

It is a native data source for ArcGIS and is used for data editing and automation. Some of common datasets included in workspaces and geodatabases are feature classes of points, lines, polygons, and annotation for discrete features, descriptive attributes held in tables, and raster datasets and raster catalogs for imagery.

The metadata are also developed within this step based on Federal Geographic Data Committee's Content Standard for Digital Geospatial Metadata. This is the default metadata editor in ArcCatalog. This editor enters values for some ESRI-defined elements, which are specified by the ESRI profile of the Content Standard for Digital Geospatial Metadata; this document is available as a white paper from ESRI's Online Support Center.

- *Data manipulation:* this step is taken place to integrate, normalize, uniform, and update data and information into the same GIS format. This is because all data and information are collected from many sources with different scales. Collecting, managing and enhancing theses data and information into the same format and more accurate are the first task to be done before further investigation. For examples, landform map is classified in more detail and improved using data from interpretation of aerial photo, Landsat TM5, and field data. Soil map is updated using field data. Landuse map, geologic map and other maps that developed before the year 2000 are re-coordiated to WGS84 Zone46N. Catchment area map obtained from PSU (2000) is re-bounded to more accurate using DEM data and GIS application in ArcGIS.

After the data collection and manipulation are finished, data analyses can be subsequently carried out. The data analyses are focused on two different aspects; they are 1) soil erosion and heavy metal distribution in catchment area and 2) sedimentation and heavy metal distribution in lake. Both analytical procedures are described in sections 1.6.3 and 1.6.4, respectively.

1.6.3 Soil Erosion and Heavy Metal Distribution in Catchment Area.

Evaluations of the source and level of contaminated heavy metals in the study area are carried out using GIS application. Detailed description of this working procedure is reported below.

Soil erosion estimation: is the first step to examine situation of soil erosion in the catchment area. The Revised Universal Soil Loss Equation (RUSLE) model, modified from USLE model) is applied to the study via the GIS processing. The RUSLE are comprised of six criteria requiring 5 main data sets, i.e., rainfall, soils, topography, slope, and land use. Two period data (years 1981 and 2002) are selected for the investigation. This is to compare the change of soil erosion. Results from this study show the level of soil erosion in each subcatchment area that appears to be the main sediment supply to the Songkhla Lake. The other model used to calculate volume of sediment flowing into the lake is Sediment Delivery Ratio (SDR). Subsequently, the SDR results are validated with direct measurement from the Irrigation Department. This validation is aimed to make the most reasonable model that can be appropriately applied for environmental plan.

Heavy metal distribution: in subcatchment area is the other task within this step of study. Heavy metal data obtained from Department of Mineral Resources (2006) both in soil sample and stream sediment are available for this study. Seventeen elemental analyses of metal and non-metal are collected for this database. However, only six elements (i.e., As, Cr, Cu, Ni, Pb, and Zn) are selected for consideration because they have close relationship and some of them are seriously toxic to the environment and human. Statistic techniques including histogram and accumulation curve are used to analyze anomalies of heavy metals before the distribution of heavy metals are complied in the map using spatial analysis of GIS application.

Heavy metal variation analysis: Consequently, the heavy metal distribution are compared with several thematic maps, i.e., subcatchment area, landform, land use, geology and soil erosion, to identify the sources and transportations of the heavy metal in specific areas.

1.6.4 Sedimentary Deposition and Heavy Metal Distribution in Lake

Total fifty nine core samples from the Middle Songkhla Lake are provided by Department of Mineral Resources. These samples are examined for lithological log, chemical analyses and Thermo Luminescence (TL) dating. Additionally, these samples are sampled selectively for grain size analysis and Cs-137 dating. Results obtained from this step are used to search and estimate the concentration of heavy metals in the lake sediment and also accumulation rate of heavy metals. Four areas, so-called Ao Ba Teng, Khlong Khop Khang, Khlong Ok, and Ao Bang Teng located in the main inlet-outlet of the subcatchment areas are specified for the study.

Lithological and stratigraphic analysis: this step is to analyze lithologic features of the lake sediment samples before correlation and construction of stratigraphic model in each specific area. Detailed of the study are described bellows.

Physical properties of sediment include lithology, color, consolidation and sedimentary structure are examined following the standard methods of Ross et al. (1978). Sediment samples collected from core samples are divided for gain size analysis and measurement of water content. Stratigraphic correlation analyzed from this thesis is based on visual description of cored sediments and their properties such as grain size, water content, dry density and color. Subsequently, all the data are manipulated and analyzed using Rockware®2004 software to correlate the sedimentary layers and concentration of heavy metal. Finally, stratigraphic collection is transferred to the GIS format for further investigation.

Analysis of depositional rate: is subsequently calculated based on the stratigraphic data obtained from the last section in cooperation with TL-dating data from DMR (2006) and Cs-137 data from (Chittrakarn et al., 1997). The sedimentation rate is later presented in the map that can be manipulated in GIS formats using spatial analysis tools of ArcGIS 9.2.

Heavy metal distribution analysis: this step is to review the geochemical analyses. Elemental analyses of 100 samples within 27 drill holes are obtained by Inductively Coupled Plasma-Optical Emission Spectroscope (ICP_OES); they include Al, As, Ba, Be, Ca, Co, Cr, Cu, Fe, K, La, Li, Mg, Mn, Mo, Na, Ni, Pb, Sb, Sc, Sn, Sr, Ti, V, Y, Zn and Zr. Among these elements, only six elements (i.e., As, Cr, Cu, Ni, Pb, and Zn) are selected for the study of distribution and contamination. The selected heavy metal data are investigated using 3D interpolation by kriging techniques. Consequently, the results show distribution of heavy metals in each specific area.

1.6.5 Discussions

Discussion in several aspects such as rate of sedimentation, soil erosion, sources and transportation of heavy metals and heavy metal contamination in the particular areas are eventually carried out to order to environmental plan and policy of the authority and decision maker.

1.6.6 Conclusions and Recommendations

Finally, conclusions of the study are made to summary points of interest as well as some particular environmental concern. Recommendations for further study and environmental issue are also proposed.

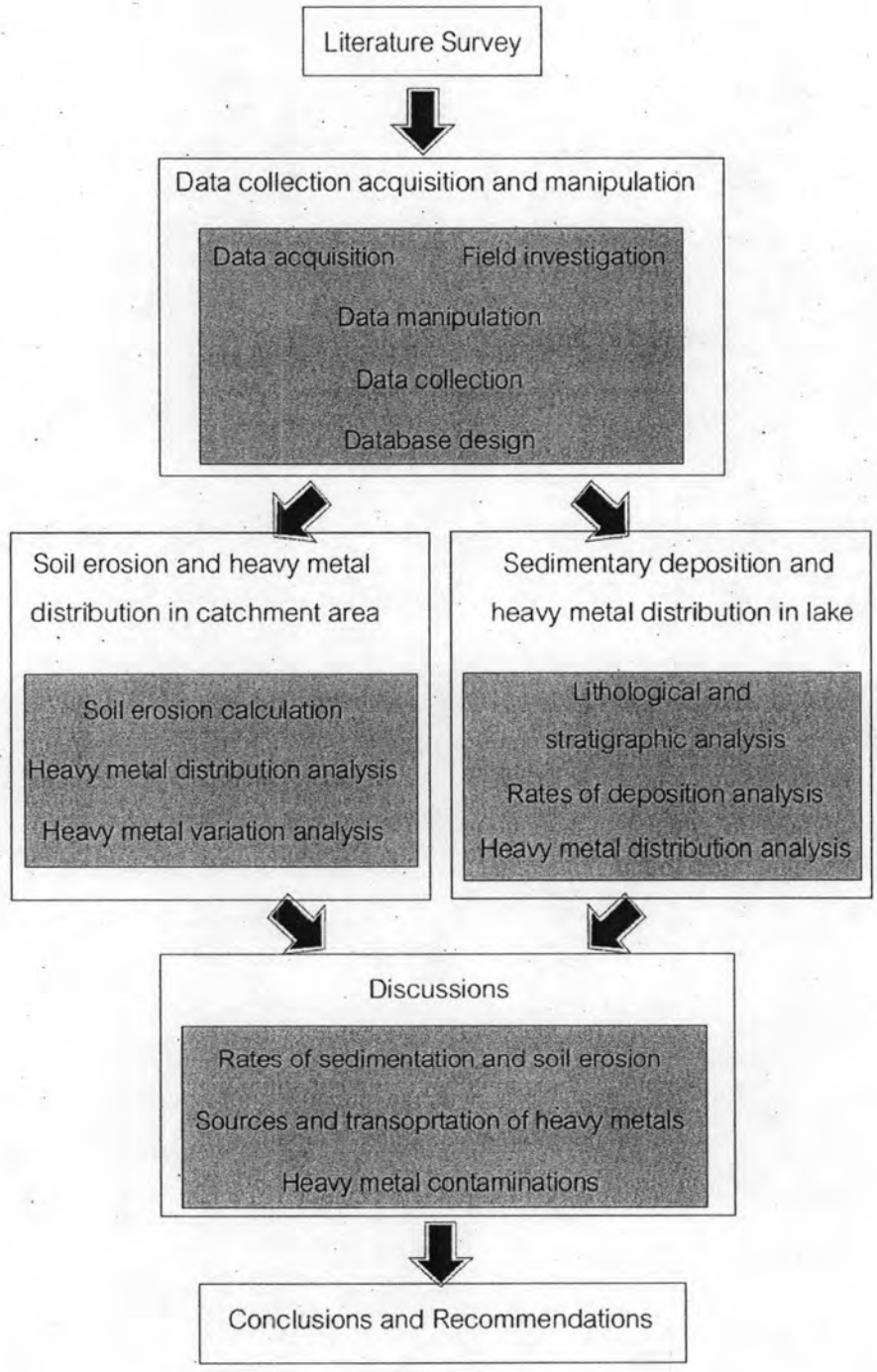


Figure 1.2 Flowchart shows the methodology for this study.