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A Worcester Polytechnic Institute Interactive Qualifying Project

Integrated Regional Model of River Basins in Southeast Asia

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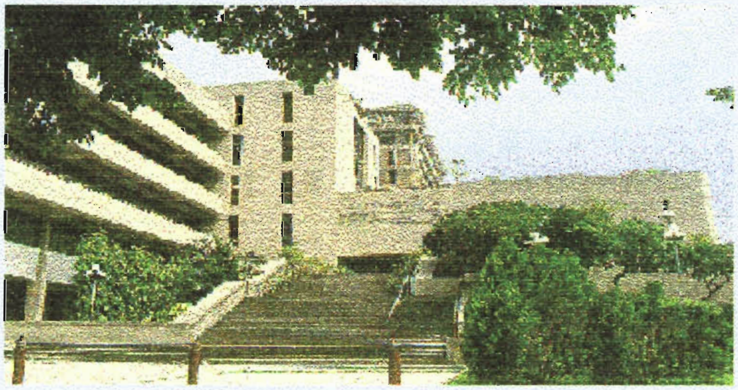

SEA START Regional Center

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Integrated Regional Model of River Basins in Southeast Asia

An Interactive Qualifying Project Report

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Abstract

With the advent of Geographic Information Systems, scientists have gained the ability to study environmental data related to geographic locations. This project completed in Bangkok, Thailand, focuses on developing this technology into an assessment tool for the Southeast Asia System for Analysis, Research, and Training organization. The goal of this project is to develop a model suited for determining the effect of human activity on river basins, and to promote understanding of the relationships among environmental, social, and economic systems.

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River Basins Team '99

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Executive Summary

The state of the Earth's environmental systems is reaching a critical point. For centuries, human demands for resources, food, and shelter have taken their toll on our delicate ecosystem. Only recently, however, have we begun to fully realize that human activities have overcome the ability of the planet to rid itself of poisons. With the advent of new technologies, human life has been extended and population has been growing at an alarming rate. With an increased population come larger quantities of waste, as well as increased demands on the planet's natural resources.

We have begun to understand that we are destroying our planet and our future, but we do not completely understand the dynamics of such a complex system. However, with the advent of computer technology, modeling complex systems has become, while still extremely simplified, increasingly more accurate. With the advent of modeling software such as the ARC/INFO Geographic Information System (GIS), researchers now have the ability to study environmental data in relationship to geographic location.

This project focuses on developing GIS technology into a useful assessment tool for the Southeast Asia System for Analysis, Research, and Training (SEA START) organization. It is the ultimate goal of the project to develop a model that will be suited to determine the effect of human activity on river basins in the area. SEA START will ultimately make this model available to engineers, environmentalists, policy makers, and the public for education and development of a sustainable relationship among environmental, social, and economic systems.

In order to accomplish this goal we have chose to construct the framework for a model of the Chi-Mun River Basin in Northeast Thailand. This task demanded that we

first study the concepts of hydrology, GIS, and human factors that influence river basins. We also researched literature pertaining to the methods, including interviewing techniques, necessary to complete our project. From this information we were able to develop interviews aimed at obtaining concrete goals for this project, as well as to gain valuable insight into GIS construction and analysis. In addition, we obtained information from our interviews pertaining to the people living in the basin as well as their interaction with the river basin. Two trips to the river basin were completed in order to conduct interviews and make observations of the river basin. These observations were essential in constructing an accurate model and understanding its potential benefits.

The preliminary model was then constructed with the help of our liaison, Dr. Anond Snidvongs of SEA START, and an associate, Wirote Laongmanee. The model was designed to integrate four layers of data to calculate runoff in the basin. Due to time constrains we were only able to construct four out of the six layers we originally intended to include in the model. These four layers contained data pertaining to soil type, potential evapotranspiration (PET), precipitation and vegetation. Incorporating each of the layers into the model required that we acquire data for each layer, and compile the data in ArcView. As one of the final steps towards analyzing the model, we began to develop an Avenue script that would analyze the data that was in the open ArcView project. Complications in the syntax of Avenue prevented us from completing the analysis using ArcView. However, SEA START had an AML script available that could perform the same operations, as our proposed Avenue script would have. Although ArcView does not support AML, we were able to export the ArcView layers to ARC/INFO, which supports AML files. It was then simply a matter of debugging the script to suit our needs. Due to time constraints, we were only able to simulate 1 out of 190 sub-basins in the Chi-Mun Region. The results of this simulation revealed that the results of monthly runoff were not very accurate. However, we did find that there was a strong correlation between recorded and simulated values of runoff for this basin, which suggests that there are only small errors in the modeling script. A follow up interview with Dr. Anond helped determine if we effectively addressed the needs of the organization, and of the needs of the project. In addition, we performed a content analysis on environmental, political, and economic issues to determine possible future uses of the model. Through this analysis we have determined that the model would be of great use for water management recommendations, environmental/human impact assessment, and other analyses that SEA START might deem appropriate.

After analyzing the results for all areas of the project, we have recommended that more layers be added to the model. In order to make this model a more accurate description of the world we live in, it is necessary to add human-related layers. These layers should be associated with human activity in the basin that has affected water flow, as well as incorporate information describing human systems that can be affected by changes in the environment. The benefits of adding these layers is twofold, as it will more accurately model the movement of water from cell to cell, as well as allow analysis of the impact on human social systems in relationship to environmental issues. Accordingly, we also recommend how to use the model for environmental/human impact assessment. For instance, the model can be used to make an assessment of the impact of building dams. This will enable the user to determine human impacts on the river basin and how these environmental changes will eventually impact humans. Finally, we recommend that this project be continued through future Interactive Qualifying Projects (IQP) and a Major Qualifying Project (MQP). Through our interviews we have learned that building a complete GIS takes many years. A MQP would focus on the more technical aspects of the project, while IQP's would focus on promoting the model, and assessing the users and what they want from the model.

This model can benefit many people in various ways. However, the work we have done in this project is only the foundation for what is to come; this work must be continued to constantly improve and update the model to make it as accurate and applicable to environmental problems as possible. The model should change and upgrade with advances in technology. It is our hope that the framework for this model will be applied to other river basins to promote sustainable development in other areas besides Southeast Asia. We believe that this model has the capability to aid policy makers and scientists in working together to preserve a balance between human needs and environmental well being.

1.0 Introduction

In this age of technology and advancement, awareness of the state of our global ecosystem has brought about rising concern that we are poisoning this system. It is often assumed that the ecosystem is in a state of equilibrium. However, our environment is a complex dynamic system, composed of feedback structures that are just beginning to be studied and understood. Growing awareness of the human impacts these feedback structures has caused great concern in political and scientific communities.

As an integral part of the global ecosystem, river basins provide a unique opportunity to study the effects of human activity on the environment. For centuries, bodies of still and flowing water have been a dumping ground for human excrement, and wastes from industrial and domestic use. It is of great concern that dams, bridges, roads, houses, and factories are being built over river basins, the planet's natural filtration systems. This development causes the rate of contaminant diffusion out of the water to be altered, creating an overall decrease in the ability of the planet to rid itself of these poisons.

In addition to pollution, the planet faces a major problem of water management. With an increasing population and a limited supply of potable water, resources must be organized and distributed in a responsible manor. This is an especially significant problem in Thailand. Due to a current drought in Northeast Thailand, worsened by El Niño, there is a significant problem of accessibility and availability of water in Thailand. This has led to a major debate on water management in Thailand, and specifically in Northeast Thailand. Farmers complain that there is no water to irrigate their crops, and with especially dry seasons, their crops are putting out a very low yield. Some policy makers propose to solve this problem by the construction of more dams to create larger reservoirs for better irrigation. Others say that these dams cause more harm than good by making problems worse for people downstream by, damaging the wildlife in the area, and by disrupting the natural balances in the ecosystem. Opponents of the dam projects suggest that the only thing needed to help the farmers is better water management. Suggestions for better water management include altering irrigation schedules and implementing more efficient irrigation systems. The fact is, nobody knows which side is right due to lack of understanding.

Recognizing the problems at hand, the Southeast Asia Systems for Analysis, Research, and Training Regional Center (SEA START RC), in cooperation with the University of Washington, has proposed a project to study the effects on the "basic processes and characteristics of rivers and their drainage basins" from human activity and natural events such as droughts, floods, and climatic changes. The data to be collected will allow for qualitative and quantitative analyses, which will lead to an accurate prediction of how the rivers and river basins will react to different variables. SEA START RC seeks to analyze environmental data and present this information in an accessible and comprehensible manner. This can provide many organizations, such as government and scientific agencies, with a valuable decision support tool. Such river basin models will allow users to integrate new information with previously gathered data to further increase the accuracy of future studies.

The goal of this project is to provide the SEA START RC with the framework for an effective and more accurate database and modeling platform for the Chi-Mun River

Basin, located in Northeast Thailand. This project will expand the capabilities of the current NAGA version 1 model as an effective predictive tool. We will research the Chi-Mun region, and determine factors that may affect the flow the water through the river basin and human interaction with the river basin. In addition, we will make a judgment of which of these factors should be included or excluded to make the model more accurate. In order to assess the accuracy of the model, we will assemble it from data collected in the region prior to the construction of Pak Mun dam in 1994; we will then simulate the construction of the dam and record the simulated changes to the river basin. A comparison of the simulated and recorded changes in the river basin will allow us to determine the performance of the model.

This project will apply Geographic Information Systems (GIS) as a tool for measuring the effects of human activity on river basins. We will develop the framework for this model using the ARC/INFO GIS. A GIS is a modeling platform that utilizes geographic data and computation engines, allowing the user to perform analyses based on geographic location. This model will initially analyze six "factors" in a river basin; a factor will be defined as an attribute of the model that has an effect on the hydrology of the river basin. The six factors we will focus on initially will be those used in the previous NAGA version 1 of the START GIS; precipitation, temperature, population, vegetation, soil properties, and potential evapotransporation. From this data set we will be able to extrapolate visual images using the GIS software to aid us in our analysis.

Analyses of the activity that the GIS model simulates will allow SEA START RC to assess the impact of variables on river basins, starting specifically with the Chi-Mun River Basin. This analysis will allow researchers to make educated predictions about the future behavior of water in a particular basin. This derived outcome will allow estimation of the future impact on human social systems as a result of changes in the condition of the river basin. Part of this project will involve identifying which human activities are responsible for environmental changes in the river basin.

With the pace of development and the rate at which the population is increasing in Southeast Asia, it has become essential that research be conducted to allow understanding of these effects on the environment. From comprehensive studies, predictions of the impact on river basins due to past and future developments can be made. In the future, SEA START RC will be able to use this model to aid policy makers in their decisions about natural resources, allowing these future decisions to be made informatively so that a balance among economic, political and environmental interests can be achieved.

2.0 Background

This chapter covers basic knowledge necessary to understand the context for our project. In addition, it contains information necessary for grasping the detailed aspects of our project. Included in this chapter is information on Geographic Information Systems, river hydrology, the Chi-Mun (Khorat) River Basin, and the SEA START organization.

2.1 Geographic Information Systems

Our project utilizes a Geographic Information System to analyze the affects on river basins. The (ESRI) ARC/INFO workstation version is the software that will be providing us with our spatial analysis engine. The ERDAS Imagine version 8.1.0 imaging system will provide the image processing capability, and will work with the ARC/View3 map and spatial display software provided by ESRI.

2.1.1 What is GIS?

A Geographic Information System, or GIS, is a computer-based modeling and analysis platform. These systems have the unique characteristic of incorporating statistical data and digital imaging to create a superior representation of spatial data. GIS systems have allowed social and physical scientists to probe into such topics as overpopulation, pollution, deforestation, and natural disasters, in a more accurate and efficient manner was possible than prior to the creation of this technology (1). GIS systems are capable of "creating maps, integrating information, visualizing scenarios, solving complicated problems, presenting powerful ideas, and developing effective solutions to complex problems."(1) This diverse array of applications makes GIS a valuable and useful tool which we can use in the analysis of effects on a river's hydrology and morphology.

2.1.2 How does GIS work?

The mapping capabilities of GIS create a model composed of thematic layers that are stacked above digitized maps for easy reference. These layers are composed of "spatial objects" that represent different entities in a given area. An entity is defined by Masters as:

> "A phenomenon of interest that cannot be subdivided into phenomena of the same kind. The definition of Entity types assumes that phenomena have uniform characteristics that can be classified according to a specific set of attributes." (6)

Each layer is comprised of "spatial objects" that all have commonality in their physical attributes. Layering can be accomplished in one of two ways; the layered view and the Object view.

2.1.2.1 Layered View

The GIS layered view represents each individual spatial object on an individual layer. The lowest of these layers serves as a reference, allowing the user to locate the position of a specific attribute, and is usually a map of some kind. Due to the "thematic" representation of data in this method, it is important that data be stored in a database that allows the software to easily separate the data into the distinct thematic classifications.

Another valuable characteristic of Layered GIS is that both continuous and discrete objects can be observed. Continuous objects include items such as roads and rivers; discrete objects include buildings and individual trees. However, due to the digital nature of the GIS platform, even continuous objects can be thought of as a set of discrete points along the surface of the thematic layers sampled at a high spatial frequency.

2.1.2.2 Object View

The GIS object view stores information on distinct discrete figures, such as roads, buildings, and sewer mains. "Object-oriented" GIS requires that each object be:

> "Identified and the characteristics of those entities (objects) to be defined so that other like identities can be classified. The relationships between objects also needs to be specifically identified and modeled in the system " (6)

Object-oriented modeling, or, as it is also called, feature-oriented modeling, allows a model to derive and compile data sets based on similarities in their physical attributes. This allows the user to be able to query the system about specific "concentrations" of an object. Conversely, the system can also be prompted to outline an area given specific information as to the characteristics of the objects. This allows physical and social scientists to study characteristics of a system and to use their observations to describe what is occurring in the system.

Typically, the feature-oriented method is used in urban settings, because of the large amount of discrete objects present. However, it may also be used in a rural situation that involves man-made "objects". For studying dynamic systems through continuous time, the layered view would most likely be used, because it is more suited to doing so.

The techniques of modeling using GIS can also be further expanded into either a vector or a raster analysis. Vector analysis uses a series of (x,y) coordinates to locate an attribute in space. Raster analysis uses a grid system, in which each grid represents a given attribute. Geographic location in a raster model can still be found utilizing the location of the grid in the system and its association with a given point on the surface of the model.

2.1.2.3 Raster Modeling and Geographic Information Systems

Raster modeling refers to a specific method of computing using GIS. Raster modeling requires that the user develop a grid of cells, which are individually assigned a coded value that identifies the cells' characteristics. Raster modeling is a discrete process, in that it utilizes data taken at regular, uniform intervals. The sampling area is most often a square or rectangle, but may also be a triangle or hexagon. For our project, we will be utilizing one kilometer squares for our grid cells.

2.1.2.4 Vector Modeling and Geographic Information Systems

Vector modeling refers to the second primary method of computing using GIS. Vector models utilize three spatial objects, namely points, arcs, and polygons, to represent geographic data. Vector models are most commonly used for spatial and aspatial queries, based on the geographic features of its coverages. Vector models utilize data in many forms, but the most common form is that of digitized maps. Vector models can be converted to be used in raster applications; this technique will be applied to our GIS.

2.1.2.5 Arc Macro Language (AML) and Avenue

AML and Avenue are accessories to ARC/INFO and ARC/VIEW respectively. AML and Avenue are programming languages designed specifically to improve the ease of processing and analyzing spatial data. Each uses a set of commands to direct its counterpart to perform specific tasks and analyses. These languages will be used to program the dynamics of the model into the computer so that it can automatically perform the hundreds of operations that previously would have had to be processed by hand, eliminating any manipulation errors due to command entry.

2.1.3 Synopsis

The development of a GIS model can be accomplished by establishing a set of common goals and data parameters that eventually lead to an overall design approach. The design itself demands that all forms of analysis be identified, so that the appropriate modeling scheme can be chosen. The job of the designer is to establish the data that is important and useful, and the analysis that he/she may wish to perform on that data to arrive at a given outcome. Based on this outcome, the user(s) of the given model will be able to make clear and concise observations, and recommend courses of action.

2.2 River Hydrology

One of the most important aspects of a river basin, or any body of water, is its hydrology. Hydrology is the study of the movement of water and its properties as it flows from one point to another. Hydrologists study the hydrolytic cycle to understand the movement of water above, on, and below the earth's surface. Water evaporates off the earth's surfaces, including oceans, lakes and rivers. The accumulated moisture forms clouds, and then water is returned to the earth's surface as rain. The precipitation falls on vegetation and is absorbed by all surrounding plant life. If there is an excess of precipitation, more than the amount the vegetation can absorb, the water infiltrates into the groundwater or runs off into a nearby body of water.

There are many methods by which the water moves throughout earth(precipitation, infiltration, runoff, evaporation etc.)-many factors affect this movement of water. For example, vvegetation, soil type, climate, and amount of impervious area all can affect the rate of water infiltration into groundwater. Water passes through soil and sand rather quickly, but if water encounters an impervious surface such as concrete or asphalt, the surface water will drain directly into a body of water, sewer, or other man made drainage system, and will not infiltrate into the groundwater. This can increase the flow of contaminants into the water system; it is very difficult to remove contaminants in groundwater. Surface water is more susceptible to changes in the surrounding environment than groundwater; however, unlike groundwater, surface water is able to rid itself of contaminants using grass, plants, other vegetation, and exposure to oxygen as natural filters to help restore itself.

Entities near or in a watershed have an effect on water quality. Industry, mines, farming, livestock, roads, construction, fire, population, climate, and recreational areas all affect water quality and the rate of runoff. The amount of precipitation in a watershed affects both water quality and the rate of runoff. If there is a large amount of precipitation there will be greater volume of runoff into a body of water. A greater volume causes the runoff rate to be higher. The rate of runoff movement can be affected by topology of the land, vegetation, chemical content, sediment, organic wastes, climate, pollution, geology, and impervious area. If there is a high amount of runoff, or if the runoff moves at a high velocity, metals and other contaminants, the amount of sediment, and turbidity all increase, and erosion occurs. This in turn makes the water undrinkable and possibly dangerous to humans and the environment. If the rate of runoff is too slow, the bodies of water into which the runoff is deposited may dry up or increase in temperature, allowing microbes to grow.

Water can also be contaminated by air pollution. When water is evaporated it is made susceptible to many contingencies in the atmosphere. Entities such as smog and other air pollutants can contaminate evaporated water in the gas phase while it is in the air and cause this water to precipitate as acid rain. (42)

2.3 Chi-Mun (Khorat) River Basin

The river basin that will be modeled in this project is the Chi-Mun or Khorat River basin. This river basin was chosen for its size, availability of data, low level of difficulty to model, location, and prevalence of many entities that are easy to simulate (dams, droughts, monsoons, etc.). The Chi-Mun River Basin is described in detail in the next sections. These sections cover the geography, hydrology, agriculture, damming and life in the Chi-Mun River Basin.

2.3.1 Geography of the Chi-Mun River Basin

The Chi-Mun River Basin is conveniently located entirely within Northeast Thailand. Data from river basins in Thailand is readily accessible because information does not need to be obtained from sources outside of the country (Figure 1: Map of Thailand). The Chi-Mun River Basin contains many dams, including Sirindhon Dam, Pak Mun Dam, and Lam Pao Dam. These dams are used for irrigation, flood control, and hydroelectric power. Dams are an excellent choice for simulation because of they noticeable changes the cause within the river basin. The effect of these large dams has been easily observed through the years, and will be noticeable in our model. In recent years, for example, fishery stocks have been decreasing steadily upstream from many of these projects.

The Chi Basin is located between 15^0 20^0 N and 17^0 50^0 N latitude and 101^0 20^0 E and 104^0 50^0 E longitude. The basin has an area of approximately 27,370 Sq. km. The Chi River, the major river in the Chi basin, flows west to east, and is approximately 1,010 km in length. The Chi River merges with the Mun River at Ubon Ratchathani and continues westward to the Mekong. Ten provinces are included within the river basin: Chiyaphan, Nakorn Ratchasima, Khon Kaen, Loei, Udon Thani, Mahasarakham, Kalasin, Roi Et, Yasothon and Ubon Ratchathani.

The Mun River basin is located just south of the Chi River Basin. This basin is located between 14^0 and 16^0 north latitude and 101^0 and 105^0 east longitude, and is

Figure 1: Map of Thailand, Northeast Region is in Green Blue colors. (60)

approximately 90,000 sq. km. The major river in this basin is the Mun River. In Ubon Ratchathani the Chi River meets up with the Mun River, and both empty into the Mekong River. This point at which the three rivers meet is called Khong Chiam, or the Three Colors. The different colors of each of these rivers can be observed at this point. There are eight provinces in the Mun River Basin: Khorat (Nakhon Ratchasima), Buri Ram, Surin, Si Sa Ket, Ubon Ratchathani, Roi Et, Yasothon, and Amnat Charoen.

2.3.2 Hydrology in the Chi-Mun Region

In order to understand how the rivers flow through the Chi-Mun Region, the hydrology of the rivers must be examined. This understanding of hydrology is essential in order to build an accurate model of the river basin. Various aspects of the hydrology of the Chi-Mun River Basin are discussed in the following sections.

2.3.2.1 Climate in the Northeast Region

Northeast Thailand, the region that contains the Chi-Mun River Basin, has a tropical climate. Occasionally, however, cold air from Siberia and China will enter the river basin. The air movement through the Chi-Mun River Basin is dominated by two seasonal monsoons, one originating in the northeast and the other in the southeast. The pattern of these monsoons consists of two distinct seasonal circulation-surface winds. The winds first flow adamantly from the northeast quarter, and then flow equally as persistently from the opposite (southwest) quarter. The two monsoons are closely associated with atmospheric pressure in other regions of Asia. The monsoons are also affected to a lesser degree by atmospheric pressure conditions over Australia and neighboring oceans. The season of the southwest monsoon, otherwise known as the rainy season, is from mid-May through early October; this monsoon is prevalent when atmospheric pressure over Asia is relatively low. The northeast monsoon lasts from early November to mid-March and is dominant when atmospheric pressures are comparatively high. The Equatorial Trough Zone (ETZ) is the boundary zone between these two air streams. This zone passes over the region many times during active and inactive points of the monsoon. From time to time, the zone passes over the area with low-pressure systems from the north and east. The magnitude of the weather is dependent on the degree of convergence occurring within the zone. Intervals between these two dominant weather patterns are transitional periods, characterized by variable winds.

The air streams that constitute the southwest monsoon originate from semi-permanent high-pressure cells over Australia and the Indian Ocean. Through its passage over warmer equatorial water, the air current originating over Australia is rapidly modified. It becomes moist and unstable by the time it merges over Sumatra and Malaysia with the flow from the Indian Ocean. The flow is tropical, and maritime in nature, when it arrives over the lower Mekong Basin. The southwest monsoon season brings large amounts of rainfall, high humidity, and high temperatures. Due to the influence of anticyclone circulation aloft there is a short drought period of one to two weeks in July or June. After the period of drought, the rainfall is heavy from tropical disturbances such as typhoons and other tropical storms. Flooding occurs when there are two or more of the tropical storms in a short period of time, or when the ETZ is in the active stage.

The colder season of the northeast monsoon has two transitional stages. The first is from mid-March to early May. Increased precipitation, cloudiness, and humidity characterize this summer season. The second transitional period is from mid-October to early November and features rapid changes greater than those occurring in the summer season. This transitional period produces less rainfall because it is the time at which the southwest monsoon is leaving and it is before the northeast monsoon begins (58).

2.3.3 Agriculture of the Chi-Mun River Basin

The largest crop in the Chi-Mun River basin is rice. Most farmers grow rice for at least half of the year. The northeastern farmers will grow sticky rice and plain white rice; the sticky rice for themselves, and the white rice to sell. During the second half of the year, the farmers will grow a secondary crop. There are many different types of secondary crops that farmers will grow in the off season; pineapple, tomato, and tobacco are examples of secondary crops in Nong Khai. In Ubon Ratchathani, watermelon and peanuts are grown; in Roi Et, sweet corn and peanuts are secondary sources of money. In Si Sa Ket, pumpkins, garlic and onions are grown in the off season; Surin farmers grow marbury in addition to their rice crops. The central region of Northeast Thailand it is very dry, and it is therefore difficult to grow many crops. Some of the crops grown in this area are kenaf, tapioca, and salt (58).

2.3.4 Life in the Chi-Mun Basin

The Chi-Mun River Basin is located in the northeast region of Thailand, also known as Isan. Isan is one of the largest regions in Thailand and encompasses approximately one third of the entire land area. The Chi-Mun is one of two river basins in this region; the other is the Sakhon Nakhon River Basin. Both river basins are classified as being "dry tropical zones". This means that in the dry season the amount of water entering the region, in the form of precipitation, is much less than that leaving the system through evaporation. However, during the monsoon season, there is a tendency for the rivers to flood because of overflows in the Mekong, as well as in other rivers in the northeast.

Due to this extreme change in water availability over the course of the year, and support for "agricultural industrialization" in political circles, several dam projects have been initiated to regulate the change in water levels throughout the year. Historically, the Isan region has been a relatively prosperous region that embraced subsistence farming. The soil did not tire from overuse, nor did the stocks of fish become depleted. Once Thailand began exporting agricultural products, however, farmers grew as much of a crop as possible so that they could pay their taxes and put food on their tables. As the demand for Thai exports increased, the Thai government began investigating the possibility of irrigation projects that would help farmers increase their yields, and simultaneously increase the country's revenue. Projects of this type have been in development since the late 1960s, and have taken hundreds of thousands of hectares (2.2 hectares/acre) of land from farmers. The extent of the environmental impact caused by the construction of these dams is still unknown. However, no impact study can measure the hardship imposed upon the residents who were involuntarily removed from their farms to make way for some of these projects. Watershed newsletter (46) reported that the compensation for families involuntarily removed from their homes to make way for the Pak Mun Dam project was estimated at 35,000 Baht per rai; a rai is a unit of land measure equal to .16 hectare. However, the fair market value of the land per rai in the Khong Chiam region, as quoted by the Land Administration Department, was approximately 40,000 Baht per rai.

Relocation and lack of adequate compensation, however, are not the only hardships facing the people of the Chi-Mun River Basin. The obvious change in river morphology associated with the construction of dams has blocked fish from moving upstream to their nesting ground. Despite efforts by the fisheries department to stock the rivers, fishermen are having difficulty catching anything. In fact, "industrialization" of fishing in this river basin has made it impossible for smaller fishermen to compete with the larger, better-equipped fishing companies. Consequently, an increasing number of local markets are stocking their shelves with fish from other Thai regions and even from Laos.

Fishermen are not the only residents in Isan suffering from "improvements" made by the construction of dams within this basin. Farmers are also having a difficult time producing a crop which will meet their yearly needs. This difficulty is due to increased salinity in the irrigation water, especially during the dry season. To illustrate the overall impact on this portion of the basin since the construction of the dam, consider the following statistics taken from a report entitled Fish, Forest, and Food.

- 75% reduction in the number of families receiving income from Mun River fisheries;
- 25% of 177 surveyed families fishing the Mun River in 1993 were not meeting their daily basic subsistence needs;
- 74% decrease in the daily average commercial fish catches;
- 30% decrease in average daily fish catches constituting family food requirements.

(46)

There is also little evidence showing that the situation has improved since 1993.

What is surprising is the fact that the Thai government has already started construction on at least twenty new dams in this basin alone. As part of a 62 billion (US) dollar, three-phase project, an estimated 6,580 million cubic meters of water would be diverted from the Mekong River into the Chi-Mun River Basin each year. This project is scheduled to be completed in 2032 and will provide irrigation to approximately five million rai in fifteen provinces in the northeast.

Consequently, as part of this construction, the Isan province will bid farewell to thousands of hectares of farmland and forest which will be permanently flooded. Fishermen are bound to suffer, as the number of fish reaching the upstream region diminishes. The question of whether the benefits of this project outweigh the resulting environmental impact still remains.

2.4 Southeast Asia System for Analysis, Research, and Training (SEA START)

START is an organization whose goal is to create a system whereby scientists and institutions from various regions can more effectively collaborate on global change research and easily share collected data with the scientific community and any other parties. Conducting a global scale research effort is extremely difficult; therefore, START Regional Centers have been established, including the Southeast Asia START Regional Center. By distributing these research efforts throughout the world, it is feasible to efficiently mobilize manpower to collect information that can be merged into a widely available medium.

Through the regional network created by START, the governmental and policymaking bodies of countries associated with START are able to use information gathered on global change to create policies that take into account the findings of scientific research. START promotes enhancement of developing nations' scientific capabilities via training and access to data and technology. In conjunction with other established programs, such as the International Human Dimensions of Global Environmental Change Program (IHDP), the International Geosphere-Biosphere Program (IGBP), and the World Climate Research Program (WCRP), START is aimed at finding answers to scientific uncertainties and ultimately providing a largely effective way to educate the global community on the environment (4).

SEA START is part of six regions of the global START network. SEA START RC focuses on the Southeast Asian areas of China-Taipei, Vietnam, Laos Thailand, Cambodia, Philippines, Malaysia, Singapore, Brunei Darussalam, Indonesia, and Australia. Under the same operational objectives of the overall START, SEA START RC is situated in the Environmental Research Institute at Chulalongkorn University in Bangkok, Thailand.

3.0 Literature Review

The purpose of this chapter is to describe results of previous relevant research. In this chapter we cover several topics including Geographic Information Systems and human impact on river basins. Also included in this chapter is information pertaining to methodologies that will be implemented in order to fulfill the requirements of our goal statement.

River basins are complex dynamic systems that create a demand for efficient, accurate, and cost effective methods of analysis. These analyses can be accomplished using Geographic Information Systems, as outlined in the previous chapter. To be able to understand which human activities have an impact on river basins, and perhaps even the reasons why they have an impact, we must first understand each activity.

Another aspect of this project that needs to be reviewed is our methodology. As we are not experts in Geographic Information Systems, we naturally looked to the experts, and exploited our access to the World Wide Web to align ourselves with experts in the field who have spent years performing these types of analyses. The remainder of this chapter discusses in detail the individual aspects of our literature review.

3.1 Geographic Information Systems Currently in Use

Geographic Information Systems (GIS) are an integral part of this project. We will be using GIS to model river basins in Southeast Asia. GIS is utilized by many different organizations worldwide for a variety of reasons. GIS is a method that combines computer science with geography; it is defined in Understanding GIS as "a computer system capable of assembling, storing, manipulating, and displaying geographically referenced information" (52). The different types of studies to which GIS can be applied include forecasting, spatial modeling, spatial databases, mapping, navigation, resource management, forestry, marine studies, digital libraries, geographic multimedia data, artificial intelligence, and internetworking (16). GIS can be applicable in the public and private sectors. GIS process information that can be tied to a geographical location on earth, and comprise it into a potentially massive database that is easily accessible and easily manipulated. GIS relate information from different sources; therefore, several computer databases can be entered into one model. In doing this, it is easy to relate information of many different sources. For example, a GIS can convey digital information that is not in map form (e.g. statistics of vegetation or rainfall, and hydraulic tabular data) into a map layout. GIS is most often used by scientists, specialists (meteorologists, environmentalists, etc.), policy makers, and institutions (colleges, companies, etc.).

3.1.1 Another Look at GIS: Generation of Long-Term Record of Contaminant Transport

In her article on Contaminant Transport Modeling, Gabriele (47) describes the watershed around the Aberjona River in Woburn, MA. The study, conducted on site, was aimed at determining the effects of transport flows based on annual precipitation and the human impact on the watershed. The team began by outlining the necessary data as well as the inherent difficulty in modeling such a system. The modeling system they were using required that data be provided on an hourly basis.

For this particular model they used the MLBRP (Modified Bartlett-Lewis Rectangular Pulses) technique. A cluster based model, this system maps each storm as a series of individual cells. These cells contain data of hourly precipitation, which are stored as a set of rectangular pulses of varying duration, and amplitude. The model can extrapolate this data and calculate total storm intensity of all cells that are active at that given point in time. The number of active cells at any given time has a geometric relation to the affected area. The duration of each cell's activity is defined by an exponential function that varies with the time that cells are within the affected region.

The advantage of modeling using this system is that it can easily integrate the two sets of data needed to complete study without directly affecting the model. Normally the time dependence of the precipitation data would clash with the non-specific flow data of the river itself. However, as a result of the rectangular pulse storage of data it is possible to keep the actual flow data separate from precipitation, while at the same time allowing the user to extrapolate models from preprocessed data and still obtain an accurate model of the contaminants in the system.

The goals of this model parallel those of our own project. In the article Gabriele states that:

> Additional information (for development of this model) includes, for example, determining the relative impacts of (1) urbanization (2) water withdrawals, (3) changes in source concentration; and (4) storm events, on the transport of contaminants through rivers. (9)

Certainly, urbanization and demands on water are as much a reality in Thailand as they are in Boston. Since human activities in Thailand are comparable to those of the United States, we can assume that the region undergoes some of the same effects. Thus, just as stream flow is affected in Boston, it is also has repercussions in Thailand.

Urbanization is the cultivation of open land into a large area featuring impervious surfaces, smog, pollution, and large amounts of people. As population increases, the demand for housing, roads, and commercial buildings also increases. This increases the amount of impervious area along the watershed. Impervious areas lead to man made diversion of water, in that these impervious areas do not become flooded with water. This process greatly increases the rate of water flow out of such areas, and thus has an effect on hydrology of the given watershed.

3.1.2 Process Oriented Modeling with GIS in Landscape Ecology

The tools necessary for this project are not limited to GIS. However, it is important to have an understanding of the basic techniques involved in using a GIS. Thus it is appropriate that we research the techniques of previous groups and organizations that have built GIS in the past. A web page entitled "Process Oriented Modeling with GIS in Landscape Ecology"(9) was chosen to represent some of these techniques.

This article outlines how one could approach modeling an environment as a set of thematic and spatial descriptions, if the model is to be of any use as a decision support tool. To begin to model a process-oriented system, an analysis of data from a completely subjective point of view must be conducted. Stimuli must be isolated in order to determine the absolute effect of a given stimulus on the system. Data on causal relations can be either obtained on site, or from analysis of existing resources. The reason we are afforded such leniency is the qualitative representation of GIS systems. Since dependency on hard quantitative analysis is necessary, we can use statistical analysis to provide accurate models of what the author refers to as "a proportionate description of the processes".

The author also differentiates between the different subsystems of landscape ecology. This allows the researchers to keep an accurate "account" of each of the subsystems' processes and correlation systems. The process system is a collection of data on stocks and flows. Stocks are any accumulation of a given "item" in the subsystem. Thus the data on the hydrosystem might be collected as follows:

1) Water flowing into a body of water, i.e., rainfall, runoff, and rivers, can be considered inflows
2) Water that is contained in some form, i.e., ice, lakes, or ponds, is considered to be a stock
3) Water that is leaving a system, via evaporation, rivers, or drainage, is referred to as an outflow.

From this basic information about the dynamics of a hydro-system we can establish a system of collecting data on inflows, stock, and outflows that can be used in modeling a region.

The correlation system contains information on how all of the stocks and flows in the process system are related. Thus the correlation system contains equations, directives, and other components that will allow the model to function accurately, offering the capability for a more precise representation of a system over time. Time, or "temporal component", as the author points out, is just as important as any other variable in the system. Modeling time correctly will determine whether or not the model will be a valuable tool in predicting outcomes of influences upon the system.

One inherent problem with GIS systems is that they are only able to facilitate spatial data, and do not have any basic geographic concepts imbedded into the computational algorithms. Thus it is the implementation, and design of data analysis structures, that will ultimately shape the final result. GIS is, however, the forerunner in fast, economical data collection and is the technology of choice for environmental studies similar to ours.

3.1.3 San Francisco Interactive Qualifying Project (IQP)

In 1998 there was a Worcester Polytechnic Institute Interactive Qualifying Project completed in San Francisco that studied drainage and Geographic Information Systems. The project was titled "Identifying Potential Storm Water Pollution Sources Using a Geographic Information System and Estimating Sediment Catch Basin Efficiency". The project was completed in conjunction with San Francisco's Public Utilities Commission, specifically the Bureau of Environmental Regulation and Management's (BERM) Water Pollution Prevention Program (WPPP). In this project a GIS system that contained mapping of potential business storm water sources covering the City and County of San Francisco was developed. The project also involved analyzing five years of influent and effluent catch basin data of four catch basins in the city. This was done to determine the removal efficiency of five toxic heavy metals in runoff (55).

Although this project focused on San Francisco drainage catch basins, and our project focuses on river basins in Southeast Asia, there are many similarities between the two projects. Both of these projects include construction of a GIS database of some kind of drainage mechanism. For these projects, observations of the dynamics of drainage, what affects the hydrolytic cycle or water flow of water of these drainage systems, and the human impact on the drainage system are a necessity. In addition, both of these projects analyze the data put into the GIS system and propose improvements to the system and the environment. The San Francisco project performed this analysis by determining removal efficiency of five toxic heavy metals. The Southeast Asia river basin project will do this by analyzing the accuracy with which the model can predict run off within the river basins.

3.1.4 Flood Modeling in the Chi-Mun River Basin, Thailand

One of the most important uses of a GIS river basin modeling system is prediction. The rivers in Southeast Asia have various functions and purposes. Many people rely on the rivers for their way of life and for development of society. This is why it is so important to protect the rivers and to try to estimate the effects of change in the surrounding communities, industry, impervious areas, and weather on the rivers and their basins.

The Danish Hydraulic Institute (DHI) has been pursuing relevant technologies in environmental and water resource investigations since the late 1970s. According to the DHI web page, "DHI offers a broad spectrum of services, software tools and model test facilities related to offshore, coastal, port, river, water resources urban hydraulics and environmental engineering". DHI have developed many GIS systems to assist in management. Their GIS system uses numerical simulation models ARC/INFO and ArcView (15). The DHI's project that is of interest for to the Chi Mun River Basin study is MIKE 11.

MIKE 11 is a MIKE BASIN program. MIKE BASIN is software package used for modeling river basins. A web page defining MIKE 11 states that MIKE 11 "accommodates basin wide representation of water availability, sector water demands, multi-purpose reservoir operation, transfer/diversion schemes, and possible environmental constraints. It can assist decision makers in identifying a sustainable development of scarce water resources for competing uses, taking into account specified priorities, rural and urban characteristics, and socio-economic constraints" (14). MIKE11 models the lower portion of the Chi-Mun river basin in Thailand. The Electricity Generating Authority of Thailand (EGAT) needed a model to ensure that strict operation criteria for the Pak Mun Dam were met. These criteria included maintenance of a certain water level of a new reservoir upstream from the dam so that it not exceed a specified limit (13). This model operates in real-time and has a flexibility that allows it to compensate for rapids and other hydraulic conditions of the Lower Mun River. The model covers 13,000km^2 of area upstream of the dam.

3.1.5 University of Washington Southeast Asia River Basin Project

A project at the University of Washington was proposed in conjunction with Southeast Asia START. Cooperatively, these agencies developed a regional model of river basins in Southeast Asia. The University of Washington model is called the

Southeast Asia Integrated Regional Model: River Basin Inputs to the Coastal Zones (SEA/BASINS). They have built "a multi-scale (including time and space) integrated regional-scale model 'NAGA' of changes in water resources of Southeast Asia as a function of land use and land cover and regional climatology over river basins to describe how materials are mobilized and transported from the land surface to the coastal zones" (48). The objective of the SEA/BASINS project to determine the physical and economic results when land-use, climate, flow of the water, and chemical run off are altered (48). The project has three needs: (1) Tools for systematic synthesis of information leading to a coherent information base that can be applied to regional evolution; (2) Predictive capability and scenario generation across multiple time and space scales; and (3) Process for communication among regional scientists, especially interdisciplinary, and productivity between scientists and policy, including visualization (48). The key issues that the University of Washington felt were important to include in their model are indirect water routing (change in land cover and regional climate), direct water diversion (dams and direct withdrawal), and changing water quality (48). The University of Washington River Basin Project is used as a backbone for our project; we will use the University of Washington GIS model as a base upon which to build the framework for our model and we will determine ways to enhance NAGA Version 1 capabilities and expand upon the information in the system.

3.2 Human Impact on River Basins

Humans have the potential to create magnificent structures and develop intelligence and technology no other species can create. People have excelled at developing objects that benefit mankind. Unfortunately, some benefits come at a cost, and often that cost may be to the environment. To understand how human beings play key roles in the changes in the environment, the impact people have made to the environment must be examined.

Many of the world's rivers are being altered in ways that are detrimental to the ecology of the area. These changes can have an economic impact as well. For ages, rivers have been, as Dombeck puts it, "depositing their rich silt and building up a diverse ecosystem". As a result of projects that interfere with the river's natural flow of water, rivers dry up or are fragmented to a degree that the once lively environment with numerous life forms is diminished or completely wiped out. This alarming trend is becoming apparent on a worldwide scale as more dams and other water-diverting structures are created. Water is being redirected to developing areas and to farm areas for irrigation. Over-tapped rivers have become dry land that can be overrun by new vegetation. Along with this fact, people are constructing buildings in place of these rivers. (18)

All of the rivers whose freshwater do not reach the sea have the potential consequence of creating "water shortages" and ecological damage that can hurt the economies of those who rely on the rivers. Collectively, the dams in the world might be said to resemble a sort of 'plumbing system' that human beings have created over the past several decades. Unfortunately, earth's ecosystem cannot be engineered to fit humans' needs without having harmful effects to other parts of the ecosystem.

The cutoff of nutrients to lower parts of the river results in a habitat that cannot provide enough support for the species that are there, and as a result, species have become endangered. Disappearing along with animal life are the farmers and fishermen who had been around for thousands of years. Around the Nile River, the number of commercial fish species being harvested reduced from 47 to 17 as a direct result of the construction of the High Dam at Aswan. Another example of the damage humans can cause is the damage found around the Ganges River. The Ganges has been altered so that the water does not reach the Bay of Bengal; as a result, during dry seasons the area suffers from poor crops, dried river beds, and saline buildup which harms the habitat of indigenous life. This particular basin lost approximately $25,000,000 as a direct result of these alterations. The Aral Sea once supported 60,000 jobs in the 1950s, but now there are no jobs. The dry land in the region contained a "toxic dust-salt mixture" that was being picked up by wind and dropped off on crops in the surrounding area, consequently killing those crops. Lowered river flow allows salts and chemical levels to become exceedingly high for drinking, and fosters disease-carrying organisms (32).

Lakes and seas are two of most affected bodies of water when water from rivers is diverted to suit human needs such as irrigation. In addition to the rivers themselves tapering away and drying up, seas are reduced in volume and area, and even divided into separate smaller bodies of waters. The decrease in river flow damages plant life, which in turn endangers the animal life of the region. Coupled with other forms of pollution, waterfowl population is diminishing. The Syr Darya delta had a drop from 173 to 38 in the number of nesting bird species (32).

Society needs to "recognize that there are limits to the amount of water that can be diverted from rivers" (32). This is true of all the earth's resources, as was pointed out by Jay Forester his book *World Dynamics*. Realizing that resources are finite, governments have created laws controlling further environmental damage and promoting cleanup efforts to repair the damage that has been done already. As a result, an economy may undergo a short period of regression, but the overall economic outlook will improve as time goes on. Developing countries may find it more difficult to follow such policies; they may only maintain minimum requirements, allowing rivers to support the ecology for fisheries and delta economies. In an effort to reduce water use, however, farmers can modify the irrigation methods they use to acquire more efficient ways to manage this valuable resource (43).

A group effort to restore and protect watersheds is needed (43). The importance of watersheds lies in the fact that they serve as nature's filters; they catch water, hold it, and finally release it in a cleaner form. In conjunction with maintaining watersheds, forestry projects are also important since they play a major role in maintaining stability in the areas around flowing water. Postel points out that "Healthy watersheds retain natural flows; recharge aquifers; are resilient to disturbances such as flood, fire and drought; and are more capable of absorbing the effects of human activities." Collaborative efforts involving local landowners, farmers, ranchers scientists, environmentalists, government agencies, and local citizens will ideally enhance the effects of laws created in favor of conservation of natural resources. This collaboration between groups can allow the sharing of ideas and interests. By this sharing, it is hoped there will be development of cooperatives that will arrive at solutions for saving the deteriorating ecosystems. Collaboration also provides a sense of unity amongst people who respect the environment (33).

One negative human impact on a river and its basin is chemical pollution. An essential aspect of river hydrology is the concentrations of chemicals in water. Although not all rivers will contain some of these harmful chemicals, examining some examples of chemical pollution in rivers will provides us with a better understanding of the types of thing that can impact a river, and the result of the polluted rivers.

One example of a chemical that can potentially be dangerous to a river basin ecology is arsenic. Arsenic is a strong poison that is found in the environment and when ingested, for example, through drinking water, can lead to cancer. Often found in rivers and lakes, arsenic can be a serious threat to human health. The origin of the substance may be traced to chemical manufacturers who dump waste without taking necessary precautions to prevent environmental harm. Research conducted at MIT has produced a better understanding of the variations of arsenic in the aquatic ecosystems and how it is formed, taking into account the numerous factors that affect its formation. Developing methods to obtain better samples of the chemical levels has allowed scientists to determine the toxicity of water, such that we know which basins are contaminated. This has led to development of methods used to concentrate the hazardous materials present in a given body of water for removal. Purification and reallocation of dangerous materials to designated disposal areas are some of the goals of the research. Further research is being conducted in hopes of cataloging other key factors, such as catalytic entities that influence the pollutants, so that steps can be made to provide a cost-effective manner of removing harmful substances from the drinking water of villages (23).

In spite of increased efforts to reverse the damage humans have inflicted on nature, sometimes there are limitations as to how much can be done to repair the environment. Studies of the Mill Creek watersheds in Boston were conducted in attempt to come up with a plan to meet water regulations set by the United States government. The studies used different modeling, surveying, and sampling techniques to come to the conclusion that some regulations may be set a bit too high to be realistically followed because certain pollution factors are irreversible. It is important to establish agencies whose goal is to combat pollution preventing further damage, yet it is also important to recognize the uncertainty of the success these programs may have (49).

3.3 Interviewing Skills

Interviewing people may seem like a simple task to gather information. One merely generates questions related to the topic of interest; an interviewer then questions people belonging to a predetermined size and demographic. The last step would be to record and analyze the results in some fashion. This seemingly easy task, however, requires a lot of careful planning in advance. It involves a detailed layout of the procedures in creating appropriate and useful interview questions. It also requires careful selection of a target audience who will be knowledgeable and willing to provide accurate information. Of equal importance is the sampling technique to verify that the results to this group can be extrapolated. Methods of approaching interview subjects exist. Also, an organized procedure for using the results from the interview must be laid out as well.

Planning interviews involves several phases. One phase is to design the questions to be posed to the interviewees. The answers must help solve a problem and be specific enough to be used as evidence to support an argument or point of view. When designing the questions, the interviewer should keep the objective of the interview in mind and questions similar to the following in mind:

- What information do you want to obtain from the people you are interviewing?
- Will the respondent be willing to answer completely without bias?
- How long will it take to answer the question and whether the respondent will want to spend that amount of time?
- What will you do with the answer to the question?
- Do the multiple choice-type questions narrow the potential response too much?
- Is this question too hypothetical for the respondent to come up with an answer?
- Will this question cause the flow of the interview to be thrown off?
- Are these questions appealing to the respondent?

  In order to avoid bias, and ambiguity, especially in Thailand we must consider the following:

  - Are the questions carefully worded?
  - Will an in-person interview intimidate the interviewee?
  - Is your presence going to influence the respondents' response to your question?
  - Is the setting neutral enough so that there is no outside influence?

- Will the question obtain the respondents' rationalize opinion as opposed to his or her personal reaction?
- Would phone interviews or mailed questionnaires work much better? (8)

3.3.1 Interviewing Methods

Many interview methods have been developed and standardized. The interviewer must decide on the style of interview and what type of information, qualitative or quantitative, that is expected to be gained from the interview. A particular method's rigidity of structure and the size of the target audience can vary simultaneously. A few of the methods include in-depth qualitative interviews, focus group and standardized interviews. (8)

In-depth qualitative interviews are most appropriate when "a rich, detailed, holistic picture" of the person's experience is sought. This method is generally very flexible in nature and can be adjusted to the interview subject as the interview proceeds. The structure of this type of interview is casual and allows for the interviewer to elicit detailed information from the person through open-ended questions. The disadvantage of this method is it is time-consuming and ineffective if testing hypotheses or gathering factual information was in mind.

Focus groups are conducted in a manner similar to the way in-depth qualitative interviews are done. They differ in that they involve several people in a group setting. This method is useful when there is some common experience that the subjects share, such as their reaction to some new program. It is general used when the interviewer can expect something of a "debate" on differing views. Focus groups are not good for discussing personal topics that may make some people embarrassed, however. As with in-depth qualitative interviews, this method is good for getting detailed information from people; in addition, focus groups are less time-consuming since several people are interviewed simultaneously. The disadvantage of this method lies in its inability to model a larger population and the likelihood of external influence on individual opinions, which may be avoided if the subject is interviewed separately.

Standardized interviews are very structured. This type of interview begins with a set order of questions to be asked; virtually no deviation should occur. Every interviewee is questioned in the same way: the interviewer has control in a standardized interview. This type of interview is useful to obtain factual answers and can be conducted via phone or mail; it is ideal for testing hypotheses. Information from this method is generally expected to be able to serve as a sample that can be generalized for a larger population. Interview bias is reduced since this interview method is standardized for anyone being interviewed, and this method is much less time-consuming compared to the qualitative ones. Unfortunately, the tradeoff is inflexibility compared to other methods (8).

Once a method is chosen and the goals of the interview are decided on, the interview framework itself should be created. A few useful guidelines for the physical layout to follow are:

- Make the form visually appealing
- Provide sufficient space for responses
- Arrange questions in a logical order

- Keep questions worded as simple as possible and in a language that is best for the interviewee

All interviewers must go through the process of choosing the participants, determining the number of interviews that should be conducted, preparing to interview, conducting the interview, and analyzing the results.

A request for an interview must be made. The interview is usually requested by sending a business letter, which briefly describes the purpose of the interview and the intent of the research project being conducted, and reassures the subject of the confidentiality of information collected. Next, one should provide contact information, and allow any concerns the interviewees may have to be addressed. Anticipating questions that may be given in the interview can provide the interviewee with confidence in continuing with the interview. The interviewer should familiarize himself or herself with relevant information, in order to be more effective in conversing with the interview subjects. Another important consideration is ethical in nature; the subjects should be informed of the research purpose and how their responses will be used. No omissions of information should be made, and any promises made to them must be kept (8).

Choosing the right participants for in-depth qualitative interviews and focus groups is an important step in the interviewing process. Generally, people who have expertise and experience in the field of interest are chosen. The number of people interviewed should be comparable to the number of people for the standardized interview. Also, the standardized interview should include a random sampling of people since the selected subjects are to represent a larger body. In order to verify that this sampling is truly random, and well represents the larger body of people, demographic information must be collected. Ideally, a random selection by computer of a database interviewees should be performed. Both in-depth qualitative interviews and focus groups will generally end at the discretion of the interviewer, who will decide when enough information has been obtained. The number of interviews to be conducted for standardized interviews should be relatively large; the larger the percentage of people interviewed is, the more likely it will be that the sampling is as representative as possible.

The interviewer should understand the terminology associated with the project. Testing the questions prior to the actual interview is an excellent way to prepare as well. For the standardized interview, much advanced planning will be needed since the process will be like a script; the interview has a planned introduction and agenda, which must be followed precisely. Since focus groups are qualitative in nature, when interviewing these focus groups the interviewer will act more as a "moderator" rather than actively interviewing a particular individual. Preparation will mainly focus on resolving any problems or items that may stray from the topic. Similarly, in-depth qualitative interviews must not be too involved in the conversation, but rather must direct the interviewee to speak about the history and background in an orderly fashion that can be logically followed.

During the interview itself the interviewer(s) must pay close attention to the subject speaking and at the same time take notes on the responses to open-ended questions posed by the interviewer. The interviewer will generally follow questions by more questions to delve deeper into the topic in detail. Other examples and other questions should follow logically. There should be a balance between formality and casualness in the interview process, and the interview should eventually conclude on a positive note, leaving future contact with the subjects open. In this situation, the interviewer will need to provide clarification when necessary and encourage feedback on anything that might not have been answered clearly.

Once all the data has been gathered, the information should be consolidated and processed using appropriate analysis methods. For example, quantitative data would likely use a regression analysis model if one is trying to establish a relationship between interviewees and responses. Quantitative data is also analyzed using confidence tests. Qualitative data will involve careful analysis of notes and perhaps viewing the interview over again to understand the responses thoroughly. From this careful examination of the response, conclusions can be drawn (8).

3.4 Statistical Analysis

For analytic purposes, it would be ideal if all data could be measured, calculated, and stored with infinite precision and accuracy; however, we cannot acquire and store information in such detail. Thus, it is necessary to store data and other acquired information with the greatest accuracy possible and known precision based on that accuracy. Statistical analysis is the method which allows one to determine the relative accuracy of a particular set of data in relation to another set of data pertaining to the same measurement or calculation. The remainder of this section will outline some important terminology and equations for performing statistical analysis.

3.4.1 Sources of Error

Varma defines statistical error as "the difference between the true value and the estimated value" of a particular piece of information (59). Varma also states that there are typically four types of error that effect the result of measurements and calculations, namely:

- Errors of Origin
- Errors of Manipulation
- Errors of Inadequacy
- Bias Errors

Errors of origin are statistical errors that are incurred from bias of the observer, or from the use of data which is inherently unstable. Errors of manipulation arise from improper manipulation of counts, measurements, and descriptions of the acquired data. Bias errors are the direct result of intentional manipulations of data by previous observers. Finally, errors of inadequacy are errors incurred from a lack of or inadequate amount of data.

3.4.2 Measurement of Error

Two methods for measuring statistical error exist: absolute and relative error. Absolute error is the measure of the actual difference between a recorded value and an estimated value or in an equation:

Absolute Error = Actual Value – Estimated Value. (eq. 3.4.1)

Relative error is a measure of the ratio between the absolute error and the estimated value or:

Relative Error = Absolute Error/ Estimated Value. (eq. 3.4.2)

3.4.3 Standard Deviation

Standard deviation is the most common measure of dispersion. Dispersion is the measure of variability or deviation of a value in a series from the arithmetic mean of that series. Arithmetic mean, or average, is a value within a series which best represents the series itself. Standard deviation is calculated using the following formula:

$$\sigma = \sqrt{(\sum dm\text{^}2)/n} \qquad \text{(eq. 3.4.3)}$$

This equation shows that the standard deviation (σ) is equal to the square of the arithmetic mean of the square of the deviations (*dm*) from the mean of a series that contains *n* elements.

3.5 Linear Regression Analysis

Regression analysis is a statistical method for determining functional relationships among variables. The relationships are written in the form of equations that relate a single dependant variable 'y' to any number of independent variables, 'x_1'to 'x_n '. Such an equation is expressed in the form:

$$y = b_0 + b_1{*}x_1 + b_2{*}x_2 + b_n{*}x_n\,. \qquad \text{(Eq. 3.5.1)}$$

The constants b0, b1, b2...bn are referred to as regression coefficients. These coefficients are determined through another set of equations and utilize the data represented in the model.

Linear regression is a specific class of regression in which we assume that for the range of values observed, a line provides a reasonable approximation to the actual relationship between the dependent 'y' and independent 'x' variable(s). Linear regression can be performed on any equation that follows the following format:

$$y = \beta 0 + \beta 1 * x1 + u \, . \qquad \text{(Eq. 3.5.2)}$$

According to Chatterjee, this equation is not linear because of the relationship between x and y, but rather because the regression coefficients $\beta 0$ and $\beta 1$ enter the equation linearly. Thus, the following equations are also considered linear:

$$y = \beta 0 + \beta 1 * x + \beta 2 * x^2 + u$$
$$y = \beta 0 + \beta 1 * \log x + u \qquad \text{(Eqs. 3.5.3-3.5.5)}$$
$$y = \beta 0 + \beta 1 * \sqrt{x} + u$$

Any regression equation containing more than one independent or 'x' variable is referred to as multiple regression. Simple regression refers to an analysis of an equation which contains only one independent variable.

In performing linear analysis, ultimately the goal will be to obtain the least squares solution for Equation 3.5.2. The solution will represent the physical mechanisms that are actually developed in the data representation. These mechanisms are of course functions of the environment the data represents. However, it is not simply satisfactory to solve for Equation 3.5.2; One must also be able to provide information pertaining to the correlation, estimation errors, and the significance of the least squares solution. Only with this information can we validate the solution. To calculate 'R', or the correlation coefficient, we need to know the deviation of each datum for both the y and x axis. From this deviation data, we will create a ratio between the summation of the 'dy' and the summation of the 'dx' values. The closer this value is to zero, the greater the correlation between the line and the data is.

The significance of the regression will be based on the number of data points present in the analysis. Significance is a measurement of the reliability of our result should new data be added. Therefore, with the addition of data, the correlation coefficient should not vary a great amount.

Overall, the slope of the line will determine the relationship between the dependent and the independent variables. If the slope is positive, the correlation is said to be positive; that is, as 'x' increases, so does 'y'. Similarly, a negative slope will indicate a negative correlation between the two variables, and a slope of zero will indicate no correlation (59).

4.0 Methodology

The first course of action for our project is to establish clear goals that satisfy the needs of our sponsor, SEA START, while also fulfilling the requirements of an IQP. To determine SEA START's perspective, we intend to interview Dr. Anond Snidvongs to verify whether our approach to the problem is consistent with the needs of the organization. This interview will identify what changes should be made to the objectives and goals of the project so that SEA START's needs are met. This interview is described in detail in Section 4.1.1, Interview with Dr. Anond Snidvongs of SEA START. We may follow up this interview with others at SEA START if necessary. Next an interview with Khun Poonsook of Chulalongkorn University is described in Section 4.1.2; the purpose of this interview was to determine if Khun Poonsook had data that would be beneficial to this project. Interviews given on the trips to the Chi Mun River Basin are described in Sections 4.1.3, Ubon Ratchathani and Nong Khai Interview and Discussions Meetings, and 4.1.4, Khon Kaen Interview and Discussion Meetings.

In order to determine the predictive capability of our GIS to measure human impact on the river basins in Southeast Asia, we will be modeling the Chi-Mun River Basin. In an effort to understand the complex dynamics of the basin, we will be visiting several locations within the region to observe first hand the land, rivers, people and their lifestyles. In addition, we will be gathering and collecting data from regional environmental centers, and conducting interviews of environmental professionals and residents. In doing so, we hope to gain insight into the factors that affect the river's flow and/or its chemical makeup. We will observe the river's surroundings to see what substances drain into the basin, and the methods by which these substances reach the river. This is described in detail in Section 4.2, Trips to the Chi-Mun River Basin. Observation will ensure we have taken into account all pertinent human factors, and may identify other similar human factors that were not previously considered.

The next objective to be completed is the GIS modeling. This is described in detail in Section 4.3, Construction of the Geographic Information System. We will start with the University of Washington Southeast Asia River Basin model, NAGA version 1. We will study this model to learn what data is included in the model and how the data is organized. Along with this, we must look at the model itself and decide which layers to add in the future, accounting for the factors we have identified from our interviews and observation in the region.

After the completion of the Integrated Regional Model of River Basins in Southeast Asia and results of the data implementation have been produced, an analysis of the results must be performed. This analysis will allow us to determine the improvement of our model represents over the previous version. We will perform a detailed regression analysis of the results of the data implementation, comparing the simulated results to actual recorded results. In the analysis of the data, we will look for correlation between the simulated results and actual recorded data. It is our hope this will allow us to evaluate the capabilities of our model as a predictive tool. This analysis will be discussed in detail in Section 4.4. Analysis of the GIS Model.

4.1 Interview Discussion

Proven, effective interviewing techniques will be used whenever possible. The goal of each interview is to obtain information pertinent to our project. Through examination of the nature of the information that is necessary to acquire, a combination of a *standardized interview* and an *in-depth qualitative interview* was needed. The intent of the hybrid interview was to maintain a structured interview format without limiting the interviewer to obtaining only factual data. It is important to allow the interviewees to express their professional standpoints, share their knowledge from experience, and give qualitative information, as well as to provide the necessary technical data.

The basic approach to this form of interview is:

- Present the overall reason for the interview;
- Proceed by open discussion of prepared interview questions, yet control the interview's tempo (similar to standardized interviews);
- Permit interviewees ample time to think about replies;
- Allow slight digression from questions for qualitative information (Similar to in-depth qualitative interviews);
- Ask immediate follow-up questions to delve into greater detail of responses from interviewees;
- Retain notes on everything that interviewees say for examination;
- Obtain future contact information for follow-up interviews and/or contacts to new people who would be useful to speak with as well.

In addition to the interview style presented above, standardized techniques will be used when appropriate. The initial interview follows the combination interview method discussed in the beginning of this section. The first few interviews will be lengthier and more open-ended since the exact objectives and goals needed to be quickly and firmly established. The interviews will be allowed to stray slightly from the questions posed because much information, such as procedures for access to resources, will be given to assist us in acclimation to the environment and culture of Thailand. After the first few open-ended interviews, interviews that are more structural will likely be used to acquire other, more specific information.

4.1.1 Preliminary Discussion with Dr. Anond Snidvongs of SEA START

Interviewing is one of the most direct means of obtaining information for research needs; it involves interactive contact with the people who are of interest to the research project. However, even before actually conducting the interview, objectives for holding an interview need to be established; a common set of goals must be decided upon, prior to outlining a detailed procedure in achieving those goals. The purpose of the interview with our liaison, Dr. Anond Snidvongs, is to present him with our intended project objectives and acquire his approval of them. The intentions of the interview include establishing a common ground between Dr. Anond's objectives for our project work and the fulfillment of the requirements for the Worcester Polytechnic Institute Interactive Qualifying Project. Having identified the reasons for engaging Dr. Anond in the interview, clear questions must be posed.

The objectives of the questions that will be asked are:

- Obtain Dr. Anond's view of the project goals;
- Present current objectives and have Dr. Anond provide us with feedback;

- Ask for Dr. Anond's opinion about any objectives we may have excluded;
- Acquire necessary contact information that may be valuable to the project.

To start the interview, the current objective statements our group has in mind will be stated. Next, we will commence with the actual questioning unless Dr. Anond has any concerns that he would like clarified before starting.

4.1.1.1 Discussion Format with Dr. Anond

The following are the discussion questions that will be asked:

- What is your view of the goal of this project? (Explain)
- Do you agree that one of the objectives of the project is to expand upon the University of Washington's River Basin Model?
- Do you think determining human impacts on river basins is an appropriate objective for this project?
- If not, do you think it is acceptable to pursue this objective on our own in order to make this a complete Interactive Qualifying Project?
- Do you think that another objective of this project is to incorporate the data of human effects on river basins in the new GIS?
- Do you think another objective of this project is to analyze the results of the applied GIS model in order to determine the human impact on river basins and the impact of river basins on human beings?
- Do you think there should be any other objectives included in the project?

- Do you think it is necessary to interview others to achieve a better understanding of certain aspects of this project? If so, who are they, what they do, and how might we contact them?

Following the interview, the responses will be recorded in an orderly fashion. Using the newly gathered information, we should have a strong sense of the tasks we will be completing in conjunction with SEA START. Also, a timeline with the goals outlined will be created to facilitate an organized approach in creating an exceptional IQP.

4.1.2 Meeting with Khun Poonsook Vimuktayon of Chulalongkorn University

A professional working in the Department of Energy Promotion at Chulalongkorn University, Khun Poonsook Vimuktayon is an important person with whom we would speak. She is extremely knowledgeable about hydrological systems, especially river basins. She was selected to be an interviewee because of her ability to provide us with the data necessary for the GIS model. Specific information such as the topography of the Chi-Mun River Basin may also be available from her, or at least she might know where to locate it. Meteorological data and climatic data and the data collection stations' location are also likely to be obtainable through Khun Poonsook. Knowing the data collection station locations, we will be able to plan an excursion to Northeast Thailand. Some questions to be posed include:

- Do you have these data sets available for the Chi-Mun River basin?
  - Precipitation
  - Temperature

- PET
- Vegetation
- Population
- Land-use

- What historical developments have there been in the region in terms of agriculture, industry, climate, or precipitation?
- What would have a major effect on the hydrology in this region?
- Are there any special features of the Chi-Mun River Basin?
- What problems are found in the region? Specifically are there water quality problems?

Khun Poonsook is thought to hold much data that will be useful for the GIS model. Also, her insight on problems and features of the Chi-Mun River Basin will help broaden our perspective on factors to consider when modeling the basin, and may potentially lead to ideas for making recommendations.

4.1.3 Ubon Ratchathani and Nong Khai Interview and Discussion Meetings

An essential step in fully understanding the nature of the factors that affect the hydrology of a river basin is to visit the region in person. Observation of the surroundings will allow for identification of potential new factors that may assist in refinement of the GIS model. A more detailed historical background will be sought while speaking with people who live in the area. From a technical point of view, it is important that the source and procedure of data collection is known and the data is accurate. Comparison of different sized river basins would assist in creating a model as well. To obtain this information we hope to interview professors, scientists, and engineers that have worked with GIS in the past so they can give us knowledge and input that they have learned through their experiences. We would also like to interview people in computer science departments who may have digitized GIS data of the region. The goals of these interviews are to obtain digital data to put into our GIS, and to learn the techniques of building a GIS. With the above mentioned points in mind, the purpose of the trip was to answer the following questions:

- How are the data being collected? With what frequency?
- What is the land-cover usage?
- What type of agriculture is done?
- What kinds of industry had developed in the region?
- What are pollution intensities in the region?

Unlike the initial interviews conducted, the ones in Ubon and Khon Kaen will use the standardized interview format to maintain simplicity. The people we will interview are expected to have a limited English background, thus making it too difficult to conduct a discussion style interview. As with all interviews, all recorded results will be analyzed and incorporated into our project report as deemed fit.

4.1.3.1 Interviewing at Sirindhon Dam Information Office with Prakit Yaprohm

Data on the hydrology of the Chi-Mun River Basin is pertinent to our project. Therefore, one of the first sites we will visit is the information station at Sirindhon Dam. The objective is to gather information that could be used in the GIS model, as well as information regarding the region's agriculture, industry, water treatment, irrigation, and fishing. Through the help of Ms. Hathairath Chiansaen, an assistant to the contact at Ubon Ratchathani, communication will be facilitated to conduct the interview. Since the information center would not have certain data sets, such as population, questions to be posed mainly consist of topics that relate to dam creation and hydrology.

The interview and discussion questions:

- For what is the Sirindhon Dam used? Irrigation or Hydroelectricity?
- Can you provide detail on the capacity of the reservoir? What irrigation range does the dam cover?
- What types of hydrological or climatic data on the Chi-Mun River basin are available through you?
- Were there studies conducted before and after the dam creation to assess environmental impact and human impact?

With the questions answered, background knowledge on the capacity and uses of the dams can be gained. If data is available, it will be applied to the GIS model. The question on studies on environmental impact studies will allow us to develop possible recommendations for future dam-creation projects.

4.1.3.2 Meeting at Ubon Ratchathani University with Professor Surajit Phuphak

In addition to the research accomplished, advice and direction from experienced experts would be useful in construction of the GIS model for this project. Professor Surajit Phuphak has much experience in working with the ArcView software and with Idrisi™ software, and he teaches a college course on GIS at Ubon Ratchathani University. ArcView is the Windows 95™ - based software that will be used for the model, while the Idrisi™ software is used by Professor Surajit in conjunction with satellite imagery. The interview's purpose is to obtain relevant data on the Chi-Mun basin and to gain knowledge for improving the model. The following questions will be used as a guide during the interview process.

Interview and discussion questions:

- Can you provide a brief description of the Mun River?;
- What types of hydrological or climatic data on the Chi-Mun River basin are available through you? At what scale is the data available? (Village? Province? Frequency of data collection?)
- Are you aware of any research to assess impacts on environment and humans that was conducted before and/or after the creation of dams?
- What work have you done with GIS? Are you currently working on a project that utilizes the GIS software?
- Do you have any suggestions to improve the GIS model that will be created for this IQP project? Which additional layers?
- Can you overlay layers of the GIS model for analysis?

The results of the interview with Prof. Surajit Phuphak should provide our group with valuable advice on the technical aspects of the project, allowing us to improve upon the GIS model. It is expected that a better understanding of methods for conducting analysis and about software packages that are proven effective in GIS modeling will result from the interview. Also, additionally if any data, preferably digitized, were available through Professor Phuphak, that would expedite the project.

4.1.3.3 Meeting at Bridge Management Department

Various data sets must be collected for the model, and those sets will very likely be available at the bridge management department since the department retains records on recorded data. Due to the Thai-English communication barrier, an accompanying contact from Ubon Ratchathani University, Dr. Wanwalai, will assist us in attaining the relevant information for the Chi-Mun Basin. This meeting is expected to be brief and aimed at collecting any data that would not be available in Bangkok.

Interview and discussion question topics:

- What types of hydrological or climatic data on the Chi-Mun River basin can be obtained from your database?
- Where can we gather data additional to what you have available?

Data obtainable from the station should be useful for the project. Since this interviewing site is primarily a data collection place, little more is expected from the interview, beyond gathering the statistical data for the project.

4.1.3.4 Discussion with Dr. Wanwalai of Ubon Ratchathani University

Visiting the actual sites of the dams that will be simulated is a valuable step to possibly reveal new aspects or ideas that will improve the GIS model. From going to the region, we can obtain first hand insight to increase the complexity of the river basin model and incorporate issues that may have been overlooked. The last of the series of interviews and meetings during the first visit to Northeast Thailand is with Dr. Wanwalai Athivaspong, M. Sc. (Biochemistry). She is the vice-president for Planning and Development at Ubon Ratchathani University. Being the primary contact in the Ubon Ratchathani region, Dr. Wanwalai will be providing the us with key information about the Chi-Mun River Basin and introducing our group to a variety of professionals. The people that we will meet should allow us to acquire data and to acquire knowledge for creating an accurate model.

The following discussion question topics:

- What types of industry are in the Chi-Mun River Basin?
- What pollutant types can be traced to the industries?
- Has there been any change in industry quantity?
- How is water used in the industries?

- What impact do they have on water quality?
- How has fishing changed?
- What kinds of crops are grown in the Chi-Mun River Basin area?
- What statistical types of information of the region as a whole could you tell us?

The GIS model can possibly include some of the information from the responses to the questions posed. For example, a new layer representing industrial activity might be useful. Although time constraints will not allow for implementation of all possible layers, recommendations on ideas from the meeting can be made. Furthermore, knowledge of the agriculture types and the water consumption of different crops can give us insight into how water flow might be affected. Some background on impacts of projects such as dam constructions will complement our knowledge of environmental impacts from other human activities.

4.1.4 Khon Kaen Interview and Discussion Meetings

The main purpose of the visit to Khon Kaen is to collect data for the GIS model and to expand our knowledge of GIS modeling. Since the stay in Khon Kaen will be relatively short, any meetings will be fairly brief and to the point. We interviewed a variety of different people to obtain information for the project. To maximize the outcome for the trip, we outlined a general layout of information that will be collected on the trip. Following formalities and introduction of our project goals and objectives, we will discuss how to obtain the desired data. The basic data types that we will request for the GIS model are:

- Precipitation

- PET
- Land-use
- Socio-economic
- Agricultural
- Vegetation
- Population
- Temperature
- Industry

Depending on the subject's professional field, we will pose more relevant and detailed questions. We will pose questions for subjects with knowledge about the GIS and regional data and inquiries for locating the information, if they do not have it. If we interview as experts on GIS software and techniques we will ask advice on improving our own methods to create the model. Before any of the actual meetings take place, we must schedule the meetings in advance. A listing of questions and discussion topics that may be asked follows:

- Do you have any data (from data types previously listed) on the Chi Basin and or the Mun Basin?
- What type of software do you use for modeling your GIS projects?
- What projects are you currently working on? What is the estimated completion time schedule?
- What types of layers are being used in your GIS model? What additional layers do you find potentially useful in improving accuracy in the model?

The first person at Khon Kaen we will contact is Dr. Suwit Laohasiriwong, Deputy Director at Mekong Institute of Khon Kaen University (KKU). Meetings with other key professors of Khon Kaen University will be arranged through Dr. Suwit. Dr. Suwit will also arrange logistics for the stay. The other contact in Khon Kaen is Dr. Kriengsak Srisuk, who should to be able to speak about GIS data available at KKU.

The information acquired in Khon Kaen will be applied to the GIS model. If there is available data that will be useful for our model we will ask to borrow it and inputted this data into our model. We will use any new knowledge of creating GIS models on the model that we are building and in making recommendations for future projects. Additional information that might not directly apply to the project may be helpful to SEA START RC.

4.1.5 Final Interview with Dr. Anond Snidvongs

In order to assess the degree of success in our project work, it is important that we seek external evaluation. The best person to be interviewed for this would be our liaison, Dr. Anond Snidvongs, since he is the one who has most closely followed the project and oversaw it. Ideally, the model will accurately predict the run-off as hoped; however, regardless of its success, steps to further improve the model will be analyzed and put in our recommendations. It is important to identify any flaws in our modeling methods so that they will not be repeated in the next version. Unlike the more flexible interviews that we conducted, this interview will be more direct, because it is not aimed at gathering data for the current model. Rather, this interview is intended to assist in planning for the next version, which may include improvements, such as additional layers or higher resolution.

The following is a set of questions that will be asked:

- In comparison to the NAGA 1 version, have there been improvements? Or degradations?
- Do you see any fault in the construction of the model?
    - Data precision
    - Date
    - Reliability
    - Human error
- Did the model provide insight on how future projects will be planned and can be improved?
- Would follow-up Worcester Polytechnic Institute IQP (or even possibly MQP) projects be considered to further the work our project group has started with you?
- Are there any additions that you would like included?
- Is the time for completion of the project within your expectations?

Once the interview is complete, responses will be recorded and recommendations will be expanded. Conclusions on the success of the project will be noted and reported.

4.2 Trips to the Chi-Mun River Basin

A trip to the Chi-Mun River Basin will be taken to observe the river basin and its surroundings. We will observe the people living in the river basin, how they interact with the river basin, and what role the river basin plays in their lives. We will observe how the river flows through the basin, as well as the types of soil, irrigation methods, and agriculture in the river basin. The industry around the river basin will also be observed. In addition, we will be observing the amount of pollution in the river and the river basin, and possible causes of this pollution. We will conduct interviews with the local people to understand how they interact with the river basin. This trip will also include boat trips on the Mun and Mekong Rivers to observe how certain data are collected.

The first trip will begin in Ubon Ratchathani where we will meet with Dr. Wanwalai Athivaspong at Ubon University. During the time spent in Ubon Ratchathani, we will be talking to/interviewing the students of Dr.Wanwalai's class and other locals about the river basin and how it affects their lives and those of others. In addition we will be making our own observations of the river basin and gathering data that has been collected in the region to be used in our model. We will also be traveling to, observing, and taking notes on the Sirinthon Dam, which is located 70 km east of Ubon, so that we may simulate the construction of it in our GIS model. The second trip will be to Khon Kaen, where we will meet with Dr. Suwit Laohasiriwong at Khon Kaen University. Similar to the trip to Ubon Ratchathani, interviews, observations, and gathering of data will be performed during our stay in this region.

4.2.1 Interviews Conducted During the Trip to Ubon Ratchathani and Nong Khai

Interviews performed on this trip are an important method for understanding the people of the area, their culture, and their interaction with the river basin. This will allow us to see how changes in the river basin affect the everyday lives of the people in the river basin. Interviews will also be conducted in order to obtain an understanding of how the data that will be used in our model was collected. This will allow us to determine any bias in the data that may need to be compensated for in the construction of the GIS model. The structure and content of these interviews have been described in detail in Section 4.1.3.

4.2.2 Interviews Conducted During the Trip to Khon Kaen

Interviews conducted on the trip to Khon Kaen will be conducted similarly to the interviews conducted in Ubon Ratchathani and Nong Khai. The interviews are a cross between the traditional interview and a discussion. The purpose of these interviews is to attain information and data that could be used to construct our GIS model. These interviews and discussion are described in detail in Section 4.1.4.

4.2.3 Observations of the Chi-Mun River Basin

When observing the river basin we will examine the rivers and streams, dams, irrigation, plants and crops, soil condition, impervious area, industry, pollution, climate, effect of drought, and how the people use the river basin. These observations will allow us to have a better understanding of what makes up and affects the river basin. It will enable us to see first hand what is in the river basin, and how all parts of the river basin interact with each other. We will be able to see the real life objects which we will be simulating in our model. By making these observations, we will also be able to compare the GIS results to observations made in the river basin. We will record the observed data using photography and our handwritten notes. The notes will be transcribed onto the computer following our return to Bangkok.

4.2.3.1 Rivers and Streams in the River Basin

Observation of the rivers and streams will include looking at the salinity and turbidity of the water, which can be determined by the amount of debris in the water, its color, clarity, etc. Another observation that must be noted is what the water moves through (dirt, rocks, sand, etc.). In addition, the amount of water in the river or stream must be noted. All of these factors contribute to the next observation we must make, which is the approximate rate at which the river or stream flows. Another important part of the rivers and streams that must be observed is how the people use the rivers and streams (fishing, bathing, transportation, irrigation etc). The next observation that should be made is the amount of pollution in the water and what could possibly be causing it. The surroundings of the rivers and streams should also be well noted. This is important to observe to be aware what the water runoff drains through before it reaches the river or stream. These observations will allow us to understand exactly what the rivers that we are modeling look like. This will in turn enable us to make a more accurate model.

4.2.3.2 Plants and Crops Grown in the Region

The plants and crops grown in the region have a large effect on the river basin. The amounts of vegetation in an area help determine the degree of precipitation infiltration; vegetation also acts as a natural filter through which the precipitation passes before it reaches larger bodies of water, so it can also determine pollution levels. The crops that are grown in the region, furthermore, will determine the nutrient levels of the soil. For example, high demands for kenaf and tapioca in Europe motivated farmers in the Chi-Mun area to cut natural forests and replace the forests with kenaf and tapioca plants, which depleted the soil of nutrients (37). This caused two major changes in the area. First, cutting down the forests destroyed the land's natural filters, contributing to a large decrease of water quality in the Chi-Mun River Basin over the past few decades. In addition, the planting of kenaf and tapioca depleted the soil nutrients. This depletion of nutrients has prevented the farmers from planting other crops that require certain nutrients to grow. Therefore, the amount of forest and small plant life is important to observe during our trip to the river basin. In addition, the types of plants are important to observe. The major crops that are produced in the region are also important to be noted. The condition of the plants (rich and full in color, dehydrated, limp, etc.) is another important observation of the surrounding plants. These observations will allow us to find out what is around the river basins, and what may affect the flow of water through the river basin.

4.2.3.3 Type of Soil and its Condition in the Region

Soil type is a very important factor in a river basin. A river basin is made up of the area of land that drains precipitation into a body of water. The rate of drainage and the amount of sediment picked up during the drainage process are largely affected by the soil. Soil types, as well as other factors, have a large influence on the amount of infiltration and runoff. Runoff usually drains into a larger body of water such as a river or lake, while infiltrated water seeps into groundwater (which flows into larger bodies of water eventually, but not directly as runoff does). Therefore, knowledge of the condition of the soil is very important to understanding the flow of water through the river basin. We will be observing the color and texture of the soil. The type of soil, such as sandy, clay, high nutrient, dusty, or rocky, will be observed and noted on our trip to the river basin. During our trip to the river basin the amount of moisture in the soil is important to observe. This observation will also allow us to determine factors that may affect the flow of water through the river basin, enabling us to make a more accurate model.

4.2.3.4 Impervious Area Located Within the River Basin

Impervious areas consist of asphalt, concrete, buildings, paved roads, etc. Impervious areas impact the drainage of water in river basins. They temporarily block the infiltration of precipitation into the groundwater, and cause large amounts of fast moving runoff that pick up a great deal of sediment. The result of this is debris and topsoil flowing into the rivers, as well as increased levels of contaminants. We will be observing the amount of impervious area in the regions that we visit. These observations will allow us to determine factors that affect the water flow that we may want to consider using in the model.

4.2.3.5 Industry Located Within the River Basin

Industry influences a river basin in many ways. Industries produce many kinds of pollutants such as chemical and thermal pollutants and solid refuse; some of these pollutants are discarded on the land and some are discarded in the water. We will be observing the number of industries in the area and, to the extent possible, the pollution they cause in the river basin. We will also observe where the pollution is most intense, based on the water samples Dr. Wanwalai's students take and analyze. We will also observe the effects of the people working in the industry and living in the river basin. These observations will also allow us to determine factors that may affect water flow and quality. Through analyzing the observations we may discover new layers that should be added to our model to make it more accurate.

4.2.3.6 Pollution in the River Basin

There are many sources of river pollutants. In addition to industrial pollutants such as chemical pollutants from paper mills, there are also organic pollutants from domestic wastes and vegetation. Observation of the different kinds of pollutants, the intensity of the pollution, and the sources of these pollutants will be made on our trips to the river basin. Through these observations we will be able to understand some of the human impact on the river basin.

4.2.3.7 Climate of the River Basin

Climate is very important to the dynamics of the river basin. Climate determines the types of crops that can grow and be harvested in the river basin. Climate has a large effect on the evapotranspiration of the water, and therefore on the flow of the river basin. Events such as droughts and monsoons, which are a result of Northeast Thailand is climate, have a large impact on the crops in the river basin. Climate, temperate, humidity, wind, cloudiness, and evaporation will be observed on our trip to the river basin. These observations will allow us to be more aware of the climate, which we are simulating in the model.

4.2.3.8 People and Their Interaction with the River Basin

Observations of the people living near and around the river basin are an important element to this project. These observations are one way of showing how people interact with the river basin, what role the river basin plays in their lives, and how the people and the river basin impact each other. Quantity of people, lifestyle, occupation, quality of life, and methods of waste disposal are all characteristics that must be observed. Other important observations include how the river is directly used by people (bathing, fishing, electricity, irrigation, boating transport, etc.) and how changes in the river and the river basin affect peoples' lives. These observations will allow us to determine data that should be added to the model to display the human role in the river basin.

4.3 Content Analysis of Recent Publications

The significance of content analysis to this project is to identify important social issues through examination of various documents (ranging from official documents to periodicals). From the records, relevant trends related to the river basins and water management in Thailand will be identified. The main sources of information will consist of the material available in environmental periodicals, library collections, and current newspapers. The analysis will be of current and closely related issues.

The first step to the process of performing a content analysis is to regularly collect any form of literature available with pertinent information. Each article will be summarized and recorded in a logical manner. The information from the articles will be examined to identify trends in issues, such as dam construction and the impact that results. Another relevant topic is the types of water management policies that have been established, and the reasoning behind the policy-making. These issues are very much related to the GIS model that will have been created.

The GIS model's direct purpose is to predict the effects of some change in the region. Policy-makers and other authorities could greatly benefit from a GIS model that will allow them to make more informed decisions concerning irrigation projects, for example. Reviewing all the collected information is likely to reveal cases where using a GIS model will help decide whether, for instance, creating a dam will destroy the vegetation and wildlife of the surrounding regions. Resolving conflicts of interest between opposing parties can be eased if a reliable predictive tool is used. Trends found in the literature analyzed for the content analysis will allow for a clear connection between the GIS model and the real world.

4.4 Construction of the Geographic Information System Model

The purpose of constructing the GIS model is to promote further study of the effect of human social systems on river basin topography. Conversely, the analysis of the results of this model will aid in determining any possible future implications of river basin projects for the human social system. The results of this model will be made public in an effort to promote environmental awareness and policy changes that will preserve the watershed areas for future generations.

4.4.1. GIS Implementation

The actual construction of the GIS system will first involve collecting data from several authorities within Bangkok as well as within the Chi-Mun Basin. As a team, we will also make recommendations as to data fields that we feel are important for studying effects on fluvial systems.. We will collect data before an event to use as a set of initial conditions. In addition to that primary set of data, we will also have to obtain a set of data that was collected after the event so that we can compare it to our simulated results.

Construction of the GIS will depend solely on the availability of spatial data to construct the thematic layers that we will be using to determine human impact. Choosing these layers will be dependent upon the task the GIS is meant to accomplish. In this case, the GIS should be able to analyze the runoff as in the NAGA version 1 model.

The first step in construction will be to digitize any maps, including maps of the topography of the region. The topographic map will serve as the base upon which all successive layers will be placed. Once the topography is digitized in the computer, predetermined geographic locations on the map will be assigned as our reference points. Usually, these points are chosen to be at a given latitude and longitude, and are spaced evenly across the map; however, other geographically referenced points can be used when establishing reference points. These points are labeled with tics. A tic, as defined in Understanding GIS, The ARC/INFO® Method is a "registration or geographic control point for a coverage (layer) representing known locations on the Earth's surface" (52). The figure 2 is taken from the same book and illustrates the use of tics

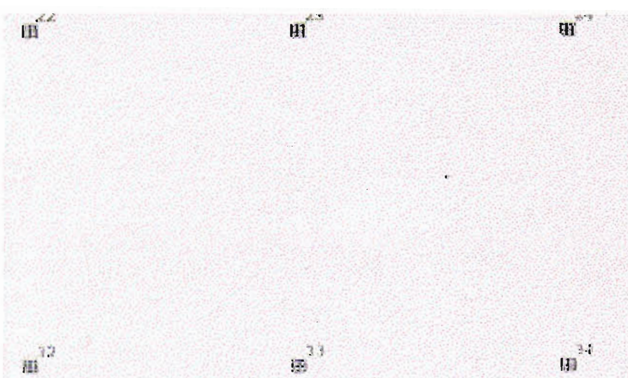

Figure 2: Use of TIC(s) for a Coverage

Tics allow ARC/INFO® to both align the thematic layers and convert the digitized information from inches into Universal Transverse Mercator meters.

Once the topography is established, we can begin to construct the polygons, arcs, and points necessary to represent the spatial features of our model. *Polygons* are enclosed areas within coverages, which represent an area of a given characteristic. For example, if a soil coverage was generated, a polygon might be used to delineate sandy soil, and another might be used for rich soil. *Arcs* connect two points on a coverage. Arcs do not have to be straight, but rather can be shaped into curves and sharp turns using vertex points. Modeling rivers and roads is a common example of the use of arcs. *Point* features can be used to illustrate discrete objects such as buildings, telephone poles, and road signs.

Once the basic elements are added to each coverage we must identify and classify them. This is accomplished by attaching a special type of point feature, the *labeling point*. A single labeling point is found in each polygon. This point identifies the polygon with an identification number, which relates the spatial data that characterize each polygon feature to the appropriate polygon. Similar labels are affixed to arcs and points as well.

The characteristic information that describes these features are stored in *attribute tables* (AT). Attribute tables are specific to each feature of the GIS. The three primary attribute tables that will be dealt with in our model are the Polygon Attribute Table (PAT), the Arc Attribute Table (AAT), and the Point Attribute Table (PAT). (52) These tables store characteristic information relevant to each feature. For example, a section of road may have an AAT, which contains information on the number of lanes, the material the road is made out of, and the identification number of the road. Each attribute would be stored in columns, and the information specific to a particular stretch of road would be stored in a row.

One feature of the ARC/INFO® GIS is its ability to relate data in one attribute table to data in another. For example, the following figure represents two PAT from a land parcel example in Understanding GIS, The ARC/INFO® Method.

STREET	VALUE	PARCEL NO.
Orange	101,000	1011-23-547
Lemon	145,000	1011-23-455
Orange	98,500	1011-23-446
Orange	126,000	1011-23-511
Lemon	139,000	1011-23-472
Orange	100,500	1011-23-440

PARCEL NO.	OWNER	ZONING
1011-23-446	Jones Title	R-2
1011-23-440	Jones Title	R-1
1011-23-472	R. Smith	R-2
1011-23-547	S. Brown	R-2
1011-23-511	J. Stevens	C-1
1011-23-455	R.Davies	C-1

Figure 3: Relate Example

The first table in this example lists the location, cost, and identification number, and the second contains the identification number, the owner's name, and the zoning classification for each parcel. For example, if we were interested in the location of R-2 parcels valued at less than $120,000, the GIS could search through the parcel IDs to find matches that exhibit these two characteristics, and highlight them on a map.

Construction of the model will begin after we return from our observation trip to Ubon Ratchathani. This model will be developed with the help of Khun Wirote Laongmanee, START's in house expert on GIS modeling. The GIS database will be stored on one of the two Sun Sparc stations using the Postgres database system. The GIS itself will be developed using ARC/INFO version 7, on a Unix based machine.

4.4.2 Developing Model Characteristics

Before any simulations of the GIS model are run, we first have to prepare the layers and the associated data. An AML or ARC Macro File, provided to us by the

University of Washington, establishes the modeling characteristics for each layer. The following diagram illustrates the dynamics of this model in detail.

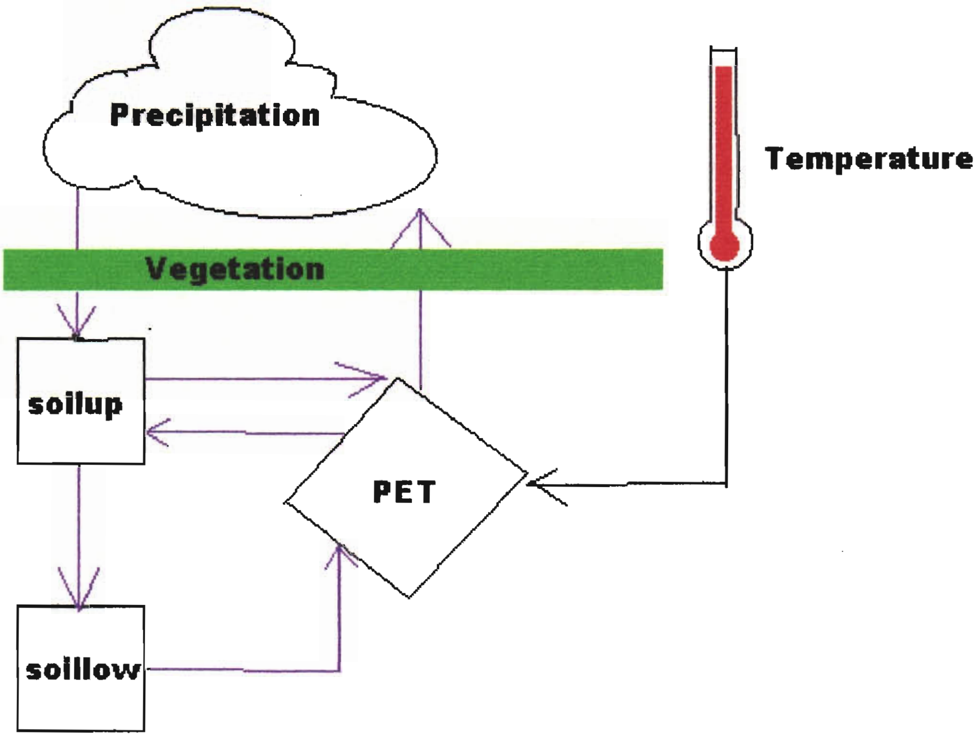

Figure 4: University of Washington AML Model Description

The dynamics for this model are actually quite simple. The storage capacity in each of the soil layers (SOILUP, SOILLOW), as well as the type of vegetation, Potential Evapotranspiration (PET), and elevation regulate the amount of water in any given cell. The dynamics of water storage and movement are described in the following sections.

4.4.2.1 Phase One: Precipitation Intercept

This function determines how much precipitation penetrates the vegetation level and reaches the soil surface below. Currently all vegetation is classified into two categories, forest cover and grasslands. If a cell is classified as grassland, 70% of all precipitation in that cell will penetrate directly to the soil surface and be stored in SOILUP. If the cell contains vegetation that is classified as forest, only 12.5% of the total precipitation will reach SOILUP. These figures account for the evaporation of moisture from the surfaces of the vegetation and soil surface.

4.4.2.2 Phase Two: SOILUP and SOILLOW

This function determines how much water can be stored in each cell. The model will be capable of calculating the available water capacity (awcmm), the soil storage capacity (sscmm), and the wilting point (wpmm) for each cell of soil. Transpiration is limited by the availability of moisture in the soil. As the amount of soil moisture decreases, the surface tension of the water on the soil particles increases. Once this tension has exceeded the osmotic pressure of the roots, water can no longer be absorbed. The point at which this transition occurs is referred to as the wilting point. For given percentages of sand, silt, clay, and bulk density, the soil will exhibit a different capacity for storing water. The following equations will be used to calculate each of the three soil characteristics:

AWCMM = PLEXW;

WPMM = LL;

SSCMM = SAT – LL;

BULK DENSITY =BD;

For soil with more than 75% and:

LL = 18.8 – 0.168* SAND;

PLEXW = 42.3 -.381*SAND;

For soil with sand <75% and silt<70%:

LL=3.62-0.444*CLAY;

PLEXW=10.79-0.05004*SILT;

For soil with sand <75% and silt>70%:

LL=5.00-0.244*CLAY^2;

PLEXW=10.79-0.05004*SILT;

For all soils:

SAT = (1-BD/2.65)*85.0.

4.4.2.3 Phase III: PET and Actual Soil Transpiration

This function of our model will allow us to calculate the quantity of water that is lost through evaporation off the soil surface and transpiration through root systems of plants. This phase will utilize the wilting point data to determine transpiration rate. This rate will be corrected by PET data that our team will calculate and insert as an additional layer to the GIS. For the purpose of this model, data pertaining to precipitation, temperature, and location were used to calculate PET using the Thornthwaite equation (eq. 4.3.1)

$PE_m = 16*N_m*(10*T_m/I)^a$, where

PE = Monthly PET;

Nm = Monthly Latitude Adjustment Factor; (eq. 4.3.1)

Tm = Monthly Mean Temperature;

I = Heat index for year (calculated);

a = Heat index adjustment factor (54).

4.4.2.4 Phase IV: Runoff and Discharge

This is the calculation phase of the model. Utilizing the data contained in each of the layers, the model will determine the amount of runoff through a series of complex equations, which are described in Appendix IV. The model will also determine the direction of discharge from each cell. To simplify the process, movement of water from cell to cell will rely solely on elevation data from our topography layer. Water will move from its current cell to the adjacent cell of lowest elevation. For example, consider the following figure:

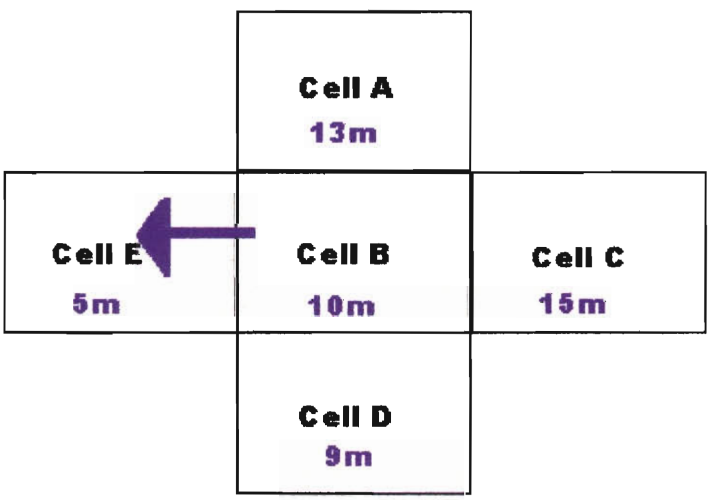

Figure 5: Illustration of Water Discharge Algorithm

There is water in Cell B that has to flow to an adjacent cell, either A, C, D, or E. From our algorithm we know that A and C are no longer possibilities because their elevations are greater than that of B. Of the remaining cells, E is chosen because it is at an elevation lower than that of D.

4.4.3 Simulation Criteria

Simulation of this model will progress in the following manner. After the construction of the model, several simulations will be run with all conditions initially set to zero. Running the model for several iterations, the variables will finally stabilize and then we can restart the simulation using these results as our initial conditions. It is also possible to simply set the initial conditions to known conditions of soil water capacity, etc.

Our first simulation will utilize the data we have as a test run to make sure that the model is performing as it should. After simulating the course of one year, we will perform the analyses outlined in the following section, namely statistical and linear regression analysis. The next simulation will utilize actual precipitation and temperature data for the twelve-month period of August 01, 1992 to July 30, 1993. The simulation will be reset and then rerun, and analysis of these results will be performed. If time permits, we will study the effects of adding a dam to the basin. This will be accomplished by changing the value of elevation at the geographic location of an existing dam such that those cells have greater elevation than cells adjacent to them.

4.5 Analysis of the Geographic Information System

Analysis of the GIS model will involve basic statistical analysis, linear regression analysis, and a short interview with Dr. Anond pertaining to his satisfaction with the results of the model. We chose these methods because of the variety of feedback that they can provide. The following sections outline each method and its uses in our analysis of the performance of the GIS model.

4.5.1 Basic Statistical Analysis

The results of our statistical analysis will help us determine how well our model performed relative to data already collected within the basin. Calculating the average deviation of the simulated results from the actual data will allow us to estimate the accuracy of our model. The results of this analysis will be used in developing recommendations pertaining to further development of the model.

4.5.1.1 Linear Regression Analysis

The results of this analysis will compare the simulated results of our basin model with actual runoff data from collecting stations in the region. Linear regression will show how well the data we simulated fits the actual data. Ideally we should find a one to one relationship between the two sets of data, however, realistically this result is not attainable. However, considering deviation, as well as the correlation coefficient R^2 we will be able to determine how well our model performed. The closer R^2 is to the value of one, the greater the correlation between the two sets of data. Subsequent models, will need to perform additional regression analyses, in order to determine correlation amongst the different factors.

4.5.1.2 Follow-up Interview with Dr. Anond Snidvongs

The results of this analysis will aid us in validating the results of the previous methods, as well as indicating the usefulness of the presentation medium. This interview will also identify future improvements to the model, which should be included in our recommendations chapter.

5.0 Results and Analysis

This chapter includes the results of our interviews, trips to the Chi Mun River Basin, analysis of GIS, and content analysis.

5.1 Interviews

This section describes in detail the results of the interviews conducted throughout this project.

5.1.1 Preliminary Discussion with Dr. Anond Snidvongs of SEA START

The initial interview with Dr. Anond produced successful results. We were able to clarify uncertainties of project goals and objectives that we still had prior to arriving on the project site. The purpose of the interview was effectively achieved as we discussed the steps that need to be taken to arrive at our goals. To summarize the results, the following is a list of paraphrased responses and suggestions that were made:

- The goal of the project can be modified to accommodate our WPI IQP requirements and it can be refined later on depending on what is possible to achieve;
- Data before and after events that have an effect on environment need to be collected in order to simulate and event and observe the accuracy of the predictive tool;
- New factors may be added to the GIS model for the updated version;

- Selection of a region to base the model on needs to be made and that selection will likely be decided by the available topography and data for the area. Examples of the data to be included are population, land-cover and humidity.
- Trips to the mouth of the river would be beneficial to the project through in-person observations;
- Some points to consider in data collection are water quality and salinity levels;
- Background research is necessary to be conducted on the Chi-Mun River basin. Primarily the information most likely will be available at the libraries of Chulalongkorn University. Some issues to keep in mind are soil, agriculture, people, administration system, parks, dams, reservoirs, economy, land-use, human activity, environmental problems, biochemicals and logging;
- Data availability needs to checked immediately to set the project in motion;
- Khun Poonsook Vimuktayon, a professional in the Department of Energy Promotion, will likely be able to provide us with data and a meeting will be arranged with her. Meetings with other people who would be useful in providing information for the project will be arranged in the future.

5.1.2 Meeting with Khun Poonsook Vimuktayon of Chulalongkorn University

Our meeting with Khun Poonsook Vimuktayon proved very resourceful because she was able to provide us with a large volume of hydrological and meteorological data that is pertinent to completing the GIS model. In addition to volumes of relevant data, she provided us with knowledge of the nature of the Chi-Mun River basin region. Below are highlights of the findings:

- The Chi-Mun River basin region is a plateau and quite flat;
- Thailand's climate is effected by the dry and wet seasons, November to March and mid-May to early October respectively;
- The dry season has a noticeable affect on the hydrology of the water system;
- Salinity is a major concern for water quality in Northeast Thailand;
- Droughts have been a major problem for Thailand.

5.1.3 Interviews Given During Trip to Chi-Mun River Basin

During our trips to the river basin we conducted several interviews. From these interviews we located data sources and obtained more background information on the dams and agriculture in the region. These results are discussed in detail in the following sections.

5.1.3.1 Interviewing at Sirindhon Dam Information Office with Prakit Yaprohm

The Sirindhon Dam Information Center seemed to be an ideal place to gather background information for the dams that will be simulated in the model. Even though very general information and possibly biased views on the impact of the dam to the environment were given, the data that was available still extended our background knowledge of associated organizations and dam projects of interest.

Findings:

Prakit Yaprohm from the Sirindhon Dam information station was not able to provide us with specific data on the dams that we will simulate. More literature on associated organizations, namely Electricity Generating Authority of Thailand (EGAT), was provided. In addition, numerous detailed Pak Mun Dam information was provided, including;

- A video depicting the creation of the Pak Mun Dam and research efforts done to preserve the environment;
- Pamphlets containing background and statistical information on the Pak Mun Dam and EGAT;
- Packets with detailed facts on the Pak Mun Dam.

The Sirindhon Dam was constructed for irrigation purposes. According to Mr. Prakit, since the creation of the dam, the surrounding regions have benefited from the irrigation work. The dam only irrigates the nearby area and it has successfully kept the region well irrigated year-round.

5.1.3.2 Meeting at Ubon Ratchathani University with Professor Surajit Phuphak

Data specific for only the Chi-Mun River Basin was not readily available as desired. but positive results came out of the interview nonetheless. Types of data available and information on creating an accurate GIS model was obtained. Below are highlights of the interview results.

Findings:

- Village level data on the different provinces of Northeast Thailand can be collected and is retrievable through Chulalongkorn University and at the Ministry of Science, Technology, and Environment;
- Socio-economic data is available under ArcView format;
- The Pak Mun Dam's creation has adversely affected fisheries;
- Data obtained needs to be validated for accuracy and updates;
- Precise sub-fields of certain data sets need to be specified to be able to have a consistent accumulation of data from the many Chi-Mun River Basin regions that will be a part of the model;
- Insight on color differentiation of satellite imagery was attained;
- Mr. Surajit is currently working on a detailed GIS model focused on the Ubon Ratchathani province of Thailand. The project is estimated to require a few years to complete;
- Mr. Surajit gave an overview on using ArcView and Idrisi to create a model and to simulate changes in the system;
- Raster modeling is preferable to vector modeling in terms of prediction.

5.1.3.3 Meeting at Bridge Management Department *Wednesday (28-1-99)*

Due to the communication barrier, a interview directly from us was not possible. However, it was made aware to us that Khun Poonsook in Bangkok has duplicates of the data that is available at the station. Instead of copying the information at the station, Khun Poonsook's sources in Bangkok will be utilized.

Interview findings:

- Khun Poonsook in Bangkok has duplicates of the data that is available at the station.

5.1.3.4 Discussion with Wanwalai Athivatpong of Ubon Ratchathani University

Professor Wanwalai shared her understanding of Northeast Thailand's background. She was able to locate a variety of literature and images that contained information that would be useful in broadening our background knowledge of the region. In addition, she updated us with some information on current events. Below are highlights of the findings:

- A table containing the industry counts and specific industry types was retrieved. Types one and two use less water than type three does. Types one and two may be industries such as rice mills, weaving factories, or engine factories. Type three might be a rice farm, tapioca farm, salt factory, vegetable canning factory, or noodle factory.
- Many species of fish have disappeared from the Mun River, including the tiger fish. Regulation and laws are not very strict and illegal fishing methods, such as electric shock or poisons, contribute to the disappearance of the fishes.
- Dams hurt fish species that do not naturally use fish ladders. Without going up stream as before the dam was created, the fish will not be able to reach its spawning grounds, and consequently its population will gradually diminish.

- A variety of crops is grown in the region. Environmental efforts are being made to shift nutrient intensive crops to less demanding ones, thus use land more efficiently. Educational programs and reimbursements are used to encourage farmers to change from crops such as tapioca, to something such as rubber trees.
- Some of the crops grown include tomatoes, pineapple, tobacco (only along the Mekong River), watermelon (Ubon Ratchathani), baby corn (Roi Et), pumpkins, chalets, garlic and marbury. Every province has silk weaving.
- Northeast Thailand has the biggest area and population in Thailand but the lowest income. Most of the jobs there involve farming.

5.1.3.5 Khon Kaen University Interviews

The main focus of these interviews was to collect the data to be used in construction of the GIS model and also to gather any advice on improving the model. Even though it was not possible to follow the initial plans for the trip exactly, the results from the visit to Khon Kaen were very informative and proved useful in expanding our knowledge on GIS modeling and locating resources for the data being sought for the project.

Results:

Originally a meeting with Dr. Kriangsak was in order; however, due to his departure on important business, a meeting with his assistant, Dr. Wichi Sibunlue, was arranged. Regardless of his limited knowledge on the project, Dr. Wichi was helpful in answering our questions and directing us to a multitude of people with whom to speak. With the help of Dr. Wichi, we were able to quickly locate and arrange appointments with other professors who have expertise in GIS and/or would possibly have the resources we were seeking. Dr. Wen Pen, who is working under the Environmental Engineering Department, was able to answer some of the questions we posed. Dr. Wichi and Dr. Wen Pen showed us detailed maps on their current project and searched their resources to identify data that would possibly be of value to us.

Following the meeting with Dr. Wichi and Dr. Wen Pen, we visited Dr. Vichian Plermkamon for GIS information. Dr. Vichian was in the process of working on a project similar to our own. Furthermore, we went to the GIS and Remote Sensing department in the Computer Center to meet Dr. Thani. However, she was not able to provide data for our project due to the scale of information in her possession.

Highlights of the outcomes of the meetings are listed below.

- Much of the specific data for the GIS model was not available, including vegetation and temperature. The available data include the region's topography and precipitation. No socio-economic or industrial data was found. The data that they had on the Chi-Mun basin was not complete for all provinces and was all in SPAN format. Dr. Wichi recommended searching for population data in Bangkok.
- Dr. Thani has a large amount of remote sensing data; too much for the scale that is intended for the GIS model of our project.
- Instead of the ARC/INFO™ software used in the GIS projects at SEA START RC, SPAN is the software package that is being used. To make the SPAN output into a more presentable report form, CorelDraw was used to edit the maps. It is possible to

export SPAN formatted data to ARC/INFO™, but that would require extensive work. Certain soil data sets can be obtained in Excel™ format.

- Dr. Wichi Sibunlue is working on the Kong-Chi-Mun Project. That project involves establishing a hydrogeological model for the management of salt contamination in the Kong-Chi-Mun area in Northeast Thailand. Dr. Kriengsak and his team are working with the Department of Energy Development and Promotion and the Ministry of Science, Technology and Environment.
- Dr. Vichian Plermkamon from the Department of Agricultural Engineering used three layers in his current project so far; the layers are Precipitation, Land-use and Soil Type. Additional layers, such as Population, will be added in the future. The model he is working on will predict run-off, which is similar to the objective of the GIS model we will create, and he expects it to be completed within a few years. The model he was working on is specific to the Nam Pong basin only.

5.1.4 Results of Final Interview with Dr. Anond Snidvongs

This final interview with Dr. Anond is an important step to evaluate the degree of success of the project and to complement the recommendations. Dr. Anond's responses were positive, as we were able to complete the project with results. The following are answers to the interview questions posed:

- For the first stage it is not expected to arrive at a final product. However, the process to complete the project has started and that is the important as refinements will be improved;

- Much has been improved over the old NAGA 1 version. The resolution is much finer, from the 100-km scale to the 1-km scale. The work could not be done in Seattle, Washington so the work done locally in Thailand will be greatly beneficial;
- There were some things that were originally planned that could not materialize because of complications. For example, some dynamic vegetation data was not possible to be used and static data was used instead. The highest quality soil map was not available so an alternative lower quality one was used instead. The digital elevation map may not be completely accurate because of the editing that was done.
- The project work definitely helps in planning future projects. An immediate project following the completed work is to convert ARC/INFO™ data to ArcView format with Avenue scripting language. Some of the scripting needs to be debugged to reduce the size because of the vast capacity of hard disk space it is occupying;
- Future WPI IQP and MQP projects are a good idea especially to extend the work already started. Certain basins have a lot of room to improve in the collection of data for them. Additional components to the model can be augmented;
- Chemical layers would be a very useful addition to the model. Correlating regional and coastal ecosystems would also be looked into more depth. Connection to other projects would also be advantageous;
- The project was completed as much as was expected. Even if the model were not running, the collected data and preparation work that was completed would already been considered a success.

5.1.5 Information Obtained from Interview and Meetings

A wide variety of information was collected during our many interviews. This section includes information on dams and organization that we obtained through our interviews and meetings.

5.1.5.1 Damming in the Chi-Mun Region

Prior to the creation of the model for the Chi-Mun River basin, understanding the dynamics of the region is essential. Uncovering what research and development previously had been conducted in the region will assist in the GIS modeling through inspection of factors found to be important in affecting the hydrology of the river basin. Data collection from before and after the creation for human structures that alter water flow will be particularly useful since the basis of the modeling is to predict the change in the hydrology when such a structure is built.

Before discussing what projects were done in the Chi-Mun River Basin, some topographic information should be indicated to mark the precise location of the basin. The rivers join up with the Mekong River in the eastern end of the basin; the two rivers have a combined 18 billion cubic meters of average annual runoff at Ubon Ratchathani. Elevation levels of the basin range from 900 to 1,200 meters above mean sea level. Like other Southeast Asian regions, the basin receives about ninety percent of its rainfall during the period from May to October. For the area, March and April are the hottest months while December and January are the coldest; temperatures range from 4.9°C up to 43.4°C. The large area of the Chi-Mun River Basin and its water resource invites a lot of irrigation projects to be carried on in the region.

Numerous irrigation projects have been developed because of water shortages in the Chi-Mun River basin. Projects have consisted of either reservoirs for water storage, or canals divert the stream flow to areas where it is needed. To name a few damming projects, the Lam Takhong and the Thung Samrit projects cover the Mun River; the reservoirs have areas of 40,000 acres and 60,000 acres, respectively. The Bantoon Bantiew and Saeng Badan projects cover the Chi River with reservoirs 11,000 and 70,000 acres in size, respectively. The main characteristics of these projects are dam construction and reservoir storage components. The dams' heights vary from 24 to 39 meters and their combined storage capacity is approximately three billion cubic meters. The National Energy Authority (NEA) and Royal Irrigation Department (RID) were the organizations responsible for development, construction, and operation of these dams.

Some other irrigation projects in the vicinity include the Nam Yang Project, the Nam Mun Project, and the Nam Chi Project; these all involve distribution systems and drainage systems of varying magnitudes. Such projects also may call for conveyance canals to deliver water to service areas. In the past, developments were experimental irrigation programs, but they evolved to utilize more of the potential of the rivers, as more research, development, and technical and financial support became available. Studies and analyses on numerous data sets, including "engineering, hydrologic, geologic, economic and soils data", were used for further planning of other major projects. U.S. Department of State AID and the Government of Thailand also worked to come to agreements on projects based in the Chi-Mun River Basin. Much of the planning consisted of calculating costs, scheduling completion dates and assessing feasibility issues. Also, complications, such as in accuracy in topography, can cause difficulties in the construction. Besides studies aimed to investigate the workability of projects, land-use and economic issues should be studied as well; some of the relevant data include farming data and food output data.

5.1.5.2 Electricity Generating Authority of Thailand (EGAT)

The Electricity Generating Authority of Thailand (EGAT) is the primary source for electrical power in Thailand. EGAT provides nearly 17,000 megawatts of power to Thailand annually, of which approximately 16.9 percent (2,800 MW) is attributed to hydroelectric generation. To supply customers with ample power for the near future, EGAT has designed a new Power Development Plan (PDP) that covers a 12-15 year span starting in 1997, and outlines all major activities and projects. The newest PDP will focus on purchasing capacity from private companies, eliminating any further need for expansion of EGAT facilities (56). In the past, EGAT has been involved in massive construction plans including dams in the Chi-Mun Basin, and a joint project with Laos, Myanmar, and China.

5.1.5.3 Pak Mun Dam

The Pak Mun Dam is a large hydroelectric dam located in Northeast Thailand. It is specifically located in the Ubon Ratchathani Province across the Mun River at ban Hua Heo, in the Khong Chaim District. The dam is located about 5.5 km upstream from the merging of the Mekong and Mun River, and 82.5 km downstream from the town of Ubon Ratchathani. The National Energy Administration (NEA) and the French government initiated the development of the dam in 1967. In 1979, the Electricity Generating Authority of Thailand (EGAT) took the project over and continued the planning. EGAT confirmed the project's feasibility, and ecological and environmental studies were finished in January of 1982. These studies showed that approximately 4,000 households would have to be relocated due to the increase in the size of the reservoir. Cabinet approval came on May 15, 1990. Soon after its approval, construction of the dam began under close supervision of the two Cabinet-appointed committees chaired by the governor of Ubon Ratchathani Province, comprised of representatives from many concerned government agencies. These two committees are Committee for Compensation of Land Rights and Properties and the Committee for Resettlement. Construction began in June 1990 and was completed in December 1994. The cost of the dam project was about 6,600 million Baht. The dam is 17 meters high and 300 meters long, and it has a discharge capacity of 18,500 cubic meters per second. It has four 34-MW bulb turbine generators, with a yield of 280 million kW. The transmission system consist of 115-kV double circuit line of 70 km in length, which is connected, to the national grid through Ubon Ratchathani Substation II. The irrigation service area of this project will primarily cover 45,000 rai and eventually amount to 160,000 rai. Families that had to resettle were given .5 rai of homeplot, a new 4 by 8m house, and 10 rai of farmplot in the resettlement areas provided with irrigation system and basic facilities such as electricity, water supply, paved roads, school, medical center, and district offices.

EGAT insist that the dam has had no negative impact on the environment and the people living in the region (57).

5.2 Trips to the Chi-Mun River Basin

This section is a summary of the results of the two trips to the Chi-Mun River Basin. The first two sections are on the two trips taken to the river basin. The following sections are detailed description of the specific characteristics that were observed during the trips to the river basin.

5.2.1 First Trip to the Chi-Mun Region

The first trip to the Chi-Mun region began with a train ride to Ubon Ratchathani. While riding the train, we made observations of the countryside and the people working in the fields. Upon our arrival in Ubon Ratchathani, Professor Wanwalai greeted us. Dr. Wanwalai then took us to Ubon Ratchathani University. After meeting some of Dr. Wanwalai's students and associates, we took a trip to Electricity Generating Authority of Thailand (EGAT) to interview the EGAT Department Head, Prakit Yaprohm. A student of Dr. Wanwalai's, Dai, escorted us for the afternoon, and Dai acted as a translator for the interview. From this meeting we obtained very useful sources of information on the Pak Mun Dam and the Serengeti Dam, both of which were built by EGAT. Furthermore, we learned that there is a large amount of data on the Pak Mun Dam (a dam built for hydroelectric power), because it was built in 1994. EGAT insists that there has been little to no change in the basin due to the construction of the Pak Mun Dam. The information we obtained from EGAT will assist us in choosing which dams to simulate. The people at EGAT were very friendly and willing to help us as much as possible.

After the interview we took a visit to the Serengetti Dam, and the Pak Mun Dam. Many observations were recorded using a digital camera, non-digital cameras, and hand written notes. Observations were made on the dams, soil type, characteristics of the river and its surroundings, and the people living in the area of the dam. While lunching on a variety of Northeast Thai food, we observed local fishermen fishing and making fishing nets. After lunch we went back to the Ubon Ratchathani University where we interviewed Professor Surajit Phuphak, a professor at Ubon Ratchathani University, who is involved in a GIS modeling of the Pak Mun Dam. The modeling project Professor Surajit is working was started this year and is projected to continue for the next 4 years. Professor Surajit wrote a note in Thai to give to Dr. Jariya explaining where to acquire data that will be pertinent to our model.

Day two of our trip began with a trip to Nong Khai, which is about 500 km north of Ubon Ratchathani. There were several stops on the drive up to Nong Khai. The first stop was at a roadside farm where we observed the local farmers and what they sell. Observations of the dangerously low water level of the Mekong River were made; Many pictures were taken to document the river and its water level. Following lunch, water samples were taken of the Mekong River. These samples were taken at three different depths and eighteen tests were performed on the collected water samples. After the water samples were collected, the trip to Nong Khai was continued. Nong Khai was still another 300km from Nakhon Phnom.

Day three began with a trip to the Bridge Management Office, where Dr. Wanwalai translated a discussion with the Head of the Bridge Management Office, who suggested that we talk with Khun Poonsook, whom we had already interviewed. After the interview, more water samples of the Mekong River were taken in a similar fashion to those taken at Nakhon Phnom. Following the water sampling was a discussion with Wanwalai. This discussion was very informative and beneficial. Next we went to a rubber plantation, where we viewed a presentation on the European Union's attempt to get farmers to change their tapioca and kenaf crops to rubber and the making of rubber. We then observed the rubber trees and the crops with which they are grown.

5.2.2 The Second Trip to the Chi-Mun River Basin

The second trip to the Chi Mun River Basin was to Khon Kaen . The purpose of this trip was to attempt to obtain meteorological, socioeconomic, and physical data on the Chi Mun River Basin. In addition, the Chi River was observed in Khon Kaen. The first day of the trip was spent at Khon Kaen University. We began with a meeting with Dr. Suwit Laohasiriwong, who is a professor in the Faculty of Agriculture and Deputy Director of the Mekong Institute at Khon Kaen University. Dr. Suwit directed us to Dr. Wichi, a professor in the Faculty of Technology at Khon Kaen University, in the Geotechnology department. Dr. Wichi is the assistant of Dr. Kriengsak, a professor at Khon Kaen University who is constructing a GIS of part of the Chi-Mun River Basin in order to determine the affects of environmental changes on the groundwater in the basin. Dr. Kriengsak was traveling during our visit to Khon Kaen University and suggested that we talk to Dr. Wichi. We spoke with Dr. Wichi and he could not supply us with much data. He suggested that we talk to Dr. Vichian Plermkamon from the Department of Agricultural Engineering and Dr. Thani in Computer Sciences.

On day two of our trip to Khon Kaen, Dr. Suwit escorted us to the Chi River, where we documented characteristics of the river and its surroundings.

5.2.3 Observations of the Chi-Mun River Basin

Observations of the Chi-Mun River basin were documented in notes and pictures taken on the various trips to the river basin. The following sections are short summaries of the observations recorded during the trips to the river basin.

5.2.3.1 Rivers and Streams

The first river that was observed was the Mun River in Ubon Ratchathani. The Mun River had a blue/brown color to it. The water level seemed to be rather low; there are several dams for hydroelectric power and irrigation. The second river that was observed was the Mekong River in Nakhon Phnom and Nong Khai. The Mekong River has a brown, murky appearance. There was some noticeable pollution on the surface and banks of the river, and some oil pollution on the surface of the water. There was about one foot of visibility through the water. The Mekong was much bigger in size than the Mun River, although it too had a very low water level. The next river that was observed was the Chi River in Khon Kaen. The Chi River had a green/blue color to it. It was also smaller than the Mekong River. It also had a very low water level, and a visibility depth of about three feet.

5.2.3.2 Plants and Crops Grown in the Region

There are a variety of crops and plants grown in the Chi-Mun Region. The biggest crop is rice; both sticky rice and plain white rice are grown. Salt from farming is also a major product in the Chi region. Rubber farming is another major crop in the northern part of the Chi-Mun region. Other crops grown in the region include mango, watermelon, tomato, cucumber, pineapple, monkey apple, pumpkin, garlic, onion, tapioca, kenaf, sweet corn, peanuts, sugarcane, and bananas. There are a variety of other plants that grow in the region; it was difficult to find English translated names for these plants, but they were well documented in pictures (Appendix II).

5.2.3.3 Types and Condition of Soil

There were three major soil types in the region that we visited; sandy soil, clay soil, and soil that is more nutrient rich. Throughout the region a mixture of these soil types were observed. The most common was the sandy soil; Most of the soil observed was contained very little water. Some of the sandy soil did contain nutrient rich oxidized iron. The biggest problem with the soil seemed to be the lack of water.

5.2.3.4 Impervious Area in the Chi-Mun River Basin

The impervious area in the Chi-Mun Region is concentrated in the cities and the roads between the cities. There is a large amount of open fields and farmlands with no impervious area.

5.2.3.5 Industry Located in the Chi Mun Region

There are three types of industries in the region. The first two types use less water than the third type. Examples of the first two types are rice mills, engine factories, weaving factories, and rubber factories. Examples of the third type of factory are flower, rice product, noodle, salt, vegetable canning, and tapioca factories. Another type of factory in the northeast that produces a large amount of chemical pollutants in the water is the paper mills.

5.2.3.6 Pollution in the Chi-Mun River Basin

Most of the pollution observed in the Chi-Mun River Basin was litter pollution, but there was also organic pollution. Raw sewage is pumped into the various rivers and streams. In addition, there is boat pollution (oil, organic wastes, etc.) from the boats traveling up and down the rivers. Likewise, chemical pollution occurs from various factories. Contaminated water that runs off from the roads and cities also pollutes the rivers. Pesticides used on crops further pollute water.

5.2.3.7 Climate of the Chi-Mun River Basin

The daytime temperate of the areas that we traveled to were about 90 degrees F. There was a small breeze, and there was no precipitation during the time that we were there. At night the temperature would drop to about 50 or 60 degrees F. The people of the area complained of high temperatures for the season and very little rainfall. We have determines that this observation has not accurate enough to be used in this project. We will use climatic data recorded over time to gain knowledge of the accurate climate in the region.

5.2.3.8 People in the Chi-Mun River Basin

Many different types of people live in the Chi-Mun region. There are villagers who live far from the cities and have little modern technology. Many of the people who live in the cities own shops or work in factories or mills. Many of the people of the Northeast have Laotian features. These people also have their own Thai dialect, which resembles the Laotian and Thai dialect. A large disparity in wealth was also noted. There seemed to be many poor people, yet there are also some people who are obviously very well off. During the train ride through the countryside, we observed many small shacks. Less often, large mansion sized houses were also observed. Many of the people in this region fish far a source of income. Various kinds of fish are used in common Northeast dishes. Locals explained to us that there has been a large decrease in the number of fish over the past thirty years. Some types of fish no longer exist in the Chi and Mun Rivers. Transport over the rivers is another source of income for some of the people in the Northeast; this has caused a large amount of pollution in the rivers. Another major way in which the people of the Northeast use the rivers is irrigation. Many farmers complained of lack of irrigation due to the low water level of the rivers and reservoirs from the drought. One more manner in which the people of the Northeast interact and use the rivers is through tourism. These are many tourist sites located within the river basin, and numerous tourist hotels are located along the rivers. At most of these tourist areas there are hired workers to clean up the area for the visitors.

5.3 Content Analysis of Recent Publications Results

The first step in content analysis was to collect and read relevant literature. Following are the summaries of articles from magazines, newspapers, journals and online sources.

1) Kongrut, Anchalee. "Water flow from dams to be cut as shortage hits", BangkokPost, February 11, 1999, pg. 3.

The Royal Irrigation Department has plans to significantly reduce water flow from Bhumidhul and Sirikit dams. Warnings have been issued to Central Plain farmers to hold back from planting the third rice crops because the drastic water will create an insufficient water supply to sustain the third crop. Kicha Polparsi, deputy permanent-secretary of Agriculture and Cooperatives Ministry, reported that upper central-province-farmers are cooperating with the water rationing plans. Warnings were issued in spite of recent rainfalls that increased water levels by 25 million cu/m and marshes and canal levels by 50cm.

2) Crawford, Susan. "Mekong River Environmental Issues", The Indochina Media Memorial Foundation, April 1998, pg. 1.

Susan Crawford claims that "Southeast Asia's developing economies struggle to balance industrialization with environmental protection" (Mekong, pg. 1). Courses aimed to increase awareness on environmental issues of the Mekong River have been created. The courses will cover skills in journalism and environmental reporting. Several issues, including tourism, hydroelectric power, the politics of water, and the impact of dams on river life will be discussed by various speakers coming from the neighboring nations along the Mekong. Regional plans for the Mekong will be reviewed for their environmental impacts on the river. Further in the course, there will be investigations of projects in the Eastern Thailand where the Pak Mun Dam is located. Following the Pak Mun Dam is the Kong-Chi-Mun project, which involves irrigation and hydroelectric power. Land-use and water management issues will be an essential topic to be discussed. Eventually the three-week course will conclude with generation of environmental publications.

3) Editorial. "A 'free state' fights against a dam", The Nation, January 29, 1999.

The Chao Bon, a Mon Khmer minority, make up the population of an area in Thailand where life seems undisturbed by the outside world. The people in the region have already been squeezed tighter into the forests to the point at which they no longer avoid strangers but intermarry with them instead. The plans for the Pong Khun Petch Dam, however, have no steps for the preservation of their culture's existence. Opposing parties are taking stands on the dam's creation. Some believe it will greatly benefit those in need of water; others fear the damage it will cause to the environment, and that destruction of nature in Thailand has already been too much. Those in support for the dam may possibly be overly hopeful of the real advantages gained from it. The project appears to have tremendous support from farmers, the Irrigation Department, and land speculators. Possibly blinded by hope and lack of improved water management, the people will have to wait and see what consequences may come from another dam.

4) Maneerangsri, Woranuj and Supaphan Plengmaneepun and Smarn Sudto. "Farmers desperate for water", Bangkok Post, February 15, 1999, Business pg. 1.

Farmers in the Central Plain are becoming more desperate for water because the second crop-harvesting season is approaching quickly, but not enough water is available. Despite efforts, such as pumping water to the fields, the work is just not sufficient. The outlook for the crops is bleak; rice crop production is expected to drop to 2.96 million Baht from 4.79 million the previous year. Exports will decline by 30%. To worsen the water shortage, people from different provinces are planting beyond the 578, 500-rai limit. Farmers are threatening to destroy dams if they do not receive enough water rationing. Excessive off-season cultivation has added to the water problem. Irrigation authorities are trying to persuade farmers to plant less water-demanding crops and other crops that restore soil quality levels. Raising animals, such as chickens, can also be a source of alternative income for the farmers.

5) Chettermart, Dr. Surachet and Dachanee Emphandhu. "The tourism industry and sustainable development in Thailand", Thailand Environmental Institute (TEI) Quarterly Environmental Journal, October-December 1994. pp. 39-46.

Tourism in Thailand has increased vastly over the years; in 1960 the tourist count was 81,340 and now it is 5.7 million (1993). Tourism reached a level that called for the creation of the Tourism Authority of Thailand (TAT). With TAT, tourism continues to grow. Unfortunately, this massive influx of tourism is taking a toll on the environment. Tourist areas are being cluttered with pollution in the water and air. Development of new buildings is interfering with natural scenery.

Tourism promotion policies have only caused domestic and foreign tourism to increase without enough precautions taken for environmental conservation. The focus of the latest policy is to sustain high-quality tourism while also allowing growth in the tourism sector. Instead of rating tourism by monetary revenues and quantity of tourists, the satisfaction of tourists and quality of management at tourist locations should be accounted for. Environmental awareness needs to be increased among those who are responsible for contributing to environmental degradation. Eco-tourism has emerged as a potential tool for promoting tourism in Thailand while promoting environmental conservation; eco-tourism means "the responsible travel to natural areas which conserves the environment and improves the welfare of the local people" (Chettermart, 44).

6) Chinvarakorn, Vasana. "Diary of a protest", Bangkok Post, January 16, 1999, Outlook pp. 1, 5.

Opposing forces in Chaiyaphum rallied protests on January 5th of the construction of the proposed Pong Khun Phet dam. Those in opposition for the dam's construction are in fear of attacks from those who are branding them as communists out to start a new regime. Several villages have been persistent to oppose the dam but only some remain concerned with the original reason that there needs to be more research done before creating the dam. Others are dealing with the amount of compensation they can receive. Villagers are worried about attacks, and even women and children are preparing to defend themselves if necessary. Protestors lined up to block the way to the dam site and would not budge until sufficient assurance for adequate compensation was given.

On the supporting side of the dam, people believe the dam will provide them with the water they need to irrigate their farms. The provincial governor arrived at the scene to give the supporters assurance that the dam will be created. After a while, the demonstration was ceased and the roads were cleared.

7) Chinvarakorn, Vasana. "Dammed if they do, dammed if they don't", Bangkok Post, January 16, 1999, Outlook pp. 1, 5.

The Royal Irrigation Department (RID) has proposed the Pong Khun Phet Dam project for quite a while, but it has failed to materialize due to extenuating circumstances. The project is intended to irrigate the Upper Section of the Chi River Basin. Politicians and businessmen have been under suspicion for corruption and in one case the government is suspected to have attempted to trick villages to sell their land for low prices while under the impression the government would not compensate them. The expected lifetime of the dam is 30 years, and benefits for its creation were projected, but the impact on the environment following end of the dam's use is uncertain. The dam may increase the number of maintainable farms during the dry season, but whether the investment is worth the cost is questionable. The project does not need to go through environmental impact assessment (EIA) study since it was proposed prior to the 1992 Environmental Bill. However, construction contracts are no longer valid and construction has not commenced.

8) Pouaree, Suvicha. "Isan is still the poorest region", Bangkok Post, May 7, 1995, pp. 20-21.

Isan, the people of Northeast Thailand, are the poorest people in the country and they occupy Thailand's largest region with one-third of Thailand's population. Efforts have been made to improve the status of Isan, but since economic development plans followed international models, they only benefited those with a grasp of the large market already. Investment and industrial growth was examined to improve Isan's economic growth. Certain regions are better suited for different industries. Means for international transport directly to the Northeast Thailand would be necessary as well. Tourism has high potential to give the Northeast an economic boost. Human resource development is a key to future success; with better education, better job markets will open up to Isan. Lastly, support from Indochina countries would assist in the region overall.

9) Buakamsr, Karuna. "Livelihood of villages under threat", Bangkok Post, May 7, 1995, pp. 20-21.

Laos, Thailand, Cambodia and Vietnam have had agreements to launch massive projects to tap into Mekong's hydroelectric powers. With 200 hydroelectric dams in place, immense amounts of energy will be produced. The Kong-Chi-Moon project is an example project with the intent to make arid lands fertile. Dry farmland is a significant problem for farmers because of the great difficulty required to grow crops; loans are sometimes needed to squeeze out some crop yield. Some farmers are caught in the loaning process and are trapped in debt. Dam construction has the effect of increasing salinity in the soil, which is harmful to crops. Farmers are crying for help with their conditions, but they are helpless in their efforts.

10) Traisawasdichai, Malee. "Pak Mool: A costly Education", Bangkok Post, November 23, 1994, pg. 1.

World Bank's Environmental Department admits that the creation of a dam had made life for some people worse off. The burden has unfortunately been placed on the victims to prove the adverse effects, instead of on those who are causing the harm. Dr. Robert Goodland from Washington joined the World Bank to influence economic analysts to include environmental considerations. Goodland reports the difficulty of valuing things, such as natural resources, in financial terms. Academia is fortunately introducing ecological economics.

11) Charasdamrong, Prasong. "The Dam's Done, Conflicts Not", Sunday Post, July 3, 1994.

The Pak Mun Dam project has created inconveniences and caused damage to farmers, and now they are seeking compensation. Dam officials were surprised to receive so many reasonable claims. Electricity Generating Authority of Thailand (EGAT) has been able to refute claims, but innovative demands will continue to follow because of the unfulfilled compensations. 451 million Baht has been spent to compensate farmers, and over 2000 fishermen sought compensation for unemployment. Protesting by those opposing the dam creation delayed the project deadlines, and EGAT is suing the protestors for losses, such as lost loans. Compensation schemes were apparent during the period as villagers purchased or borrowed items they did not have before.

12) Traisophon, Temsak. "Millions hit by deepening water crisis", Bangkok Post, January 26, 1999.

A total of 4.57 million people in 34 provinces of Thailand are being affected by a water shortage. Surveys are being conducted to assess the current situation on the over-cropping of rice. The latest results show that the rai limit is being exceeded by as much as 180%. To extend the damage, roads are subsiding as a result of the drought. Aquatic life and crops are taking a toll from the dry season. The rainy season is much too far away to save the people from this dry spell, but there is not a whole lot than can be done to solve the problem. The Ministry of Interior's attempt to alleviate the situation is by sending trucks with water to the needy. Even though this method will temporarily save the people from an absolute catastrophe, it is by no means a long-term solution.

Natural events can account for some climatic changes, but human beings also have a part in affecting the climate. Many human activities have an impact on the environment; people destroy forests and create pollution that adds to the greenhouse effect. Human structures also affect the environment. Dams, for instance, can be rather troublesome to decide on whether or not to create a new one. The Kaeng Sua Ten Dam is an example of a situation in which opposing views exist on the dam. One side wants the project to go through because they will benefit from the water the region will receive; the other side opposes it for fear of damaging forests in the area. It is scenarios involving crises (water in this case) that will "provide a rude awakening to authorities to think more about long-term and more effective solutions".

13) Kongrut, Anchalee. "Plan to build dam in sanctuary rejected", http://www.bangkokpost.net/issues/drought/120299.html, February 12, 1999.

The Royal Irrigation Department proposes to destroy 1,200 rai of the Phu Khiew Wildlife Sanctuary in Chaiyaphum to build a dam in its place. The Agriculture Ministry decided against the inundation of the forestland because of the lack of evidence showing the benefits to the farmland, or what impact may result from the dam's creation. Forestry chief Plodprasop Suraswadi and other committee members voiced their concerns that the project did not provide adequate studies for the impact to the Lam Saphung River and the wildlife around the sanctuary. A study conducted in 1997 showed that the sanctuary contained many endangered species and any adverse effects to the area could wipe out the animals.

14) Anonymous. "B239m more needed for rain-making", http://www.bangkokpost.net/issues/drought/100299.html , February 10, 1999.

Water rationing has been set in place in an attempt to curb too much cultivation. Plans involving rainmaking operations are in the works to increase reservoir levels. The Royal Irrigation Department is using a rotational method to distribute the water from the Ping, Nan and Yom rivers to various provinces. Expansion of second crops has sharply affected water supply levels and the expansion has exceeded the rai limit that was in place. The drought is causing low water levels, which is affecting power plants' abilities to produce energy, and is also diminishing the water supply of dams. Centers have been set up to help villagers who have been affected by the drought. Some people have to resort to alternative methods to deal with the drought, while others have left their homes and work elsewhere to survive.

15) Arunmas, Phusadee. "Downpours since late January make water crisis less severe", http://www.bangkokpost.net/issues/drought/040299.html, February 4, 1999.

Natural downpours after January 28th in the Northeast region greatly helped increase water levels for use in crop irrigation. Additionally, improvements on salinity levels are apparent. Bhumibol in the Tak province and Sirikit in the Uttaradit province are two dams which received a good amount of water from downpours, and the amount is expected to allow for coping with the drought experienced in the Central Plains. Salinity problems are being dealt with to a good degree of success, but second-round rice crops are nullifying the government's battle against the drought. The government hopes that they will be able to curb the third rice crops and instead hope to see other types of crops and poultry.

5.4 Summary and Examination of Content Analysis of Recent Publications

Common issues are apparent in the literature that was read. The common issues include concerns about the environmental impact of damming projects, water management issues, and the balance of environmental conservation with economics. In many of the cases, failure to properly assess the environmental impact of irrigation projects has caused major conflicts. Protests were held to oppose dam creation for fear of the negative impact they would have on farmers; fishermen have already suffered unemployment because of dams. Suggestions for farmers to shift to alternative, less demanding crops, and to find alternative income sources have been suggested. Those in favor of new dams argue that dams will provide the necessary water to irrigate crops. Luckily, no severe violent occurrences have resulted from these conflicts, but the situation would be better off if it could be ameliorated.

Water management has arisen as a possible problem more than the droughts and shortage of water. Differing views on exactly how good the water supplies are have surfaced. Water quality was found to be of concern as well salinity levels; dams have often times affected the salinity level of waters.

Another noticeable issue involves the economics behind the environment. Tourism has been a booming part of the Thai economy and is continuing to increase, but an unaddressed problem is the assessment of tourism's success. People may be more concerned tourism's numbers instead of considering the effects of it on the environment. Degradation of the environment has occurred because lack of consideration of the effect of, for example, building multiple buildings too close to a river. Increased environmental awareness needs to be spread to the public to combat further damage to the environment. With the many issues apparent in the region, some method to ease the conflicts would be welcome. Often times, projects are not followed through because of insufficient studies on the impact of the construction to the environment and to the people surrounding the region. GIS alone is not a solution to all that should be considered in decision-making. However, GIS models similar to the one created for the Chi-Mun River basin can prove to be a valuable tool in assessing the amount of change to the environment a dam or other water project would make. With that ability, sustaining a healthy environment while promoting economic and social development will be more possible.

5.5 GIS Results and Analysis

This section outlines the results of construction and simulation of our GIS model of the Chi-Mun River Basin. This model was developed with the help of both Dr. Anond Snidvongs and Khun Wirote Laongmanee.

5.5.1 Construction Results

In order for simulations to be run using our collected data we first had to organize and process the information. After collecting the precipitation data from Khun Poonsook Vimuktayon, at the Department of Energy Promotion and Development, we began to calculate potential evapotranspiration (PET) using Thornthwaite's equation; this operation was performed in Microsoft Excel™. The results of these PET calculations, as well as the precipitation data collected, were then transferred to and opened in Surfer 32.

This program performs mathematical interpolations on data, which allowed us to transform our numerical data to visual maps that we could grid for use in ArcView and our model. With the aid of Khun Wirote and Dr. Anond we were able to incorporate all of this data into one directory which we called NAGA 11. From NAGA11, themes were created in ArcView from the data we had prepared and collected. Khun Wirote was able to "crop" or manipulate the visual images into the shape of the Isan region so that we would be able to perform our analysis on this region. Each theme was then gridded (rasterized), so that the simulations could be run. The grids were composed of grid cells representing 1 kilometer by 1 kilometer areas, as was requested in the design proposal presented to us by SEA START early in B-term of 1998.

As all of this was performed in ArcView, an appropriate Avenue script file was required to run the simulation. However, because of time restrictions we were unable to run the simulation using the ArcView platform. We were able to transfer the information to ARC/INFO™, however, and run the model with the AML files that SEA START already had in their possession. The following section outlines the results obtained, and an analysis of the simulation run using these scripts (Appendix C).

5.5.2 Simulation Results and Analysis

As a direct result of running the AML scripts 'hydro.aml' and 'hydroiter. aml' we were able to obtain a set of runoff data from ARC/INFO™. As this data was already gridded we were able to open the monthly runoff files in Arc/View. The result of which was a set of maps similar to that shown in Figure 6.

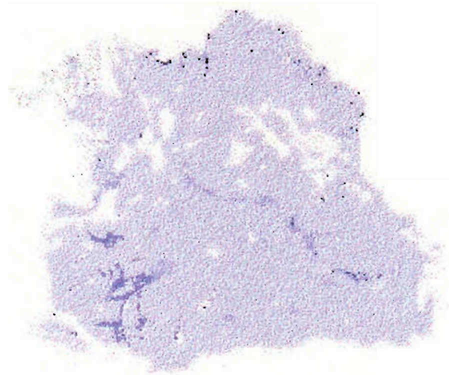

Figure 6. Map of simulated runoff in the Isan region, October 1992

To make this type of map useful, however, we had to crop this image to reflect cells only in the Khong Chiam sub basin. From this cropped image we were able to evaluate the total runoff for each month from the value attribute table (VAT) associated with that month. These tables contain data that pertain to the number and value for each cell within the specified grid. For each unique cell value, runoff was calculated by multiplying that value by the number of cells associated with that value. Total runoff for the basin in that month was calculated by summing all the unique runoff calculated in the previous step. We incorporated this data in an Excel worksheet, along with the runoff data we obtained from stage recorder station 04050127 at Pak Mun Dam.

Table 1: Table of simulated and recorded data

Year	Month	Month	Observed Runoff (St.04050127)	Predicted Runoff
1982	8	15-Aug	5750	1878.708
1982	9	15-Sep	5150	2032.591
1982	10	15-Oct	2520	2270.45

1982	11	15-Nov	958	2128.1
1982	12	15-Dec	403	1698.614
1983	1	15-Jan	330	1397.611
1983	2	15-Feb	145	1314.24
1983	3	15-Mar	166	1404.78
1983	4	15-Apr	178	1612.898
1983	5	15-May	243	1724.882
1983	6	15-Jun	409	1669.45
1983	7	15-Jul	2370	1673.071
1983	8	15-Aug	2940	1878.732

From the data stored in this table, which is shown in Table 1, we were able to easily perform both statistical and linear regression analysis.

For our statistical analysis, we first compared the recorded data to the simulated data via absolute and relative error. Values of absolute error ranged from 3871 mm less than the recorded data to 1482 mm more than recorded data over the course of the year. Relative error ranged between as little as 10% variance to values well over 200%. As these results illustrate there are inherent inconsistencies in the model that prevent it from operating properly. Dr. Anond expressed his concern that in establishing the criteria for soil the variable for soil storage capacity, sscmm, may have been improperly defined.

Further indication of the need for further modifications to this NAGA version came about as a result of the Linear Regression Analysis. We again utilized Microsoft Excel to perform the mathematical operations necessary to complete the analysis.

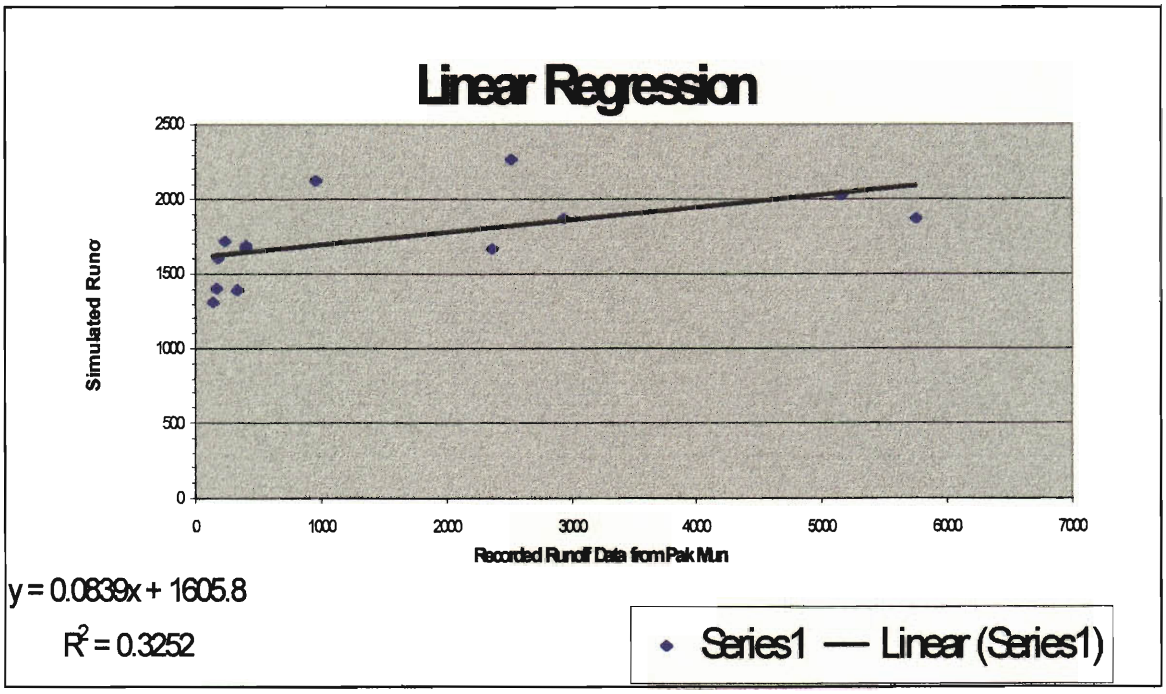

Figure 8: Linear Regression Analysis

Our linear regression analysis supports the statistical analysis we made previously, and illustrates that there is a significant amount of error present in our simulation. Ideally, if our model were to have produced results comparable to the recorded data, the slope of the regression line would have been nearly 1. Of course, this is not the case, and we find a significant deficiency in our analysis of this sub basin. However, the correlation coefficient (R^2) illustrates that there is a positive correlation between the two sets of data. This is promising, in that it indicates that indeed there is some consistency between the simulated and recorded data.

However, this information should not be in any way considered as an absolute measure of the quality of operation. This data pertains only to one sub basin out of a total of 190. It is evident that for different basins the model may perform better. Indeed, the actual performance of the model for predicting total yearly runoff was quite good. A comparison of the 18662 million cubic meters (MCM) of runoff recorded by the staff gauge at Pak Mun, to the 20805 MCM predicted by our GIS, we find a difference of only 11.8%.

Due to the difficulties incurred in developing and implementing this model and the extreme time and effort required to do so, we were only able to generate initial results for one sub basin. However, we feel that the model's performance for other sub basins may be far superior to the Khong Chiam results presented earlier in this section. In addition, our follow up interview with Dr. Anond we were able to verify that the overall model performance was quite good in comparison to the previous model. However, all parties concerned believe that further modification of the GIS is necessary for achieving the ultimate goal of using this model for policy development.

6.0 Recommendations

This chapter discusses in detail our recommendations for the continuation and suggested uses of the results of this project. The specific topics include upgrades to the GIS model, a human/environmental impact assessment, and continuation of this project through future Major Qualifying Projects and Interactive Qualifying Projects.

6.1 Upgrades to the Existing GIS Model

This section will present the steps we feel are appropriate for developing the model into a tool that will allow more complete understanding of river basin dynamics and promote legislation and development in a way which is mutually beneficial to both humanity and the environment. A discussion of adaptations to the current model via additional layers, a new AML script file, and evaluation of the human impact on hydrologic systems will also be developed.

6.1.1 Continuation of GIS Construction

Dr. Anond and Khun Wirote have discussed the desirability of running this model using ArcView and Avenue because of the Windows operating environment. Therefore, **we recommend the SEA START teams develop an Avenue script that will perform the operations of 'hydro.aml' and 'hydroiter.aml', the Arc Macro Language (AML) Script Files currently used to simulate the model in ARC/INFO.** This will allow distribution of the subsequent results and analysis criteria to policy makers and engineers without concern for the ease of operation.

6.1.2 Expansion of the Arc Macro Language (AML) File

In order to make effective use of the data collected in each of the layers, **we recommend the AML file be altered**. This will include restructuring the model algorithm to accommodate the additional layers, as well as enabling it to handle the aggregate data. The AML should ultimately incorporate all repetitive functions, to avoid user interaction as much as possible.

6.1.2.1 Detailed Classification

Future developers should expand the classifications of the current model as an alternative to the immediate addition of layers. Further classification, especially of the vegetation data, may improve the performance of the GIS model. In all cases, the developer should maintain as distinct a classification system as possible. Although it is not necessary to separate every species into distinct categories, one could consider classifying plants, for example, into forest, shrubs, rice, other crops, and grassland, as an alternative to just forests and grassland. Each of these could be further subdivided if so desired.

6.1.2.2 Addition of Menu Script

Providing accessibility to policy makers, scientists, and the public is one of the major goals of this project. However, GIS software is not presently a familiar feature on home PCs. This presents a problem when trying to convey the results of GIS analysis to those unfamiliar with the concept. Developing a graphical user interface GUI, which will allow easy access to the full capabilities of the model, is essential. This can be accomplished with the Arc Macro Language. **We recommend that a menu be developed in a Windows format** and include the following capabilities:

- Open/Close file/Quit ARC/INFO
- Analysis Options
- View controls
- Data control

These options should allow the user to perform the following functions:

- Open/Close/Quit- should allow the user to open and close a file, or quit ARC/INFO.
- Analysis Options-should allow the user to change the analysis criteria, such as initial conditions, and duration, as well as start the simulation.
- View Controls-should allow the user to move around the map, as well as zoom in and out of the coverage.
- Data Control-should allow the user to remove and add layers from the analysis, as well as allow the addition of new data to existing layers.

In addition to these menus, a command line should be included in the beginning of the new command script that will automatically start up the menu script upon starting the script. This will again add to the accessibility of the model to those unfamiliar with ARC/INFO™.

6.1.3 Additional Layers

The links between human activity and environmental change are complex and difficult to decipher because of the complex dynamics of the ecosystem. A model designed to evaluate and mimic such a system, accordingly, must also be complex. Thus our model should take into consideration not only the effects of vegetation, PET, soil, etc., on the hydrolytic cycle, but human factors as well. In order to allow study of these human factors in a GIS format, **we recommend that additional layers be included and additional information to develop these additional layers be collected**. The following sections present some examples of layers we have identified as necessary, and why.

6.1.3.1 Impervious Area and Drainage Systems

A layer containing information pertaining to **impervious area and drainage systems** would allow the model to account for changes in water flow incurred from human design. Human design is the term we will use to describe the construction of any object for the betterment of human existence. The addition of this layer will allow the model to simulate the movement of water in a more appropriate manner. No longer would the modeled water simply flow to cells in lower elevations, but would now also be redirected by human design to cells that it normally would not reach in a given amount of time. This will affect the amount of water stored in each cell at any given time, and will ultimately improve the reliability of the model to accurately predict water movement in the system.

6.1.3.2 Industry and Urban Water Management

A layer pertaining to **urban water management** would contain data on the usage of water near industrial sites, as well as account for the water purification capability of urban areas. This will enable calculation of point sources of pollution (PSP), and can be used in calculating contaminant loading in water as it moves through the system. The addition of this layer would promote a need for defining a soil attribute that would account for the earth's natural ability to remove these contaminants. Contaminant transport has previously been modeled using GIS, and before continuing, the developer should read Section 3.1.5 and refer to the article referenced therein.

6.1.3.3 Population Demographic Information

A layer pertaining to **population demographic information** would contain data pertaining to the population of the regions in question. Education, occupation, annual income, and age are some of the characteristics that should be considered. The purpose of this layer is to determine if a correlation between this data and the level of water quality exists.

Furthermore **we recommend that census data of the number of people with certain types of illnesses** be layered in the model. This will enable the user to make associations between environmental changes in the river basin and health of the people living in the river basin. This analysis will help policy makers determine human effects on river basins. In addition this analysis will represent the human/river basin interaction.

6.1.3.4 Water Quality Data

Water quality should be studied in relation to human activity. **The levels of dissolved oxygen, biological oxygen demand, chemical oxygen demand, coliform bacteria, fecal bacteria, alkalinity, chloride, hardness, ammonia, nitrate, phosphorous, heavy metals, total solids, total dissolved solids, suspended solids, color, water temperature, pH, salinity, conductivity, and turbidity** should be incorporated in a layer of the model. The severity of these substances and characteristics will affect water quality. These properties determine the ability of organisms to live in the water, and also determine how potable the water is. Changes in the river environment, such as industries, boating, and other human effects, will alter the properties of the water; adding these characteristics to the model will allow the user to examine how humans affect the water quality. In turn, with additions of other layers that measure illnesses, as mentioned in the Section 6.1.2.3, the user will be able to determine how the construction of new industries and other human activities will influence the people living in the area.

6.1.4 Use of Remote Sensing Data

Remote sensing utilizes satellite technology to obtain high definition imagery of land surfaces. Unlike more conventional terrain-based data collection methods, wide detailed images of land can be captured. With color-coding methods, such as certain shades of green being used for forestland, mapping land-use, for example, can be facilitated, and accuracy can be improved. **We recommend the addition of remote sensing layers to the GIS model to be explored**, as it can potentially enhance the accuracy of the model by improving upon the land-coverage layer and elevation levels of the land. The only foreseeable factors that might make this option to the GIS model unfeasible are computing capacity and cost. Satellite images require large amounts of storage capacity and computing power to process; to obtain the images can also be expensive.

6.2 Environmental/Human Impact Assessment

We recommend that the developed GIS be used in making environmental/human impact assessments. There is certainly a volume of supporting material proving the usefulness of GIS as a tool for assessment of the human impact imposed upon environmental systems. What is not documented, however is the use of GIS to determine the impact of environmental changes on human social and economic systems. Certainly, it can be argued that humanity depends on the environment for natural resources, transportation, and the necessities of life. Therefore, it should be just as simple and useful to compute the change in tangible human data due to the changes in the river basin as it is to do the opposite. When referring to tangible human data, we are considering all human statistical data that can be measured, such as change in gross domestic and national products, life expectancy, and economic decay or growth. Consider the simple model of a river basin shown in Figure 7:

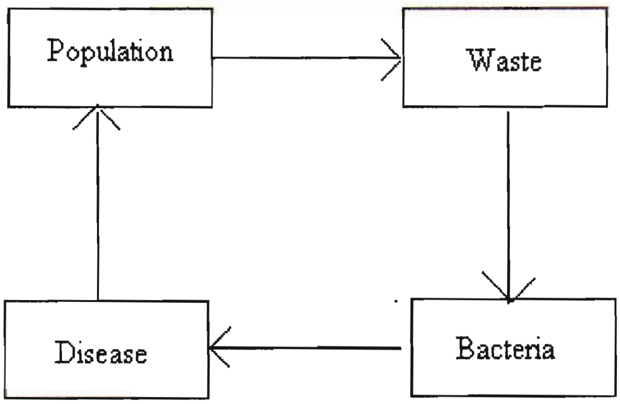

Figure 9: Dynamic Model of Human/Basin interaction

This model illustrates the interaction between human population and bacteria in the river water itself. According to the dynamics of this model, as population increases so does the amount of pollution in the water. As the amount of pollution increases the amount of disease-causing bacteria increase, promoting disease, which in turn decreases the population. Of course, this is a simple, qualitative example of reality, but it illustrates the links that can be made between humanity and the environment. If we are to find a sustainable means of balancing human needs and environmental capacity, we must be able to understand the interaction between the two systems.

Using GIS, we can develop models that are more complex, and utilize the existing layers to examine the relationship between human and environmental systems. The feasibility of this model will be dependent upon the availability of equations describing the effect of changing environmental systems on human activity. Once this capability is fully developed, however, environmental engineers will have the ability to evaluate the impact that construction may have on either system, and propose mutually beneficial alternatives.

Based on this example, and the information we obtained from our content analysis, the need for a method of impact assessment is becomes apparent. In the case of dams construction, there have been very real consequences, both to the fisheries and other environmental systems, as well as to the humans living in the region who depend on the water in the basin for their livelihood. However, decisions on the project have not been driven by data from scientific forecasts. That is why we recommend that the GIS model be **developed for use in human/environmental impact studies**. These studies would, as illustrated above, measure the effect of human activity on the river basin, and in turn measure the subsequent change in human activity. This would allow policy makers, and engineers to work together to find the solution best suited to meeting the needs of the project, while maintaining environmental conditions.

6.3 Proposal for Future Worcester Polytechnic Institute Projects

Through our research and interviews, we have learned that it takes many years to develop a GIS model of a river basin. Due to this fact, we recommend that this project be continued through future Interactive Qualifying Projects and Major Qualifying Projects in conjunction with Worcester Polytechnic Institute and the SEA START organization.

We recommend Major Qualifying Projects (MQP) to develop the capabilities of the GIS model. Computer science and civil engineering students should work together on this MQP to provide coverages of all of the technical areas of the project. Specifically, work should be done on: making the model more accurate, calibrating the model, verifying data from other watersheds, makeing use of remote sensing data, making certain layers of the model upgrade automatically (possibly in real time), developing new techniques to obtain and store data in the correct format, and developing dynamic inputs. The students accomplishing this MQP will have to familiarize themselves with the current model before beginning the model upgrading. This MQP should take several months to accomplish; a large amount of this time can be spent in the United States. Ample amounts of data can be obtained more easily in the United States, including NASA remote sensing data, real time temperature and precipitation data. In addition, new techniques of measuring data which are being developed in the United States. It will be easier to lean of these new techniques while in the United States. Due du to the long list of tasks that are necessary to complete this model we suggest that two or MQPs be conducted to complete this model. There are available funds to support this type of MQP; fellowships are available through the START organization with a recommendation from the SEA START section of START. Many other grants are available through international and Thai organizations. MQP students cannot accept payment for their work, but these fellowships and grants can be used to pay for the students' housing and travel expenses.

We also recommend that **another Interactive Qualifying Project (IQP) be performed to continue the work of this project**. An IQP would include promoting the use of the upgraded model. It will also include determining the potential users and obtaining responses from model users. Data should be collected and analyzed using a questionnaire or survey to determine what the users want in order to improve the model further. This project will also involve organizing training workshops and PowerPoint presentations on how to use the model, as well as marketing the model. Developing these workshops and presentations in English so they can me used in other regions is another objective of this IQP.

Such projects will be very beneficial to SEA START, as well as interesting for WPI students. They will also further the productive cooperation between WPI, Chulalongkorn University, and SEA START.

6.4 Summary of Recommendations

In conclusion, we have made several recommendations in order to achieve the goals of the SEA START RC organization. First, we have made recommendations for improving the GIS Model. Specifically we gave information on finishing the construction of the preliminary model, and suggested layers to be added to make the model more accurate. Using our observations of the people in the river basin and how they interact with the river basin, we suggested that layers be added to the model to represent the human/river basin interaction. In addition, we have recommended that the GIS model be used for environmental/human impact assessment. Using the model in this way will enable the user to make assessments of the impact of humans on the environment and how this impact on the environment eventually affects humans. Our last major recommendation was to continue the work on the model in future IQP's and

MQP's. MQP's would concentrate on the technical component of the project, while IQPs would concentrate on promoting use of the model and assessing the model's users. We feel that with these recommendations, the goals of SEA START will be accomplished.

7.0 Conclusion

The project's accomplishments will provide the scientific community and policy-making bodies with a valuable tool to better understand the complex interaction between human and hydrologic systems. To expand on the NAGA version 1 model's predictive capabilities, we assessed additional aspects of the modeling for their potential value. Particularly, we explored the option of constructing additional layers. Through our interviews we expanded our knowledge of GIS and collected data for our model. The model we constructed was of the Chi-Mun River Basin in Northeast Thailand. Preliminary results from the new GIS model illustrated that further improvement is necessary. However, we have been successful in establishing a foundation for subsequent project teams to develop this model into a useful tool for SEA START, as well as for policy makers.

In addition to the GIS model, we conducted research to further our understanding of the current issues of Thailand. From our trips to the Chi-Mun River Basin and content analysis, we gained an understanding of the plight of the region's farmers. The problems found in Northeast Thailand range from droughts to the balance of economics with environmental conservation to water management issues. With the knowledge of farmers' hardships and the results of the construction of the GIS model, it becomes apparent how future versions of our project will be applicable to developing mutually beneficial solutions among human and environmental systems.

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Appendix A:
Glossary

Glossary of Important GIS Terms

AML- The ARC Macro Language. A high-level, algorithmic language that provides full programming capabilities and a set of tools for building menus to tailor user interfaces for specific applications.

arc - 1)A string of x, y coordinate pairs (vertices) that begin at one location and end at another. Connecting the arc's vertices creates a line. 2) A coverage feature class used to represent linear features and polygon boundaries. One line feature can contain many arcs. Arcs are topologically linked at their endpoints (nodes) and to the areas (polygons) on either side. Arcs start and end at a node and can define areas to the left and right of their direction of travel (determined arbitrarily at the time of data capture). The descriptive attributes of arcs are stored in the arc attribute table (AAT)

base map-A map containing geographic features, used for locational reference.

cell- The basic element of spatial information in a grid data set. Cells are always square. A group of cells forms a grid . Cells store values that can be related to the value attribute table (VAT).

coverage- 1) A digital version of a map forming the basic unit of vector data storage in ARC/INFO. A coverage stores map features as primary features (arcs, nodes, polygons, and label points) and secondary features (tics, map extent, links, and annotations). Associated feature attributes tables describe and store attributes of map features. 2) A set of thematically associated data considered as a unit. A coverage usually represents a single theme, or layer, such as soils, streams, roads, or land use.

digitize- 1) To encode map features as x,y coordinates in digital form. 2) To employ a digitizing tablet to record x,y or x,y,z values for map features. Lines are traced to define their shape. A digitizer button, pressed periodically along the line, records the x,y coordinates. So, a digitized line is a series of x,y coordinates.

digitizer-1) A device that consists of a table and a cursor with crosshairs and keys used to record the locations of map features as x,y coordinates. 2) Title of the person using the device to automate maps.

GIS- Geographic information system. An organized collection of computer hardware, software, geographic data, and personnel designed to efficiently capture, store, update, manipulate, analyze, and display all forms of geographically referenced information.

grid- 1)A raster geographic data set for use with ARC/INFO's GRID software. An x,y location references each grid cell. Cells store values in value attribute tables. 2) One of many raster-based data structure composed of cells of equal size arranged in columns and rows. The value of each cell, or group of cells, represents the value of the feature.