CONTAMINATION MODELING IN SELECTED AREAS OF CAMERON HIGHLANDS USING GEOGRAPHICAL INFORMATION SYSTEM (GIS)

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By

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Dissertation submitted in partial fulfilment of
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CERTIFICATION OF APPROVAL

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Approved by,

(AP. Dr. Abdul Nasir B. Matori)

UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

July 2009

CERTIFICATION OF ORIGINALITY

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

NOOR AZHANI BINTI SAAD

ABSTRACT

The study entitled 'Contamination Modeling in Selected Areas of Cameron Highlands using Geographical Information System (GIS)' is aimed to model the flow of contaminants from its possible sources to the surrounding within the study area. Data needed in this study are; the location of sources of contaminants, contour line map, land use map and river map of Cameron Highlands. These data are in different layers with different features and information. These data were then operated under GIS software using its operation like map overlays, spatial analyst and hydrologic modeling. Several output maps were produced from the operations. Interpretation of the output maps were taken place afterwards to determine the most critical areas that are seriously affected by the sources identified. From this study, GIS tool is decided to be a convenience tool for modeling since it can complement some of the conventional method's weaknesses.

ACKNOWLEDGEMENT

First and foremost, I would like to praise God the Almighty for His guidance. Though difficulties occurred, His guidance gave me the chance to still complete this Final Year Project (FYP) successfully.

Here, I would like to use this special opportunity to express my heartfelt gratitude to my project supervisor, AP. Dr. Abdul Nasir B. Matori who guided and supervised me throughout the whole period of completing this project.

My deepest appreciation goes to Mr. Abdul Basith, a postgraduate student of Universiti Teknologi PETRONAS (UTP) who helped me in the learning process of the software used in this study.

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CHAPTER 1
INTRODUCTION

This chapter will describe the background of the study, problem statement, objectives and scope of study.

1.1 Background

Cameron Highlands is famously known for its intensive horticulture especially vegetable and flower cultivation. Large amount of nutrients and pesticides have been used since then. Nutrients like nitrogen and phosphorus are needed by the crops to help them grow healthily. But, high volume of nutrients used for cultivation can give an impact to the environment. Pesticides, which are used to kill the pest, are also one of the causes that contribute to water pollution and soil contamination.

Water and soil can also be contaminated from the other sources like storage tanks, septic systems, hazardous waste site, landfills etc. The contaminants from these sources have the abilities to flow and spread to the surrounding in any possible ways; depending on the characteristics of the contaminants and the soil structures themselves.

A technology called Geographic Information System (GIS) is used to model the flow of the contaminants from its possible sources to the surrounding. GIS technology is a computer-based data collection, storage and analysis tool that combines previously unrelated information into an easily understood maps. GIS uses layers, called "themes" to overlay different types of information with each theme represents a category of information to the geographic background. Throughout this study, the entire information gathered will be modeled and analyzed using ArcView version 3.2 software.

1.2 Problem Statement

Before the introduction of the GIS technology, the flow and effect of the contaminants to the surrounding was hardly detected. The detailed information can only be obtained through on-site evaluation. People were sent to the site to take samples for the respective areas. Larger areas will require more people to take the samples. Then, another group of people were needed to do the testing for verification. Usually, the data obtained from the testing are in numerical form, which are hardly to visualize. People will need more time to analyze and relate those data. Once an error was spotted, the entire processes starting from the sampling need to be redone again. This is very troublesome to the person in charged. This kind of method is very laborious, time-consuming and quite costly.

1.3 Objectives

The main objectives of this study are;

1. To model the flow of contaminants from their sources to the surrounding
2. To find the critical area affected by those sources of contaminants

1.4 Scope of Study

1.4.1 Study Area

The study areas, which are in Ringlet, Tanah Rata and Brincang of Cameron Highlands is located in the mountainous spine, known as Banjaran Titiwangsa in the Pahang state. It is also known as the major supplier of legumes and vegetables to both Malaysia and Singapore. Cameron Highlands is also famous as one of the Malaysia's prime tourist destinations.

Cameron Highlands is located at the altitudes between 1070m to 1830m above sea level. This mountainous area has a relatively cool climate range from 13 to 23°C which is very suitable for the vegetable and flower cultivation. It covers an area of 35960 square kilometers.

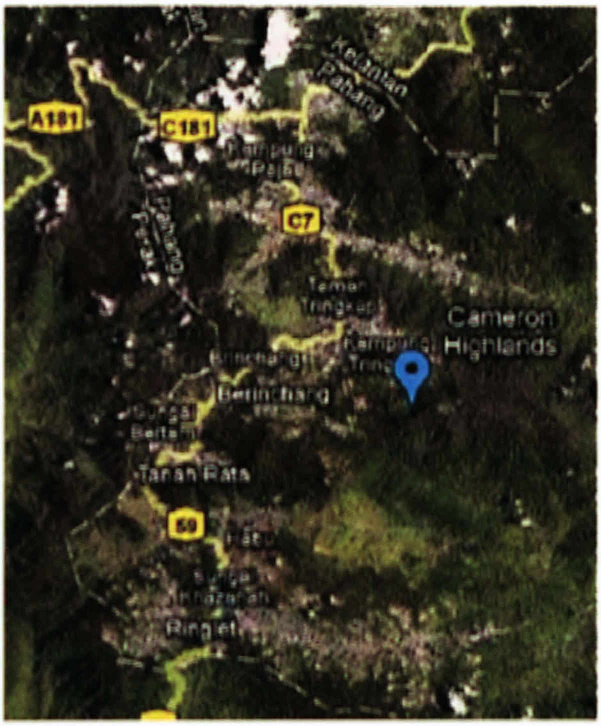

Figure 1.1: Cameron Highland's Map (source Google Maps)

1.4.2 Data and Software Used

This study will utilize ER MAPPER and ArcView version 3.2 software provided with Spatial Analyst and Hydrologic Modeling extensions to model the flow of contaminants from their sources to the surrounding. Data needed for this study are as below:

- Sources of contaminants in Cameron Highland
- Contour line map of Cameron Highland
- Land use map of Cameron Highland
- River map of Cameron Highland

Some of the data needed were extracted from the Landsat image such as the land use map of Cameron Highlands using ER MAPPER software. Each of the data obtain will represent different layers with different information in the ArcView software. Then, those data layers will be overlaid onto each others, interpreted and analyzed to meet the objectives. In order to get a good data interpretation, there is a need to have a good understanding of the geological conditions and hydrological properties of the study area.

1.5 The Relevancy of the Study

This study is planned to be finished within the time frame specified. For the first semester, the author is expected to fully understand the topic and be able to use the software required in this project, which is ER MAPPER and ArcView version 3.2. During the second semester, the actual modeling process will take place where the GIS operations like map overlays, spatial analyst and hydrologic modeling will be applied.

There is some limitation to this study, which is the author is the beginner user of both of the software and does not undergo proper training. So, to compare with the expert, the modeling process will take a bit longer than usual since the author needs more time to learn the software herself.

Due to the time constraint, this study is not aimed to verify the types of contaminants in those affected areas through experimenting since the study area covers major part of Cameron Highlands which is approximately about 35960 square kilometers. Instead, this study is hoped to model the flow of contaminants in a more easily understood way.

CHAPTER 2

LITERATURE REVIEW AND THEORY

Review for the study was taken abundantly from journals and internet. Basically, spots to be highlighted for the study comprises of the definition of the environmental pollution, Cameron Highlands' soil properties, possible sources of contaminants and modelling process using Geographic Information System (GIS). Here are some notes taken for the study:

2.1 Environmental Pollution

2.1.1 Water Pollution

Water pollution is the contamination that occurs inside the water bodies such as lakes, rivers, oceans and groundwater. Water pollution can be defined as an undesirable change in water quality resulting from human activities **(Thomas Harter, 2003).**

The water body can be contaminated by any type of substance called contaminant that can cause the water become unclean and unsuitable for a particular purpose. The substance can be a manufactured chemical, but just as often it might be microbial contamination. Water contamination also can occur from naturally occurring mineral and metallic deposits in rock and soil.

People used to believe that the layers above the aquifer which comprises the soil and sediment layer as the medium of filtering unnatural pollutant from the surface from infiltrating down to groundwater. However, by the year 1970's, people started to realize that those soil layers did not adequately protect the aquifers. Despite this realization, a significant amount of pollutant had already been released into the soil and groundwater.

2.1.2 Soil Contamination

Soil can be contaminated by man-made chemicals or other alteration in the natural soil environment. Typically, soil contamination is arises from the rupture of underground storage tanks, application of pesticides, oil and fuel dumping, wastes leaching from landfills, percolation of contaminated surface water to subsurface strata or direct discharge of industrial wastes to the soil. The most common chemicals involved are pesticides, petroleum hydrocarbons, solvents, lead and other heavy metals. The level of contamination is usually correlated with the degree of industrializations and volume of chemical usage.

2.2 Cameron Highland's Soil Properties

Soils in Cameron Highlands are mainly derived from two parent materials: acid intrusive cover most of the area and a small part are from schist, phyllite and limestone. Humus in virgin soils in the north of the Highlands reaches 80-100cm depth (Gunung Brincang Series), falling to 40cm in Tanah Rata Series and to a negligible layer of humus in the Ringlet Series of the south where altitude is less and temperatures higher. Most of the pesticides are absorbed by the topsoil which are enriched by organic fertilizer, and are not leached beyond the top 10cm layer (**W. Y. Wan Abdullah, *et al.*, 2005).**

Table 2.1: Soil characteristics under forests **(after Lim et al.., 1987)**

Soil series	*Horizon depth*	*pH (H_2O)*	*Clay (%)*	*Silt (%)*	*Sand (%)*	*Organic Carbon (%)*	*Nitrogen (%)*
Brincang	A2, 10-16cm	4.4	19.9	17.6	62.4	0.38	0.04
	Bhir, 16-36cm	4.5	6.6	26.4	67	0.82	0.06
Tanah Rata	A2, 0-10am	4.1	4.5	6.4	89.2	0.63	0.04
	Bhir, 32-75cm	4.7	23	17.9	59.1	0.71	0.06
Ringlet	A, 0-7cm	4.4	22.2	32.9	44.9	2.05	0.18
	B2lt, 39-60cm	4.9	42.5	20.9	36.6	0.79	0.07

Table 2.2: Soil properties under cultivated land **(after MARDITECH, 1998)**

Soil planted with crops	*pH*	*Organic carbon (%)*	*Nitrogen (%)*
Cabbage	6.5	3.17	0.34
Chrysanthemum	6.2	2.40	0.33
Carnation	6.2	2.98	0.36
roses	6.2	2.45	0.33

A study by **MARDITECH (1998)** on soil properties under cultivated land gives a different result especially for pH, organic carbon and nitrogen. Agricultural activities did influence the soil properties on those regions.

2.3 Possible Sources of Contaminants

Groundwater pollution of aquifers has generated growing interest in recent years. The finding in groundwater of some plant protection products, nitrates, mineral oils and halogenated hydrocarbons is evidence that this is a common phenomenon and derives from many anthropogenic activities (**Trevisan, *et al.*, 2000**).

The contamination of groundwater is a serious problem. Nitrate in groundwater comes from diverse sources such as nitrogen fertilizers, animal wastes, municipal wastes, landfill, septic tanks and soil organic matter **(Patni, *et al.*, 1998)**. Pesticide use raises a number of environmental concerns. Over 98% of sprayed insecticides and 95% of herbicides reach a destination other than their target species, including non-target species, air, water, bottom sediments and food **(Miller GT, 2004)**.

According to **H. Vijith and R. Satheesh (2006)**, the extensive used of fertilizers and pesticides in the rubber, tea and other agricultural practices influenced the groundwater quality of that region. The influence of lithology over the quality of groundwater is negligible if the majority of the area comes under single lithology, i.e. charnockite. The groundwater was examined for the physical and chemical parameters (pH, DO, TH, Cl, NO_3, PO_4) to determine its suitability for drinking, domestic, agricultural and industrial purposes.

The fertilizers that are commonly used in the cultivation of crops are nitrogen, phosphorus, potassium organic fertilizers (NPK), chicken dung and other organic fertilizers. **W. Y. Wan Abdullah and friends (2005)** conducted a dye tracer tests on cultivated land in Tanah Rata Series to model the nutrient and pesticide transport in Cameron Highlands. From the tests, they found that water-flow pathways in the undisturbed soils showed that most of the tracers infiltrated less than 10cm. In the 15cm ploughed soils, about 60% of the tracer infiltrated to 20cm depth while in the deep ploughed soil of 60cm, the results showed that only about 20% of the tracer infiltrated to 50cm depth.

Ramsis B. Salama and Rai S. Kookana (2001) in their paper concluded that the loss of nitrogen to the surface runoff during intensive (unsheltered) vegetable production was the main sources of contaminants in Cameron Highlands. Under cabbage plantation, about 3% of applied nitrogen was lost in runoff. The loss was most rapid soon after application of the fertilizers and decreased during the growing season. Due to the high rainfall which about 2500mm per year, nitrogen loss to the surface runoff and then to surface water bodies and continue with the nitrate leaching to groundwater. Losses of nitrogen by leaching in cabbage farms were about 8% of the nitrogen applied.

2.4 Modeling Process using GIS

P.Sunil Raj Kiran, R.Santhosh Kumar, K.Stalin, P.Archana, L.Sridevi and A.Selva Radha on their paper entitled *GIS Techniques for Groundwater Contamination Risk Mapping* attempted to produce groundwater vulnerability and risk maps using DRASTIC system. They designed the maps to show the area with the greatest potential for groundwater contamination on the basis of hydro geological conditions and human impact. They used Geographical Information System (GIS) to create a groundwater vulnerability map by overlaying the available hydro geological data from thematic maps. The resulting map was then integrated with a land use map to assess the potential risk of groundwater to pollution in the area. The final map showed results and stressed the need for the GIS to test and improve on the groundwater contamination risk assessment methods.

Jorn Hoffmann and Per Sander (2006) in their study described the geographical information systems as an ideal problem-solving environment where remote-sensing data and interpretations can be merged with discrete and continuous data from other sources to better understand relationships that may otherwise go undetected.

Furthermore, **Lee S., Park E. G., Lee S., Cho M. and Lee D. (1999)** in their studies revealed the applicability and convenience of groundwater modeling by modifying input data from the GIS database, and timesaving effect compared to previous methodology. Especially in zoning of hydro geologic parameter, it becomes much easier to change the zone and its value. On the favor of this, it is possible to simulate the groundwater system on the various conditions.

CHAPTER 3
METHODOLOGY

After getting a general overview of the project, all the relevant information on the topic was searched through the internet and library. The information gathered fell under those categories:

- Environmental Pollution
- Possible Sources of Contaminants
- Cameron Highlands' Soil Properties
- Modeling Process through Geographical Information System (GIS)
- Geographical Information System Tools

All the materials obtained were gone through and summarized. For a better understanding, consultation from lecturer needs to be done continuously from time to time.

The flow of the methodology for the study is simplified in the **Figure 3.1** on the next page.

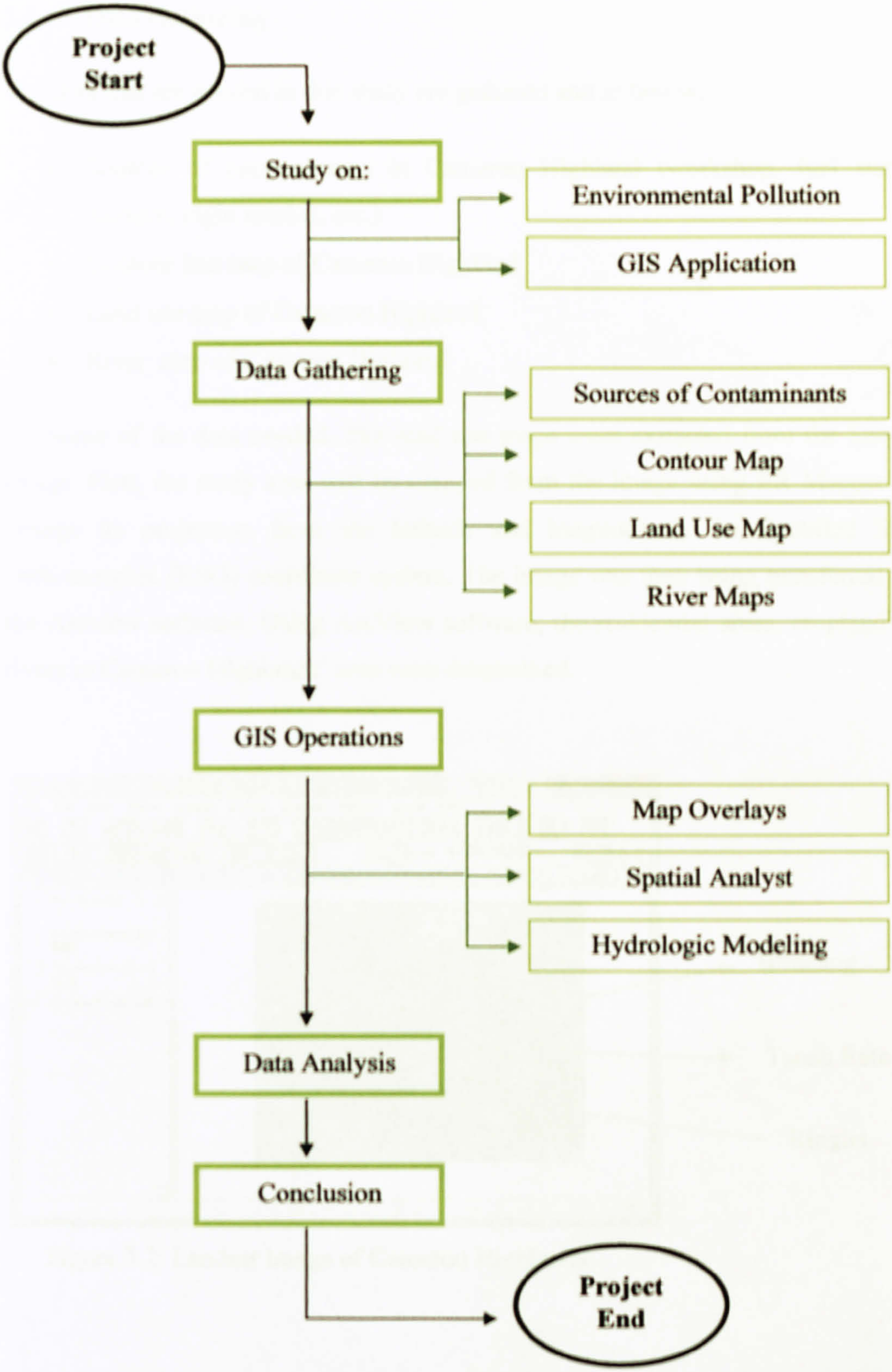

Figure 3.1: Methodology of the Study

3.1 Data Gathering

The data that are needed in this study are gathered and as below:

- Sources of contaminants in Cameron Highland (workshop, fuel station, laundry, night market, etc.)
- Contour line map of Cameron Highland
- Land use map of Cameron Highland
- River map of Cameron Highland

Some of the data needed, like land use maps were extracted from the Landsat image. First, the study area will be cropped from the image using ER Mapper and change its projection from the latitude and longitude to the Rectified Skew Orthomorphic (RSO) coordinate system. The image was then being transferred into the Arcview software. Using ArcView software, the residential areas, cropland and rivers in Cameron Highlands' area were determined.

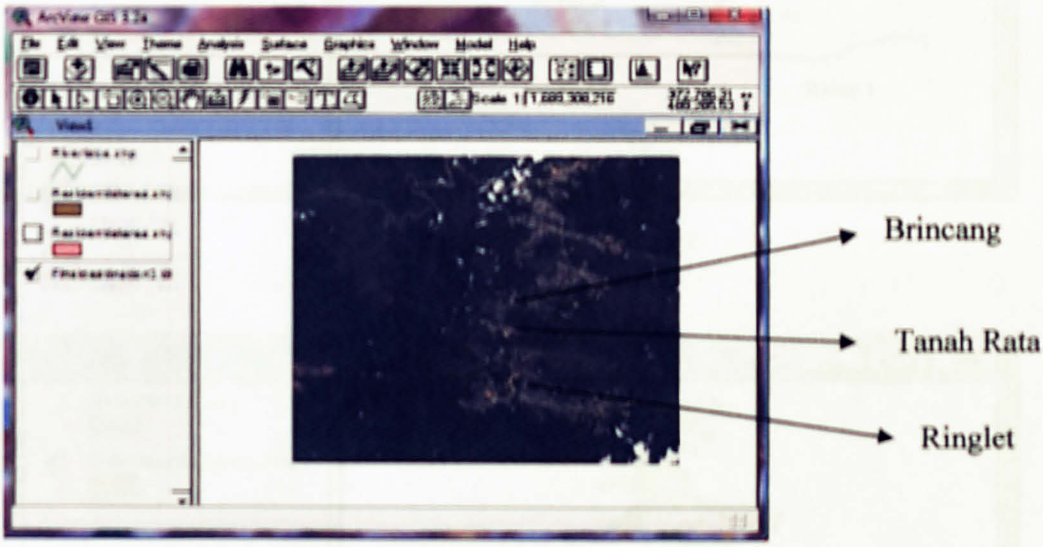

Figure 3.2: Landsat Image of Cameron Highlands

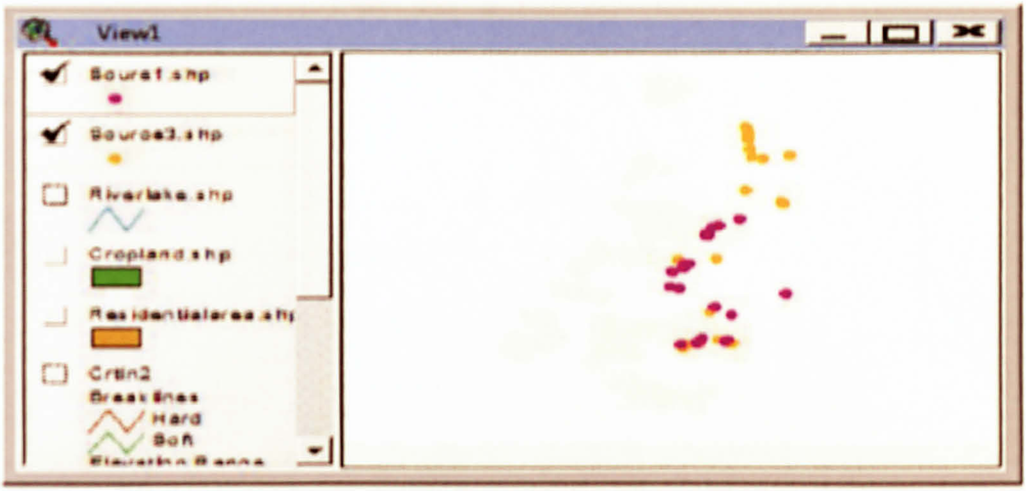

Figure 3.3: Point Sources of the Contaminants Layer

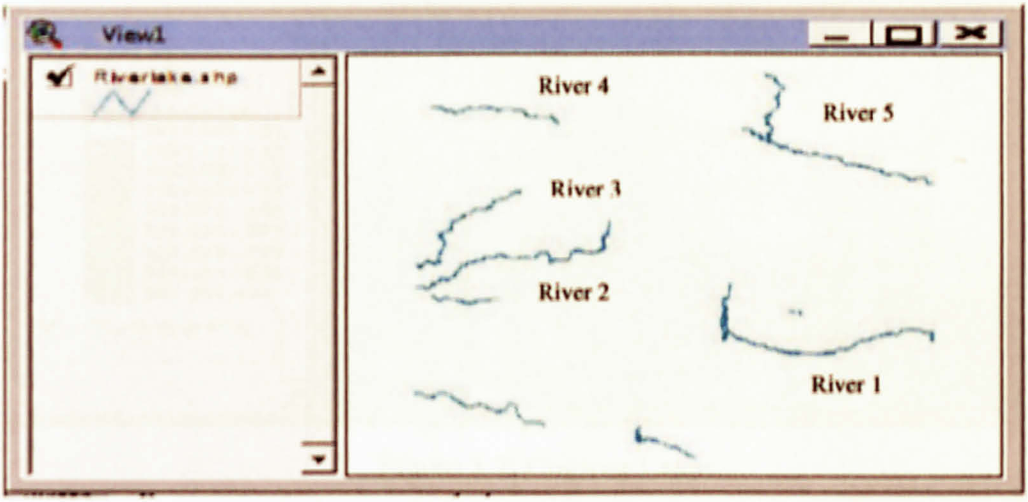

Figure 3.4: River Layer

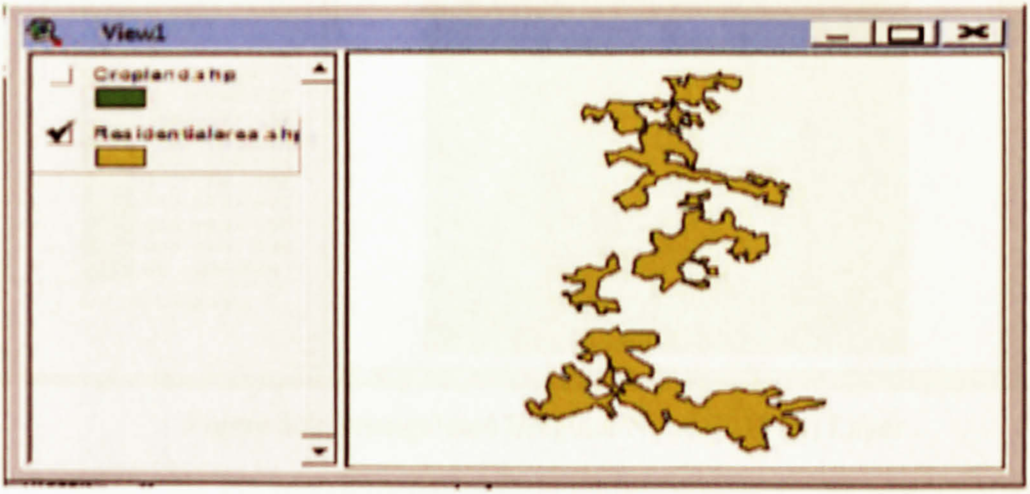

Figure 3.5: Residential Areas Layer

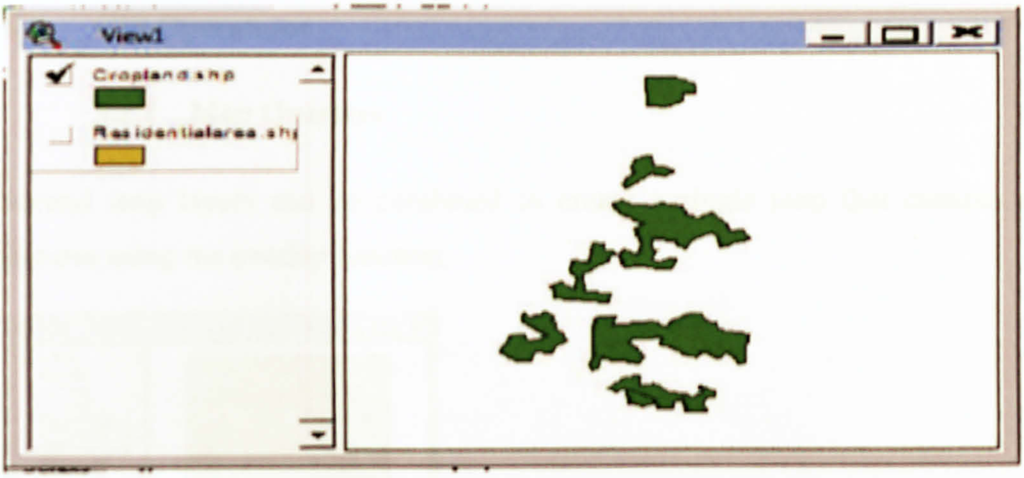

Figure 3.6: Croplands Layer

Figure 3.7: Contour Layer

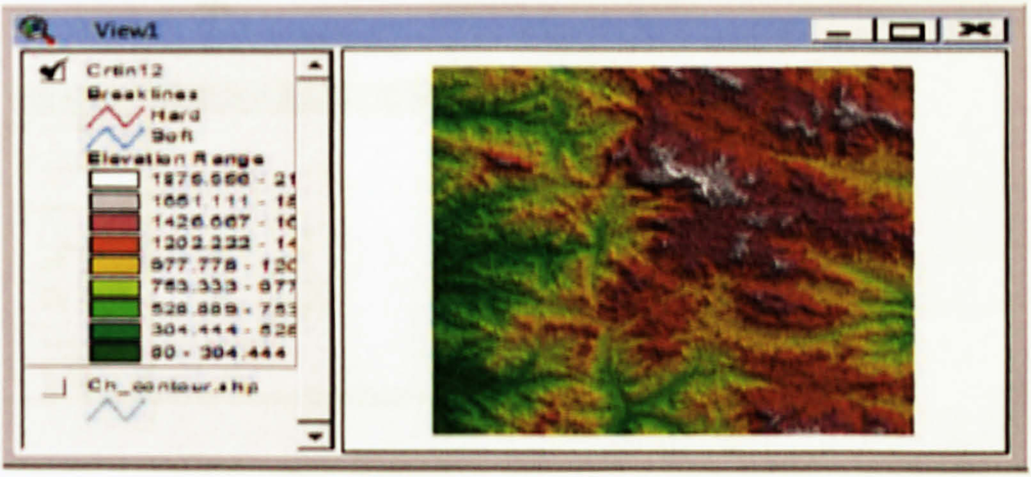

Figure 3.8: Triangulated Irregular Network (TIN) Layer

Each of these data will represent different layers with different information in the ArcView software.

3.2 GIS Operations

3.2.1 Map Overlays

Several map layers can be combined to create a single map that consists of all features using the overlay function.

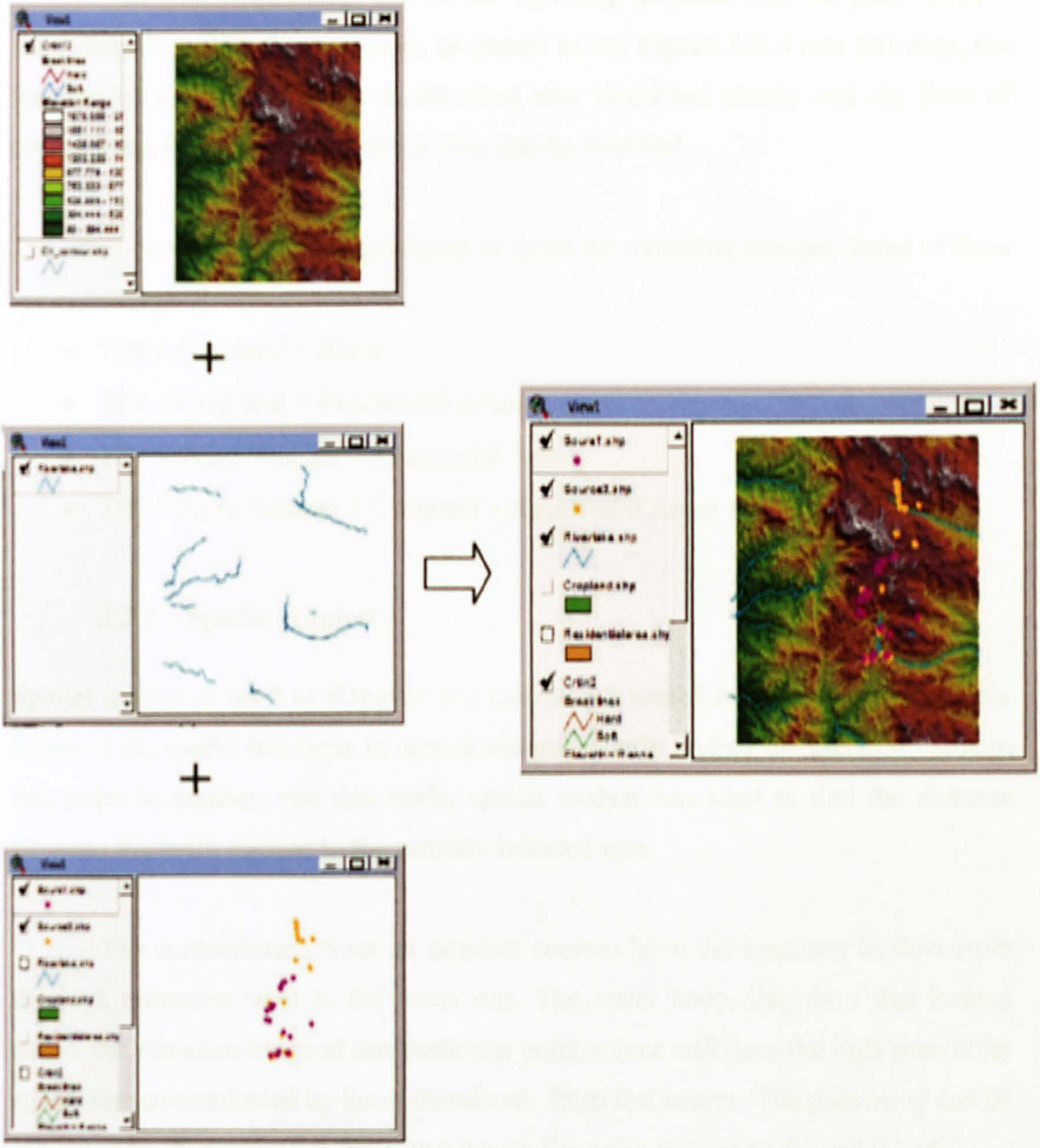

Figure 3.9: Map Overlay of Several Layers

The contour map that was converted to the Triangulated Irregular Network (TIN) map will be the base map. TIN map is a map that combined a certain range of elevation and assigned the group with a color. Different colors in the TIN map represent different elevation range.

The first output map will be the TIN map overlaid with the point sources map altogether with the river map, as shown in the **Figure 3.9.** From this map, the location of the point sources to the river was visualized clearly and the flow of contaminant from the sources to the river can be modeled.

The other overlay maps were produced to assist the modeling process. Some of them are as below;

- TIN + Cropland + River
- TIN + Cropland + Residential Areas
- TIN + Point Sources + Residential Areas
- TIN + Point Sources + Cropland + Residential Areas + River

3.2.2 Spatial Analyst

Spatial analyst is used to discover and understand spatial relationships in the data. Some of the useful functions in spatial analyst include finding the distance between one point to another. For this study, spatial analyst was used to find the distance between the point sources to the possible infected area.

The contaminants from its possible sources have the tendency to flow from the high elevation level to the lower one. The water body, like river that located below the elevation range of one particular point source will have the high possibility to become contaminated by the contaminants from that source. The possibility can be predicted by measuring the distance between the point sources to the water body.

3.2.3 Hydrologic Modeling

Hydrologic modeling was used to determine the flow direction and flow accumulation of contaminants being carried away to certain region. It is actually based on the elevation properties. Flow direction / flow accumulation is derived from the high elevation to the lower one.

3.3 Data Analysis

After undergoing all of the operation processes mentioned earlier, the final output can then be analyzed and interpreted in order to meet the objectives of the study that has been set before.

CHAPTER 4
RESULTS AND DISCUSSION

4.1 Result Analysis

4.1.1 Effect to the Residential Areas

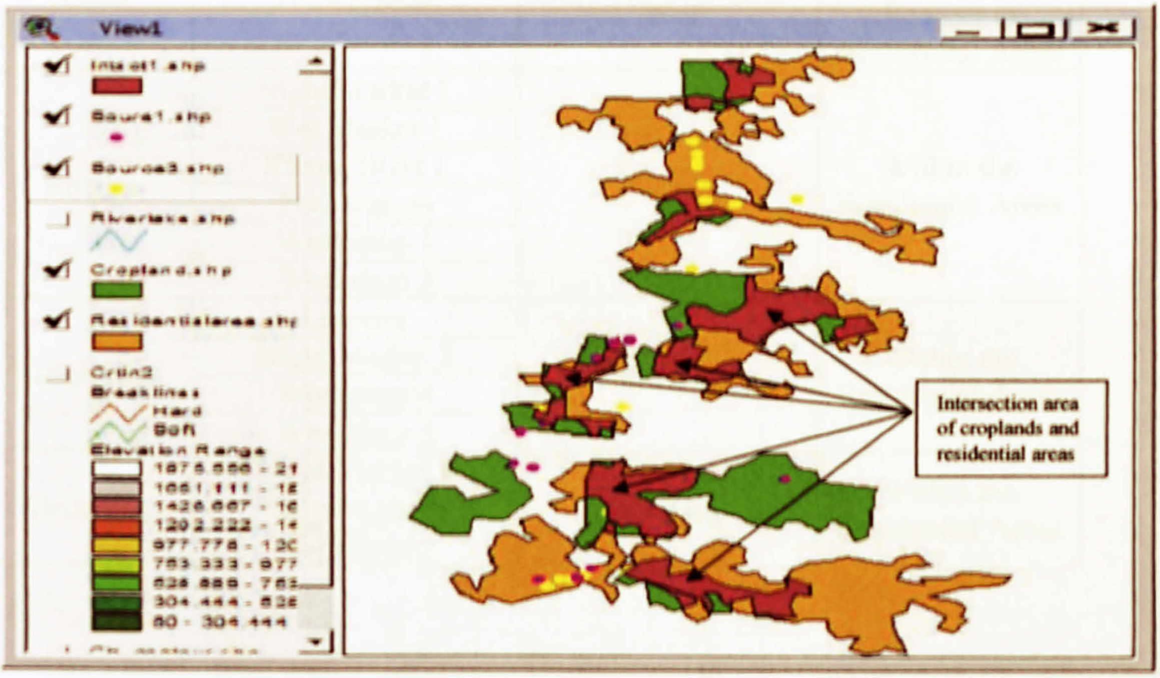

Figure 4.1: Intersection of Croplands and Residential Areas Layers

By using the intersection operation, the areas that overlap onto each other can be determined. The maroon colored areas in **Figure 4.1** are the intersection areas of the croplands and residential areas. The intersection areas cover quite a large area from the total areas. This means that the croplands are fall within and close to the residential areas. This result can be predicted since Cameron Highland is famously known for its intensive horticulture.

From the **Figure 4.1** also, it is shown that the point sources are distributed within and close to the cropland. Meaning that, the point sources, croplands and residential areas are overlapping onto each others.

Because of that, the contaminants from those sources, point sources and croplands are in direct contact with the residential area and can cause a direct penetration of contaminants into the soil within and close to the residential area.

Table 4.1: Summary of the Location of Point Sources to the Residential Areas

Series	Point Source	Possible Infected Area	Point Sources Location with Respect to Residential Areas
Ringlet	Night Market 1	Ringlet	Within the Residential Areas
	Wet Market 1		
	Kilang BOH 1		
	Fuel Station		
	Workshop 1		
	Workshop 3		
Tanah Rata	Laundry	Tanah Rata	Within the Residential Areas
	Night Market 2		
	Workshop 4		
	Workshop 5		
Brincang	Night Market 3	Brincang	Within the Residential Areas
	Night Market 4		
	Workshop 6		

4.1.2 Effect to the River

The contaminants from its possible sources have the tendency to flow from the high elevation level to the low one. The water body, like river that located below the elevation range of one particular point source will have the high possibility to become contaminated by the contaminants from that source. The possibility can be predicted by measuring the distance between the point sources to the water body.

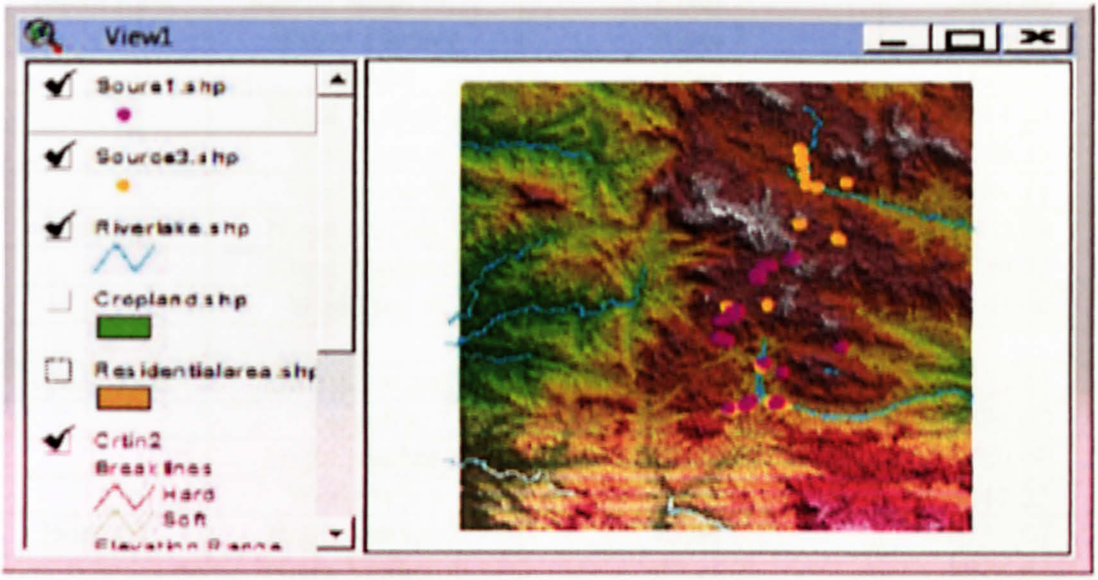

Figure 4.2: Map Overlay of Point Sources and Rivers

By using spatial analyst, the distance between the point sources to the river can be determined and was summarized as in **Table 4.2** shown on the next page. From the table, it shows that River 1 which is in the Ringlet Series has higher possibility of become contaminated than the other rivers since quite a number of point sources are located within 1 km distance to the river. The nearest source is the workshop which is 230.96m distance approximately followed by wet and night markets and fuel station.

Table 4.2: Summary of the Distance from the Point Sources to the River

Series	Point Source	Possible Infected Area	Distance (m)
Ringlet	Wet Market 1	River 1	365.18
	Night Market 1	River 1	577.41
	BOH Factory 1	River 1	1841.53
	BOH Factory 2	River 1	7921.73
	Fuel Station	River 1	879.48
	Workshop 1	River 1	292.15
	Workshop 2	River 1	974.43
	Workshop 3	River 1	230.96
Tanah Rata	Kilang Kuari JKR	River 1	2403.06
	Bharat Factory	River 1	2896.25
	Laundry	River 1	2814.05
	Night Market 2	River 1	2814.05
	Workshop 4	River 1	3250.35
	Workshop 5	River 1	2481.11
Brincang	Night Market 3	River 1	4662.08
	Night Market 4	River 1	5749.31
	Workshop 6	River 1	4363.00
Tanah Rata	Bharat Factory	River 2	5523.11
	Laundry	River 2	5880.49
	Night Market 2	River 2	5880.49
	Workshop 4	River 2	5447.25
Brincang	Night Market 3	River 2	6733.67
	Night Market 4	River 2	8916.64
	Workshop 6	River 2	6881.19
Brincang	Night Market 4	River 5	5541.43

Point sources in Ringlet give the most impact to the River 1 since this river is located within the Ringlet itself. However, the point sources in other series like Tanah Rata and Brincang also can give contribution of the contamination to the River 1 especially in Tanah Rata since the distance between the point sources to the river is within 3 km distance. The flow of contaminants from the Tanah Rata and Brincang will be slower than in Ringlet because the distance is farther. The accumulation rate of contaminants will be faster from Ringlet, followed by Tanah Rata and Brincang.

River 2 will be the second that has high possibility of become contaminated by the point sources like laundry, workshop, night market etc. River 2 is located quite far from the point sources with the nearest source is Bharat factory in Tanah Rata which is 5523.11 m distance followed by laundry, night market and workshop.

Meanwhile, River 3 and 4 have the least possibility of becoming contaminated since both the rivers are located far away from the point sources in Ringlet, Tanah Rata and Brincang.

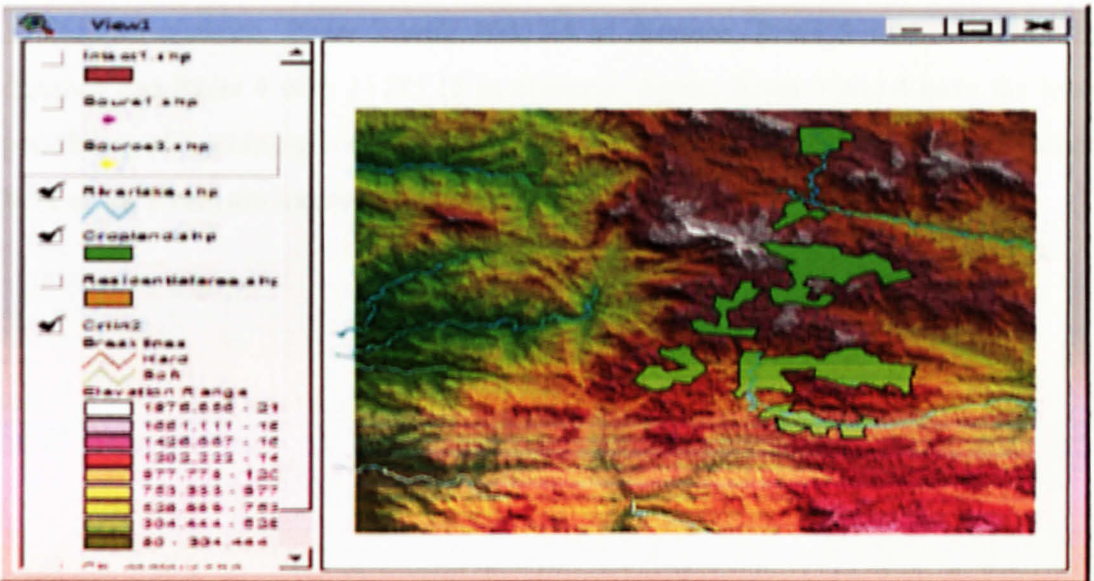

Figure 4.3: Map Overlay of Croplands and River

From **Figure 4.3**, River 1 will have the highest possibility of become contaminated by the cropland since the croplands fall within and close to the river 1. The other rivers are located further from the cropland. The distance of the cropland to the river was summarized in the **Table 4.3** on the next page.

Table 4.3: Summary of the Distance from Croplands to Rivers

Sources	Possible Infected Areas	Distance (m)
Cropland	River 1	Within the cropland area
Cropland	River 2	5082.24
Cropland	River 3	11708.82
Cropland	River 4	11775.15
Cropland	River 5	3002.52

From **Table 4.3**, River 1 is the nearest to the croplands followed by River 5 with 3002.52 m distance, River 2 with 5082.24 m distance, River 3 with 11708.82 m distance and River 4 with 11775.15 m distance. Again, River 3 and 4 have the least possibility of becoming contaminated from the contaminants of the croplands since both of the rivers are located far away from the croplands.

4.1.3 Contaminants Flow Direction and Accumulation

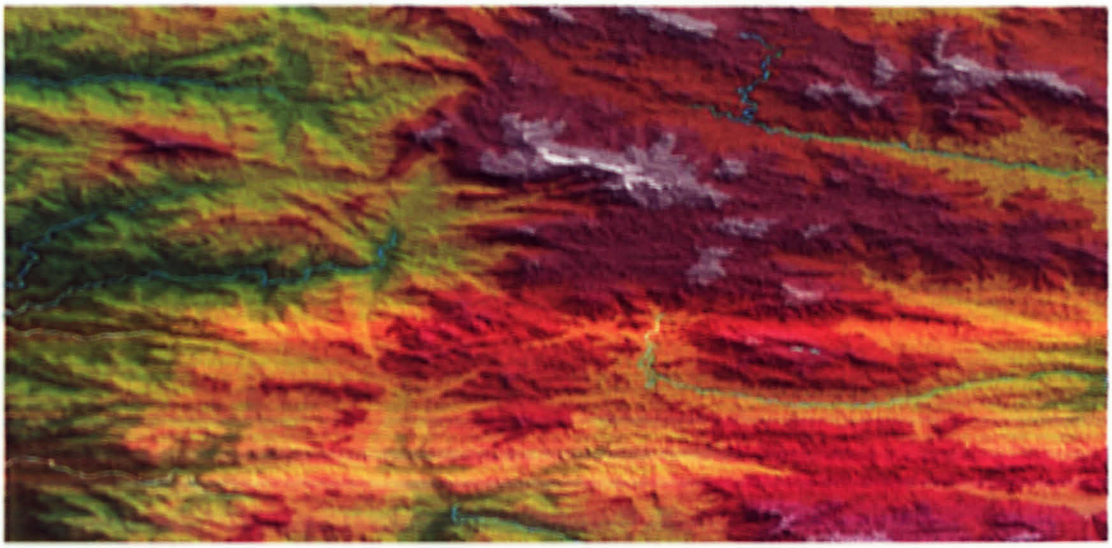

Figure 4.4: TIN Map

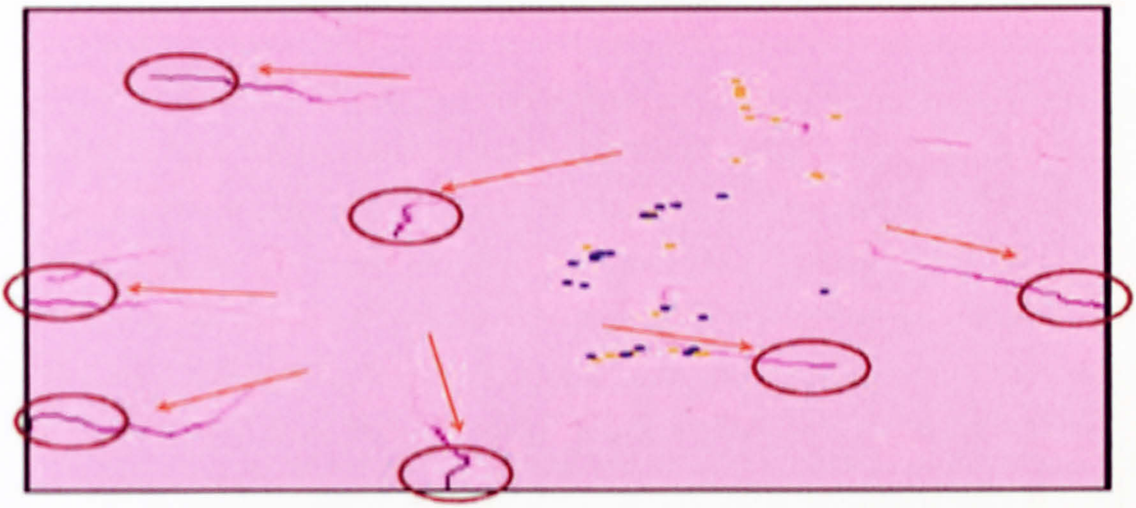

Figure 4.5: Flow Accumulation Map

The contaminants can be carried away to certain regions and being accumulated. The path of the flow can be derived using hydrologic modeling extension in ArcView. The flow accumulation map shows the direction of contaminants flow and accumulation. The flow is from the thinnest line to the thickest purple line according to the arrow shown. Meaning that, the contaminants are accumulated more in the thickest line compared to the thinnest line.

The areas within the red circle are the accumulation points of the flow. These areas will have the highest possibility of becoming contaminated by the contaminants' flow. Based on the flow accumulation map, there are seven regions that are highly affected by the sources of contaminants in Ringlet, Tanah Rata and Brincang.

Besides, to compare the flow accumulation map with the TIN map, it was clearly seen that the path of the flow was derived based on the elevation range of area. The path of the flow will be from the highest elevation to the lowest one. All the purple lines are located at the lowest elevation level, which is dark green in color in the TIN map. The contaminants are also mostly being carried away by the water from the river.

4.2 Cameron Highland's Soil Structure

Table 4.4: Humus Depth in Cameron Highlands **(after W. Y. Wan Abdullah *et al*, 2005)**

Series	*Depth (cm)*
Brincang	8-100
Tanah Rata	40
Ringlet	negligible

Most of the pesticides leaching can be absorbed by topsoil which is enriched by organic fertilizer. From the table above, there is a negligible layer of humus in the Ringlet Series where the altitude is less and temperature is higher. So, the soils in Ringlet Series tend to have high probability of being contaminated by the pesticides than in Brincang and Tanah Rata Series.

Referring to the **Table 2.1**, sand is shown to be the major constituents of the soil characteristics at Brincang and Tanah Rata Series which comprises over than 50% of the total constituents. Meanwhile for the Ringlet, sand is also the major constituents but it only covers lesser percentage ranging from 36.6 to 44.9%. Sand tends to have high permeability value than clay and silt, which means that the substance can be easily flow throughout the sand particles. The flow of contaminants will be easier and faster in sand particles rather than in clay or silt. So, contaminants will be transported more deep into the ground in Brincang and Tanah Rata Series than Ringlet Series.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

As the conclusion, the objectives of this study were successfully met where the directions of contaminants flow were identified. Flow accumulation map was produced to show the direction of contaminants being carried away to certain regions.

From the analysis, it was found that Ringlet is the critical area that has the highest possibility of becoming contaminated by the identified sources of contaminants. The contamination's point sources are mostly located within and close to the residential areas, hence it could be said that the possibility of the residential areas to be affected by the contamination is there. Besides, River 1 in the Ringlet series has the highest possibility of becoming contaminated since the contamination's point sources are mostly located within 1 km distance from the river which is the closest distance compared to the distance from the other rivers.

For the recommendation, the actual modeling process using map overlays in spatial analyst extension can be done in order to obtain the risk map that shows the area with the probability to being affected by the contaminants.

Since this study only meant for modeling purpose only, further verification process can be conducted to find the exact types of contaminants in the critical areas. The result to be obtained can then be correlated with the modeling result in this study for the verification.

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APPENDIX

PROJECT GANTT CHART

Milestone for the Final Year Project