CHAPTER II

THEORETICAL BACKGROUND AND LITERATURE REVIEWS

2.1 Study Area

2.1.1 Location

Mae Sot District, Tak Province in the northern Thailand covers an area of 1,986 km^2. Mae Sot is located at latitude 16° 43' north, and longitude 98° 34' east, about 500 kilometers from Bangkok and 12 kilometers from the Thai-Myanmar border. The district is classified into 10 sub-districts namely; Mae Sot, Mae Ku, Pha-Wo, Mae Tao, Mae Kasa, Tha Sai Luat, Mae Pa, Mahawan, Dan Mae La Mao, and Phra That Pha Daeng (Figure 2.1).

The Padaeng zinc deposit is located at Doi Padaeng, Phra Tat Padaeng sub-district at latitude 16° 39'N and longitude 98° 40'E, which is about 11 kilometers southeast of Mae Sot city centre (Figure 2.2). The accessibility by road from Mae Sot to the deposit is southward through highway 1090 (Mae Sot-Umphang) for 7.5 kilometers and then turn eastward to zinc deposit area. The Padaeng zinc deposit consists of a relatively large secondary-deposit of Thailand and a smaller primary-ore deposit which operated by the Padaeng Industry Public Company Limited and the Tak Mining (see also Figure 2.2).

2.1.2 Topography and Climate

Topography of the Mae Sot District illustrated in Figure 2.3 presents a markedly difference between eastern and western parts. Geographically, a mountain range and inter-mountain basin occupy the whole part of the eastern area whereas the western area consists of low lands of river terrace and alluvial plain. The highest elevation of Phra That Padaeng sub-district where zinc deposit and mines are located is about 690 meters above mean sea level.

The climate of the study area is similar to the other western provinces, which is a tropical savanna climate. There are three distinct seasons including hot, rainy, and cool season. The hot season lasts from March to May with little rain. The rainy season begins in June and lasts until October (floods often occur in this area). The last, cool season start from November through February, with moderate and infrequent rain showers.

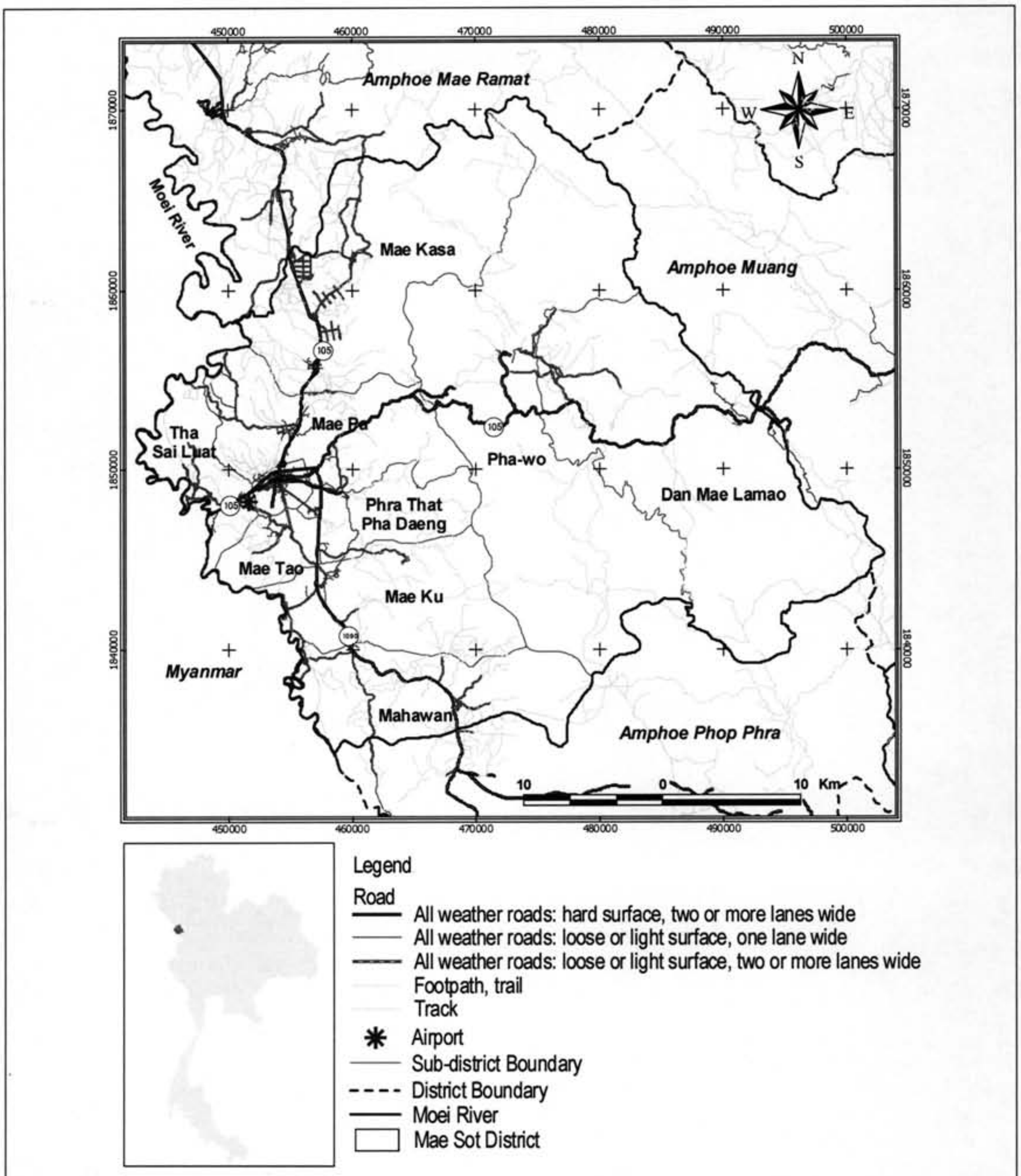


Figure 2.1 A map showing location and sub-districts of Mae Sot District, Tak Province (Adapted from Land Development Department, LDD).

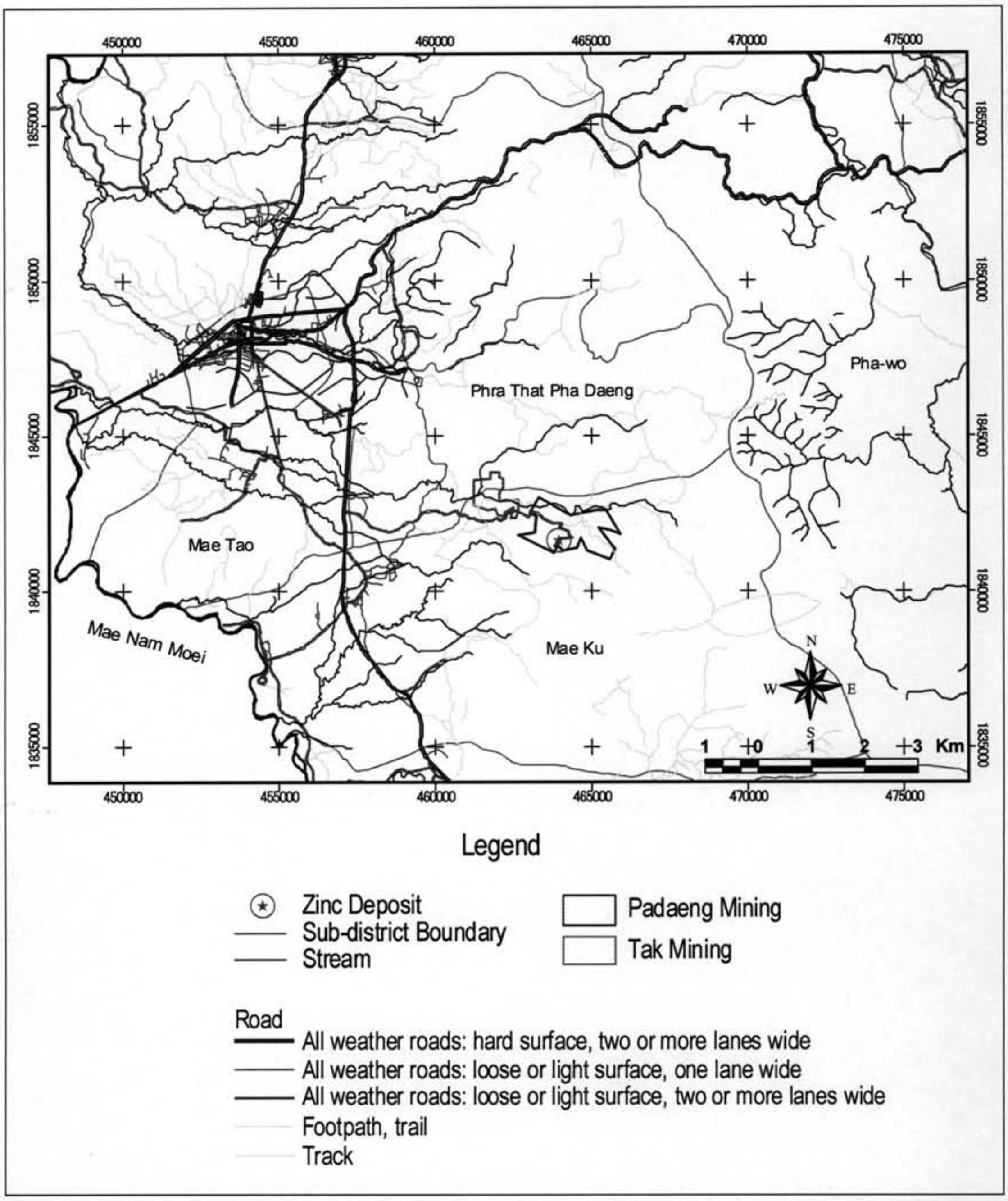


Figure 2.2 A map showing a location of zinc deposit and mine operating area (Adapted from LDD and Department of Mineral Resource, DMR).

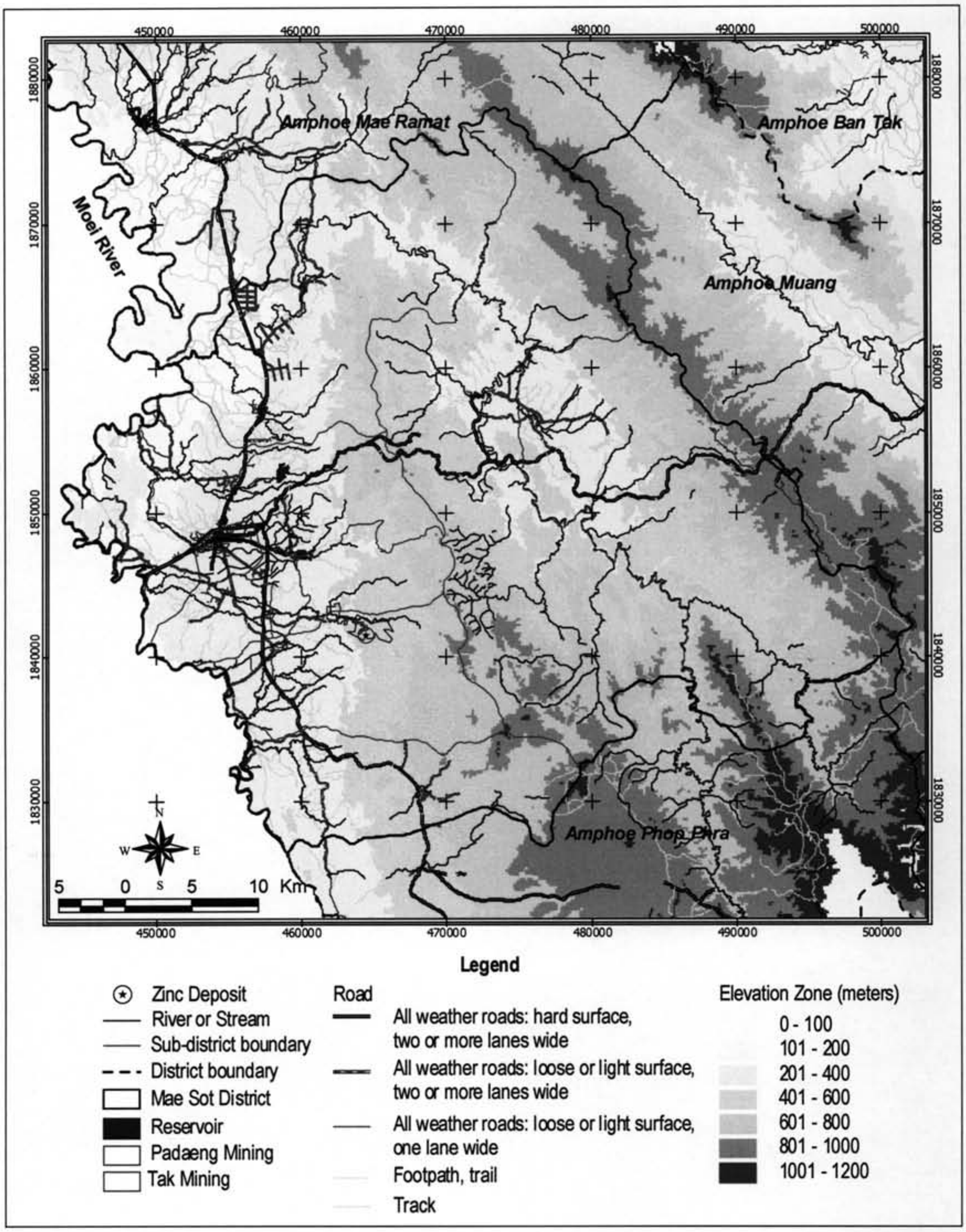


Figure 2.3 Map shows the topography of Mae Sot District, Tak Province (Adapted from LDD).

2.1.3 Hydrology

Hydrology of the study area as showed in Figure 2.4 can be implied that some part of the study area involved with the Mae Moei Basin. Mae Moei Basin is a part of Mae Moei River which is a main river flowing along the south-north borderline between Myanmar and western Thailand. From the aerial photographs and satellite images of the study area, the National Research Center for Environmental and Hazardous Waste Management, NRC-EHWM (2005) divided the Mae Moei River basin at the Mae Sot District into seven sub catchments, which are Huai Luang, Huai Pong, Huai Mae Tao, Huai Mae Ku, Huai Mae Ku Luang, Huai Phak La, and Huai Mae Paen. The drainage pattern of this area dominantly presents as a dendritic that resembles the pattern of trunk and branches of any tree. In addition, there are some man-made irrigation canals, which are constructed for an agricultural purpose. Generally, tributaries in this area flow westward from the mountainous area on the east to the low lands on the west before running to the main Mae Moei River. The two most concern streams are Mae Tao creek and Mae Ku creek. Mae Tao creek, approximately 25 kilometers long, starts at Ban Thum Sua and flows west passing zinc deposits, where the Padaeng Industry Public Company Limited and Tak Mining are located, to the alluvial plain, before merging with the Mae Moei River. In addition, a short stream about 2 kilometers long, called Mae Ku creek flows southwestwards to the Mae Moei River; part of the mining activities of the Padaeng Industry Public Company Limited slightly involves the Mae Ku catchment area (Srisathit, 2004).

2.1.4 Geology and Mineralization

Regional geology and mineralization of Mae Sot District have been studied for a long time by several organizations such as the Department of Mineral Resources (DMR) and the Padaeng Industry Public Company Limited.

The geology of the Padaeng zinc deposit is compatible to the Huai Hin Fon Formation which is grouped into the Upper Triassic-Jurassic Age (Figure 2.5). The Huai Hin Fon Formation consists of grey to dark grey limestone and light grey-bedded limestone with ammonite, brachiopods and coral reefs, inter-bedded with calcareous shale, sandstone and grey to brownish red lime-conglomerate. Their orientation is in NE-SW striking and about 50 degree dipping to NW. Major structures are faults with NW-SE trending by vertical dipping and N 23 E trending by 80 degree E dipping.

Ore minerals are mainly characterized by secondary zinc minerals, e.g. hemimorphite ($Zn_4Si_2O_7$ $(OH)_2.H_2O$), smithsonite ($ZnCO_3$), hydrozincite ($2ZnCO_3.3Zn(OH)_2$) and loseyite ($Mn(Zn)_7(OH)_{10}(CO_3)_2$). They usually occur along fault zones, particularly formed as mineralization veins in sandstone, and in dolomite.

The deposit was probably formed by the infiltration of zinc solution that was a result of oxidized primary zinc sulphide and subsequent groundwater transportation before being redeposited along the fault plains, fractures and pore spaces of sandstone and dolomitic limestone. Groundwater probably carried the zinc solution further to reconcentrate and redeposit particularly at the break of high gradient and low gradient (Department of Mineral Resources [DMR], 2002 and Naraballobh et al., 1992).

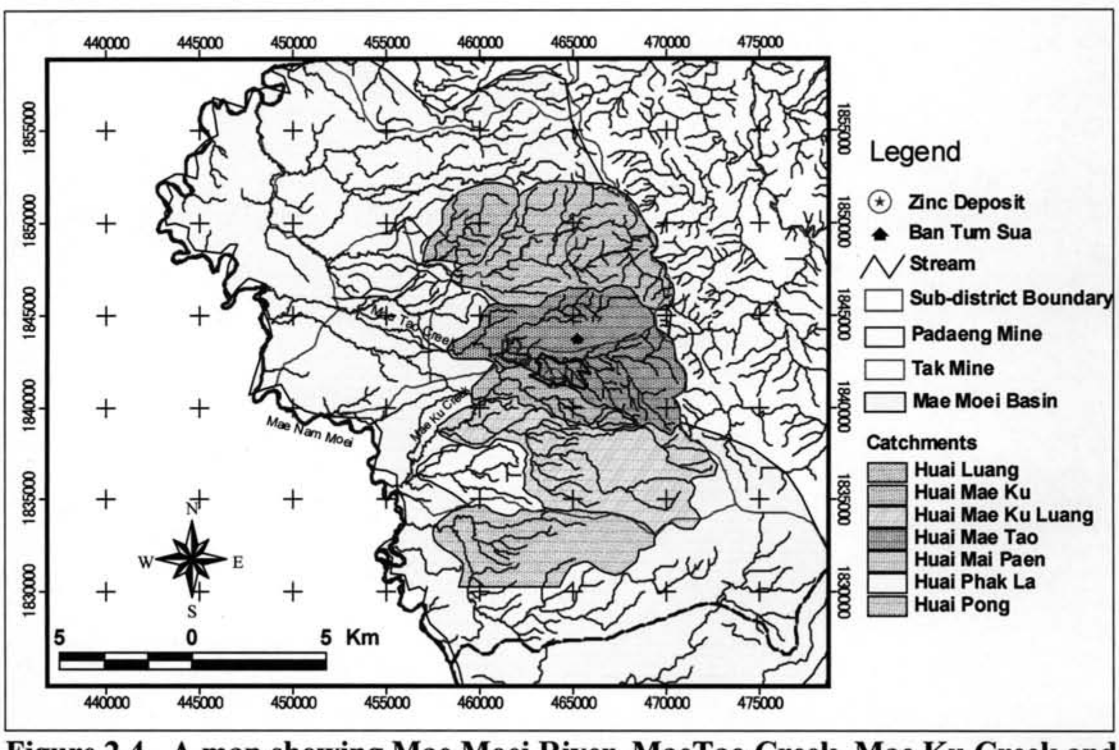
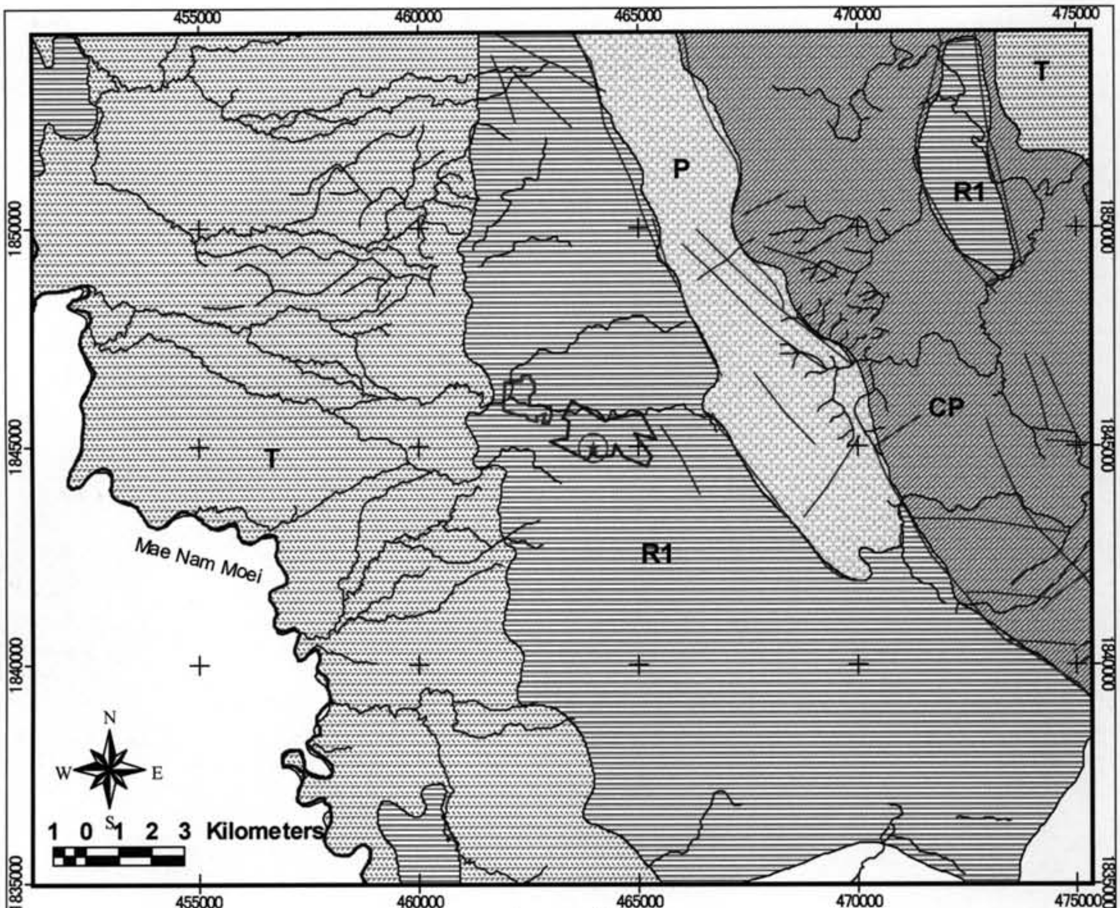


Figure 2.4 A map showing Mae Moei River, MaeTao Creek, Mae Ku Creek and 7 subcatchments in the study area (Adapted from NRC-EHWM and LDD).



Legend

(★) Zinc Deposit /\/ Stream /\/ Fault ☐ Padaeng Mining ☐ Tak Mining

Legend	Explanation	Formation	Age
T	Shale and oil shale with fossils of fishes, insect, and plant; conglomerate; sandstone; limestone, gray to light with fossils of gastropods; lignite and marl	Mae Sot	Tertiary
R1	Limestone, gray to blackish-gray and limestone, light gray, well bedded with fossils of ammonites, brachiopods and coral reefs; interbedded with calcareous shale; sandstone and lime-conglomerate, gray to brownish-red	Huai Hin Fon	Upper Triassic-Jurassic
P	Massive limestone, dolomite unfossiliferous; gray limestone, shale, and sandstone	Doi Pha-Wo	Permian
CP	Banded limestone with chert nodules: gray shale; sandstone and carbonaceous shale	Pharaka	Carboniferous-Permian

Figure 2.5 A map showing a regional geology, rock units and structure around the study area (Adapted from LDD and DMR).

2.1.5 Landuse

From the study on landuse of the study area and its adjacent, it can be classified into 5 major types of landuse. (Department of Primary Industries and Mines [DPIM], 2006)

(1) Forest area: most the whole area in the eastern part present as a mixed deciduous forest with lots of teak. There are also reforest area.

(2) Agricultural area: the surrounding area of the Padaeng Deposit is mainly occupied by agricultural area, especially paddy fields which are harvested only one crop per year. The other economic plants are soybeans, corn and garlic which are grown after the post harvest period of rice. Some cattle fields are also found in this area (Wangvipula, 2004). (Figure 2.6)

(3) Residential area: is mostly located along the floodplain area in the western part. There are a few villages in the valley.

(4) Mining area: as mentioned above, there are 2 zinc mines in this area.

(5) Others: the other kinds of landuse are restricted for public purposes, for example, reservoirs (Figure 2.7), roads and creeks.

Figure 2.6 Paddy fields and cattle fields in the study area.

Figure 2.7 A reservoir in the study area.

2.2 Geographic Information System (GIS)

The decline of environmental quality and natural resources is occurring and of great concern to all countries. This always leads to an on-standing conflict. The environment needs to be preserved, but natural resources have to be utilized for human life and activity. As a result, approaching well-management is more difficult and sophisticated; hence, new concepts in environmental and natural resource management have been developed. Most cases of the global environment and natural resources problems have an obvious spatial dimension; therefore, Geographic Information System (GIS) has been considered as a tool for approaching this aspect (Gumbricht, 1996).

2.2.1 What is GIS?

The GIS is a computer-based information system designed to facilitate the integration and analysis of geographically referenced data. Generally, it is capable of displaying, evaluating, analyzing, capturing, storing, combining and extracting conditional information from maps and associated attribute data (Mallawaarachchi et al., 1996).

2.2.2 Benefit of GIS

The GIS is applied to model and map the spatial interests that are critical for the decision-making process. Because of its ability, the GIS is being widely used in several fields; for example, development planning, scientific investigations, resource management, environmental management and conservation, pollution control and monitoring, ecological modeling, disaster planning, modeling flood impacts, urban GIS, facilities management and marketing analysis.

For mapping, the power of a GIS is obtained from its ability to relate different information in a spatial context; it can then reach a conclusion based on the relationship. With a GIS, attribute data can be linked to location data such as people to addresses, buildings to parcels and streets within a network. These pieces of information can be then layered and categorized for a better understanding. Analyses can be performed in each layer and also between several layers. Furthermore, by combining data with some analytic rules, a specific model can be generated for better decision-making (Environmental Systems Research Institute, Inc, 2005). Moreover, a GIS can also transform existing digital data, which may not yet be in map form, into the form for better recognition and easier utilization (U.S.Geological survey, 2005). These advantages are very powerful and can be applied in mineral resource and environmental management which its aspect really have to use attribute data (e.g. chemical analyses, mineral occurrences, populations, plants etc.) to be integrated as well as spatial analyses. The functionality of a GIS can then be applied to reach the target. The functionality of a GIS has been classified as 1) all data collection and input; 2) storage and retrieval; 3) manipulation; 4) analysis and synthesis; 5) output operations.

The goal of a GIS application for environmental and mineral resource planning is to take all data, both spatial and attribute, and transform them, through overlying and analytical operations, into new information which can support the decision-making (Kliskey, 1995). In order to achieve a database for this study, ArcView 3.3 and PCI Geomatica 9.1 software was used to simplify this task.

2.2.3 GIS Application

The cadmium contaminated area in Mae Sot district is one of the spatial dimension problems; therefore, the GIS is appropriately applied to resolve this issue. Appropriated GIS software was used to enhance, interpret and integrate all available data. The analyzed data is in turn yield many relationships, patterns, or trends intuitively which are not capable of being seen with traditional charts, graphs and land spreadsheets. An effective managing plan may be suggested based on all outputs from the study.

2.3 Cadmium (Cd)

Cadmium (Cd) is a naturally occurring metallic element, one of the components of the earth's crust and present everywhere in our environment. It is a lustrous, silver-white, ductile, very malleable metal. Its surface has a bluish tinge and the metal is soft enough to be cut with a knife, but it tarnishes in air. It is soluble in acids but not in alkalis. Some chemical and physical properties of cadmium are showed in Table 2.1. Cadmium is widely used in special alloys, pigments, stabilisers, coatings and above all (almost 70% of its use), in rechargeable nickel-cadmium batteries.

Table 2.1 Chemical properties of cadmium

Atomic number	48
Atomic mass	112.4 $g.mol^{-1}$
Electronegativity according to Pauling	1.7
Density	8.7 $g.cm^{-3}$ at 20°C
Melting point	321 °C
Boiling point	767 °C
Vanderwaals radius	0.154 nm
Ionic radius	0.097 nm (+2)
Isotopes	15
Electronic shell	[Kr] $4d^{10}$ $5s^{2}$
Energy of first ionisation	866 $kJ.mol^{-1}$
Energy of second ionisation	1622 $kJ.mol^{-1}$
Standard potential	-0.402 V

Source: http://www.lenntech.com

Cadmium can mainly be found in the earth's crust. There is no cadmium ore is mined for the metal because it always occurs in combination with zinc. Generally 3-5% of cadmium is produced as a byproduct of zinc mineral especially; CdS which is a significant impurity of the smelting zinc ore, sphelerite (ZnS). The main producing country is Canada, and the major suppliers are the USA, Australia, Mexico, Japan and Peru (Holding, 1988a).

Normally a very large amount of cadmium (about 25,000 tons a year) is released into the environment and it is normally transported continually between the three main environmental compartments, air, water and soils. Cadmium waste streams from the industries which are, for example, instance zinc production, production of artificial phosphate fertilizers and bio industrial manure, mainly end up in soils. Cadmium waste streams may also enter the air through waste combustion and burning of fossil fuels and it also enters the water through disposal of wastewater from households or industries. Cadmium strongly absorbs to organic matter in soils. When cadmium is present in soils it can be extremely dangerous because it can increase the uptake through food chain. Acidic soils enhance the cadmium uptake by plants resulting to the animals that are dependent upon the plants for survival. Cadmium can accumulate in their bodies, especially when they eat multiple plants. In aquatic ecosystems cadmium can accumulate in mussels, oysters, shrimps, lobsters and fish.

Human normally absorb cadmium into the body either by ingestion or inhalation and a little by dermal exposure. Cadmium entering the body by ingestion mostly comes from foodstuffs (both plants grown in soil and meat from animals). Other high exposures can occur when people smoke or breathe in cadmium which is released from hazardous waste sites or factories. It can severely damage the lungs. Cadmium is normally accumulated in the human kidney for a relatively long time, from 20 to 30 years. Cadmium is first transported to the liver through the blood and form complexes with proteins and then transported to the kidneys. It accumulates there and damages filtering mechanisms. This causes the excretion of essential proteins and sugars from the body and further kidney damage. Therefore, the World Health Organization (WHO) has noticed established a provisional tolerable weekly intake of cadmium (PTWI) at 7 μg/kg body weight. The well-known issue occurring in Japan (1950s and 1960s) where cadmium contamination of rice fields, along with nutritional deficiencies for iron, zinc and other minerals, led to renal impairment and bone disease (Itai Itai disease) in exposed populations.

Cadmium will invariably be present in our society, either in useful products or in controlled wastes. Today, its health effects are well understood and well regulated so that there is no need to restrict or ban cadmium products which, in any event, contribute so little to human cadmium exposure as to be virtually insignificant.

2.4 Zinc (Zn)

Zinc is a lustrous bluish-white metal. It is brittle and crystalline at ordinary temperatures, but it becomes ductile and malleable when heated between 110°C and 150°C. It is a fairly reactive metal that will combine with oxygen and other non-metals, and will react with dilute acids to release hydrogen (Holding, 1988b). Some chemical and physical properties of zinc are showed in Table 2.2. It is used principally for galvanizing iron, more than 50% of metallic zinc goes into galvanizing steel, but is also important in the preparation of certain alloys. It is used for the negative plates in some electric batteries and for roofing and gutters in building construction.

Table 2.2 Chemical properties of zinc

Atomic number	30
Atomic mass	65.37 $g.mol^{-1}$
Electronegativity according to Pauling	1.6
Density	7.11 $g.cm^{-3}$ at 20°C
Melting point	420 °C
Boiling point	907 °C
Vanderwaals radius	0.138 nm
Ionic radius	0.074 nm (+2)
Isotopes	10
Electronic shell	[Ar] $3d^{10}$ $4s^2$
Energy of first ionisation	904.5 $kJ.mol^{-1}$
Energy of second ionisation	1723 $kJ.mol^{-1}$
Standard potential	- 0.763 V

Source: http://www.lenntech.com

Zinc is the most abundant element in the Earth's crust. The dominant ore is zinc blende, also known as sphalerite. Other important zinc ores are wurzite, smithsonite and hemimorphite. The main zinc mining areas are Canada, Russia, Australia, USA and Peru. World production exceeds 7 million tones a year and commercially exploitable reserves exceed 100 million tones.

Zinc occurs naturally in air, water and soil, but zinc concentrations are rising unnaturally, due to human activities. Most zinc is added during industrial activities, such as mining, coal and waste combustion and steel processing. Some soils are heavily contaminated with zinc, and these are to be found in areas where zinc has to be mined or refined, or were sewage sludge from industrial areas has been used as fertilizer. When the soils are polluted with zinc, animals will absorb concentrations that are damaging to their health. Water-soluble zinc that is located in soils can contaminate groundwater. Finally, zinc can interrupt the activity in soils, as it negatively influences the activity of microorganisms and earthworms. Water is also polluted with zinc by the large quantities of zinc in the wastewater from industrial plants. Some fish can accumulate zinc in their bodies, when they live in zinc-contaminated water. When zinc enters the bodies of these fish it is able to bio magnify up the food chain.

Zinc is a trace element that is essential for human health. It supports a healthy immune system, is needed for wound healing, helps maintain human sense of taste and smell, and is needed for DNA synthesis. Zinc also supports normal growth and development during pregnancy, childhood, and adolescence. Zinc is found in a wide variety of foods and drinking water. The health risks of too much zinc are eminent health problems, such as stomach cramps, skin irritations, vomiting, nausea and anaemia. Very high levels of zinc can damage the pancreas and disturb the protein metabolism, and cause arteriosclerosis. Extensive exposure to zinc chloride can cause respiratory disorders. The upper level of zinc intake for an adult man is set at 45 mg/day (690 mmol/day) and extrapolated to other groups in relation to basal metabolic rate. On the other hand, zinc deficiency occurs when zinc intake is inadequate or poorly absorbed. It leads to growth retardation, hair loss, diarrhea, delayed sexual maturation and impotence, eye and skin lesions, and loss of appetite and weight loss. Zinc can be a danger to unborn and newborn children. When their mothers have absorbed large concentrations of zinc the children may be exposed to it through blood or milk of their mothers.

2.5 Literature Review

Some previous works which studied on this contaminated site and also on GIS applications for environmental and natural resource management have been reviewed.

Namboonruang, Nanglae, and Phadermrod, (2005) studied the cadmium contamination in Mae Sot district, Tak province. Objectives of their study were (1) to classify the level of contaminated area using the GIS; (2) to study the optimum ratio of soil amended material in order to minimize the transportation of heavy metals to rice; and (3) to recommend utilization of the contaminated area. They conducted their works on a paddy field at the Mae Tao watershed with total study area of 100 km^2. Two hundreds ninety three soil samples were collected and analyzed for their amounts of zinc, lead and cadmium and the average amounts of each were 53.80 ± 0.09, 0.13 ± 0.00 and 0.14 ± 0.00 mg/kg, respectively. From chemical analysis, they evaluated the risk of heavy metal contamination in the area by combining all three types of them using the Map Calculator. As the result, the area was classified into 5 levels, according to the amount of cadmium contamination: lowest contamination, low contamination, moderate contamination, high contamination and highest contamination. Each level occupied an area of 0.34, 5.82, 20.06, 59.95 and 13.83% of the total area, respectively. Soil samples from the highest contaminated area were experimented on to find the appropriate lime requirement to readjust the natural pH. The experiment was done by adding 4 levels of husk ash (i.e. 0, 25, 50 and 75% by weight) into non-glutinous rice, which was cultivated in the experimented pots for 120 days, and then the soil was analyzed again for heavy metal concentration. They concluded that 25% of husk ash was the optimum level to decrease heavy metal accumulation. Moreover, they also recommended the appropriate management for each area with different levels of contamination.

Simmons et al. (2004) applied an Irrigation Infrastructure-base Cadmium Hazard Mapping Model (Irr-Cad) onto a cadmium contaminated area in the same study area in order to evaluate the spatial distribution of cadmium and to quantify the food chain cadmium contamination risk in rice-based agricultural systems. The results showed good correlations between predicted values and observed values; hence, this can indicate that Irr-Cad has the effectiveness to predict the spatial distribution of cadmium.

NRC-EHWM (2005) studied the distribution of cadmium and bioavailability in cultivated soil and crops in the vicinity of the zinc mine in Mae Sot district. The research team of the NRC-EHWM conducted a field study for collecting a few types of specimens (i.e. stream sediment, cultivated soil, plant and water) and observing geologic setting and sedimentation throughout the area. Collected specimens were analyzed to determine cadmium and zinc concentrations. Total cadmium concentrations in stream sediments were found to be higher than the average of the general sediment (below 1 mg/kg); in addition, total concentrations of cadmium and zinc in cultivated soils were relatively high based on the soil standard (Cadmium and compounds should not exceed 37 mg/kg) (Pollution Control Department, 2004). It can be presumed that the zinc deposit and mining activity may lead to significant levels of cadmium distribution that is in turn related to cadmium-contamination potential.

Maneewong (2006) studied on the cadmium contaminated area in Mae Sot District, Tak Province. The research plan were (1) to investigate the cadmium distribution in stream sediment and suspended solid along the Huai Mae Tao and Haui Mae Ku and (2) to estimate the crucial fraction of cadmium in stream sediment that might be impact the environment in the study area. Consequently, the causes of the contamination were then defined. The sample locations were firstly designed based on the geographical feature, drainage pattern and mining location. The distance between each sample site was set at about 1 km. depended on stream bending and junction. However, Global Positioning System (GPS) was used to check the geographic references of all sample locations during the field investigation. Three samples groups (stream sediment, suspended solid and water) were collected along the Huai Mae Tao, Huai Mae Ku and Huai Nong Khieo. Suspended solid are assumed as the most recent sediment supplied in to the study area and the stream sediment are somehow older in periods of weathering and transportation, which however came from the same sources. For stream sediment, they were taken from top layer (0-5 cm.) of sediment set in stream; meanwhile, suspended solid and water were taken by collected 2 liters of water from the center of streams. After sample collection, the next step was a laboratory analysis which following the EPA method for identify the total concentration of all samples groups (*EPA method 3051* for stream sediment digestion, *EPA method 3050B* for suspended solid digestion, and *EPA method 3015A* for water digestion). In addition, the BCR 3-step suggested by the Standards, Measurements and Test Program (SM&T-formerly Community Bureau of Reference, BCR) of the European Union was selected for fractional concentrations in stream sediment. BCR 3-step is the method for determining the different forms of metals which are; BCR1: Exchangeable which is easily released into the environment, BCR2: Reducible which is represents the contents of each metal bond to iron and manganese oxides, BCR3: Oxidiziable which means trace metals may bond to various forms of organic matter, and Final residue which means the final fraction calculated from the difference between the aqua-regia extractable metal contents and the sum of the metal contents released by the sequential extractions. Both total concentration and fractional concentration were then quantified by using Inductively Coupled Plasma-Optical Emission Spectrometer (ICP-OES). From the chemical analysis, total cadmium and zinc concentrations in water samples showed lower values than the detection limit of ICP-OES. The results also showed that the suspended solid from Huai Mae Tao yielded the highest average total cadmium concentration (18.26 mg/kg), whereas the average total cadmium concentration in suspended solid collected from Huai Mae Ku and Huai Nong Khieo were 7.75 mg/kg and 6.32 mg/kg, respectively. Regarding to total zinc concentration in suspended solid, averages of all three creek; Huai Mae Tao, Huai Mae Ku and Huai Nong Khieo were not clearly different (7,767.14 mg/kg, 7,722.99 mg/kg and 6,232.91 mg/kg, respectively). For evaluation of total cadmium concentration in stream sediment, the results showed that the average from Huai Mae Tao (37.11 mg/kg) was higher than those from Huai Mae Ku and Huai Nong Khieo (7.99 mg/kg and 5.67 mg/kg, respectively). However, total zinc concentrations in stream sediment from Huai Mae Tao which contained total zinc of 1,231.47 mg/kg was also higher than those from Huai Mae Ku and Huai Nong Khieo (316.55 mg/kg and 63.08 mg/kg, respectively). The last one of the chemical analysis results is fractional cadmium and zinc concentrations in stream sediment from each creek. The first creek, Huai Mae Tao, showed high values of BCR1 and BCR2 of both cadmium and zinc (36.21% and 51.38% of cadmium and 45% and 50% of zinc, respectively). On the other hand, stream sediment from Huai Mae Ku contained a high value of BCR2 of cadmium; about 30-40% and high values of BCR1 and BCR2 of zinc (both about 45-50%). The last creek, most of stream sediment from Huai Nong Khieo presented as a final residue of cadmium (60.91%) and as a BCR2 of zinc (about 50%). From all chemical results, it can be concluded that Haui Mae Tao significantly presented high level of heavy metals, both zinc and cadmium. This should be the result from runoff which transports the sediment from Doi Phadaeng where two zinc mines are located. The comparison between heavy metals content from Huai Mae Tao and those from Huai Nong Kheio (which is located in another site of Doi Phadaeng and set as a control sample site) showed the markedly different values so it indicated that cadmium contamination may be partly involved with the zinc mine operation, besides; natural weathering and human activities such as cultivation have also considered as a cause of contamination. Furthermore, the period of weathering and transportation were considered as a main factor of the contamination and it also implied that zinc and cadmium in this case are not in soluble form since total concentrations of both heavy metals in water samples were very low.

Janpho (2006) investigated the distribution of cadmium and zinc in soil along the Mae Ku floodplain, Mae Sot district, Tak province and also studied the relationship between cadmium and zinc in soils. Consequently, grid system was applied for soil samples collection. The laboratory analysis was designed to analyze cadmium and zinc for both total concentration and bioavailability fraction concentration by using ICP-OES. Total cadmium and zinc concentration were analyzed following the EPA standard method 3051. Moreover, the bioavailability of cadmium and zinc were analyzed following the Standards, Measurements, and Testing (SM&T-Formerly BCR) method. For this study only the BCR step1 (BCR1) was conducted in order to find out the concentrations of cadmium and zinc in soils which are in the form that has the potential to be up taken by plants and the organisms in soil. From the results, it can be concluded that total cadmium and zinc concentrations in soils from the Mae Ku floodplain ranges from 0.42 to 101.69 mg/kg and 29.34 to 2,347.74 mg/kg with a mean value of 4.93 mg/kg and 209.94 mg/kg, respectively. Most of total cadmium concentration in samples (75.76%) was lower than 3 mg/kg. The site anomalies were found in 2 samples which contained a high value of both total cadmium and zinc concentration (more than 80 mg/kg and more than 1200 mg/kg, respectively). These two sites located in eastern part of the study area. Total cadmium and zinc concentrations in soil samples show a significant positive linear relationship. Moreover, bioavailability fraction concentration of cadmium and zinc range from 0.03 to 63.78 mg/kg and 2.04 to 1,033.92 mg/kg with a mean value of 2.48 mg/kg and 55.46 mg/kg, respectively. The ratio of bioavailability fraction concentration and total concentration of cadmium and zinc are 0.36 and 0.02, respectively. This indicated that the area of Mae Ku floodplain has been encountering the cadmium-contaminated soil problem. Eventually, this study assumed that the major source of cadmium contamination may be from human activities, particularly zinc mines. The sediment from high land in the eastern part where zinc mines are located was transported with runoff and then deposited into soil in the floodplain area. This results in the cadmium contaminated in the Mae Ku floodplain area.

DPIM (2006) investigated the contaminated site for the causality, boundary, and severity of Cadmium contamination in agricultural soils at Mae Sot District, Tak Province. Environmental samples were accumulated systematically for 2 years throughout the areas covering 96 km^2 of upstream area, colluvium and mineralizing land, and agricultural alluvial plain. Total of 259 soil samples from 53 spots at the depths of 0-20, 20-40, 40-60 and 60-200 cm were drilled with hand auger. Samples of water, stream sediment and mine tailing were also collected. Chemical analysis for cadmium, zinc and lead concentrations were undertaken using AAS and ICP. The results of chemical analysis for surface water indicated a safety to the surrounding environment as Cd, Zn, and Pb concentrations met the surface and ground water standards. Moreover, with neutral and slightly basic condition (pH 7.0-8.5) as observed in the study area, these heavy metals would be precipitated and no longer transported far from the places of origin. For stream sediments, both sample data sets from Mae Tao creek, which flows through the mining areas, and from Mae Ku creek, which does not, showed relatively high concentrations of zinc and Cadmium. For tailing sediments, it showed an extremely high Cadmium concentration in on-site residual ponds and not spread over to the outside environment. From this study, DPIM presume that Cadmium contaminated in downstream paddy soil was not principally originated from mining activities but could be potentially transported from mineralizing area in which large quantity of Zinc and Cadmium were embedded in original soils and rocks. However, from the investigation of soil samples, the contaminated area was finally defined to spread over approximately 18 km^2 mainly of mountainous mineralizing land and colluvium. Upstream soils, however, showed negligible heavy metal concentrations whereas nearly 50% and 20% of soil samples from downstream colluvium and alluvial plain respectively were highly contaminated with cadmium exceeding 37 mg/kg, which is reported by National Environmental Committee Notification as the maximum allowable level for residential and agricultural soils. Elevated cadmium soil was found from the surface to the depth of 40-200 cm in mineralizing area and colluvium and became shallower to undetectable in alluvial plain. However, the patterns of cadmium distribution through depth in highly contaminated area and alluvial plain were well corresponded. Statistical analysis using SPSS program was carried out to demonstrate the correlations between heavy metals in various conditions. At all sites and depths of soil samples, positive correlations of Zn-Cd, Pb-Zn and Cd-Pb were 0.794, 0.494 and 0.391 at 1% significance level, respectively. Correlation of Zn-Cd was, moreover, conspicuous in stream sediment whilst that of Pb-Zn became prominent in mine tailing. Based on all findings and evidences, DPIM concluded that geological processes since the latest uplift in Quaternary was the major cause of cadmium contamination, recent human activities such as agriculture, deforestation and mining were however inevitably additional causalities. Consequently, DPIM has imposed more stringent protection and mitigation measures to mining companies and currently implemented closer inspection and monitoring. Furthermore, DPIM has proposed in-situ remediation techniques including soil manipulation for bioavailability control and cultivation of hyper-accumulator plants and non-food crops instead of rice to resolve the problem.

Goodyear et al. (1996) have developed a new methodology for producing geochemical maps using traditional stream sediment data. Production of a map involves the integration of spatial information concerning sample sites, drainage networks and topography; this can be facilitated utilizing a Geographical Information System (GIS). The new basin-segment maps can identify areas containing contaminated land, and distinguish whether such enrichment is natural or anthropogenic. This technique has been applied to an area of 112 km^2 in Cornwall using maps prepared from a reconnaissance study, apportioning contamination to historical mine wastes and other enrichments to naturally occurring Pb-Zn mineralization. A high density stream sampling program and soil survey in the Allen Basin for the reconnaissance survey highlighted the presence of a discrete and previously described impersistent galena (and subordinate sphalerite) vein towards the south of the valley acting as a source of enrichment. Elevated concentrations of Pb and Zn in stream sediments and water reflected the presence of an anthropogenic source towards north of the basin; this was a mine-waste tip. The natural enrichment was also detected in the stream sediment and water chemistry. Plots for the downstream dispersion of Pb and Zn from the anthropogenic source were compared with the idealized dispersion model proposed by Hawkes. Only a limited correlation was found between the model and the field measurements, being closest when metal concentrations approached background. Refinement of the model using GIS may improve its reliability and, therefore, the accuracy of the contamination source separation and identification technique.

Lasserre, Razack and Banton (1999) applied a simple GIS-linked model for groundwater nitrate transport on a 20 km^2 hydrogeologic catchment located in the Poitou-Charentes region (Western France), particularly vulnerable to agricultural nitrate pollution. The GIS used in this study was IDRISI, a raster GIS developed at Clark University and the transport model, based on advection transport only, was directly incorporated into a GIS subroutine using the Pascal computing language. The model was coupled with an unsaturated zone transport model named AgriFlux, which is a mechanistic stochastic model attempts to describe all phenomena by taking into account the spatial variability of the input parameters using their statistical distribution in a Monte Carlo approach. The first module of AgriFlux application is HydriFlux, simulates water flow in the soil, taking into consideration water input and water uptake. The second module simulates the fate of nitrogen, by representing the nitrogen cycle processes. A comparison between the simulated nitrate concentration leaving the root zone (calculated by AgriFlux) and the measured nitrate concentration in groundwater (observed in the six wells during the 2 years) showed the measured concentrations were within the range of the simulated concentrations, indicating that AgriFlux correctly simulates the magnitude of the nitrate fluxes and that the groundwater quality of the study area is highly dependent on the spatial distribution of the leaching nitrates. In order to compare the GIS-linked model with a more complete model, simulations were also performed with MT3D-MODFLOW. The mean relative difference between measured and MT3D simulated concentrations ranges from 3 to 21%. These results support the validity of the GIS-linked model.

Bossew et al, (2001) studied on the caesium-137contaminated soil in Austrian. Since the accident at the Chernobyl NPP on 26 April 1986, some parts of Austria had been affected particularly strongly by the fallout. Subsequently, extensive sampling of grass, hay and raw milk and other foodstuff by the authorities and institutions involved in radioactivity measurement, yielded ''grass maps'' and ''milk maps'' which were used for ''exposure management'' by controlling feeding of the cattle and distribution of milk in order to keep radioactive exposure of the public due to ingestion as low as possible. Also, data about the actual soil contamination were collected by different institutions. In order to produce a consistent, country-wide survey of the Chernobylborne ^{137}Cs soil contamination, they decided to compile the data, to have more measurements carried out in parts of the country which had not yet been covered sufficiently, to evaluate them statistically and to display them graphically. The data are complied and stored in the geographic information system (GIS). The mean contamination with ^{137}Cs is 21.0 kBq/m^2, of which 18.7 kBq/m^2 is due to the Chernobyl accident, whereas global fallout contributes 2.3 kBq/m^2. Maximum values of total ^{137}Cs contamination are nearly 200 kBq/m^2. Total deposition of Chernobyl ^{137}Cs on Austrian territory is1.6 PBq or a fraction of around 2% of the ^{137}Cs released from the reactor. 2115 measurements were used to draw the Austrian caesium map. The geographical pattern of fallout distribution shows regional differences of contamination as high as 1:100.

Sanyong and Amarakul (2001) introduced GIS to study on the diseases distribution of 338 Jack fruit trees (*Artocarpusheterophyllus* Lamk.), 126 Bael fruit trees (*Aegle marmelos* Corr.) and 36 Ma Kiang trees (*Eugenia paniala* Roxb.) The study area covered on 7 provinces in the lower Northern Thailand which consisted of 50 districts and 81 sub-districts in Kamphaengphet, Nakhonsawan, Phitsanulok, Phichit, Sukhothai, Tak and Uttaradit provinces. Field survey on morphological study found that the average of perimeter on Jack fruit trees, Bael fruit trees and Ma Kiang trees were 81.3, 67.4 and 133.5 cm, respectively. The percentage of plant diseases distribution on Jack fruit showed the leaf spot disease caused of *Colletotrichum artocarpi* and die back disease caused of *C. gloesporioides* were 85.8% and 60.7%, respectively. In this investigation discovered a new disease which destroy stem of Bael fruit in Thailand. Bael fruit stem showed die back symptom caused by *Hysterium* sp. which was 28.6% of the total. Ma Kiang showed no serious plant disease, there were lichen on their stem, sooty mold caused of *Meliola* sp., and agal disease caused of *Cephaleuros virescens* which were 11.1%, 5.6% and 2.8%, respectively. The results indicated that the disease distribution on Jack fruit, Bael fruit and Ma kiang are different in each area. All those results were set up as a database and then input to GIS for query and display which means GIS could create the mathematical model for distribution and showed as a map. Therefore, GIS program is a best tool for disease forecasting. Moreover, in case of plant disease prevention and control, the data of soil suitability index and rainfall are important.