ลักษณะทางอุทกธรณีวิทยาใต้ดินระดับตื้นและภาวะของบรรยากาศพื้นผิว บริเวณเขาเจ็ดลูกและพื้นที่ใกล้เคียงจังหวัดพิจิตร

นางสาว ดารินพร เจียมประดิษฐ์กุล

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาหลักสูตรปริญญาวิทยาศาสตรมหาบัณฑิต
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HYDROGEOLOGICAL CHARACTERISTICS OF THE SHALLOW SUBSURFACE AND GROUND ATMOSPHERIC CONDITIONS IN KHAO CHET LUK AND ADJACENT AREA, CHANGWAT PHICHIT

Miss Darinporn Jeampraditkul

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ดารินพร เจียมประดิษฐ์กุล : ลักษณะทางอุทกธรณีวิทยาใต้ดินระดับตื้นและภาวะของบรรยากาศพื้นผิวบริเวณเขาเจ็ดลูกและพื้นที่ใกล้เจียงจังหวัดพิจิตร, (Hydrogeological characteristics of the shallow subsurface and ground atmosperic conditions in Khao Chet Luk and adjacent area, Changwat Phichit.) อ. ที่ปรึกษา: ผศ.ดร. นภดล ม่วงน้อยเจริญ, อ.ที่ปรึกษาร่วม: อ.บุศราศิริ ธนะ 236 หน้า. ISBN 974-17-5269-5

การศึกษาสภาพอุทกธรณีวิทยาระดับตื้นและบรรยากาศพื้นผิวบริเวณเขาเจ็ดลูกและพื้นที่ใกล้เคียงจังหวัดพิจิตร รวมพื้นที่ 677.136 ตารางกิโลเมตร โดยการใช้วิธี Theissen Polygon ในการวิเคราะห์ปริมาณน้ำฝนและข้อมูลทางอุตุนิยมวิทยาเฉลี่ยของพื้นที่ ระหว่างปี ค.ศ.1975 ถึง ปี ค.ศ. 2000 เพื่อนำไปสู่ข้อมูลสภาวะสมดุลของน้ำในช่วงเวลาดังกล่าว เนื่องจากภายในบริเวณพื้นที่ศึกษาไม่มีสถานีตรวจวัดอากาศและน้ำฝนเพียงพอในการศึกษา

การวิเคราะห์สภาวะสมดุลของน้ำในการศึกษาครั้งนี้ ได้แก่ ปริมาณน้ำคงเหลือบนพื้นผิวในพื้นที่ศึกษาซึ่งมาจากข้อมูล ปริมาณน้ำที่เข้าสู่ระบบเฉพาะปริมาณน้ำฝน และ ปริมาณน้ำที่ออกจากระบบพื้นผิว ได้แก่ ค่าการระเหย ค่าปริมาณการคายน้ำของพืช และ ค่าซึมผ่านผิวดิน เมื่อนำมาหักลบกันจะได้ปริมาณน้ำที่คงเหลือบนพื้นผิวสมดุลของน้ำที่ได้จากการศึกษาพบว่า ในปี 1975-76 ช่วงฤดูฝนชุกมีน้ำคงเหลือจำนวน 108.797 x 10^6 ลูกบาศก์เมตร ฤดูแล้งขาดแคลนน้ำจำนวน 489.945 x 10^6 ลูกบาศก์เมตร ;ในปี 1988-89 ฤดูฝนชุก มีน้ำคงเหลือจำนวน 13.536 x 10^6 ลูกบาศก์เมตร ฤดูแล้งขาดแคลนน้ำจำนวน 524.228x 10^6 ลูกบาศก์เมตร; และในปี 2000-01 ฤดูฝนชุกมีน้ำคงเหลือจำนวน 132.676 x 10^6 ลูกบาศก์เมตร และในฤดูแล้งขาดแคลนน้ำจำนวน 485.608 x 10^6 ลูกบาศก์เมตร

จากการศึกษาพบว่าพื้นที่ที่ทำการศึกษา จะมีน้ำใช้เพียงพอเพื่อการเกษตรกรรมเฉพาะในฤดูฝนชุก แต่ เป็นพื้นที่แห้งแล้งในฤดูแล้ง ที่ต้องมีการจัดสรรการใช้น้ำไว้ใช้ประโยชน์ให้พอเพียงกับความต้องการตลอดทั้งปี

ภาควิชา......ธรณีวิทยา...... ลายมือชื่อนิสิต...

สาขาวิชา.....โลกศาสตร์...... ลายมือชื่ออาจารย์ที่ปรึกษา...............................

ปีการศึกษา.....2547.......... ลายมือชื่ออาจารย์ที่ปรึกษาร่วม...........................

44722264723 : MAJOR EARTH SCIENCE

KEY WORD: water budget / precipitation / evapotranspiration / transpiration / infiltration

DARINPORN JEAMPRADITKUL : HYDROGEOLOGICAL CHARACTRISTICS OF THE SHALLOW SUBSURFACE AND GROUND ATMOSPHERIC CONDITIONS IN KHAO CHET LUK AND ADJACENT AREA, CHANGWAT PHICHIT. THESIS ADVISOR, ASST.PROF.NOPADON MUANGNOICHAROEN,Ph.D., THESIS COADVISOR : Ms. BOOSSARASIRI THANA, 236 pp. ISBN 974-17-5269-5

A 766.136 sq.km. area at and around Khao Chet Luk, Changwat Phichit was studied for the hydrological characteristics. Without sufficient climatological stations and hydrological gauge stations available in the study area, the Theissen polygon was used to estimate areal rainfall and climatology data from the year 1975 to 2000. This is to estimate the Water budget during that period.

The Water budget was calculated using precipitation data as the input and the evaporation, transpiration and ground infiltration as the output with the remaining-water surface flowage or storage being result. Water budget is indicated by the amount of the surface remaining-water in year 1975-76 which in the rainy season was 108.797 x 10^6 m^3 surplus, and in the dry season, 489.945 x 10^6 m^3 deficit. In year 1988-89, the rainy season was 13.536x 10^6 m^3 surplus, the dry season was 524.228x 10^6 m^3 deficit. In year 2000 -01, the rainy season was 132.676x 10^6 m^3 surplus and in dry season was 485.608 x 10^6 m^3 deficit.

The study indicates that in this area the water will be enough for the household and agriculture usages in the rainy season. The problem will be an extremely short of water in the dry season. This area needs a good planning for the water budget management for a year- round demand.

Department………Geology……… Student's signature…………………………

Field of study……Earth Science… Advisor's signature…………………………

Academic year….2004…………… Co-advisor's signature……………………..

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CHAPTER I
INTRODUCTION

1.1 General statement

All organisms on earth need water, thus making the study of the science of water to be important. Water on the earth exists mainly in the hydrosphere and atmosphere, which extends about 15 km. up into the sky and down to about 1 kilometer depth in the upper part of the crust. Water circulates in the hydrosphere through a maze of paths, constituting the hydrologic cycle. The hydrologic cycle is the main focus for hydrology which leads to a water balance study. Water balance is a focus which the scientists are aware of because of its complexity and difficulty to an understanding of the interaction between climate, soil and vegetation.

Nowadays, Thailand has a problem of water management by which the governmental bodies, instead of sharing the basic data, trying to understand the hydrological concepts only in their own involvement. This present study is thus trying to get some better understanding of a part of the complex hydrologic cycle, using the available but limited and scattered data in a geographic area as the basic information.

1.2 Objectives of the study

The purposes of this study to estimate the amount of surface water remaining from the precipitation, evaporation, transpiration and infiltration from the data available in an area, at a specific period of time. Rainfall or precipitation was the calculated amount of input water. Soil groups and soil physical properties were used to obtain the infiltration data. Landuses and coefficient of plant transpiration data were computed for transpiration and evaporation while the level of water table and ground lithological data were also noted. These were to calculate for the surface water balance by which the surplus water was considered to be the surface running water, if non to be storage.

1.3 Description of the study area

1.3.1 Location

The study area covers the parts of 7 Amphoes of 3 Changwats which located at the boundary between the central and northern Thailand (Figure 1.1), namely

Changwat Phichit	: Amphoe Thap Khlo, Wang Sai Phun, Muang Phichit, Taphan Hin,
Changwat Phetchabun	: Amphoe Wang Pong, Chondaen,
and Changwat Phitsanulok	: Amphoe Noen Maprang.

The area, about 679.136 km^2, is some 280 kilometers north of Bangkok. It is bounded by the Latitudes 16° 07’ 49 “ to 16° 30’ 27“N and Longitudes 100° 30’ 27“ to 100° 44’ 22“ E, UTM system grids $^{6}61000$ E to $^{6}85000$ E and $^{17}84000$ N to $^{18}11000$ N (Figure 1.2), in the topographic maps scale 1:50,000, Series L7017, Sheets 5141III “AMPHOE THAP KHLO” and 5141IV “AMPHOE WANG SAI PHUN”

1.3.2 Physiography

The physiographic terrain of the study area as show in Figure 1.3 reveals an undulating nature with the altitude ranging from 25 to 250 meters above the mean sea level. The highest elevations are on the hills to the east while the areal slope slightly tilts down to the west. The study area is divided physiographically into 4 groups as, the isolated hills, the high ground around the hills, river terrace, and flat recent alluvial deposit area (Figure 1.3). The hills are generally 200 to 250 meters above the mean sea level, and are found scattering to the northeast (Khao Ruak), central west (Khao Mo, Khao Pong, Khao Phanompha and Khao Chet Luk), and the south (Khao Nok Yung). The high ground is found around these hills, but mostly to the east of the study area, with an elevation of 75 to 100 meter above the mean sea level. The river terrace is rather flat with the elevation 50 to 75 is meter and found in the central part from the north to the south, and the recent alluvial deposit area, at the elevation below 50 meter, found to the west of the study area.

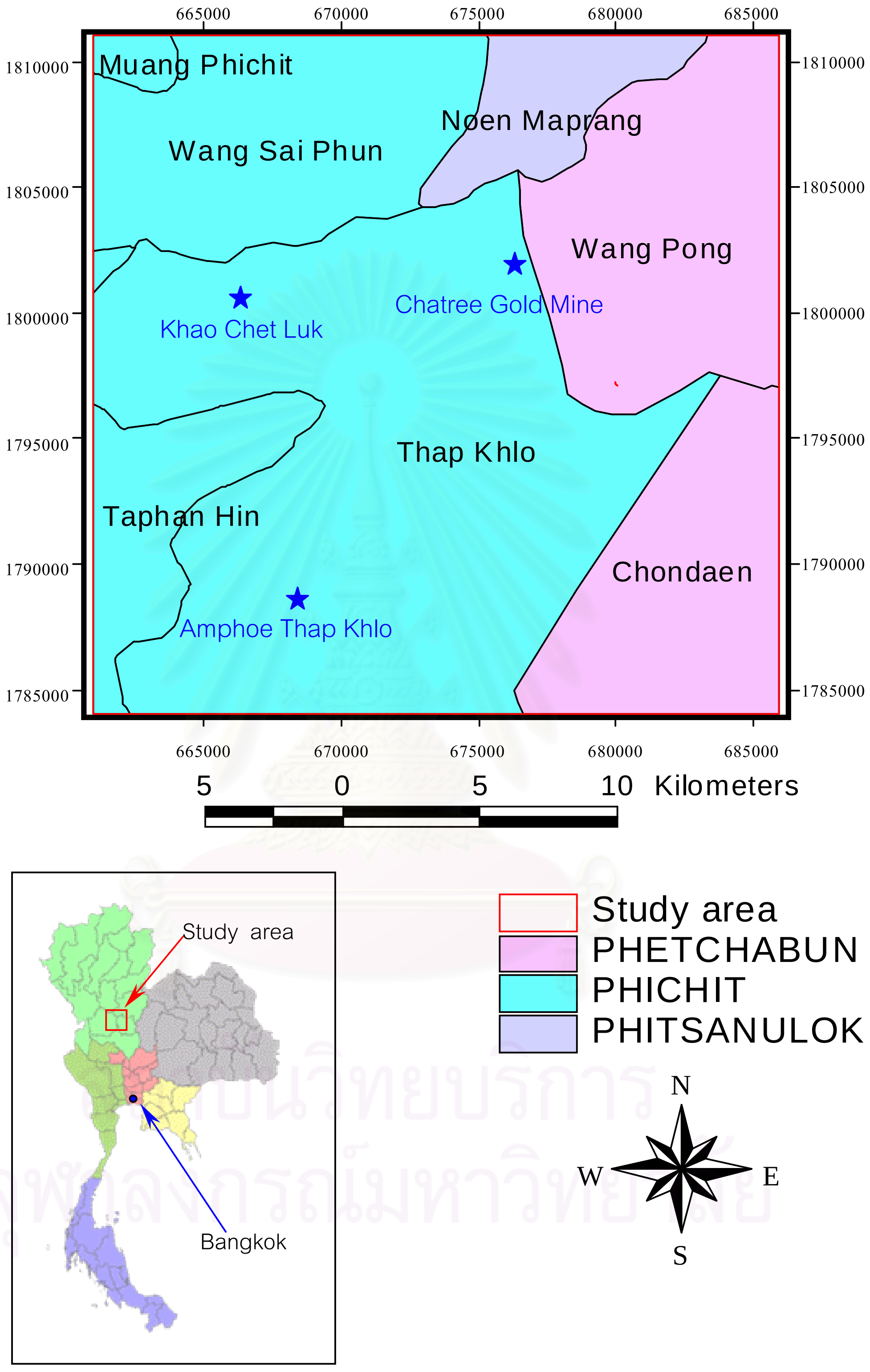


Figure 1.1. Location of the study area. The area is located in Changwat Phichit, Petchabun and Phisanulok with the administrative Amphoe boundaries being shown.

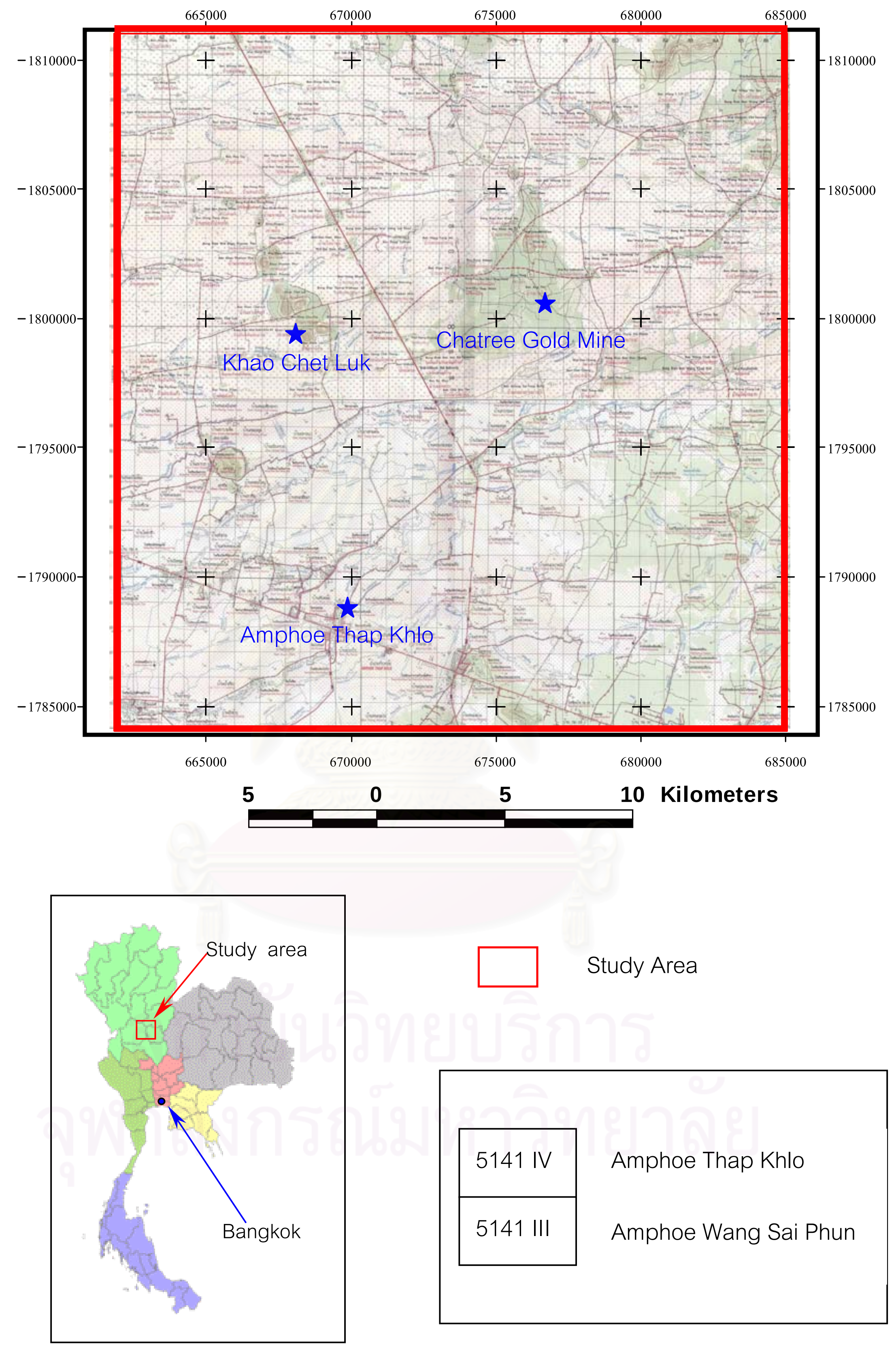


Figure 1.2. Topographic maps of study area. The area is covered in the 1 : 50,000 topographic map sheets 5141 III and 5141 IV.

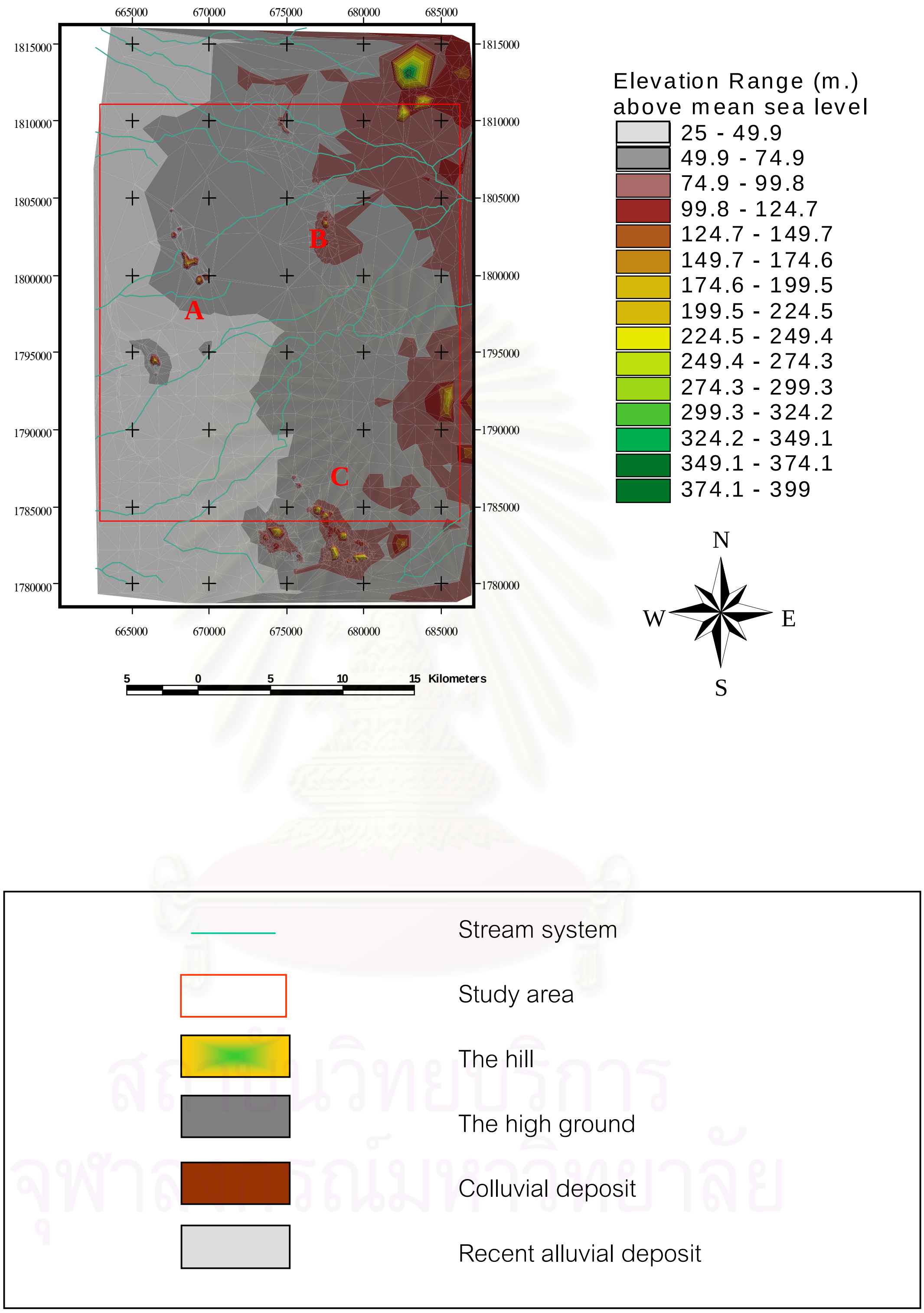


Figure 1.3. Phisiographic map of the study area. The hill group are (A) Khao Mo, Khao Pong, Khao Phanompha and Khao Chet Luk, (B) Khao Ruak and (C) Khao Nok Yung.

1.3.3 Weather and climate

The weather of the study area is under the influence of the southwest and northeast monsoons (Figure 1.4). The southwest monsoon usually starts in the middle of May and ends in the middle of October. It brings a stream of warm moist air from the Indian Ocean thus, produces a large amount of rainfall.

The northeast monsoon normally starts in middle of October and ends in the middle of February. It brings the cold, dry air from the anticyclone in mainland China over northern parts of Thailand thus brings the dryness to the country. After then, the south wind starts in the middle of February and ends in the middle of April. It brings the moisture to the country thus its influence for raining in central and eastern Thailand.

There appears to be 3 seasons in Thailand, the rainy season or southwest monsoon season, the winter or northeast monsoon season, and the summer or pre-monsoon season. The rainy season is from mid-May to mid- October, with a lot of rains and sometime with flooding being occurred in this study area. The winter is from mid–October to mid-February, it is cold and dry. After the winter, in mid-February to mid-May, it is summer which is hot and slightly humid. With little rains and high evaporation, the area normally faces drought. The climate in the study area can be summarized from the normal baseline data as following

Rainfall. Amount of rainfall is normally above 1000 mm. per year. The majority of rainfalls, about 90 %, is in the rainy season.

Evaporation. Average evaporation is less than the rainfall during the rainy season (middle of May to middle of October) and exceeds the rainfall in the dry season. The highest evaporation is in April and the lowest in December.

Temperature. The temperature normally is the highest in April and the lowest in December.

Relative humidity. Average relative humidity is the lowest in summer and then continuously increases to the highest in the rainy season.

1.3.4 Wind direction

The pattern of the near-surface wind directions is characterized by the monsoon system. The prevailing winds during the northeast monsoon season are mostly from the north and northeast. In summer, the prevailing winds are mostly from the south.

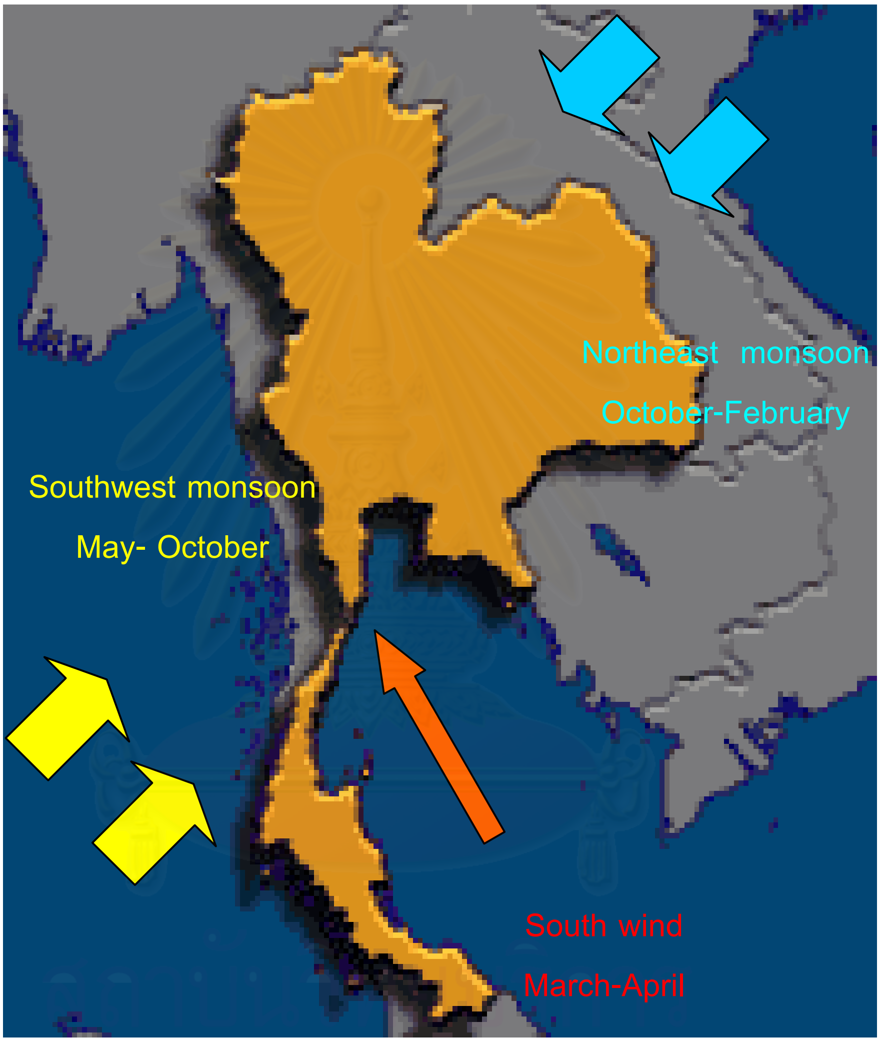


Figure 1.4. General monsoon pattern in Thailand (From Thai Meteorological Department).

1.4 General geology

The general geology of the study area is shown in Figure 1.5. The rocks in the study area can be divided into 2 groups according to the age, as the Pre-Quaternary and Quaternary groups.

1. Pre-Quaternary group

a) Permo-Carboniferous limestone and metasediments.

The Permo-Carboniferous rocks are the light gray, massive limestone alternated with metasediments. The limestone and the meta-sediments in the study area do not expose much except in the southern part of the study area (Figure 1.6). Here it is believed that the exposure is a basement high.

b) Permo – Triassic Volcanic rocks

The volcanic rocks here consist mainly of andesite, rhyolite and tuffaceous sediment with subordinate agglomerate, pyroclastic rock and diorite. The rocks expose primarily on the scattered isolated hills throughout the area (Figure 1-7). The hill chains and small isolated hills of this rock type could be the monadnocks scattering throughout the area of peneplain above the mentioned Permo-Carboniferous rock.

2. Quaternary Group

Besides the topsoils which cover almost everywhere, the main parts of the Quaternary deposits are as followings.

a) Colluvial deposits

The colluvial deposits in study area are occurred mostly at the foot of small hills with the elevation about 70-85 meter above mean sea level (Figure 1.8). They were formed by the sediment being transported down by gravity with other transportation processes. The sediment consists mainly of gravel and sand which were eroded from the volcanic rocks.

b) Low terrace deposits

The low terrace deposits are occurred in late Pleistocene. The deposits consist of clay-sand and minor gravel. In this area, the deposits are somewhat lateritic, probably because of the weathering of the volcanic rocks, to situate shallowly but above the water table. The elevation of the terrace is 50 – 70 meters above the mean sea level (Figure 1.9).

c) Alluvial deposits

The deposits are found extensively along floodplain of small streams. They lie between 25 – 50 meter above the mean sea level. The floodplain deposits are consisted of sand, silt, clay (kaolinitic and illitic), and gravel in alternated layers, but the mostly are clay with minor sand. These deposits underlie most paddy fields (Figure 1.10).

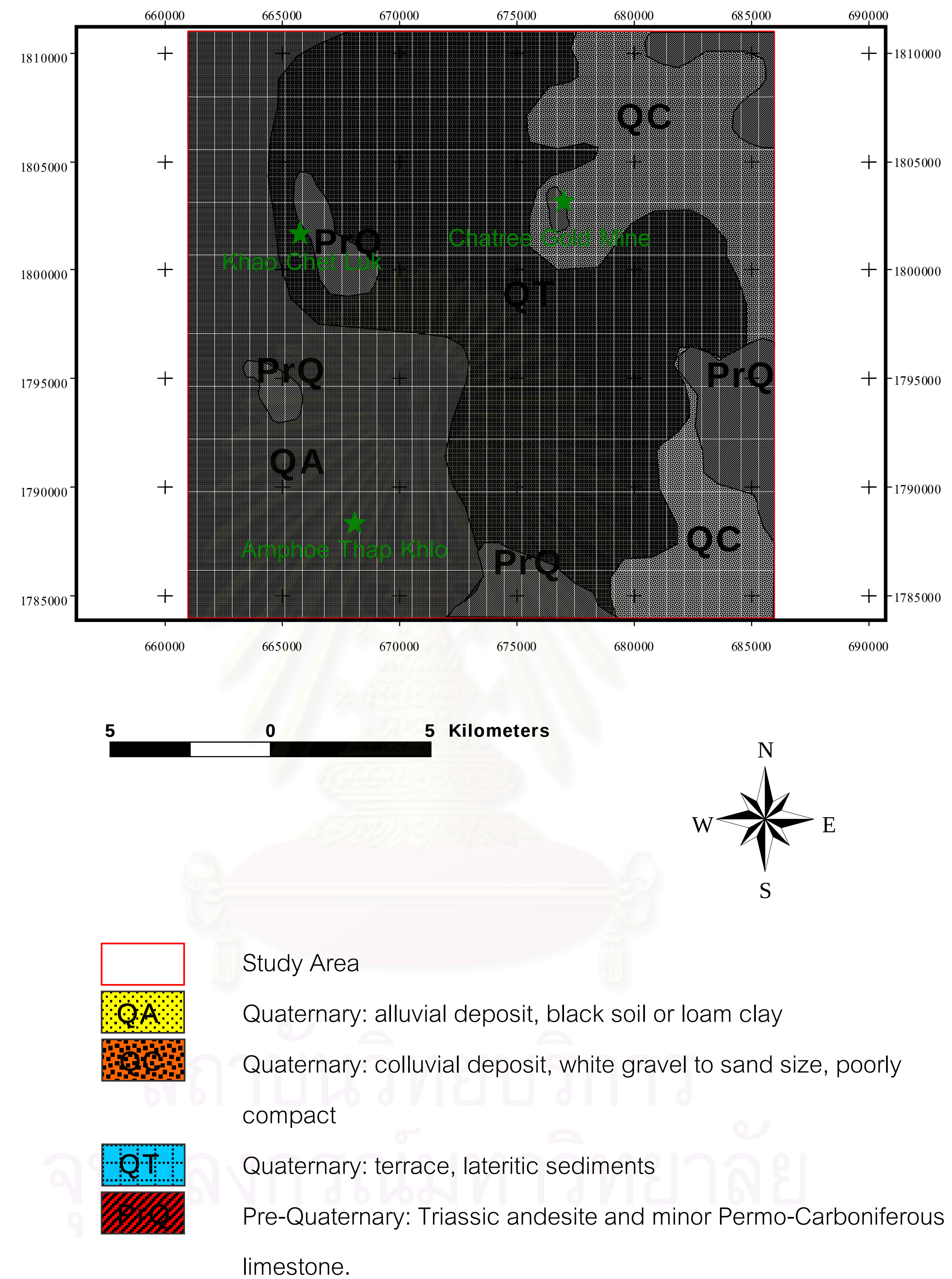


Figure 1.5. Geological map of the study area.

(Modified from Department of Mineral Resources 2003)


Figure 1.6. Permo-Carboniferous limestone of basement high.

(A)

(B)


Figure 1.7. Isolated hills of volcanic rocks. (A) Khao Ched Luk, in the central west of the study area. (B) Volcanic rocks (andesite) at Khao Phanompha.

(A)

(B)


Figure 1.8. Colluvial deposits. (A) Colluvium at the foot of a small hill. (B) Characteristics of weathered volcanic rocks (andesite) in study area.

(A)

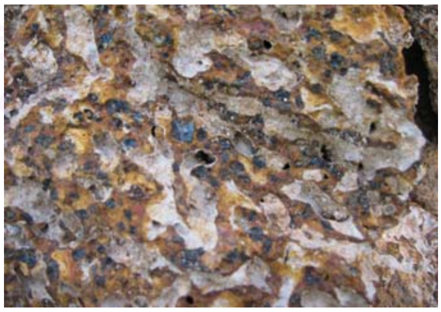
(B)


Figure 1.9. Low terrace or in situ deposit. (A) Lateritic low terrace layer. (B) The laterite of low terrace or in situ deposit.

1.5 Mineral Resources

Gold in the study area is primarily found in the quartz veins in the Permo-Triassic volcanic sequence. Many of the primary sources are of the invisible size gold, i.e. the grain size is down to 10 μm in diameter, and less visible gold that could be seen by naked eye. However the secondary process has released the visible gold from the primary sources to be deposited with the colluvial sediment not very far from its sources.

In the study area, there are 2 gold resources. The first is at Khao Mo-Khao Pong (Figure 1.11) at the boundary between Amphoe Thap Khlo of Changwat Phichit and Amphoe Wang Pong of Changwat Phetchabun. Here the deposit is being mined as the Chatree gold mine's project. It comprises two large open pits, Tawan and Chandra. The metal extraction is done using a carbon-in-leach process. Gold production rate is about 65,000 ounces per year and the byproduct silver about 160,000 ounces with the project's life of about 15 years.

The second gold deposit at Khao Phanompha–Khao Chet Luk (Figure1.12), Khao Phanompha under a management by Phichit Provincial Administration Organization, is located in Amphoe Wang Sai Phun. This deposit was explored by Department of Mineral Resources in 1993 to be a high quality gold deposit. This deposit had drawn the gold rushers from far and near to do gold panning. The deposit is now about depleting.

1.6 Methodology of Investigation

The flow chart of the study process is illustrated in Figure 1.13. The method of investigation in this study are as below.

1.6.1 Literature reviews

Only few previous related works done in this area had been observed. Most of the works were done in related to the gold finding in this area. Some of the works are noted below.

Mahoton (2002) studied the preliminary fluid inclusions of the gold found in Chatree gold deposit, Changwat Phichit. He found that the original temperature and salinity could indicate the classic low sulfidation type, epithermal system deposit.

Figure 1.10. Paddy field representing alluvial deposit near small channel in study area.

(A)  (B) 

Figure 1.11. Chatree gold mine. (A) Tawan pit. (B) Carbon-in-leach facility for gold extraction.

(A)  (B) 

Figure 1.12. Khao Phanompha gold deposit. (A) : Concession area of Phichit Provincial Administrative Organization. (B) : Gold panning at Khao Phanompha.

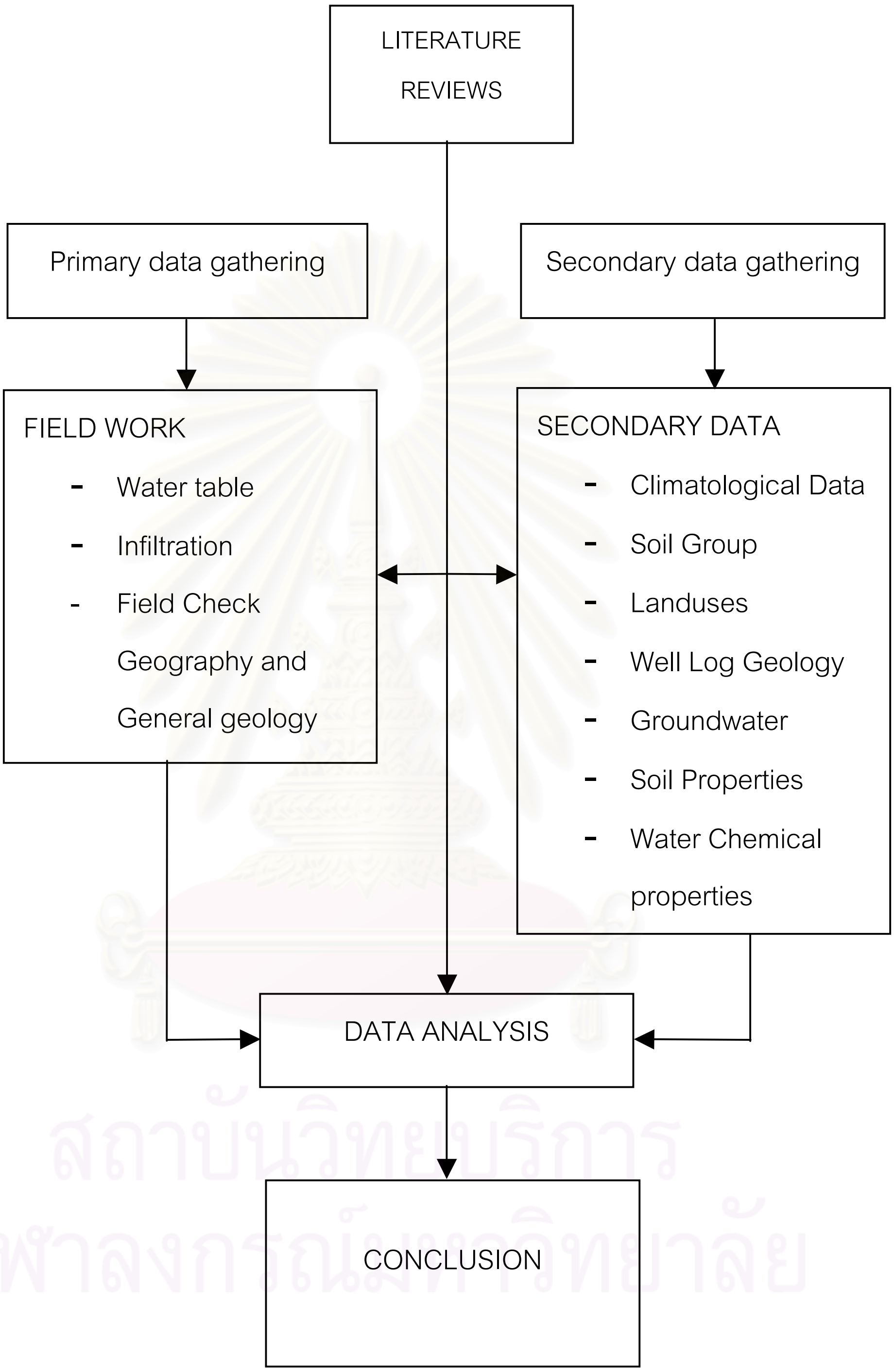


Figure 1.13 Flow chart of methodology.

S.P.S.Consulting Service (2001) studied the general environmental impact to accompany an application for a concession of the Chatree gold project of Akra Mining Co. Ltd.

Deesawat (2002) investigated the hydrothermal alteration of the Chatree gold deposit. This study is on a geological process and stress on hydrothermal alteration for the gold origin.

Chuancheuy (2003) studied some chemical properties of water from the dug wells around the study area as one of the consecutive study project, in where this present study belongs. The study was concentrated on the chemical properties of the near-surface ground water.

1.6.2 Data collection

All related data collected can be divided into 2 groups as follow.

1.6.2.1 Primary data

Field investigation to collect the primary data were done in 3 schemes.

1. Measurement of water table

Measurement of the elevation of the water table were done in 11 dug wells throughout the study area three times in 2003, in March, August and December. The measurement was to detect the seasonal change of the water table, to be calculated for the flow pattern. The water samples were also collected to be analyzed for their physical and chemical characteristics in the other consecutive study.

2. Measurements for rate of infiltration

This study was to gain knowledge of the rain water infiltrate into the soil through the ground surface in its natural condition. The measurement was done in 5 locations, each with the different soil types.

3. Measurement of soil physical properties

The soil physical properties to be measured are the pH value and soil moisture. A pH tester is used for measuring pH and tensiometer for measuring soil moisture. The measurement was done in accordant to the infiltration measurements.

The soil samples in these 5 locations and other additional 6 locations were collected for analyzing for their density and porosity. The soil properties were also analyzed in another related study. The study method and equipment used in the field study are shown in Appendix A.

4. Field check of geography and general geology

The field verification for the correctness of the interpretation of the physiography of the study area was performed during the time of the above measurements. This is to understand the study area in its correct nature.

1.6.2.2 Secondary baseline data

The secondary data which were available for this research were collected from many governmental sources as following.

- Thai Meteorological Department, Ministry of Information and Communication Technology:The information of monthly rainfall, wind direction, evaporation, and temperature in the years 1975 to 2000.
- Department of Land Development, Ministry of Agriculture and Cooperatives: The data of soil groups and their suitability to crops.
- Department of Ground Water Resources, Ministry of Natural Resources and Environment: Lithology at the ground water wells, and hydrological maps.
- Thai Royal Survey Department: Topographic maps.

1.6.3 Data analysis and conclusion

From the collected data, the remain water was calculated based on the amount of precipitation, evaporation, infiltration and transpiration. The knowledge would also lead to the shallow hydrogeological knowledge such that it would be useful for a better land development planning in an area of no irrigation system like this study area. For the calculation, the precipitation as an input was subtracted by the outputs that are the evaporation, infiltration and transpiration. A GIS Software, Arc views 3.2, was used for this study.

CHAPTER II

CLIMATOLOGY AND RAINFALL

2.1 Overview of study

2.1.1 Baseline of data

Thai Meteorological Department, Ministry of Information and Communication Technology is the governmental body who collects the climatological data throughout Thailand especially in all essential areas. The weather data are gathered and normally preliminary calculated for the monthly average, and annual maximum and minimum data. Unfortunately the data gathered in each station is different in a continuity and time period. The collection also depends on the recording system and the starting time.

The World Meteorological Organization (1969) had recommended that the minimum precipitation-network density for the general hydrometeorological purposes was as shown in Table 2.1 below.

Table 2.1. The minimum precipitation-network density for general hydrometeorological purposes

Area	Minimum density	
	km^2/station	Mi^2/station
1. Flat area region of Temperate, Mediterranean and Tropical zones.	600-900	230-330
2. Mountainous region of Temperate, Mediterranean and Tropical zones.	100-250	40-100
3. Small mountainous lands with irregular precipitation.	25	10
4. Area in arid and polar zones.	1,500-10,000	600-4,000

From Singh, P.V. (1992).

Thus, for the present study area of flat region of Tropical zone, the rain–recording stations should be 7.0 to 20.5 kilometers apart. In Thailand the climatological data, which are essential for this research, normally have 2 characteristics, the range of time of data collection, and the location of those climatological stations. The rain gage stations in Thailand are more common than the complete climatological stations which certainly including the precipitation data. For the suitability for this study, the data, thus, were collected from the various rain gages apart from the climatological data from far-away stations.

Rain gage

The purpose of establishing a rain gage network is to obtain a true representative of the rainfall in an area of interest over which the rain gages are assumed to cover. To ensure a good quality record, it is necessary to select the appropriate type of recording equipment as well as the accuracy of the rainfall.

According to Table 2.1, as the study area is approximately 677 square kilometers and located within a flat area of Tropical Zone, thus as many rain gages in and around the study area must be used. Eight rain gage stations being located here were selected as indicated in Table 2.2 and their locations of are shown in Figure 2.1. There are 2 rain - gage stations situated within the study area (Wang Sai Phun and Khao Sai School) and 6 more stations in the immediate adjacent area. The recorded precipitation data include the daily, monthly and annual rainfall. The insufficient rain gages in an area could result as the rain storms not being detected. This is unavoidable as the storms are naturally very locally to the spots or narrow areas away from those station.

Table 2.2. Selected rain gages and their distance from the boundary of the area.

Station number	Rain gage name/Province	Distance/direction from study area center	Period of record
379003	Chon Daen / Phetchabun	13.3 km / E	Jan 1977 - present
379009	Wang Pong / Phetchabun	7.0 km / E	Jan 1987 - present
386001	Muang Phichit / Phichit	20.5 km / NW	Jan 1975 - present
386002	Bang Mun Nak / Phichit	14.8 km / SW	Jan 1975 - present
386005	Wang Sai Phun / Phichit	In study area	Jan 1979 - present
386006	Taphan Hin / Phichit	9.0 km / W	Jan 1975 - present
386008	Khao Sai School / Phichit	In study area	Jan 1975 - present
386010	Sak Lek / Phichit	14.5 km / NW	Jan 1975 - present

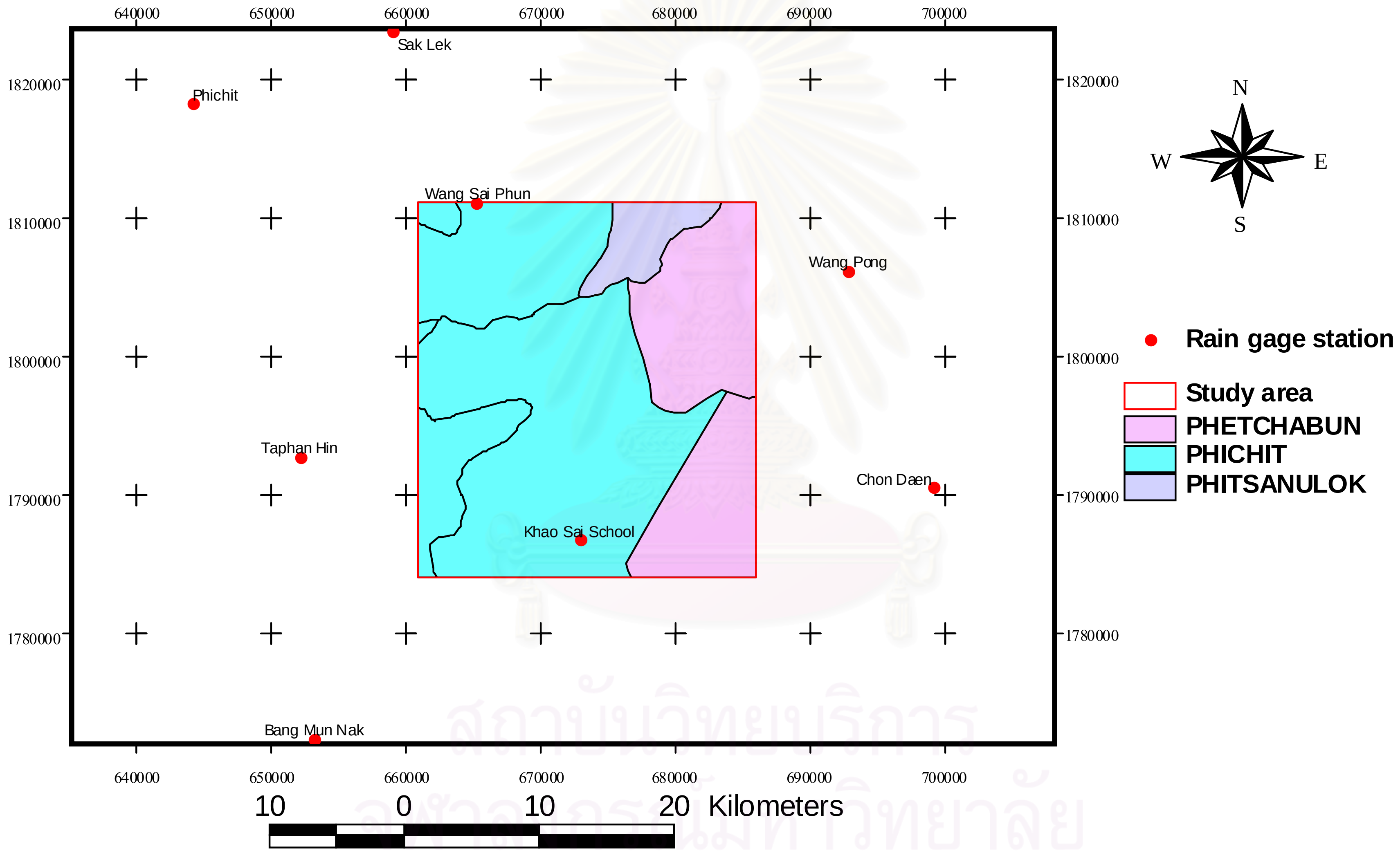


Figure 2.1. Location of rain gage stations in and around the study area.

Climatological station

Six more climatological stations were selected to obtain the climatological data. However, none of these selected stations located within the study area. An interpolation was thus used to receive the average data for the study area. The climatological data include monthly temperature, monthly evaporation, monthly sunshine days and daily and monthly wind speed and wind direction.

The climatological stations as selected are illustrated in Table 2.3 and their locations are shown in Figure 2.2.

Table 2.3 The selected climatological station and period of record.

Station number	Climatological station name/Province	Period of record
331401	Tha Wang Pha / Nan	1975 – present
351201	Utaradit / Utaradit	1975 – present
378201	Phisanulok / Phisanulok	1975 – present
400201	Nakhorn Sawan / Nakhorn Sawan	1975 – present
379201	Phetchabun / Phetchabun	1975 – present
379401	Lom Sak / Phetchabun	1975 – present

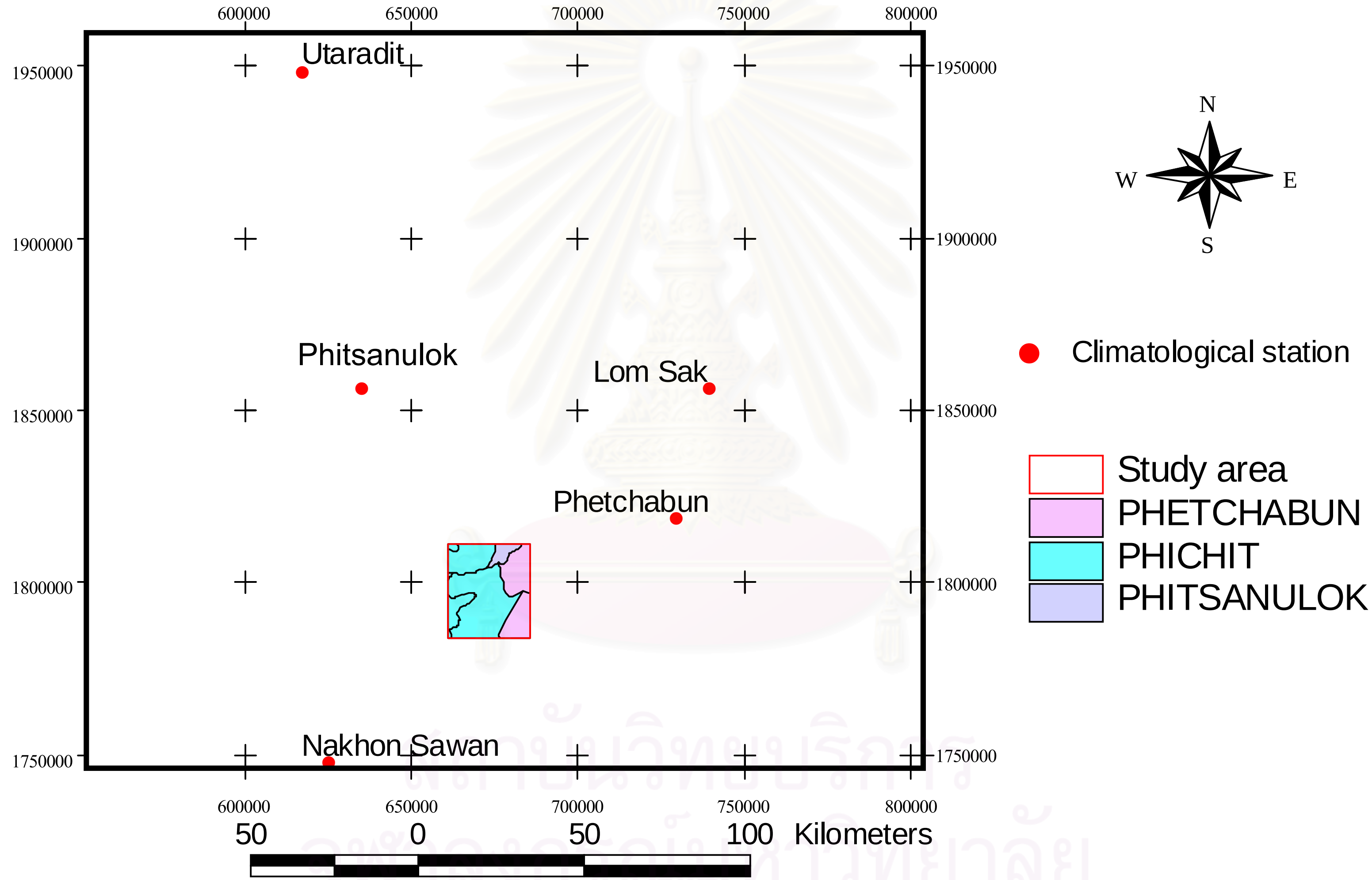


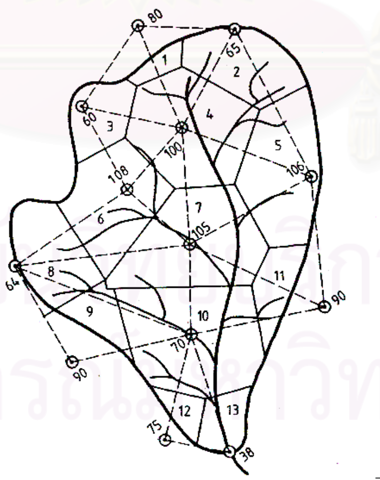
Figure 2.2 Climatological stations selected for this study.

2.1.2 Mean areal precipitation

Most hydrologic studies require a knowledge of the average amount of rainfall over a wide area. Some procedures must hence be used to convert the gage measurements which are only the spot-records into an areal average. The simplest procedure is to average arithmetically the amounts received by all gages throughout the area. Only if the gages are evenly distributed and if the variation from the mean of individual gage readings is not large, this procedure is probably as accurate as any other method. But this is not normally true, so some other procedures must be employed instead. Below is a discussion of several methods for this purpose.

2.1.2.1 Theissen polygons method

A Theissen network (Figure 2.3) is constructed by locating the selected stations in a map, connecting the stations with the straight-lines and then drawing the perpendicular bisectors to the connecting lines. The bisecting lines thus form the polygons around each gaging station which are considered to be the effective areas to be controlled by that particular station. The area of these polygons is calculated and is expressed as a percentage of the entire area.



- - - -- lines connecting the climatological stations

——— bisection of connecting lines

Figure 2.3. The Theissen polygon method for computing the mean climatological data (From Singh, 1992).

By adding the individual station precipitation reading according to its areal percentage, this gives the total amount of rainfall in the area of interest. The result is usually more accurate than the simple arithmetic averaging method previously mention. However the inflexibility of this method is the greatest limitation. The weights for the adjacent stations must be changed each a station is added to or taken from the network. (Linley, 1949).

2.1.2.2 The isohyetal method

Another method to compute the average precipitation is the Isohyetal method. In this method, a map is constructed by plotting on a suitable base the precipitation amount of each station and then drawing, in proper relative position, contours of equal precipitation (Isohyets) as shown in Figure 2.4. The average precipitation for an area can be readily computed by weighting the average precipitation between the contours (usually taken as one-half the sum of the two contour values) multiplied by the area between contours, The weights are summed up, then divided by the total area. In many cases, it is possible to estimate the average precipitations with a fair degree of accuracy by using this simple inspection.

The isohyetal map permits the use and interpretation of all available data. It is particularly adapted to display result and discuss works. If the shape of the isohyetal pattern is not definitely known, the isohyets may be interpolated between the stations (Linsley, 1949).

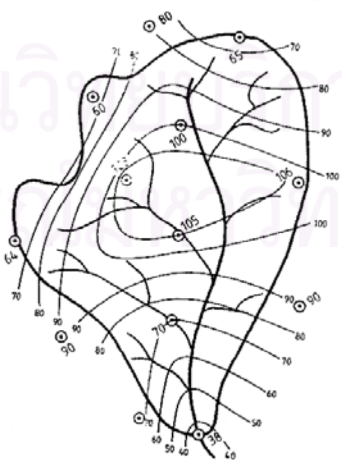


Figure 2.4. The isohyetal method for computing the mean climatological data (From Singh, 1992).

2.1.3 Filling in missing records

Many rain gage records are commonly incomplete with the breaks varying from one or two days to several years. It is often necessarily to estimate the missing data in order to utilize these partial records, especially in data-sparse areas. Several methods are available for estimating the missing data. An example, the inverse distance method, is shown below.

Inverse distance weighting method

The Inverse Distance Weighting Method involves the computing of weights of the surrounding rain gages on the basis of their distances from the gage with missing data. In this method the weights are calculated depending on the distances between the grid node being estimated and the control or rain gage positions. For example, at rainstation number A, the distances are computed by establishing a set of axes running through this Climatological station A, whose location is at (x_0 , y_0), as shown in Figure 2.5.

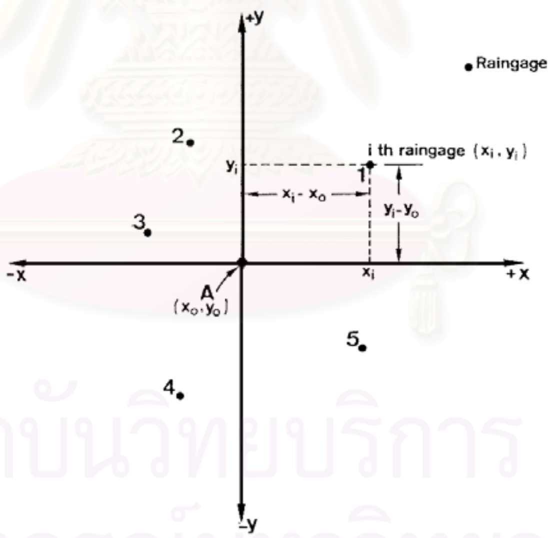


Figure 2.5. Axes establishing at the station with missing records for filling missing data (From Singh, 1992).

The square distance D_i^2 between A and another gage i is

$$D_i^2 = (x_i , x_0)^2 + (y_i , y_0)^2 \qquad \text{when } i = 1, 2, \ldots N$$

The weight of the *i* station,the location of the *i* th gage is (x_i , y_i), is a_i

$$a_i = \frac{1 / D_i^2}{\sum_{i=1}^{N} 1 / D_i^2}$$

Normally, N is taken to be no more than 5.

This technique will therefore never produce a value that is higher than the maximum value in the observed data set. The fact that the daily rainfall amounts are often confined to a small area also causes another problem when using this type of interpolation as rainfall amounts will be generated for the areas where there is no rain as well. These amounts may however decrease with distance but there is no sufficient spatial density of rain gages to explain this (Singh, 1992).

The climatological data and precipitation data for the present research have much problems of missing record. However, the writer had estimated the missing data by using this Inverse Distance Weighting Method. Preliminary data and fulfillment of missing data are shown in Appendix B.

2.2 Hydrological cycle

The hydrological cycle is a vast and complex system which circulates water over the whole planet. Figure 2.6 illustrates the various parts of this cycle. Starting with the oceans, energy from the sun powers the system, causing water to evaporate from the surface of the oceans to form large cloud masses. These clouds are moved by the global wind system and when conditions are appropriate, the water precipitates, falling back to the surface again as rain, snow or hail. Some of the water falls on to the land and is collected to form streams and rivers which eventually flow back into the sea, from where the process start.

Not all rainfall contributes to the flow of streams and rivers in this way. Some of it returns to the atmosphere as evaporation from water bodies or the ground surface, and as transpiration from plants. A further portion of rainfall percolates through the soil to reach the water table and becomes groundwater. Groundwater usually flows through saturated rock under the influence of a hydraulic gradient, which in unconfined aquifer, is the water Table

Rocks which both contain groundwater and allow water to flow through them in significant quantities are termed aquifers. Unless groundwater is removed by pumping from wells, it will flow through an aquifer towards the natural discharge points, which comprise springs and seepages into streams or rivers, and also discharge directly into the seas. The property of an aquifer which allows fluids to flow through is termed permeability, and is controlled by various geological factors.

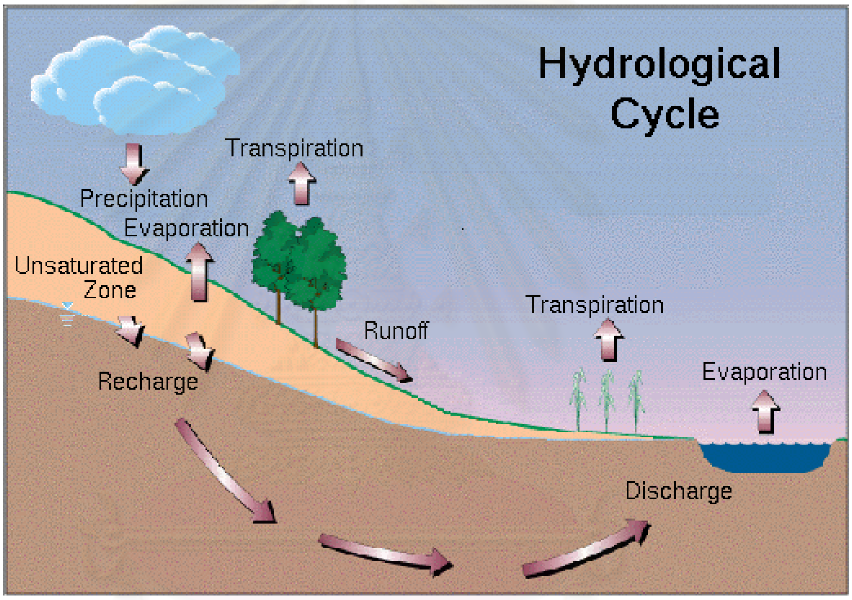


Figure 2.6. The hydrologic cycle (Modified from an original by Oak Ridge National Laboratories)

Properties of the fluid are also important, and water permeability is often called hydraulic conductivity. In both sedimentary rocks and unconsolidated sediments, groundwater is contained and moves through the pore spaces between individual grains.

The cycle of water movement is a closed system on a global basis. But it could be an open one on a local segment. When the water movement of the earth system is considered, three systems, as shown in Figure 2.7, can be recognized, the land system, the subsurface system, and the aquifer or geologic system.

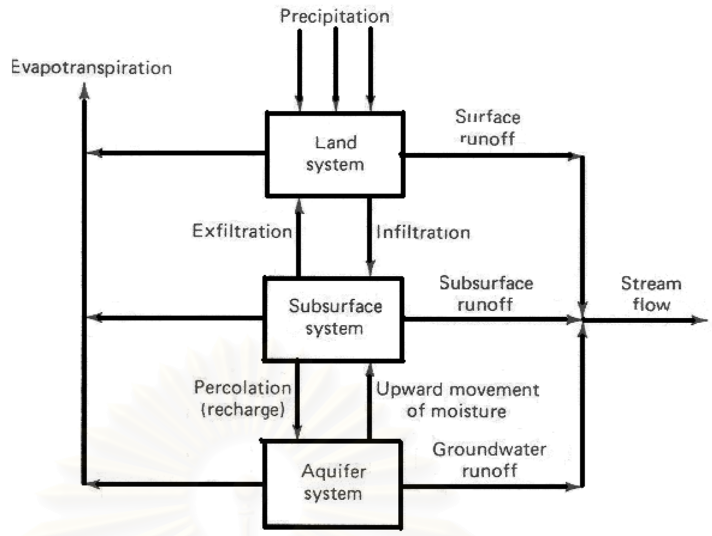


Figure 2.7. Schematic hydrologic cycle in the earth system (From Singh, 1992).

For the present study, the attention was focussed on the hydrological cycle of the land system, where the precipitation, surface runoff, and infiltration are the dominant processes of transmitting water, as shown in Figure 2.8.

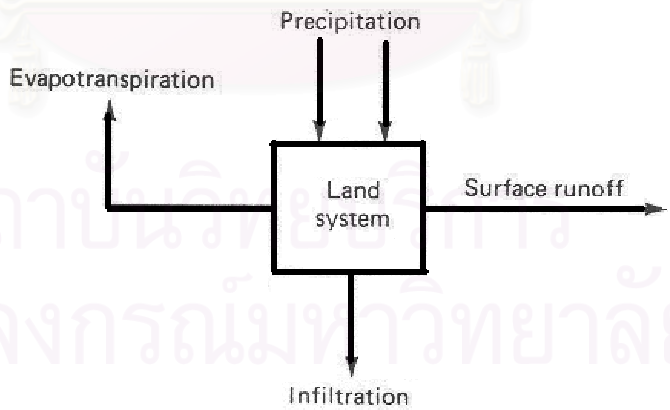


Figure 2.8 Schematic hydrologic cycle in the land system (From Singh, 1992).

2.3 Study period prediction

To study the precipitation data here, lead to an annual pattern of rainfall in and around the study area as shown in Figure 2.9. The monthly rainfall analysis will give an idea about the surface water balance as follow. From the study, May to October is the period of high amount of rainfall because of the influence of Southwest monsoon carrying humidity from Indian ocean to the land. Northeast monsoon in November to February is influenced with a coldness from mainland China, with the wind direction from the East carrying a little rain into the study area, but less than the Southwest monsoon. So in this research the precipitation data can roughly divided into 2 periods, the rainy period (May-October) and dry period (November-April)(Figure 2.10).

However, rainfall alone is not sufficient for calculating the surface water balance. Landuse is another factor as it influences the amount of output water, namely surface water flowage or storage, free water evaporation, evapotranspiration, and infiltration.

Landuse pattern in this part of the area was being observed in an other related study performed by Limpongstorn (2004), who studied the landuse changed in the years 1969, 1988 and 2000.

The complete climatological data from Department of Meteorological is available from the year 1975 but as there are the landuse data for the years 1969, 1988, and 2000, the relationship between the climatological data and landuse pattern should be noted for these years. So the estimation of the surface water balance can be done in 6 periods as following.

1. Rainy period of 1975,
2. Dry period of 1975 - 76,
3. Rainy period of 1988,
4. Dry period of 1988 - 89,
5. Rainy period of 2000,

and 6. Dry period of 2000 - 01.

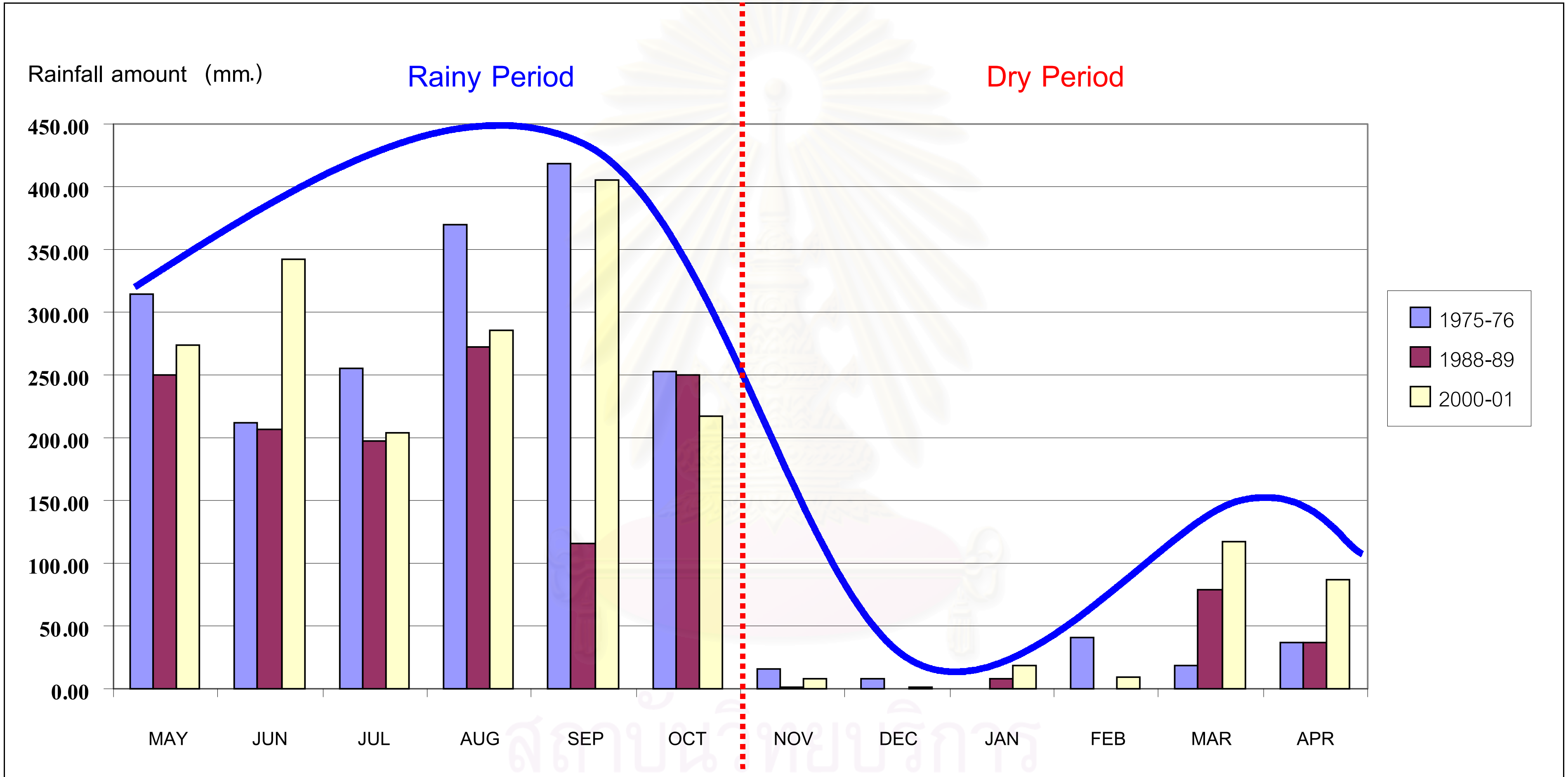


Figure 2.9. Monthly rainfall in the year 1975-76,1988-89, and 2000-01 in the study area. The data suggest 2 periods of climate, rainy period from May till October, and dry period from November to April. The precipitation data are also compared to the pattern of annual rainfall of southern most northern Thailand in 1975-2000.

2.4 Climatological and precipitation data

The study on the surface water balance is based on the water quantity of 2 groups, the input and output water in the system. The input quantity is primarily rainfall while the output is from the infiltration, evaporation and evapotranspiration, and surface flowage.

Precipitation data is the most problematic in this study as the rain gages are not wide-spread here. So the Theissen polygon method was used to obtain the representative precipitation. The precipitation Theissen polygons are shown in Figure 2.10.

Evapotranspiration is another important value for water balance study. The climatological data are needed for the calculation of the evapotranspiration value. However, there is no climatological station in the study area, so the Theissen polygon process was again chosen for an estimation of the data from the stations the nearest to the study area. The climatological polygons from Theissen method are shown in Figure 2.11.

The details of stations and the monthly rainfall are further collected in Appendix B.

2.5 Evaporation and evapotranspiration

Evaporation and evapotranspiration of water is a major concern in water budget analysis. Evaporation (E) and Evapotranspiration (ET) are important in determining the water balance of the watersheds, and in predicting and estimating runoff and groundwater storage.

Evaporation and evapotranspiration is a collective term for all the processes by which water in the liquid or solid phase, at or near the Earth's surface, transform into atmospheric water vapor. The term includes evaporation of liquid water from rivers and lakes, bare soil, vegetative surfaces, and evaporation through the apertures within the leaves of plants (transpiration).

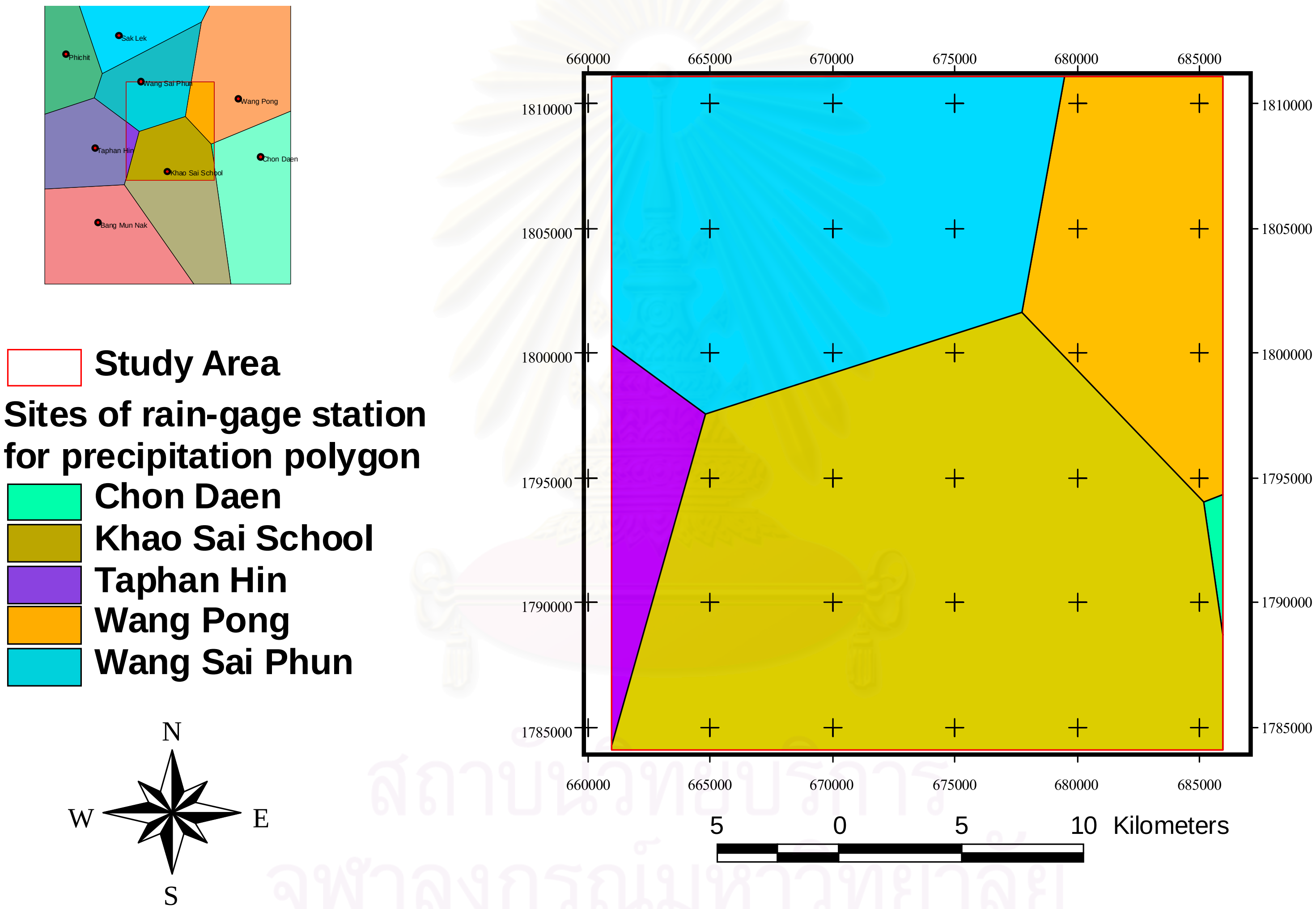


Figure 2.10. Theissen polygons of precipitation data in the study area.

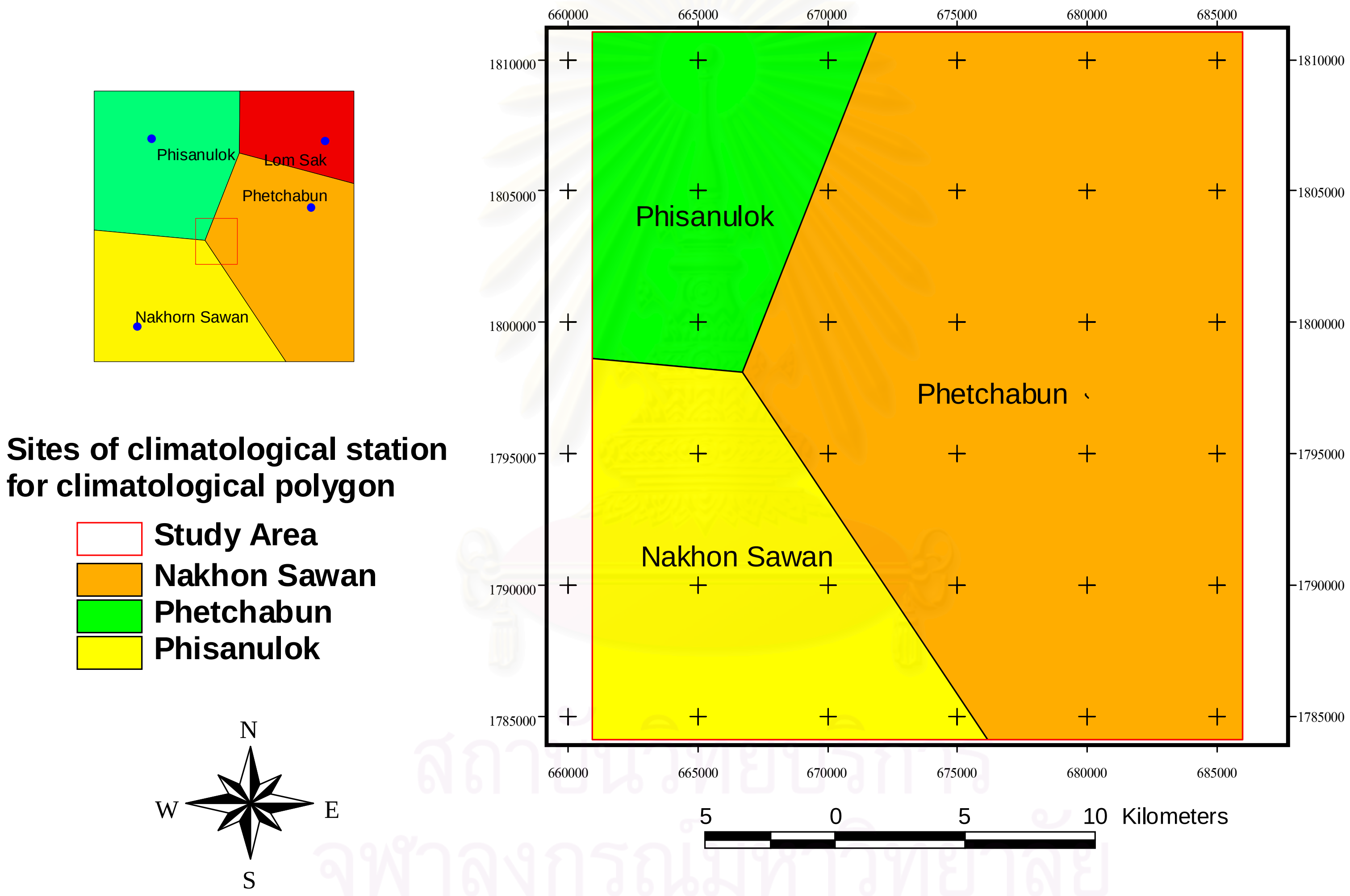


Figure 2.11. The Theissen polygons of climatological data in the study area.

2.6 Temperature

The temperature is a climatological quality which controls the hotness or coldness. It also reflects the sun radiation, and thus the air humidity which further affects the evaporation or evapotranspiration. To calculate for the evapotranspiration, thus, the information of temperature is essential to note the amount of water to be used by plant.

2.6.1 Recorded temperature

From the records of the Thai Meteorological Department, the mean temperatures in the study area are in a range 23.43 to 30.12 ^{o}C. March, April and May are normally the months of the highest temperature, about 38.91 to 40.19 ^{o}C and the maximum temperature of 43.0 ^{o}C was recorded at Phisanulok Station in April 1979, and 43.3 ^{o}C at Utaradit station in May 1963.

December and January are generally the months of the lowest temperature, about 12.12 to 12.14 ^{o}C. The lowest temperatures 1.7 and 1.9 ^{o}C were recorded at Tha Wang Pha Station in January 1974 and December 1999 respectively. The monthly temperature with the maximum, minimum, mean, average, the highest and the lowest are shown in Table 2.4 and Figure 2.12.

The monthly temperature data and other climatological data from the Thai Meteorological Department are shown in Appendix B.

Table 2.4 General monthly temperature data of the study area. .

Month	Average temperature (^{o}C)			Recorded Highest	Recorded Lowest
	Maximum	Minimum	Mean		
January	34.57	12.14	23.85	38.9	1.9
February	37.01	14.42	25.85	39.8	5.4
March	38.99	17.41	28.49	42.0	7.2
April	40.19	20.98	30.12	43.0	15.3
May	38.91	22.20	29.25	43.3	18.1
June	36.24	22.81	28.55	41.6	19.6
July	35.79	22.54	27.98	40.2	19.7
August	35.13	22.45	27.59	39.0	19.5
September	34.77	22.10	27.46	37.1	16.1
October	34.56	19.72	27.03	36.5	11.0
November	34.06	15.61	25.33	39.6	6.2
December	33.71	12.12	23.43	36.6	1.7

(Calculated from the temperature records of the Thai Meteorological Department, years1975 to 2000).

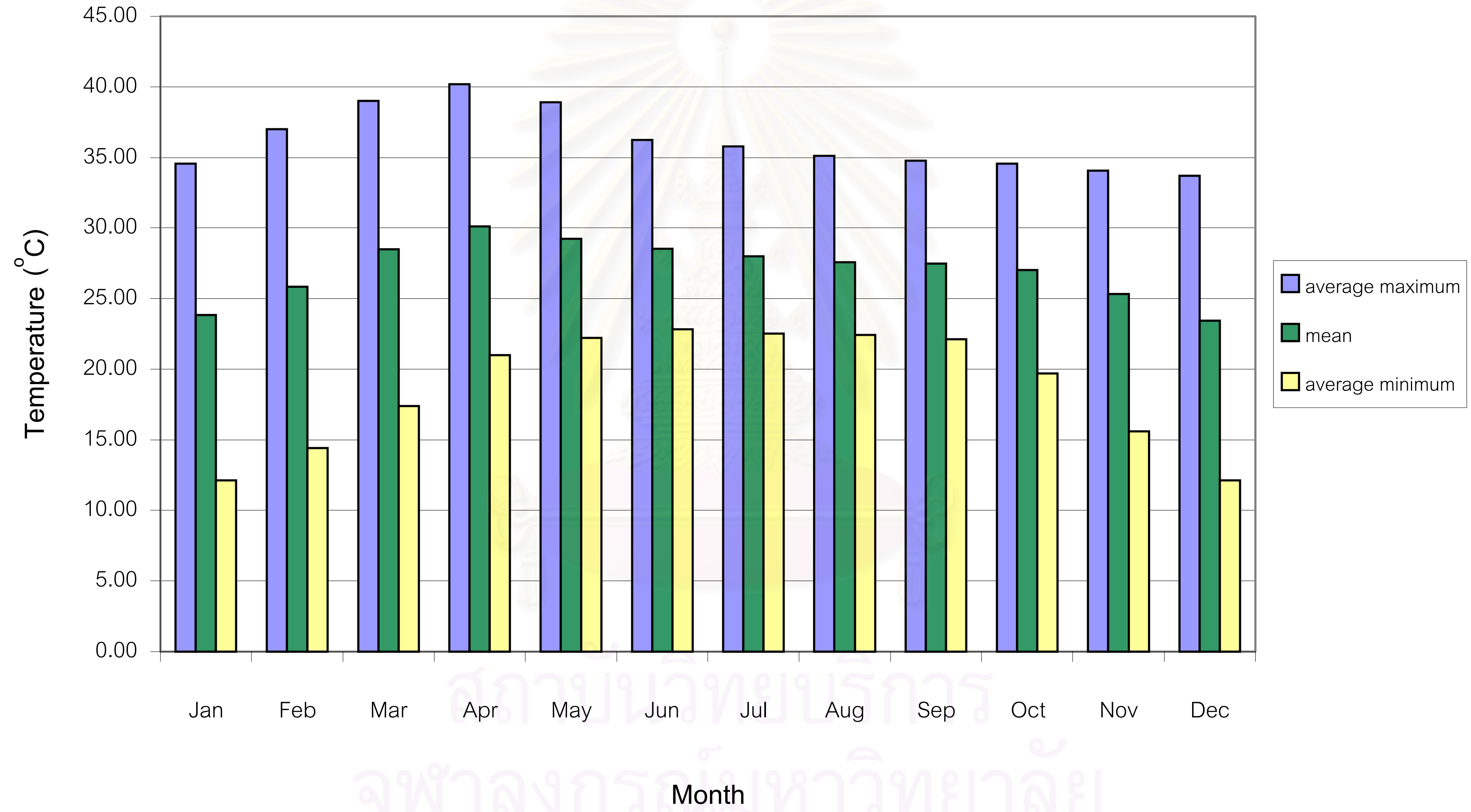


Figure 2.12. The average maximum, minimum and mean temperature in the study area.

2.6.2 Estimation of temperature

Similarly, the temperature in this study area was obtained by the Theissen method as shown in Figure 2.13. The primary temperature records were obtained from the previously mentioned climatological stations. The water balance study would be done for 3 years with all other complete data. These are as following.

2.6.2.1 Estimation of temperature in 1975-76

The temperature data were grouped for the rainy period and dry period in 1975-76, as the polygons shown in Table 2.5. The portions of polygons of the temperature are shown in Figure 2.13.

Table 2.5. Average monthly temperature of the rainy and dry periods in 1975-76.

Station	Temperature (°C)											
	Rainy period 1975						Dry period 1975-1976					
	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr
Phisanulok	28.7	28.3	27.8	27.7	27.7	27.7	25.8	22.0	22.1	25.7	28.6	30.4
Average	27.98						25.77					
Phetchabun	28.1	27.4	26.9	26.7	26.5	26.3	24.2	20.9	21.0	25.0	27.5	29.8
Average	26.98						24.73					
Nakhornsawan	29.9	30	29	28.5	27.5	27.9	26.3	23	23.5	28.2	30.4	32.3
Average	28.80						27.28					

2.6.2.2 Estimation of temperature in 1988-89

The temperature data were grouped for the rainy period and dry period in 1988-89, as the polygons shown in Table 2.6. The portions of polygons of the temperature are shown in Figure 2.14.

Table 2.6. Average monthly temperature of the rainy and dry periods in 1988-89.

Station	Temperature (°C)											
	Rainy period 1988						Dry period 1988-1989					
	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr
Phisanulok	28.9	29	28.9	28	28.8	27.3	24.7	23.7	26	27.1	28.7	31.4
Average	28.48						26.93					
Phetchabun	28.1	28	27.8	27.3	27.9	26.4	24	22.7	25.4	26.3	27.9	30.4
Average	27.58						26.12					
Nakhornsawan	28.8	28.8	28.5	28	28.3	27.2	24.7	23.9	26.5	28.2	29.3	32.3
Average	28.27						27.48					

2.6.2.3 Estimation of temperature in 2000-01

The temperature data were grouped for the rainy period and dry period in 2000-01, as the polygons shown in Table 2.7. The portions of polygons of the temperature are shown in Figure 2.15.

Table 2.7. Average monthly temperature of the rainy and dry periods in 2000-01.

Station	Temperature (°C)											
	Rainy period 2000						Dry period 2000-2001					
	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr
Phisanulok	29	28.4	28.2	28.3	27.7	27.8	26.2	25.9	26.2	26.6	28.1	32.1
Average	28.23						27.52					
Phetchabun	28	27.4	27.3	27.5	26.6	27.2	24.9	25.1	26	26.8	27.9	31.4
Average	27.33						27.02					
Nakhornsawan	28.9	28.5	28.4	28.5	27.6	27.9	25.9	26.1	27.3	28	28.9	32.7
Average	28.30						28.15					

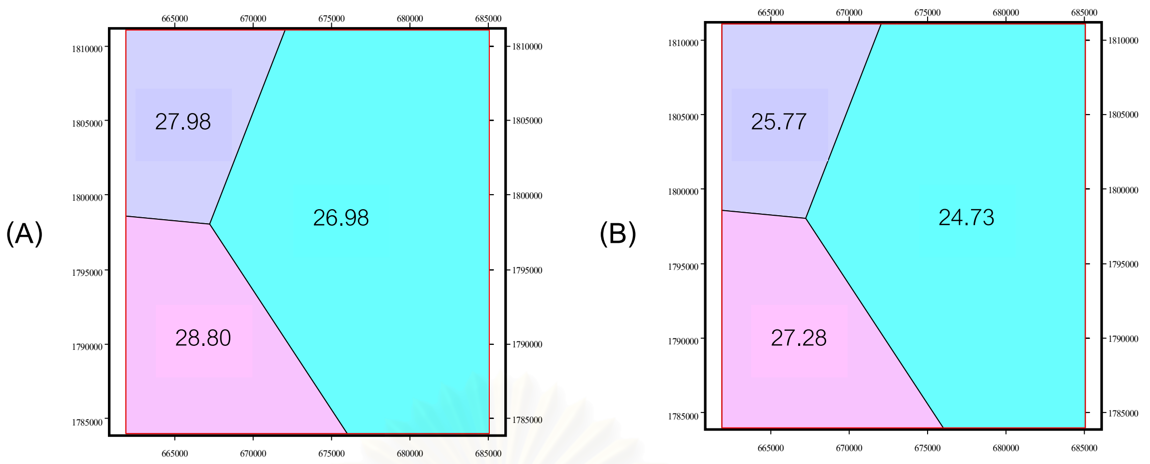


Figure 2.13. Average temperature (^{O}C) of the study area in 1975-76. (A) Temperature in the rainy period. (B) Temperature in the dry period.

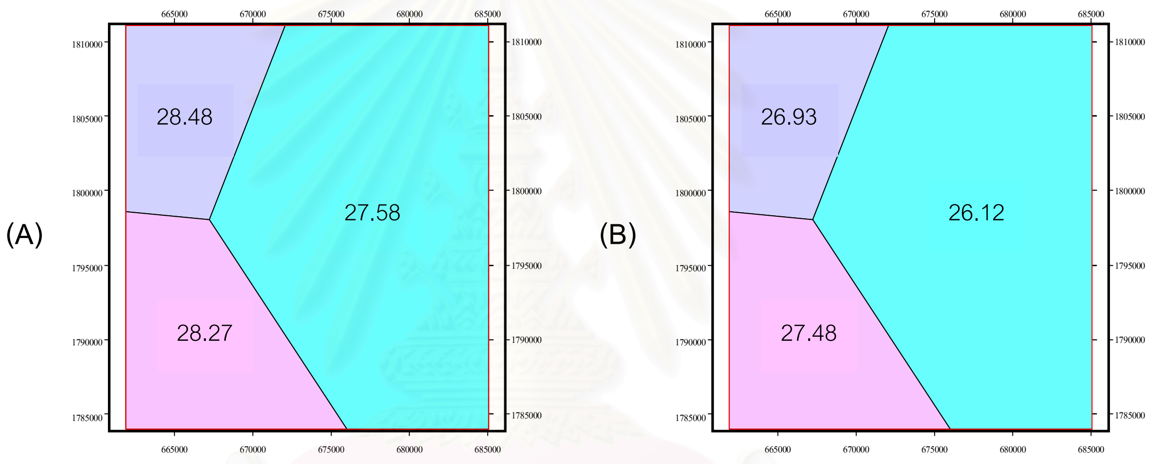


Figure 2.14. Average temperature (^{O}C) of the study area in 1988-89. (A) Temperature in the rainy period. (B) Temperature in the dry period.

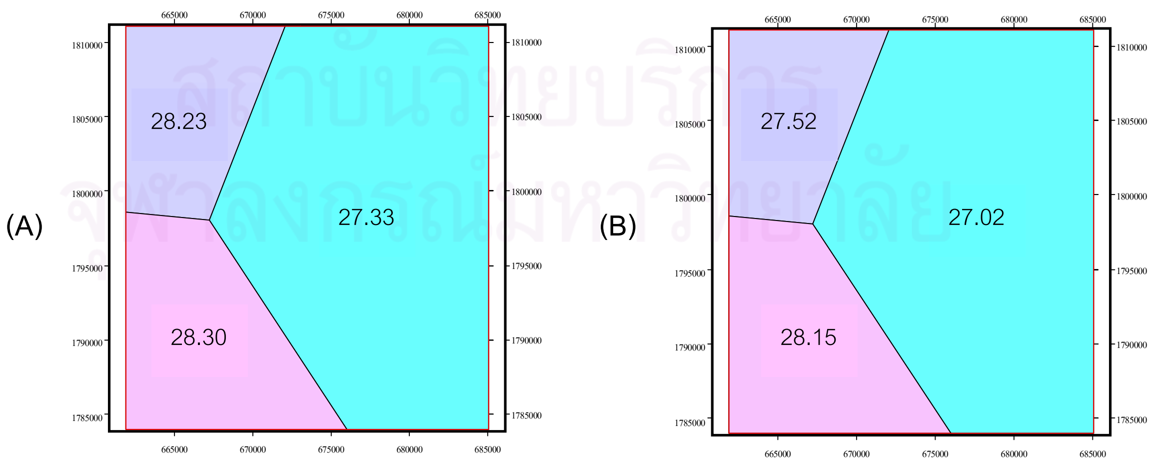


Figure 2.15. Average temperature (^{O}C) of the study area in 2000-01. (A) Temperature in the rainy period. (B) Temperature in the dry period.

2.7 Mean percentage of daylight hours

Mean percentage of daylight hours is a factor to be used for calculation of the evapotranspiration. Unfortunately, there is no available record of the day time of Thailand. To obtain the value, the Braney-Criddle record of the solar radiation and duration of sunshine (Royal Meteorological Society, 1954) is referred to as shown in Table 2.8.

Table 2.8. Mean percentage of daylight hours of the year occurring during a particular month at Latitude 0° - 25° N.

Latitude (° N)	January	February	March	April	May	June	July	August	September	October	November	December
25	7.5	7.1	8.4	8.6	9.3	9.2	9.5	9.1	8.3	8.1	7.4	7.4
24	7.6	7.2	8.4	8.6	9.3	9.2	9.4	9.1	8.3	8.1	7.4	7.5
23	7.6	7.2	8.4	8.6	9.3	9.2	9.4	9	8.3	8.1	7.5	7.5
22	7.7	7.2	8.4	8.6	9.2	9.1	9.3	9	8.3	8.1	7.5	7.6
21	7.7	7.2	8.4	8.6	9.2	9.1	9.3	9	8.3	8.2	7.6	7.6
20	7.8	7.3	8.4	8.5	9.2	9	9.2	9	8.3	8.2	7.6	7.7
19	7.8	7.3	8.4	8.5	9.1	9	9.2	8.9	8.3	8.2	7.6	7.7
18	7.8	7.3	8.4	8.5	9.1	8.9	9.2	8.9	8.3	8.2	7.7	7.7
17	7.9	7.3	8.4	8.5	9	8.9	9.1	8.9	8.3	8.2	7.7	7.8
16	7.9	7.4	8.4	8.5	9	8.9	9.1	8.9	8.3	8.2	7.7	7.8
15	7.9	7.4	8.4	8.5	9	8.8	9	8.8	8.3	8.3	7.8	7.9
14	8	7.4	8.4	8.4	8.9	8.8	9	8.8	8.3	8.3	7.8	7.9
13	8	7.4	8.4	8.4	8.9	8.7	9	8.8	8.3	8.3	7.8	8
12	8.1	7.4	8.4	8.4	8.9	8.7	8.9	8.8	8.3	8.3	7.9	8
11	8.1	7.5	8.4	8.4	8.8	8.7	8.9	8.7	8.3	8.3	7.9	8.1
10	8.1	7.5	8.5	8.4	8.8	8.6	8.9	8.7	8.3	8.3	7.9	8.1

Table 2.8. Cont'd.

Latitude (^{o} N)	January	February	March	April	May	June	July	August	September	October	November	December
9	8.2	7.5	8.5	8.4	8.8	8.6	8.8	8.7	8.3	8.4	8	8.1
8	8.2	7.5	8.5	8.3	8.7	8.5	8.8	8.7	8.3	8.4	8	8.2
7	8.3	7.5	8.5	8.3	8.7	8.5	8.7	8.6	8.3	8.4	8	8.2
6	8.3	7.6	8.5	8.3	8.7	8.5	8.7	8.6	8.2	8.4	8	8.3
5	8.3	7.6	8.5	8.3	8.7	8.4	8.7	8.6	8.2	8.4	8.1	8.3
4	8.4	7.6	8.5	8.3	8.6	8.4	8.6	8.6	8.2	8.4	8.1	8.3
3	8.4	7.6	8.5	8.3	8.6	8.3	8.6	8.6	8.2	8.5	8.1	8.4
2	8.4	7.6	8.5	8.3	8.6	8.3	8.6	8.5	8.2	8.5	8.2	8.4
1	8.5	7.7	8.5	8.2	8.5	8.3	8.5	8.5	8.2	8.5	8.2	8.5
0	8.5	7.7	8.5	8.2	8.5	8.2	8.5	8.5	8.2	8.5	8.2	8.5

From Blaney,H.F. and Criddle, W.D.,1962

As the study area is at approximately Latitude 16^{o}N the day time (in hours) of each month here could be referred from the estimation done by the Royal Meteorological Society (on the solar radiation and duration of sunshine) as shown in Table 2.9.

Table 2.9. Mean percentage of daylight hours of the year occurring during a particular month at rainy and dry period.

Average percentage of the day time hour of the year (hr.) at latitude 16^{o}N.	Rainy period						Dry period					
	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr
	9.0	8.9	9.1	8.9	8.3	8.2.	7.7	7.8	7.9	7.4	8.4	8.5

From Blaney,H.F. and Criddle, W.D.,1962

2.8 Evaporation

Evaporation is a process by which water is transformed from liquid into a gaseous state. Evaporation only occurs with free water available. It also requires that the humidity in the atmosphere be less than the evaporating capability. The evaporation process also requires a large amount of energy. For example, to evaporate one gram of water, 539 calories of heat energy is needed.

2.8.1 Recorded evaporation

The mean monthly evaporation in the study area is between 122.2 to 165.7 mm. as shown in Table 2.10. The maximum evaporation here is normally higher than 200 mm. and ranges between 208.1 to 313.2 mm. The minimum is normally lower than 100 mm., between 60.6 to 98.0 mm.

Table 2.10. Evaporation recorded in the climatological stations around the study area.

Evaporation (mm./month)	Tha Wang Pha	Utaradit	Phisanulok	Nakhorn Sawan	Phetchabun	Lom Sak
Mean	122.2	133.1	137.5	165.7	131.5	139.1
Maximum	218.0	227.0	248.1	313.2	245.3	208.1
Minimum	62.8	89.7	86.5	98.0	60.6	94.6

From Processing subdivision, Climatologic division, Thai Meteorological Department.

2.8.2 Estimation of evaporation

The evaporation for this study was obtained by Theissen method from the climatological data recorded in the stations around the study area.

2.8.2.1 Estimated of evaporation in 1975 - 76

Monthly evaporation in the rainy and dry periods of year 1975-76 in the study area was calculated as shown in Table 2.11 and Figure 2.16.

Table 2.11. Evaporation in the study area for rainy and dry periods in 1975-76

Amount of monthly free water evaporation. (mm.)			
Rainy period In 1975	Phisanulok	Phetchabun	Nakhornsawan
May.	161.8	168.6	195.1
Jun.	143.6	155.6	211.9
Jul.	120.9	138.1	174.2
Aug.	128.3	139.3	156.8
Sep.	110.6	122.1	119.3
Oct.	112.0	136.3	124.0
Total	777.2	860.0	981.3
Dry period in 1975-76	Phisanulok	Phetchabun	Nakhornsawan
Nov	105.6	136.6	137.2
Dec	96.0	162.8	139.4
Jan	98.0	151.3	158.5
Feb	105.3	142.4	172.9
Mar	139.6	199.3	255.8
Apr	163.5	245.3	275.2
Total	708.0	1037.7	1139.0
Year total	**1485.2**	**1897.7**	**2120.3**

2.8.2.2 Estimation of evaporation in 1988

Monthly evaporation in the rainy and dry periods of year 1988-89 in the study area was calculated as shown in Table 2.12 and Figure 2.17.

Table 2.12. Evaporation value in study area for rainy period and dry period in 1988-89.

Amount of monthly free water evaporation. (mm.)			
Rainy period in 1988	Phisanulok	Phetchabun	Nakhornsawan
May	162.7	168.1	158.8
Jun	159.8	153.9	131.1
Jul	181.5	171.4	137.8
Aug	137.5	133.1	116.0
Sep	137.3	145.9	128.2
Oct	118.8	108.7	112.5
Total	**897.6**	**881.1**	**784.4**
Dry period in 1988-89	Phisanulok	Phetchabun	Nakhornsawan
Nov	111.5	116.6	153.2
Dec	122.2	128.9	147.1
Jan	122.7	152.4	134.9
Feb	135.4	163.5	143.4
Mar	172.4	218.6	180.6
Apr	210.8	266.6	218.0
Total	**875.0**	**1046.6**	**977.2**
Year total	**1772.6**	**1927.7**	**1761.6**

2.8.2.3 Estimation of evaporation in 2000-01

Monthly evaporation in the rainy and dry periods of year 2000-01 in the study area was calculated as shown in Table 2.13 and Figure 2.18.

Table 2.13. Evaporation value in study area for rainy period and dry period in 2000-01.

Amount of monthly free water evaporation. (mm.)			
Rainy period in 2000	Phisanulok	Phetchabun	Nakhornsawan
May	131.3	133.6	160.3
Jun	106.6	120.6	139.1
Jul	112	112.2	131.4
Aug	105.6	114.2	132.5
Sep	96.7	97.4	121.9
Oct	96	115.5	102.8
Total	648.2	693.5	788.0
Dry period in 2000-01	Phisanulok	Phetchabun	Nakhornsawan
Nov	111.7	126	111.5
Dec	107	127.1	123.8
Jan	104.5	121.9	130.2
Feb	105.4	124.4	139.7
Mar	118.7	140.1	143.3
Apr	172.5	203.8	230
Total	719.8	843.3	878.5
Year total	1368.0	1536.8	1666.5

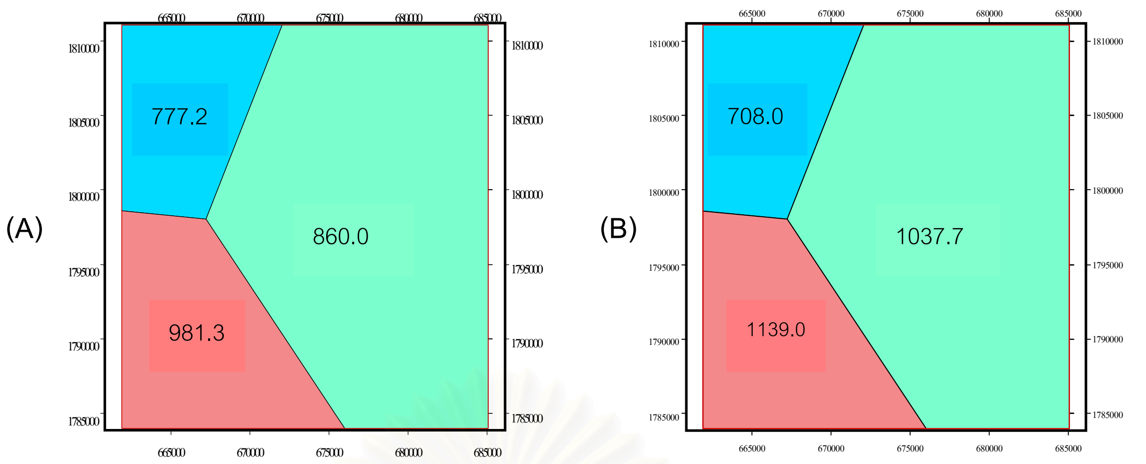


Figure 2.16. Evaporation (mm.) in the study area in 1975-76. (A) Evaporation in rainy period, and (B) Evaporation in dry period.

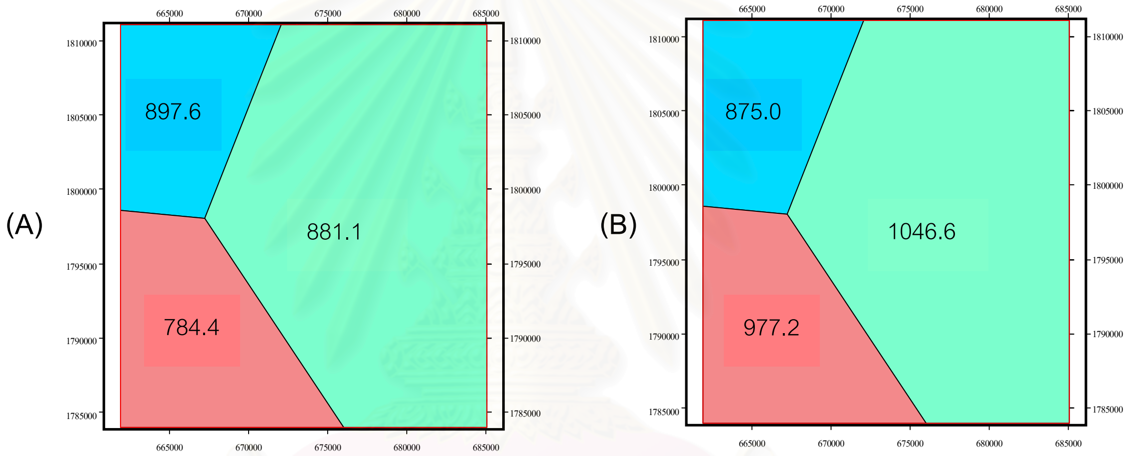


Figure 2.17. Evaporation (mm.) in the study area in 1988-89. (A) Evaporation in rainy period. (B) Evaporation in dry period.

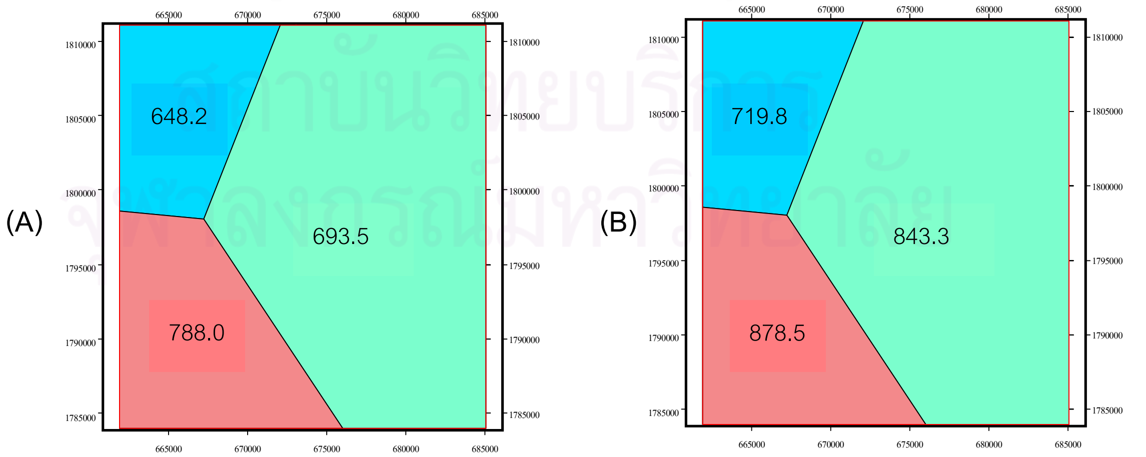


Figure 2.18. Evaporation (mm.) in the study area in 2000-01. (A) Evaporation in rainy period. (B) Evaporation in dry period.

2.9 Evapotranspiration

Evapotranspiration is the loss of water from soil and plant surfaces. This is from a combined process of evaporation which has been explained above with the process of transpiration which is the least understood aspect of the hydrologic cycle.

Transpiration is the transformation of water liquid in the vascular system of plants into the vaporous phase in the atmosphere. The process involves an absorption of soil water by plant roots, translocation in a liquid form through the vascular system of the plant and eventual evaporation into the surrounding air through leaf cavities called stomata.

Potential evapotranspiration is the rate at which evapotranspiration would occur from a large area uniformly covered with growing vegetation which has access to an unlimited supply of soil water. Advection or leaf storage effects are ignored (Singh, 1992).

2.9.1 Factors controlling rates of evapotranspiration

The major climatic factors which influence the crop water-needs, thus control the rate of evapotranspiration, are as below.

- Sunlight

The rate of evapotranspiration strongly depends on the amount of sunshine because plants use the sunlight and water for photosynthesis process.

- Temperature

Temperature is related to solar radiation. The high temperature means a high rate of evapotranspiration.

- Humidity

The rate of evapotranspiration also depends on the atmospheric humidity or moisture gradient, the rate of change of moisture upwards from the Earth's surface. The drier the air above the surface, the faster the evapotranspiration.

- Wind speed

Wind speed plays a good role in controlling the evapotranspiration rate by influencing the moisture gradient. Most of us are familiar with the clammy, sticky and humid feel of a calm summer afternoon. But if the wind gets stronger, the humidity drops.

The crop water-need (ET crop) is defined as the depth or amount of water needed to meet the water loss through evapotranspiration. In the other words, it is the amount of water needed by the crops to grow optimally. So the vegetation is an importance factor for estimation of the evapotranspiration. The evapotranspiration rate depends on the factors as shown in Table 2.14.

Table 2.14. Effect of major climatic factors on crop water needs.

Climatic factor	Crop water-need	
	High	Low
Temperature	Hot	Cool
Humidity	Low (dry)	High (humid)
Wind speed	Windy	Little wind
Sunshine	Sunny (no clouds)	Cloudy (no sun)

From Food and Agriculture Organization of the United Nations (FAO), Rome,1998.

2.9.2 Determination of evapotranspiration

Direct measurement of evapotranspiration is much more difficult than that for precipitation or water flow, and is usually impractical for an individual watershed study. As an alternative, several techniques are widely used to estimate the evaporation and evapotranspiration based on availability of more readily measured quantities. Various methods for estimating evapotranspiration have been developed for specific surface and energy exchange situations as seen in Appendix C.

The water balance method is capable of determining the total amount of evapotranspiration. In most situations, however, lack of data and measurement problems preclude usage of the method.

The climatological data which the Thai Meteorological Department collected are lack of essential values for calculation by the equation of energy balance and other complicate equations. So the climatological data which were recorded by Department of Meteorological can only suggest an estimation of evapotranspiration by using SCS Modified Blaney-Criddle equation. The detail of Blaney-Criddle is shown below.

SCS Modified Blaney-Criddle equation approach

A few equations could be used to estimate the evapotranspiration and it should base on the data availabile to decide the specific approach to be selected. Taking into account of the limited meteorological information in this study, the SCS Modified Blaney-Criddle equation is thus employed. Following is the Blaney-Criddle equation.

$$\mathrm{ET} = 25.4\,K \sum_{i=1}^{m} \frac{(1.8t_i + 32)p_i}{100}$$

Where: ET = Actual evapotranspiration,

K = Crop coefficients (see Appendix D),

m = Month of irrigation,

t_i = Mean monthly temperature, ^{o}C,

P_i = Mean percentage of daylight hours of the year occurring during a

particular month (see Appendix C).

Remarks: Data which are necessarily for calculating for evapotranspiration using Blaney-Criddle equation are estimated from the secondary data.

2.9.3 Landuse

One of the factors that affect evaporation is crop growing, which is related to the landuse. The present study is concentrated only to the evapotranspiration data while the knowledge of landuse is refered to the work to Limpongstorn's (2004) as shown in the tables below.

2.9.3.1 Landuse in 1969

From the work of Limpongstorn's (2004), there are 5 types of landuse. These are paddy or rice field, forest , orchard or plantation, marsh or swamp, and village (housing area) as shown in Table 2.15 and Figure 2.19.

Table 2.15. Landuse in the study area in 1969 (from Limpongstorn. P, 2004).

Landuse	Description	Area (km^2)	Percent
Paddy field (Rainfed)	Most of the paddy field was in Changwat Phichit, less in Changwat Phitsanulok and Phetchabun. It was interpreted that the paddy field landuse was after then growing into Changwat Phetchabun to replace the forest. This could be the beginning of a deforestation.	427.213	63.1%
Forest	The forest was the second largest area. Most forest was in Changwat Phetchabun in Tambon Dong Khui, Amphoe Chon Daen, and the east of Tambon Khao Sai and Amphoe Thap Khlo of Changwat Phichit. Forest in other areas was along the stream banks.	228.86	33.8%
Mixed field crop	It was in the northeastern part of the study area in Amphoe Wang Pong.	1.715	0.25%
Village	It mostly was along the side of main roads in Changwat Phichit.	18.021	2.66%
Marsh, Swamp	The marsh or swamp only appeared in the 1969 topographic maps. It was found among the forest in Changwat Phetchabun. The marsh or swamp had disappeared completely in the later landuse maps.	1.367	0.2%
	Total	677.136	100%

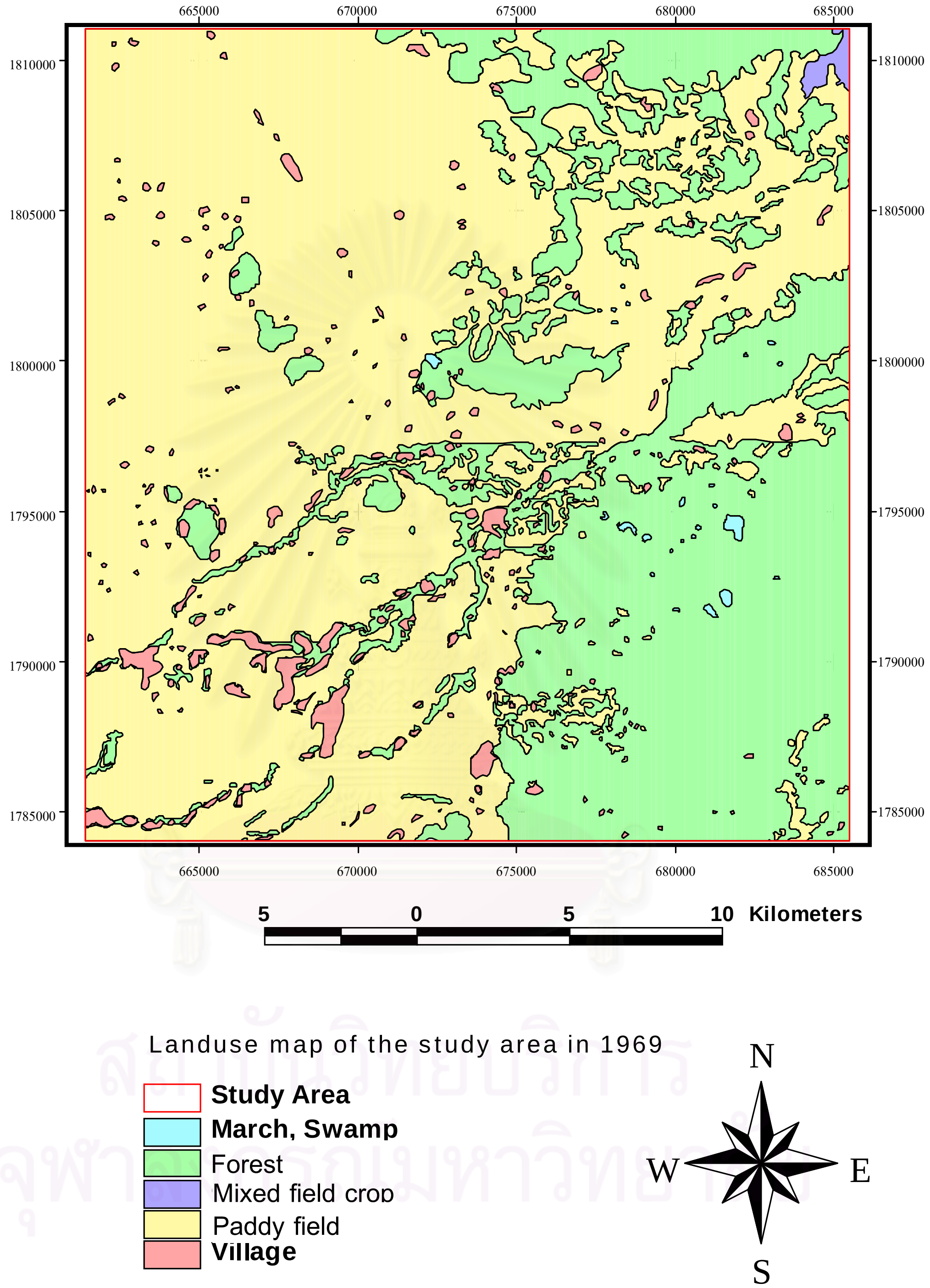


Figure 2.19. Landuse map of the study area in 1969 (From Limpongstorn, 2004).

2.9.3.2 Landuse in 1988

The landuse in 1988 can be classified in 5 types. These are Rainfed (paddy field), agricultural land, grassland, forest, and village. The details of landuse in the study area are show in Table 2.16 and Figure 2.20.

Table 2.16. Landuse in 1988 (from Limpongstorn, 2004)

Landuse	Description	Area (km^2)	Percent
Paddy field (Rainfed)	The paddy field was still the largest landuse in the area. The area was noted in every district in the study area.	499.184	73.72%
Grassland	It covered in the middle of area along the boundary of Changwat Phichit and Phetchabun and in Amphoe Wang Pong and Chon Daen to the east of the study area. This shrub-grassland could be the abandoned land after some previous uses.	9.342	1.38%
Mixed field crop	The mixed crop field had become the second largest landuse of the whole study area. The biggest area was in Amphoe Chon Daen of Changwat Phetchabun and along the boundary between Changwat of Phichit and Phetchabun and northeast of study area in Amphoe Noen Maprang and Wang Pong.	137.88	20.36%
Village	It was in the same location as 1966 but was larger	20.756	3.07%
Forest	It was found only on the hills and mountains. These are at Khao Chet Luk, Khao Taphan Nak, and Khao Cha-om conserved forest in Khao Chet Luk, Left of Wang Thong Basin conserved forest in Amphoe Noen Maprang. Other not reservation forests were Khao Ruak in the east of study area, Khao Phra, Khao Sai, and Khao Nok Yung in the south of area.	9.974	1.47%
	Total	677.136	100%

2.9.3.3 Landuse in 2000

The landuse in 1988 can be classified in 5 types. These are Rainfed (paddy field), agricultural land, grassland, forest, and village. The each type of Landuse as show in Table 2.17 and Figure 2.21.

Table 2.17. Landuse in 2000 (from Limpongstorn. P, 2004).

Landuse	Description	Area (km^2)	Percent
Paddy field (Rainfed)	The paddy field was still the largest of study area. The area also was in every district in the study area.	500.164	73.86%
Mixed field crop	The biggest area was in Amphoe Chon Daen, Changwat Phetchabun, along the boundary of Amphoe Thap Khlo, Changwat Phichit and Amphoe Wang Pong, Changwat Phetchabun, and to the northeast of the study area in Amphoe Wang Pong, Amphoe Noen Maprang, and Amphoe Wang Sai Phun. The small area was around Khao Chet Luk. Corn was the mostly planted. The others were mango, teak, and tamarind.	140.428	20.74%
Village, Town	In 2000, the largest area was in Thap Khlo municipal area, which was connected to Amphoe Taphan Hin along the main roads	23.113	3.41%
Forest	At this time the forest was only the deciduos dipterocarp forest, disturbed deciduous forest, and mixed deciduous forest. It mostly was in Changwat Phichit in Khao Chet Luk, Khao Phra, and Khao Ruak, Wang Thong forest in Amphoe Noen Maprang.	8.588	1.27%
Grass and Shrub	There was a small area in Amphoe Wang Pong and at the boundary of Amphoe Thap Khlo and Amphoe Wang Pong.	4.843	0.72%.
	Total	677.136	100%

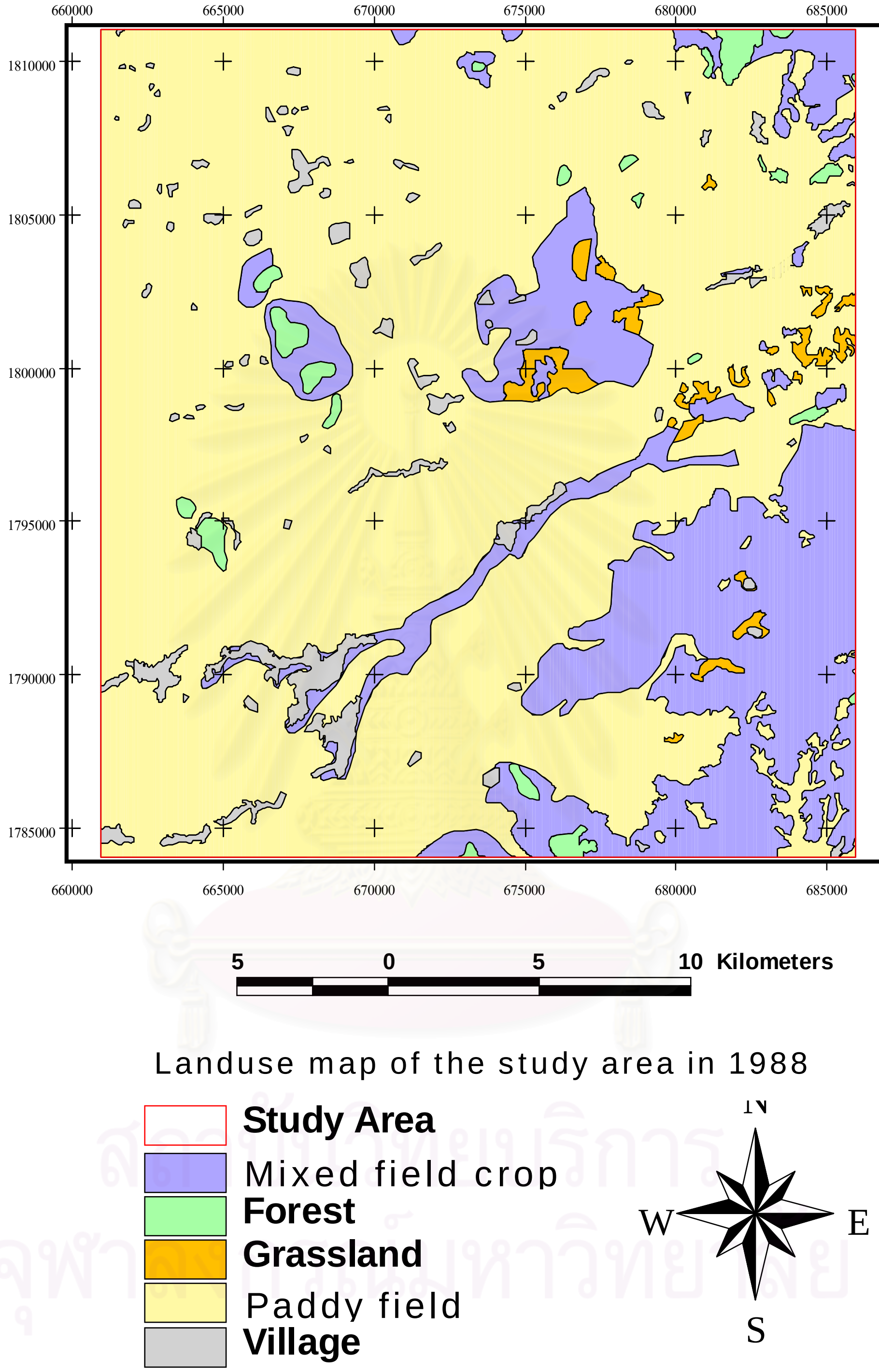


Figure 2.20. Landuse map of the study area in 1988. (From Limpongstorn, 2004)

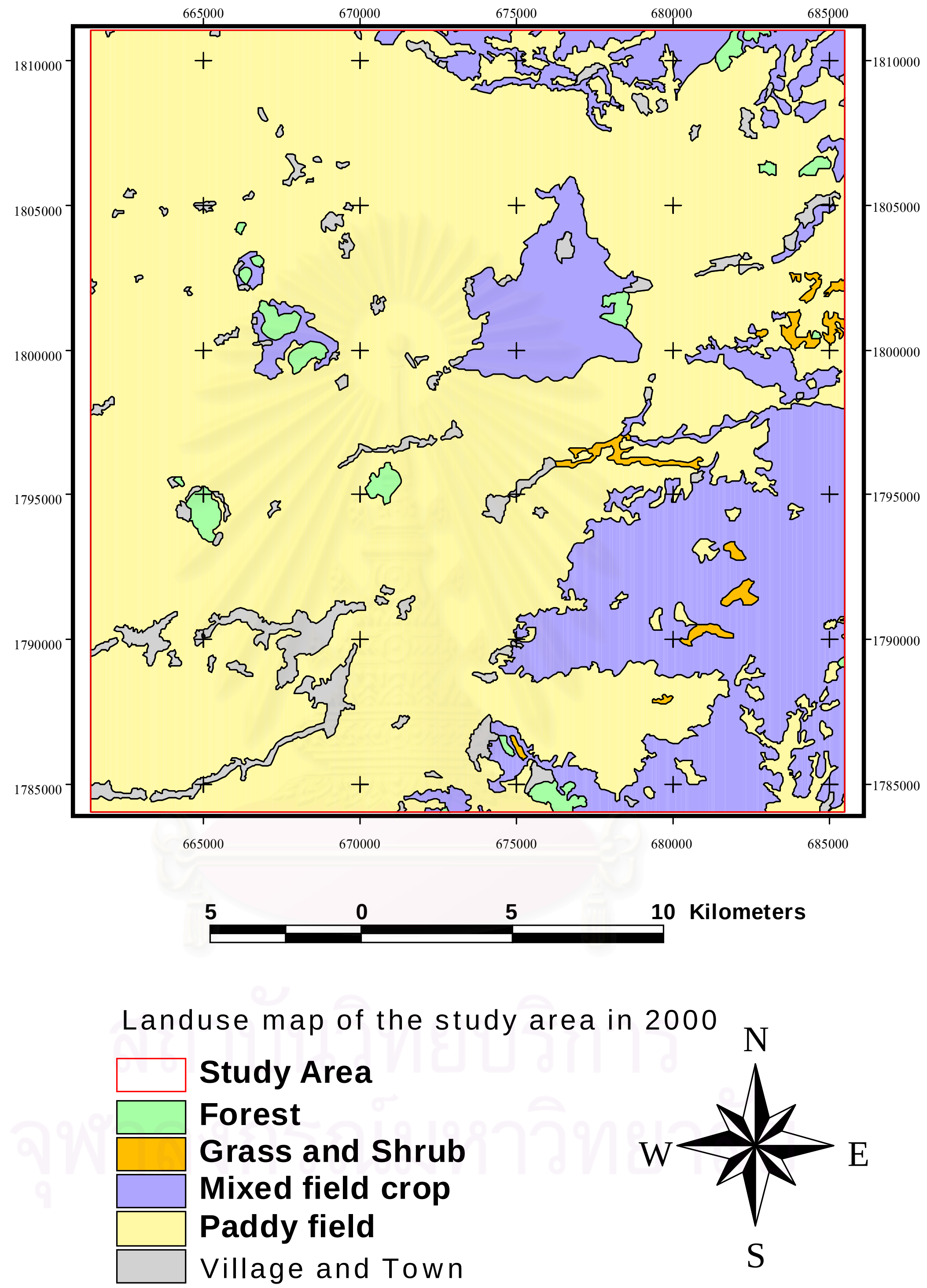


Figure 2.21. Landuse map of the study area in 2000 (From Limpongstorn, 2004).

2.9.4 Calculation method

The calculation for evapotranspiration using arcview process is as below.

2.9.4.1 Data Acquisition

The data used for calculation were obtained from a few sources.

a. Land Cover

The knowledge of landuse allows land cover information in terms of crops, thus suggests the crop coefficients.

b. Crop Coefficient

To consider the evapotranspiration using Blaney - Criddle method, the crop coefficient is needed for calculation of the value. The crop coefficient in Thailand was prepared by Official of Water Resources Development, Royal Irrigation Department, for calculating evapotranspiration data (See Appendix C). The crop coefficients which are varied through the age of plants are shown in Tables 2.18 and 2.19.

Table 2.18. Blaney-Criddle crop coefficient for long-life trees.

Month	Lemon 1-3 year in age	Lemon 3-5 year in age	Mango	Pomelo	Saccharm spontaneum	Rucy spontaneum
Jan.	1.06	1.15	1.6	1.46	0.72	0.64
Feb.	1.1	1.19	1.52	1.38	0.79	1.05
Mar.	1.36	1.45	1.32	1.15	0.79	0.5
Apr.	1.72	1.84	1.35	1.12	1.23	0.9
May	1.78	1.86	1.34	1.3	1.4	0.98
Jun.	1.77	1.88	2.35	2.21	1.41	1.32
Jul.	1.58	1.65	2.62	2.59	1.48	1.15
Aug.	1.38	1.46	3.13	2.92	1.45	1.04
Sep.	1.74	1.79	2.78	2.4	1.3	0.87
Oct.	1.85	1.88	2.75	2.36	1.2	1.2
Nov.	1.45	1.5	2.54	1.93	1.26	0.53
Dec.	1.26	1.36	1.63	1.52	0.72	0.95
Average	1.49	1.57	1.98	1.76	1.1	0.93

Table 2.19. Blaney-Criddle Crop coefficient for seasonal crops.

Week	Rice			Wheat	Maize	Sweet Corn	Sorghum	Soy bean	Ground nut	Mung bean	Water melon	Chinese Kale	Tomato	Onion
	HVY	Khao Dawk Mali	Basmatic											
1	1.05	0.60	1.20	0.42	0.44	0.56	0.47	0.48	0.59	0.37	0.81	0.52	0.66	0.55
2	1.08	0.70	1.30	0.46	0.51	0.62	0.50	0.53	0.69	0.60	1.03	0.56	0.70	0.58
3	1.15	0.82	1.39	0.52	0.63	0.74	0.55	0.62	0.76	0.94	1.271.41	0.60	0.76	0.62
4	1.26	1.04	1.45	0.70	0.79	0.86	0.63	0.77	0.83	1.10	1.49	0.62	0.86	0.67
5	1.43	1.25	1.49	0.91	0.96	0.98	0.83	1.02	0.89	1.13	1.41	0.65	0.96	0.75
6	1.51	1.39	1.52	1.01	1.07	1.03	0.99	1.12	0.93	0.94	1.27	0.63	1.05	0.90
7	1.55	1.45	1.48	1.06	1.12	0.98	1.08	1.18	0.95	0.45	1.07	0.60	1.13	1.02
8	1.55	1.50	1.46	1.08	1.14	0.93	1.12	1.20	0.96	0.30	0.83	0.58	1.19	1.08
9	1.50	1.47	1.42	1.06	1.11	0.75	1.11	1.13	0.95	0.25	0.72		1.22	1.14
10	1.38	1.40	1.34	1.00	1.03	0.66	1.08	1.06	0.93		0.65		1.23	1.16
11	1.24	1.36	1.24	0.85	0.84	0.58	1.01	0.93	0.89		0.64		1.22	1.10
12	1.13	1.20	1.12	0.57	0.62		0.87	0.75	0.82				1.19	1.05
13	1.07	1.00	1.04	0.40	0.54		0.71	0.63	0.72				1.12	1.02
14		0.90	0.97	0.32	0.50		0.62	0.56	0.62				1.01	0.98
15				0.28			0.57		0.53				0.85	0.95
16							0.55							
Average	1.30	1.14	1.29	0.71	0.80	0.79	0.79	0.85	0.80	0.67	1.05	0.59	1.01	0.90

The crop coefficient in Thailand, shown in Table 2.19, prepared by Office of Water Resources Development, Royal Irrigation Department, was partly used in this study. But it was also noted that the United Nations Food and Agriculture Organization (FAO) data for irrigation and drainage had the crop coefficient for tropical fruits and trees. In this study, thus, the crop coefficient of the tropical fruits and trees of FAO as shown in Appendix D was adopted.

c. Climatic data

Climatic data which were used for calculating evapotranspiration by Blaney-Criddle method comprise the mean percentage of daylight hours and temperature. Temperature and day time hours data for this study were already mentioned in Chapter II.

2.9.4.2 Calculation

The Blaney-Criddle equation was used in this study with some degree of confidence as all parameters needed, such as the temperature, day time hours, landuse (crop coefficient), and time of plant growth could be obtained. This process thus produced the monthly evapotranspiration maps.

As a rainfed agriculture could only be done in this area, thus rice can be grown only the rainy period. Durring a dry period the crop with less water e.g. bean could be grown.

The mixed field crops in the study area are too complicated to be separated into each type of plant. So in this study a simple estimation was made for calculation on each plant type. From the field study, it was noted that the mixed field crops were composed mostly of corn about 60% of study area, 15% for mango, 15% for teak and 10% for tamarind.

Using the Crop Coefficient from Tables 2.18 and 2.19, the crop coefficient for this study are shown in Table 2.20.

Table 2.20. Application Blaney-Criddle average crop coefficient for this study.

Rainy period	Month of growth	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Dry period	Month of growth	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.
Rice		0.965	1.43	1.47	1.135										
- Rice HYV x 0.5	4	1.14	1.50	1.48	1.15	-	-	Mung bean *	3	-	0.64	1.05	0.33	-	-
- Rice Khao Dawk Mali x0.5		0.79	1.36	1.46	1.12										
Forest	6	1.00	1.00	1.00	1.00	1.00	1.00	Forest	6	1.00	1.00	1.00	1.00	1.00	1.00
Mix field Crop		0.87	1.190	1.039	1.255	1.058	1.051	Mix field Crop		1.051	1.083	0.886	0.898	1.036	0.849
- Sweet corn x0.6		0.70	0.98	0.66	0.70	0.98	0.66	- Sweet corn x0.6		0.70	0.98	0.66	0.70	0.98	0.66
- Mango x 0.15	6	1.34	2.35	2.62	3.13	2.78	2.75	- Mango x 0.15	6	2.54	1.63	1.6	1.52	1.32	1.35
- Teak ** x 0.15		1.00	1.00	1.00	1.00	1.00	1.00	- Teak ** x 0.15		1.00	1.00	1.00	1.00	1.00	1.00
- Tamarind ** x 0.1		1.00	1.00	1.00	1.00	1.00	1.00	- Tamarind ** x 0.1		1.00	1.00	1.00	1.00	1.00	1.00
Grass		1.19	1.365	1.315	1.245	1.085	1.2	Grass		0.895	0.835	0.68	0.92	0.645	1.065
- Saccharm x 0.5	6	1.4	1.41	1.48	1.45	1.3	1.2	- Saccharm x 0.5	6	1.26	0.72	0.72	0.79	0.79	1.23
- Rucy x 0.5		0.98	1.32	1.15	1.04	0.87	1.2	- Rucy x 0.5		0.53	0.95	0.64	1.05	0.5	0.9
Village		x	x	x	x	x	x	Village		x	x	x	x	x	x

Note * Landuse in rainy season is rice, after that the land is used to grow bean.

** To consider from forest.

- No plantation and evaporation only.

x No significant evapotranspiration and evaporation

2.9.5 Estimation of evapotranspiration rate

The calculation of evapotranspiration rates was done using Arcview and its extensions. The calculation parameters were available to illustrate the change through time.

2.9.5.1 Estimation of evapotranspiration rate in 1975-76

The climatological data in 1969 were incomplete when compared with those in 1975-76. However as the landuse was not much different, so the landuse map of 1969 was used as a parameter for estimating the crop water-need in 1975-76.

Evapotranspiration rates in rainy period and dry period of year 1975-76 are shown in Table 2.21.

Table 2.21. Evapotranspiration and evaporation for rainy period and dry period in 1975-76.

Month	Year 1975-76		
	Evapotranspiration X 10^6(m.^{3})	Evaporation * X 10^6 (m.^{3})	Total X 10^6 (m.^{3})
May	114.181	0.255	114.436
Jun.	109.195	0.236	109.431
Jul.	94.295	0.209	94.504
Aug.	93.159	0.211	93.37
Sep.	78.940	50.816	129.756
Oct.	85.634	54.374	140.008
Total rainy period	575.404	106.100	681.504
Nov.	34.227	55.454	89.680
Dec.	70.548	0.246	70.793
Jan.	96.899	0.229	97.128
Feb.	57.599	0.215	57.814
Mar.	42.308	86.495	128.803
Apr.	38.484	100.553	139.037
Total dry period	340.065	243.191	583.256

Note * For the duration of no crop-planting

2.9.5.2 Estimation of evapotranspiration rate in 1988-89

Evapotranspiration rates in rainy period and dry period of year 1988-89 are shown in Table 2.22.

Table 2.22. Evapotranspiration values for rainy period and dry period in 1988-89.

Month	Year 1988-89		
	Evapotranspiration X 10^6 (m.^{3})	Evaporation * X 10^6 (m.^{3})	Total X 10^6 (m.^{3})
May	118.559	0.000	118.559
Jun.	169.400	0.000	169.400
Jul.	172.209	0.000	172.209
Aug.	140.750	0.000	140.750
Sep.	28.889	67.314	96.203
Oct.	27.640	56.416	84.056
Total rainy period	657.447	123.730	781.177
Nov.	24.982	67.825	92.807
Dec.	75.581	0.000	75.581
Jan.	106.219	0.000	106.219
Feb.	46.819	0.000	46.819
Mar.	28.555	114.611	143.166
Apr.	26.944	93.822	120.766
Total dry period	309.100	276.258	585.357

Note * For the duration of no crop-planting

2.9.5.3 Estimation of evapotranspiration rate in 2000-01

Evapotranspiration rates in rainy period and dry period of year 2000-01 are shown in Table 2.23.

Table 2.23. Evapotranspiration values for rainy period and dry period in 2000-01.

Month	Year 2000-01		
	Evapotranspiration X 10^6(m.^{3})	Evaporation * X 10^6 (m.^{3})	Total X 10^6 (m.^{3})
May	118.358	0.000	118.358
Jun.	167.505	0.000	167.505
Jul.	170.494	0.000	170.494
Aug.	141.843	0.000	141.843
Sep.	28.215	51.908	80.123
Oct.	28.158	54.126	82.284
Total rainy period	654.573	106.034	760.608
Nov.	24.982	67.825	92.807
Dec.	75.581	0.000	75.581
Jan.	106.219	0.000	106.219
Feb.	46.819	0.000	46.819
Mar.	28.555	114.611	143.166
Apr.	26.944	93.822	120.766
Total dry period	309.100	276.258	585.357

Note * For the duration of no crop-planting

Considering the evapotranspiration data and evaporation data, the evapotranspiration in a rainy period is higher than in a dry period becaused in a rainy period the growing of some plant (especially rice) a larger volume of water is used while the plants in a dry period are the kinds which used less of water . In dry period, on the other hand evaporation is high than in a rainy period because in the mostly of in the study area there is no plantation so that area are only evaporation.

2.10 Rainfall

2.10.1 Recorded Rainfall

Rainfall or precipitation is especially important for the consideration of the surface water balance, because it controls the amount of input water to the surface system. The monthly precipitation data which were uesd in this study are from 1975 to 2000 (see details in Appendix A).

Precipitation data were selected from the rain gages which have the complete data within and around the study area. Theissen method was used to average precipitation data here from 5 such stations. The data were combined for the annual rain volumes.

The annual rainfalls in the study area between year 1975 to year 2000 for each station are as show in Table 2.24.

Table 2.24. The annual rainfall in the study area from 1975 to 2000.

year	Annual rainfall (mm.)						
	Chondaen	Wang Pong	Pichit	Bang Moon Nak	Wang Sai Phun	Tha Pan Hin	Khao Sai
1975	1660.9	-nd-	2323.5	985.2	-nd-	1347.9	-nd-
1976	-nd-	-nd-	1412.7	1127.2	-nd-	1368.0	-nd-
1977	946.8	-nd-	1321.6	866.2	-nd-	1040.4	-nd-
1978	-nd-	-nd-	1150.7	1310.3	-nd-	1216.0	-nd-
1979	-nd-	-nd-	735.7	736.8	881.6	1072.4	-nd-
1980	-nd-	-nd-	1707.8	1128.7	1486.0	1400.3	-nd-
1981	1259.1	-nd-	1301.0	1111.4	1228.1	1233.4	-nd-
1982	1560.0	-nd-	1601.0	1090.3	1672.3	1209.6	-nd-
1983	-nd-	-nd-	1792.0	1296.2	1429.4	1280.2	-nd-
1984	1482.3	-nd-	824.5	860.3	1024.0	989.7	1397.5

Table 2.24 (Cont'd)

year	Annual rainfall (mm.)						
	Chondan	Wang Pong	Pichit	Bang Moon Nak	Wang Sai Phun	Tha Pan Hin	Khao Sai
1985	-nd-	-nd-	1230.6	1238.7	1527.5	1539.5	1600.7
1986	1359.0	-nd-	924.0	834.8	1186.3	927.0	857.9
1987	1583.6	1416.7	827.5	1075.4	1171.0	960.4	754.7
1988	1593.1	1030.3	1113.9	1029.0	1423.6	977.0	1397.5
1989	843.5	1215.0	1190.9	679.5	1098.4	1019.2	1039.0
1990	1329.7	1255.3	986.8	813.3	1051.5	1043.2	993.7
1991	1748.5	1638.0	1109.4	915.7	965.9	1126.7	1086.4
1992	1214.8	1248.6	950.4	650.5	677.3	1038.1	1030.3
1993	1006.4	1193.0	850.8	626.4	843.2	893.5	821.2
1994	1447.9	1815.1	1294.3	946.0	964.7	1285.2	1302.4
1995	1476.0	1771.4	1391.5	1342.7	1066.0	1445.3	1031.2
1996	1506.6	1746.1	1014.5	1391.6	1809.6	1477.2	937.1
1997	1040.9	1312.6	591.4	948.3	925.4	808.7	701.9
1998	1411.4	1904.3	1361.0	1384.5	1604.9	1463.0	1102.2
1999	1893.4	1904.3	1361.0	1384.5	1604.9	1463.0	1102.2
2000	1701.1	1474.0	1017.8	842.9	1177.1	1051.8	1018.5
average	**1410.4**	**1494.6**	**1207.2**	**1023.7**	**1219.0**	**1686.4**	**1069.1**

nd- : no data

It was noted from Table 2.24 that the annual rainfall exceeds 1,000 mm. to a good extent. The rainfall depth from these stations were again compared in Figure 2.22.

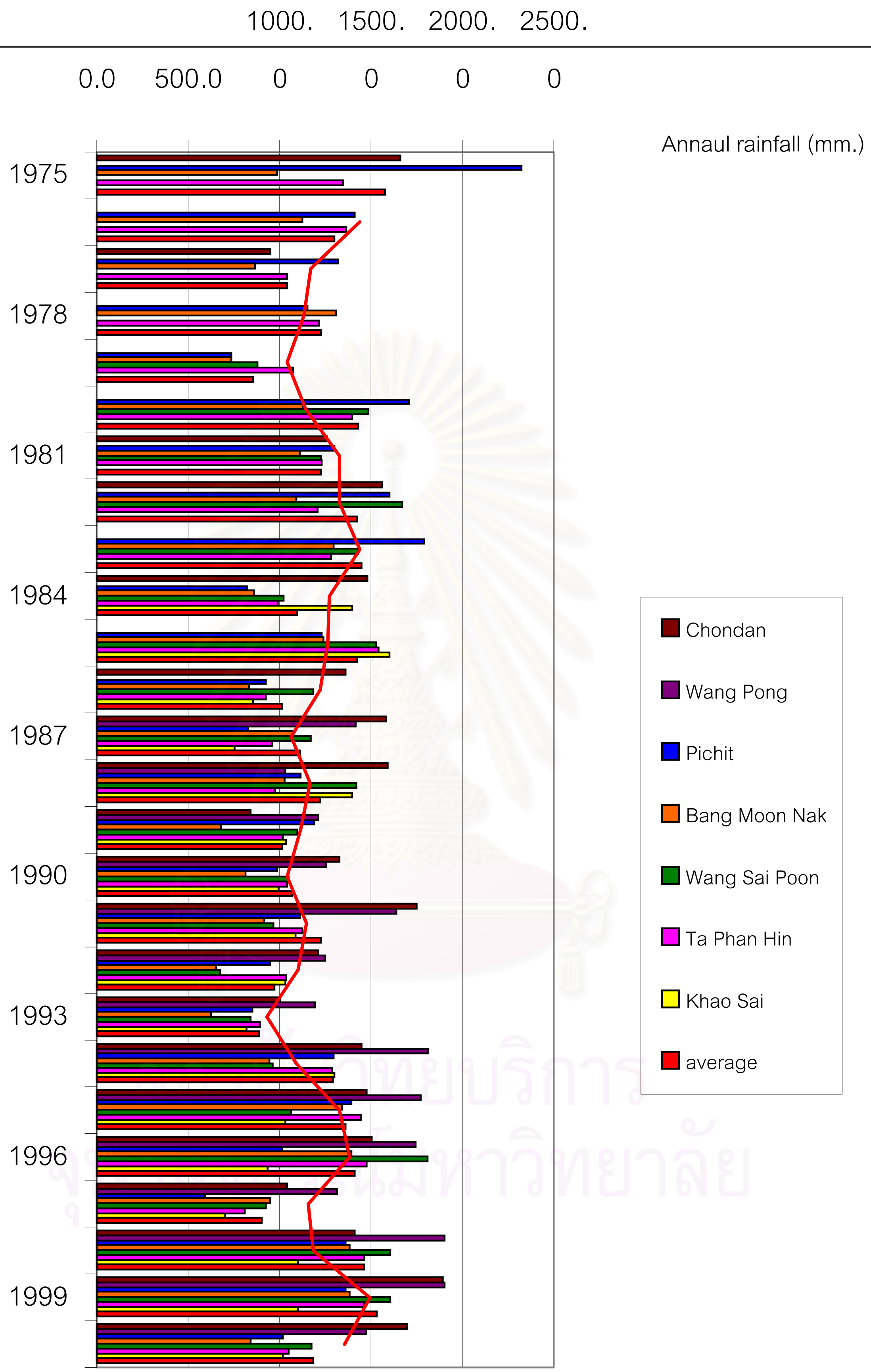


Figure 2.22. Comparison of annual rainfall from 5 rain gages in 1975-2000.

2.10.2 Estimation of rainfall

The rainfall polygons for the areal distribution in this study were obtained by Theissen method. The precipitation data below are represented in each polygons above.

2.10.2.1 Estimation of rainfall in 1975-76

The total input water into the study area for rainy period in 1975 can be summarized as in Table 2.25.

Table 2.25. Average total rainfall for rainy period and dry period in 1975 - 76.

Month	Total rainfall in study area x 10^6 (m^3)
May	108.425
Jun.	115.168
Jul.	116.777
Aug.	193.029
Sep.	144.617
Oct.	131.050
Total rainy period 1975	809.068
Nov.	7.957
Dec.	7.726
Jan.	0
Feb.	9.703
Mar.	7.062
Apr.	62.649
Total dry period 1975 - 76	95.100

2.10.2.2 Estimation of rainfall in 1988-89

The total input water into the study area for rainy period in 1988 can be summarized as in Table 2.26.

Table 2.26. Average total rainfall for rainy period and dry period in 1988 – 89

Month	Total rainfall in study area x 10^6 (m^3)
May	178.412
Jun.	114.121
Jul.	90.416
Aug.	201.838
Sep.	54.899
Oct.	173.791
Total rainy period 1988	813.480
Nov.	1.476
Dec.	0
Jan.	0.226
Feb.	0
Mar.	36.125
Apr.	25.091
Total dry period 1988 - 89	62.919

2.10.2.3 Estimation of rainfall in 2000-01

The total input water into the study area for rainy period in 2000-01 can be summarized as in Table 2.27.

Table 2.27. Average total rainfall for rainy period and dry period in 2000-01.

Month	Total rainfall in study area x 10^6 (m^3)
May	127.212
Jun.	192.110
Jul.	110.382
Aug.	175.153
Sep.	195.667
Oct.	113.404
Total rainy period 2000	913.93
Nov.	6.549
Dec.	0.960
Jan.	1.655
Feb.	4.334
Mar.	41.706
Apr.	47.085
Total dry period 2000 - 01	102.292

CHAPTER III
HYDROGEOLOGY

3.1 Overview of groundwater

Groundwater comes from direct rainfall or surface water that infiltrates into the ground after initial evaporation or moving away in the rapid surface runoff. The water moves down into the ground because of gravity, seeping through the intergranular space of sediments or through rock fracture. Some part of water is first trapped by the plant roots to enter the plant circulation system, and then be transpirate. The rest reaches further down to a depth where the ground is to be filled with water. The zone that is filled with water is called the saturated zone and the top of this zone is called the water table.

Saturated permeable layers consist typically of sands, gravels, and cavernous limestones or highly fractured rocks capable of providing a usable supply of water are known as aquifers. Groundwater is stored in and moves slowly through these aquifers along the permeability. The underlying impermeable rocks which obstruct the further downward movement of groundwater are known as the basement rocks.

Quality of aquifer depends on several geological characteristics or geological structures such as porosity, sorting and permeability of aquifer.

3.2 Hydrogeology in study area

3.2.1 Aquifers in study area

The study of the geology and geological structures favorable for groundwater storage had been done by the Department of Groundwater Resources (See Appendix E). The depth and distribution of particular aquifers in the area are shown in Appendix D.

From the available data and the field check done in this study, the hydrogeological units or aquifers were classified according to their storage characteristics, yield and other hydrogeological characteristics. The formation having similar hydrogeological characteristics has been grouped into the same aquifer unit. Table 3.1

and Figure 3.1 reveal 3 aquifers of such characteristics. They are carbonate sandstone aquifer (CSA), volcanic andesite aquifer (VAA) and Quaternary unconsolidated aquifer (QUA).

Carbonate Sandstone Aquifers (CSA)

This aquifer consists of gray massive limestone with lense of dark chert, interbedded shale horizons and sandstone. The aquifer sequences underlie the volcanic aquifers, with characteristically solution cavities. There are springs discharging from such limestone solution openings. Depth from surface to water bearing zones is from 20 to 130 m, yield 2 – 12 cu m/hr with an average 2-4 cu m/hr of potable water. The water is generally high in hardness content, however.

Volcanic Andesite Aquifer (VAA)

The igneous aquifer consists of andesite, rhyolite, tuff, and agglomerate of white, yellow, grey, and brown color. The age is Middle Triassic. The rocks expose in relatively small area. The igneous aquifer which was considered as small productive, could be encountered at a depth less than 30 m. down to 120 meters. It normally yields only 2-5 cu m/hr, with the highest about 15 cu m/hr.

Quaternary Unconsolidated Aquifer (QUA)

Unconsolidated aquifers comprise layers of loosely cemented gravel, sand, silt, rock fragments and clay. In general, groundwater is occurred in intergranular pore space. However, the capabilily of groundwater storage in the sediments depends particularly on the thickness of aquifer layers, assortment of material, shape or roundness and packing of grains. There are three types of unconsolidated aquifers according to the stratigraphic pattern in the study area.

1. Alluvial Aquifer

The alluvial aquifer comprises gravel, sand, silt and clay, which deposit in floodplains and small chanels. The average depths to aquifer about 10-25 meters, while the yield is 10-20 cu m/hr.

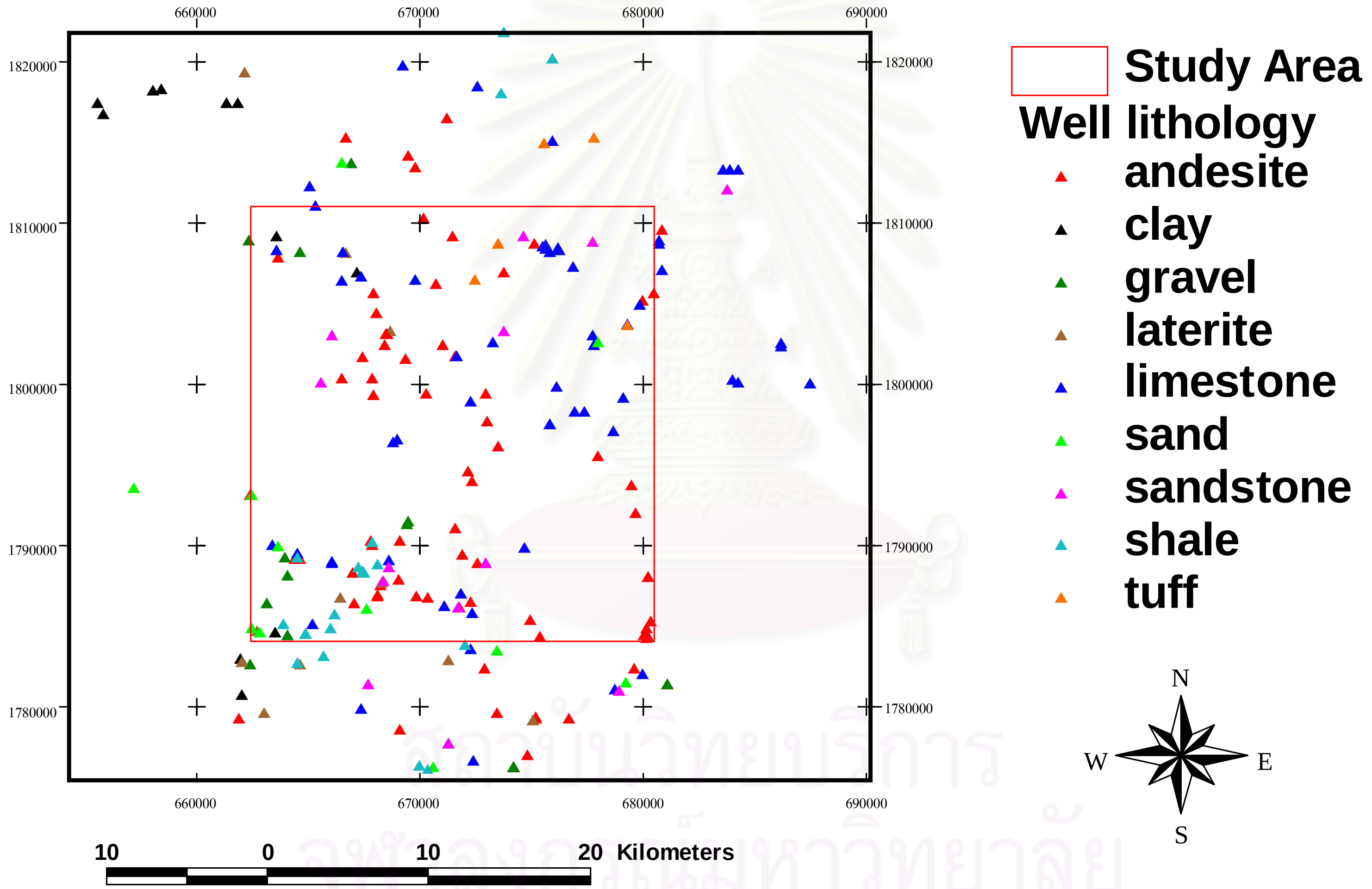


Figure 3.1. Preliminary hydrogeological aquifers (from well lithology) in the study area.

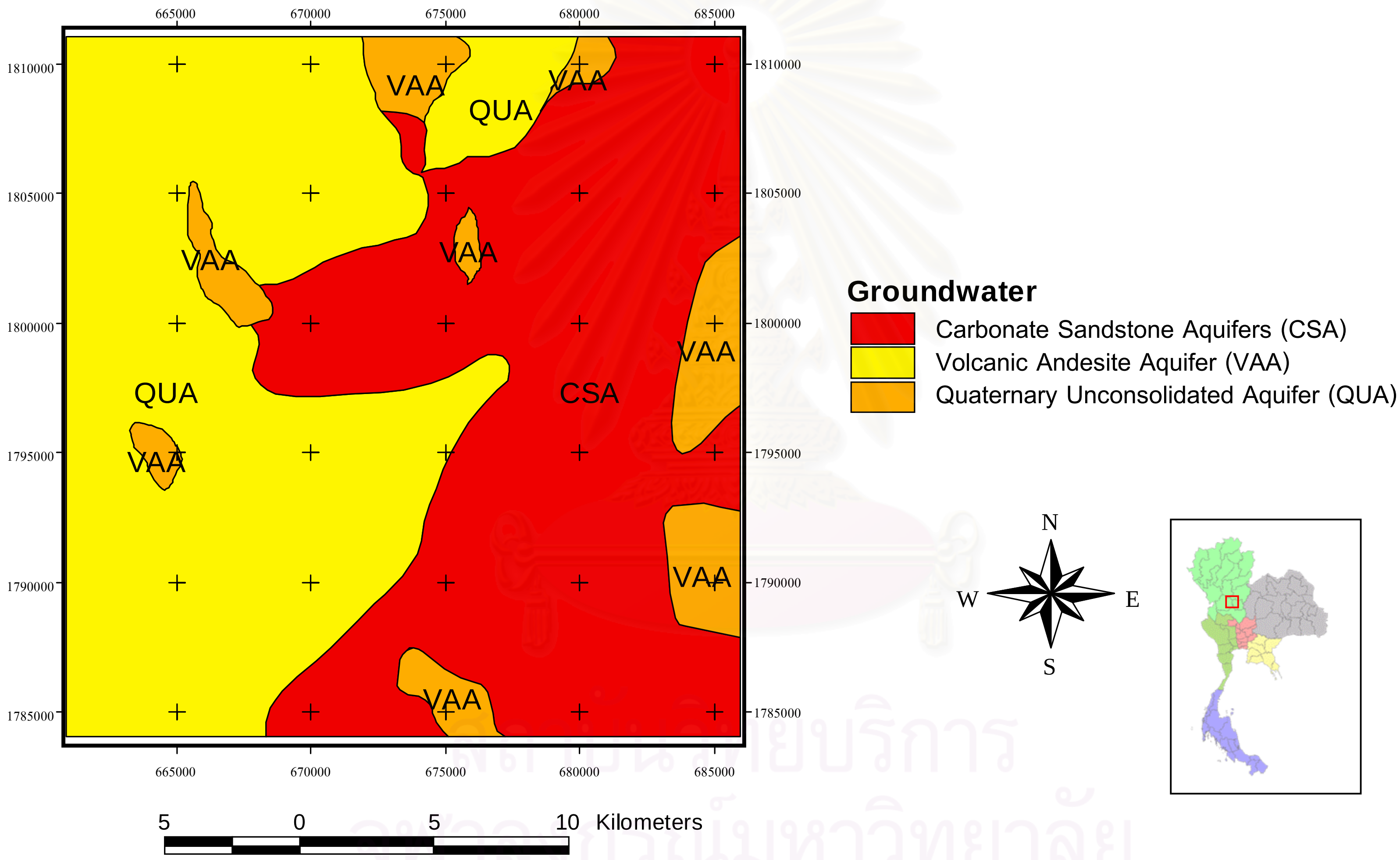


Figure 3.2. The hydrological aquifer in study area.

2. Colluvial Aquifer

The colluvial aquifer is composed of course grained materials which occurred along the foothill. The average depth of this aquifer is about 35-60 meter. Yield of wells available in this area is about 10-20 cu m/hr.

3. Low Terrace Aquifer

Terrace aquifer comprises clay, sand and minor gravel. The combination looks like lateritic soils with the cementing material from ferrous oxide minerals derived from volcanic rock weathering. The average depth of the terrace aquifer is about 40-60 meters and yield about 2-15 cu m/hr.

The hydrological aquifers in the study area are shown in Figure 3.2.

3.3 Subsurface water in study area

Subsurface water level and quality of water is an essential for this research. The water level would be used to determine the direction of groundwater flowage by way of constructing groundwater contour maps and flow nets. The directions of water flow can predict the contamination in the groundwater from the sources at the higher elevation. The water quality is also important as the basic data which indicate the contamination.

3.3.1 Water level station, water and soil sampling

Field observation for measurement of water level and collection of water samples (Figure 3.3) for some physical and chemical quality analyses were done on 21-22 March 2003, 2 August 2003, and 26-27 December 2003. Meanwhile, the soil samples at these locations (Figure 3.4) were collected for studying the soil physical and chemical properties. These works were done in the related studies to this present study (see Chuancheuy, 2003 and Limpongsthorn, 2004.)

The 11 observation positions were obtained data to calculate for a flow direction of groundwater. The locations of these position are shown in Table 3.1. While the water and soil sampling positions (the same as those for the water level) are shown in Figure 3.5.

Table 3.1. The positions for measuring water level, and water and soil sampling.

Well No.	UTM Grid reference		Ground Elevation (m.) above MSL
	Easting	Northing	
1	672520	1786606	48
2	678458	1785694	61
3	681139	1788451	89
4	682642	1795647	104
5.1	675773	1794425	70
6	668437	1795390	55
7	673402	1801985	68
8	678956	1801961	79
9	679463	1808480	87
10	672577	1809860	51
11	668220	1806748	66

Figure 3.3. Field investigation of the shallow, unconfined groundwater. (A) and (B), Water table measurement , (C) and (D) Water sampling and field test for some chemical quality.

Figure 3.4. Disturbed soil sampling for laboratorial soil chemical analysis.

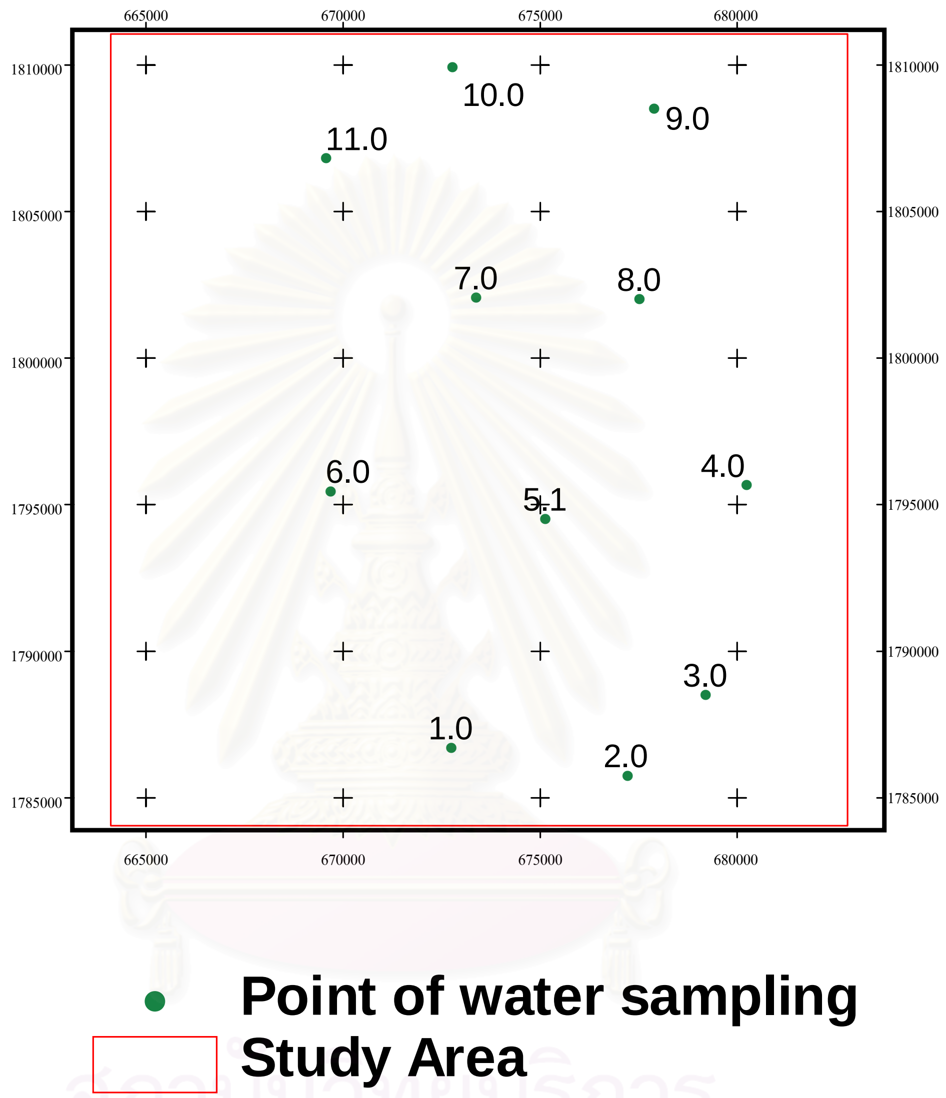


Figure 3.5. The positions for measuring water level, and water and soil sampling.

3.3.2 Groundwater Flow direction

Water-table contour are similar to the topographic lines in an extent. They essentially represent the subsurface, "elevations”, the hydraulic head.

Water table contour lines can be used to tell which way groundwater flows in a given region. Lots of observation or monitoring wells are drilled and hydraulic head is measured in these wells. Water table contours are drawn in a way to connect the points of equal head. These water table contour lines are also called equipotential lines. The line s which cross of contour lines is called a flow net. Groundwater always moves from an area of higher hydraulic head to an area of lower hydraulic head, and flow perpendicularly to the equipotential lines.

<u>Water flow method</u>

The elevation of groundwater table was measured by means of measuring the depth of water level from the ground surface. With the knowledge of the elevation of ground surface with the datum plane which is the mean-sea-level, the elevation of the water table is thus obtained. Next, it is needed to estimate the point of equal elevation Of water level by mean of inference. Then the points of equal elevation are connected to form contour lines. A contour interval is selected to be appropriate to the overall variation in water level in the area. The direction of groundwater flow is marked at the right angle to the contour lines from the higher elevation to the lower elevation. This is to construct a ground water-level contour map.

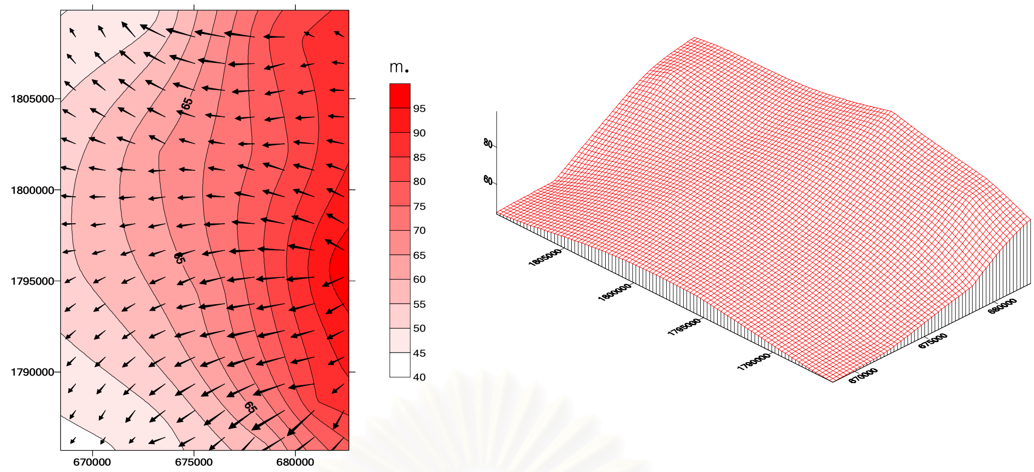
Once the contour map is made, the contours are segmented at an equal length. Flow lines are drawn at right angle to the contour at the dividing point marked on it. The flow line is extended until it intercepts the next contour line, then continued at the right angle to this new contour line. It is suggested to select a contour which will enable the flow lines to be drawn in a downslope direction.

The groundwater level study was done 3 times, in summer, 21-22 March 2003, in rainy season, 2 August 2003, and in winter, 26-27 December 2003. The study results are shown in Table 3.2 while the resultant flow nets are shown in Figure 3.6.

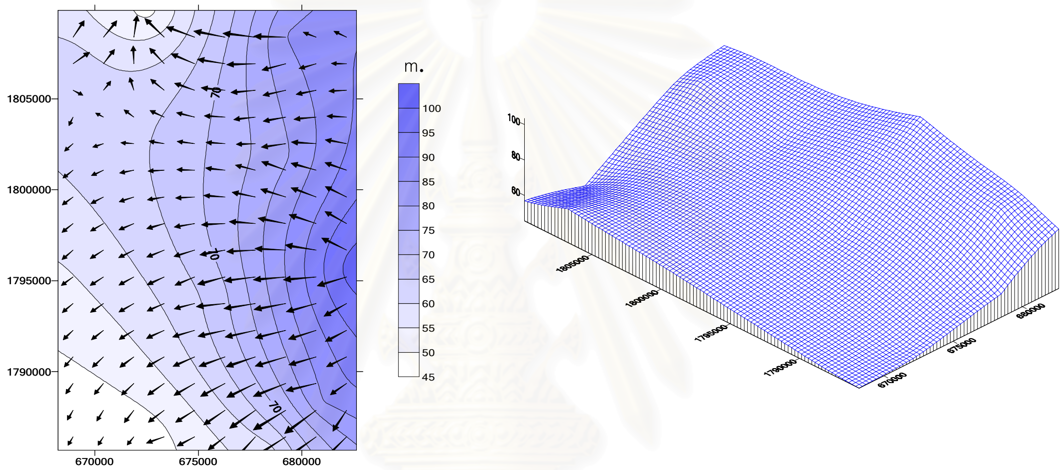
Table 3.2. Water table level in study area.

Well No.	UTM Grid reference		Ground Elevation	Measured water table depth (m.)			Water table elevation (m.) MSL		
	East	North	(m. above MSL)	(A)	(B)	(C)	(A)	(B)	(C)
1	672520	1786606	48	1.8	0.41	1.86	46.2	47.59	46.14
2	678458	1785694	61	3.12	2.4	2.74	57.88	58.6	58.26
3	681139	1788451	89	3.53	3.22	3.22	85.47	85.78	85.78
4	682642	1795647	104	4.45	0.39	4.79	99.55	103.61	99.21
5.1	675773	1794425	70	3.29	2.81	3.33	66.71	67.19	66.67
6	668437	1795390	55	1.39	0.57	1.58	53.61	54.43	53.42
7	673402	1801985	68	2.59	1.8	2.61	65.41	66.2	65.39
8	678956	1801961	79	1.63	0.77	1.84	77.37	78.23	77.16
9	679463	1808480	87	3.13	1.13	3.51	83.87	85.87	83.49
10	672577	1809860	51	4.82	2.75	4.45	46.18	48.25	46.55
11	668220	1806748	66	- no data -	1.21	2.66	- no data -	64.79	63.34

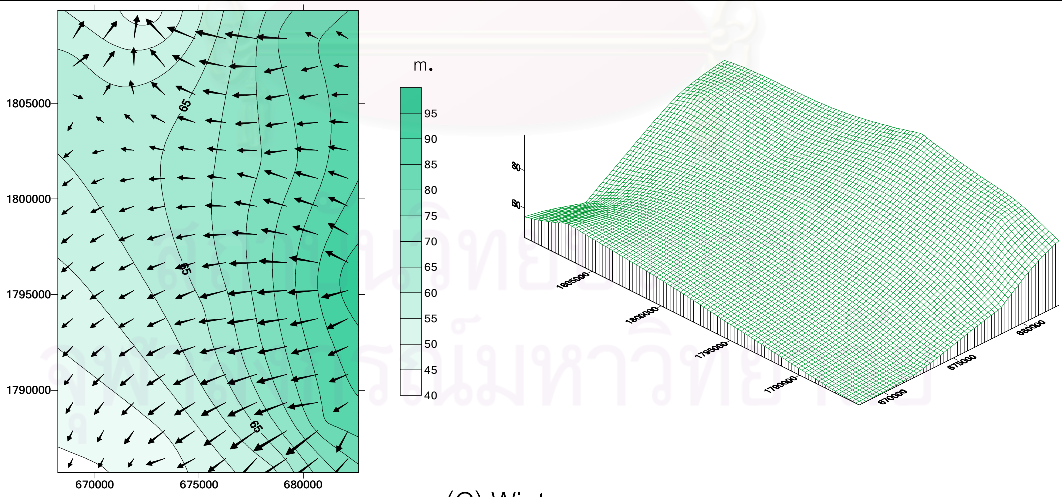
Note: The times of groundwater study are (A) 21 – 22 March 2003, (B) 2 August 2003, and (C) 26 – 27 December 2003.



(A) Summer season



(B) Rainy season



(C) Winter season

Figure 3.6. The groundwater flow direction. (A),(B), and (C) are for the times as noted in Table 3.2.

It was noted that the direction of groundwater flow pattern in the study area generally conforms the ground elevation, and the water would probably be discharged into the surface streams to the northwest and southwest corners of the study area.

3.3.3 Groundwater and soil properties

The studies for the chemical and physical properties of groundwater and of soils are done both at the site and in laboratory. The soil study was done essentially by Limpongstorn (2004) and groundwater by Chuancheoy (2003), both are the related studies to this present one.

3.3.3.1 Subsurface water and soil physical properties

The sampling of groundwater in the study area was done 3 times in summer (21-22 march 2003), rainy season (2 August 2003) and winter (26-27 December 2003), but the soil physical properties and chemical properties were studied only once on the soil sample collected in the rainy season period (2 August 2003).

Temperature

Water temperature controls the amount of dissolved oxygen. This in turn is a very important factor that affects the survival of aquatic organisms. Increasing temperature also increases the rates of chemical reaction to be taken place in water.

Causes of water temperature change include the weather, shading of vegetation, type of water aquifer, water discharge, and groundwater inflow.

The water temperature in summer of the study area is 26.3 - 29.0 ºC. In the rainy season, it is 27.2 – 30.6 ºC, and winter, 22.7 – 27.9 ºC. The fluctuation of water temperature is thus small. The highest water temperature was observed at station 8 and the lowest at station 9.

Table 3.3 Temperature of groundwater in the study area.

Station	Temperature (ºC)		
	Summer (A)	Rainy Season (B)	Winter (C)
1	28.7	30	28
2	28.8	28.2	23.8
3	27.3	27.7	22.7
4	28.8	29.8	27.8
5	29	29.6	27.9
6	26.8	28.2	26
7	28	28.8	26.1
8	29	30.6	26.6
9	26.3	27.2	25.1
10	27.6	28.7	26.6
11	-	29.4	25

(A), (B), and (C) are as in Table 3.2.

From Figure 3.6, the water temperature of study area in winter was the lowest and the highest was found in the rainy season, surprisingly not in summer. It could be because in the rainy period, new water had been discharged into the aquifer.

pH

The measurement of hydrogen ion concentration (pH) in water and soil is presented a scale from 0 to 14. A solution with pH equals 7 is neutral, with pH less than 7 acidic, greater than 7 alkaline. Natural waters usually have pH between 6 and 9 i.e. slightly acidic to alkaline water.

The factors of increasing or decreasing alkalinity/acidity are the chemical substances occurred naturally from the decaying of minerals, or from man–made substances such as industrial wastes, household chemicals such as soaps and detergents, acid mine drainage, acid rain and agricultural chemicals such as fertilizers, insecticides, herbicides etc.

Groundwater pH in the study area shown in Table 3.4 is 5.37 – 7.46 in summer. In rainy season it is 5.42 - 7.52, and in winter 5.6 – 7.43. The pH of soil is 5.42 – 7.52.

The pH data was measured are shown in Figures 3.7 and 3.8, the pH of groundwater is seemed to be controlled only by the water pattern, and not by pH of soil. It means that the seasonal changing of pH of water does not depend on the chemical of soil which might only have the initial control.

Table 3.4. The pH of groundwater and soil in the study area.

Station	pH			pH of soil
	Summer (A)	Rainy Season (B)	Winter (C)	
1	5.37	6.05	5.6	6.05
2	7.10	7.35	7.18	7.35
3	7.35	7.52	7.24	7.52
4	7.16	6.34	7.28	6.34
5	5.30	5.42	5.49	5.42
6	6.95	6.44	6.94	6.44
7	6.2	6.35	6.13	6.35
8	6.94	6.86	7.06	6.86
9	7.46	6.82	7.37	6.82
10	7.18	7.11	7.43	7.11
11		6.51	6.34	6.51

(A), (B), and (C) are as in Table 3.2.

Conductivity

Conductivity is to observe how much electrical current passes through medium. It is an indirect measurement of the presence of inorganic dissolved solids, such as chloride, nitrate, sulfate, phosphate, sodium, magnesium, calcium, and iron. These substances conduct electricity because they carry negatively or positively charge when dissolved in water. The concentration of dissolved solids, or the conductivity, is affected by the bedrock and soil in the watershed. It is also affected by human influences. For example, agricultural runoff normally has a higher conductivity because of the presence of phosphate and nitrate from chemicals used in agricultural purposes.

The results of conductivity study are shown in Table 3.5. At station 2, the water has a very high conductivity while the soil conductivity is not significantly high compared to that in water. From the field check it was noted that near the study area there was a small outcrop of Permian limestone of the basement high. This should mean that the conductivity of water at station 2 has a direct effect from the dissolved limestone than from soils.

Conductivity in the study area as shown in Figure 3.9 and the compared conductivity graph in Figure 3.10 also indicate the different pattern in all 3 periods of study here.

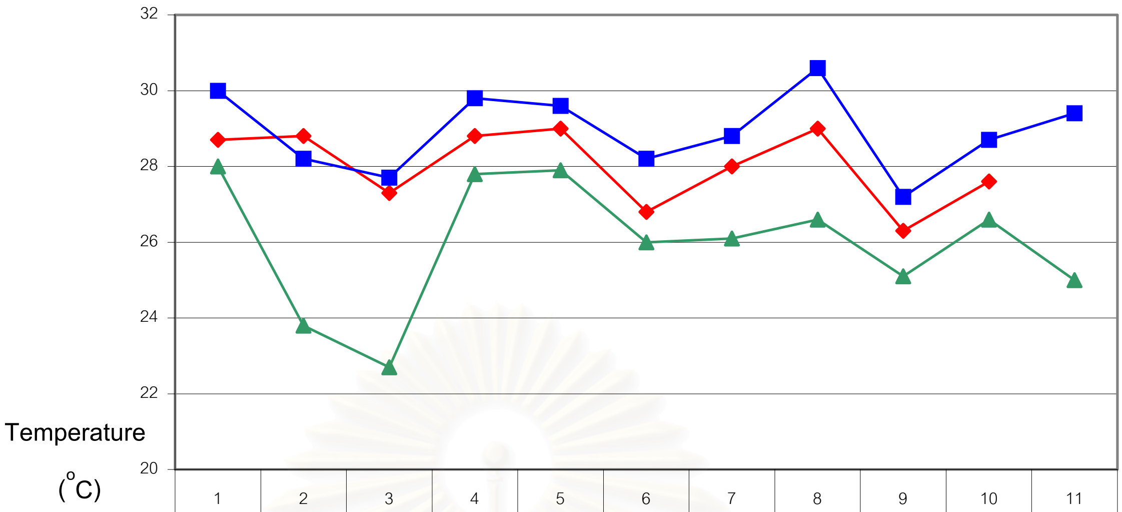
Table 3.5. The water and soil conductivity in the study area.

Station	Water Conductivity (μs/cm)			Soil Conductivity (μs/cm)
	Summer (A)	Rainy Season (B)	Winter (C)	
1	94.7	159.8	159.8	425
2	4.48 ms/cm	2.66 ms/cm	3.39 ms/cm	638
3	800.0	541.0	803.0	322
4	1019.0	208.0	831.0	514
5	116.2	115.7	119.8	558
6	405.0	292.0	288	302
7	328.0	885.0	550.0	269
8	733.0	494.0	620.0	561
9	643.0	459.0	638.0	330
10	537.0	987.0	654.0	1108
11		222	209	441

(A), (B), and (C) are as in Table 3.2.

3.3.3.2 Subsurface water and soil chemical properties

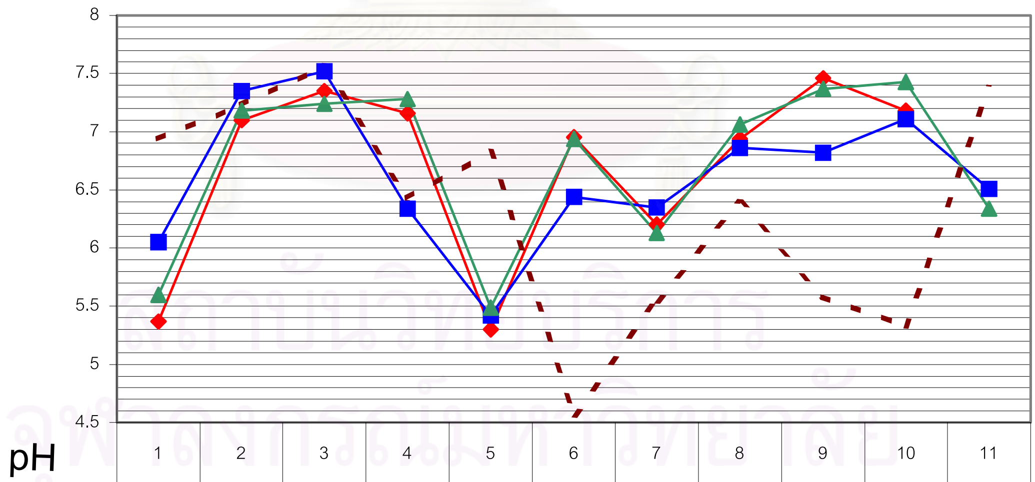
The Chemical properties of water and soil are measured about Sodium (Na+), Calcium (Ca^{2+}) Magnesium (Mg^{2+}), Hardness, Chloride (Cl^{-}), Potassium (K^{+}), nitrate (NO^{3-}) , Sulfate (SO_4^{2-}), Metals and Cyanide (CN^{-})



	1	2	3	4	5	6	7	8	9	10	11
Summer	28.7	28.8	27.3	28.8	29	26.8	28	29	26.3	27.6	
Rainy	30	28.2	27.7	29.8	29.6	28.2	28.8	30.6	27.2	28.7	29.4
Winter	28	23.8	22.7	27.8	27.9	26	26.1	26.6	25.1	26.6	25

Well

Figure 3.7. Comparision of temperature (° C) in the study area.



	1	2	3	4	5	6	7	8	9	10	11
Summer	5.37	7.1	7.35	7.16	5.3	6.95	6.2	6.94	7.46	7.18	
Rainy	6.05	7.35	7.52	6.34	5.42	6.44	6.35	6.86	6.82	7.11	6.51
Winter	5.6	7.18	7.24	7.28	5.49	6.94	6.13	7.06	7.37	7.43	6.34
soil pH	6.94	7.23	7.56	6.43	6.83	4.57	5.55	6.39	5.58	5.33	7.38

Well

Figure 3.8. Comparision of water pH in the study area.

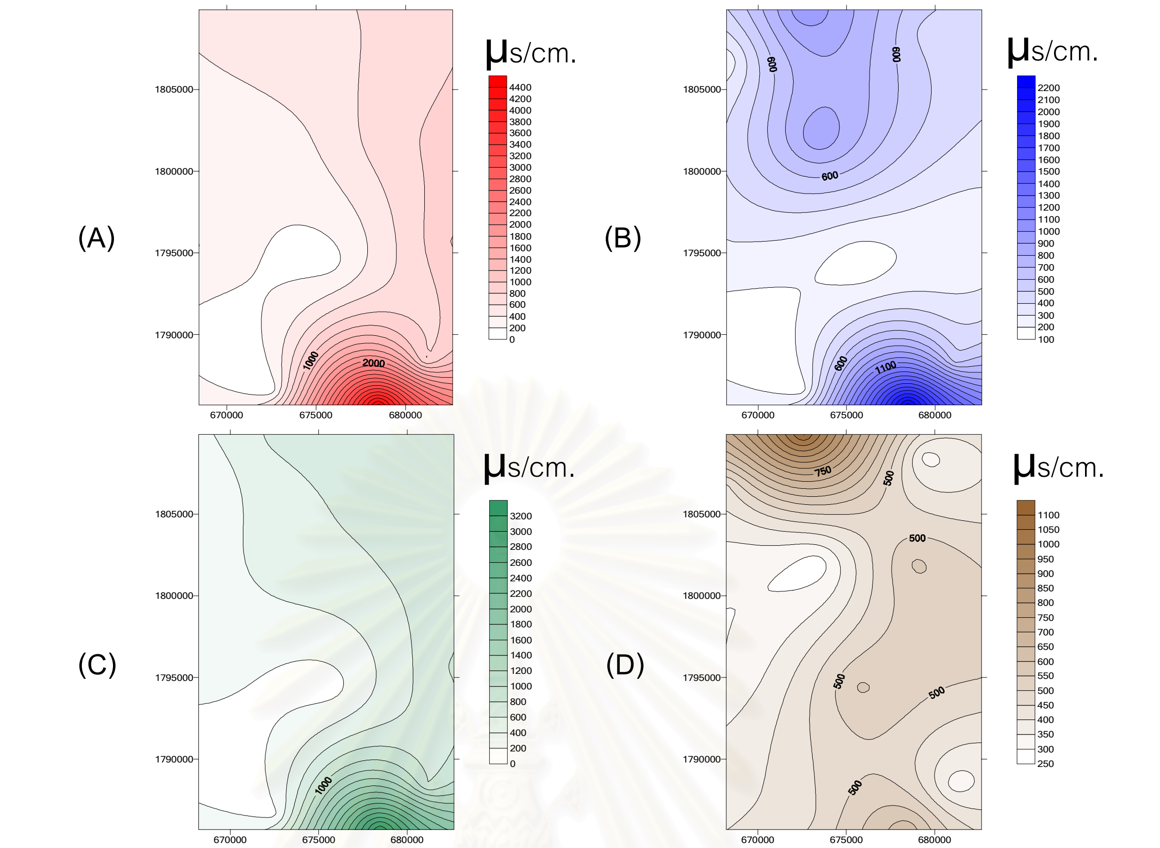
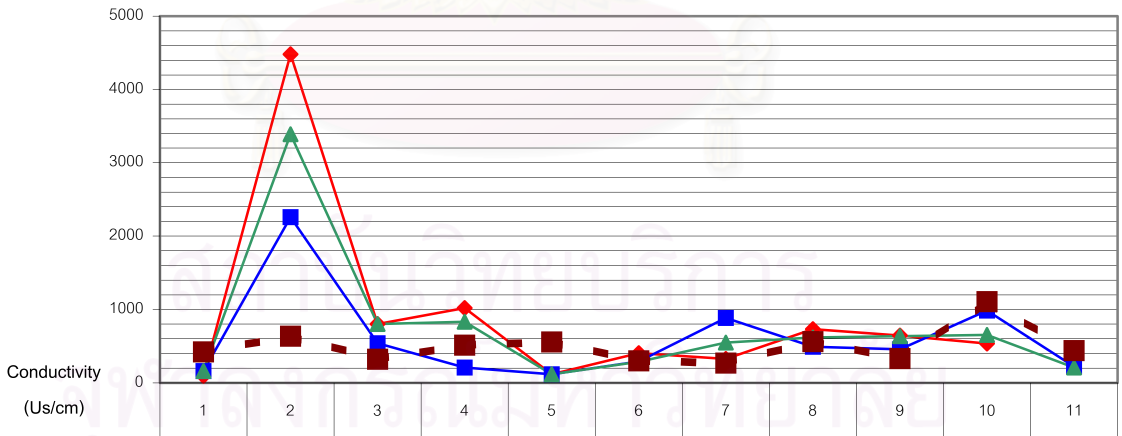


Figure 3.9. Conductivity (µs/cm.) pattern of subsurface water and soil maps. (A) Of water in summer. (B) Of water in rainy season. (C) Of water in winter. (D) Of soil conductivity.



	1	2	3	4	5	6	7	8	9	10	11
summer	94.7	4480	800	1019	116.2	405	328	733	643	537	
rainy	159.8	2260	541	208	115.7	292	885	494	459	987	222
winter	159.8	3390	803	831	119.8	288	550	620	638	654	209
soil	425	638	322	514	558	302	269	561	330	1108	441

well

Figure 3.10. Comparision of water conductivity (µs/cm.) in the study area.

Sodium (Na+)

Sodium is not an essential element of many of the common rock–forming minerals. The common primary source of sodium in natural water is from the release of soluble products from the weathering of sodic plagioclase. In areas of evaporite deposits, the solution of halite is also important. Clay minerals may, under certain conditions, release large quantities of exchangeable sodium as well. But the latter is only a miner source of sodium in natural water. Other minerals may be abundant in some igneous and metamorphic rocks and give out sodium, but this is much less importante compared to that from feldspars.

Sodium concentration pattern in the study area is similar to the conductivity pattern. Station 2 shows very high Na^+ content as seen in Table 3.6. In the rainy season, the northern part of area is rather high in sodium content. Sodium concentration pattern in the study area is shown in Figure 3.11 and the comparision graphs in Figure 3.12.

Table 3.6. Water conductivity in the study area.

Station	Water Sodium (Na^+) concentration (ppm)			Soil sodium (Na^+) concentration (ppm)
	Summer (A)	Rainy Season (B)	Winter (C)	
1	14.9	21.92	7.2	108.025
2	541.5	371.8	482.5	215.625
3	72.5	127.1	181.8	122.875
4	173.85	23.78	162.4	123.05
5	2.4	3.458	9.6	108.75
6	49.2	38.84	47.9	120.175
7	16.06	75.65	51.2	90.15
8	42.68	27.6	52.5	100.975
9	82.2	58.06	0.9	101.175
10	33.24	71.5	81.3	153.575
11		17.16	26.4	109.825

(A), (B), and (C) are as in Table 3.2

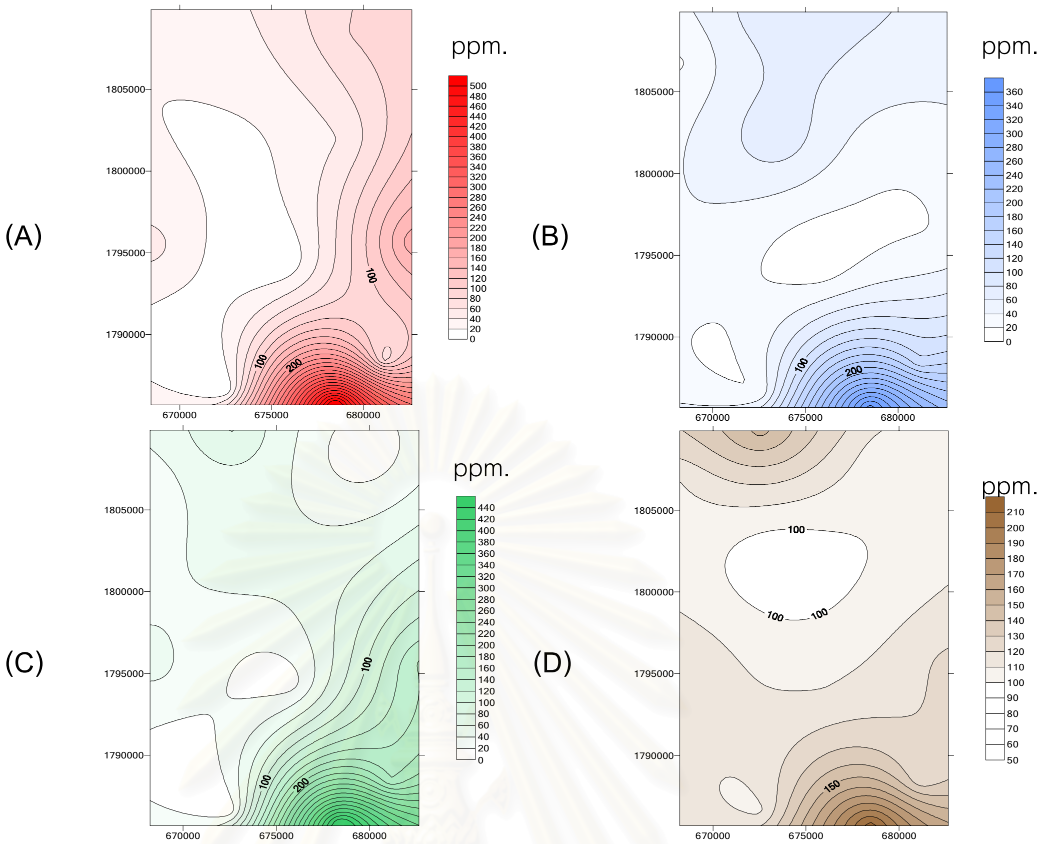
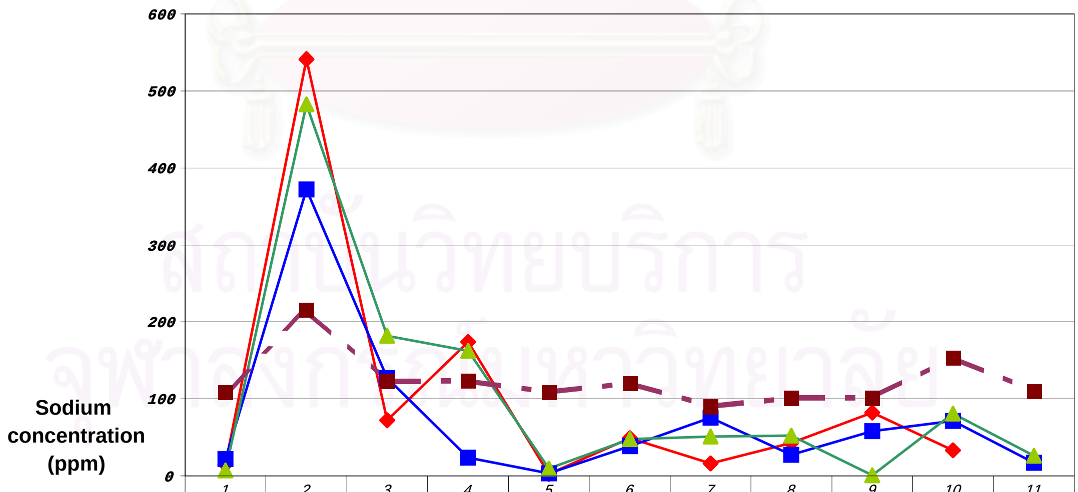


Figure 3.11. Sodium concentration (ppm.) pattern of subsurface water and soil chemical map. (A) Of water in summer. (B) Of water in rainy season. (C) Of water in Winter season. (D) Soil Chemical.



	1	2	3	4	5	6	7	8	9	10	11
summer	14.9	541.5	72.5	173.85	2.4	49.2	16.06	42.68	82.2	33.24	
rainy	21.92	371.8	127.1	23.78	3.458	38.84	75.65	27.6	58.06	71.5	17.16
winter	7.2	482.5	181.8	162.4	9.6	47.9	51.2	52.5	0.9	81.3	26.4
soil	108.025	215.625	122.875	123.05	108.75	120.175	90.15	100.975	101.175	153.575	109.825

well

Figure 3.12. Comparision of sodium concentration (ppm.) in the study area.

Calcium (Ca^{2+})

Calcium is one of the abundant element in the Earth' s crust, and is extremely mobile in the hydrosphere, thus it becomes one of the most common ions in subsurface water. Calcium is the principal chemical for hardness, having come from limestone, dolomite, and gypsum or calcified gypsiferous shale. Subsurface water in contact with the sedimentary rocks of marine origin may receive calcium from those rocks. The igneous and metamorphic rocks being weathered also release calcium from minerals such as apatite, wollastonite, fluorite, feldspar, amphibole, and pyroxene. Calcium concentration in the study area is shown in Table 3.7

Table 3.7. Calcium concentration of groundwater and soil in the study area.

Station	Water calcium (Ca^{2+}) concentration (ppm.)			Soil calcium (Ca^{2+}) concentration (ppm.)
	Summer (A)	Rainy Season (B)	Winter (C)	
1	9.32	13.2	12.86	2000
2	455	210.5	254.5	9400
3	11.95	17.5	31.5	1020
4	36.35	12.04	34.2	3200
5	15.74	14.62	14.46	3200
6	26.4	20.7	32.05	800
7	12.38	72.2	48.7	800
8	34.6	17.45	30.6	1520
9	51.6	34.85	55.2	1320
10	29.15	48.5	65.2	1800
11		18.55	27.75	8000

(A), (B), and (C) are as in Table 3.2.

Calcium pattern in the study area indicate a high calcium content at Station 2 which locates in the southtern part of the study area. This conforms with the magnesium concentration in water. Calcium concentration of soil does not follow that of water as the calcium concentration in soil is much higher than in water as seen in Table 3.7 and Figure 3.13.

Magnesium (Mg^{2+})

Magnesium is the second important cause of hardness. The common sources of magnesium in the lithosphere are dolomite in sedimentary rocks. Olivine, biotite, hornblende and augite in igneous rocks and serpentine, talc, diopside, and tremolite in metamorphic rocks are also the major sources. In addition, most calcite contains some amount of magnesium, so a solution of limestone commonly yields abundant magnesium as well as calcium.

The magnesium pattern in Table 3.8 also shows a high magnesium content at station 2. The magnesium pattern is similar to that of calcium concentration pattern and shows no direct relationship to that of soil, too.

Table 3.8. Magnesium concentration of water in the study area.

Station	Water magnesium (Mg^{2+}) concentration (ppm.)			Soil magnesium (Mg^{2+}) concentration (ppm.)
	Summer (A)	Rainy Season (B)	Winter (C)	
1	0.162	0.7	0.253	42
2	143	59.75	74.5	130
3	1.7	2.4	4.75	130
4	39.6	3.36	30.1	280
5	0.259	0.245	0.324	230
6	12.85	6.66	8.5	140
7	0.366	3.25	2.9	100
8	9	5.72	9.4	260
9	11.4	9.75	13.3	280
10	7.38	5.34	17	370
11		5.42	7.55	320

(A), (B), and (C) are as in Table 3.2.

The similar patterns of calcium and magnesium in the study area may suggest that they get influence from limestone, as the patterns do not coincide with that of soil. The limestone is easily dissolved and gives calcium and magnesium to groundwater. The pattern of calcium and magnesium are shown in Figures 3.13 and 3.14, and the graphs of concentration of calcium and magnesium are shown in Figures 3.15 and 3.16 respectively.

Hardness

Calcium and magnesium ions are the major contributors to water hardness when water flows through the rocks that contain minerals such as gypsum ($CaSO_4.2H_2O$), calcite ($CaCO_3$), dolomite ($CaMg(CO_3)_2$), etc.. Hard water has a noticeable taste, produces precipitates with soaps which inhibits lathering and forms precipitates in boilers. Temporary or bicarbonate hardness is due to $Ca(HCO_3)_2$ which deposits $CaCO_3$(s) as scale on boiling water. Magnesium ion levels are often high in irrigation water and can cause scouring in livestock. Ca^{2+} and Mg^{2+} can combine with Cl^- or SO_4^{2-} causing permanent hardness which cannot be removed by boiling. The classification of hardness as show in Table 3.9

Table 3.9. Classification of hardess (From Water Quality and Treatment, American Water Works Association, 1990.)

Classification	Amount of calcium and magnesium (mg/l or ppm.)
Soft	0 - 17.0
Slightly hard	17.1 – 60.0
Moderately hard	60.1 – 120.0
Hard	120.1 – 180.0
Very Hard	180 & over

The hardness of water in the study area is very high in Station 2 as the information of the groundwater hardness of the study area is shown in Table 3.10.

Table 3.10. Water hardness in the study area.

Station	Water hardess (ppm) in summer (A)		Water hardess(ppm) in rainy season (B)		Water hardess (ppm) in Winter (C)	
	Total	Hardness Scale	Total	Hardness Scale	Total	Hardness Scale
1	15.06	Soft	22.62	Slightly hard	7.47	Soft
2	684.50	Very hard	431.55	Very hard	557.00	Very hard
3	74.20	Moderately hard	129.50	Hard	186.55	Very hard
4	213.45	Very hard	27.14	Slightly hard	192.50	Very hard
5	2.66	Soft	3.70	Soft	9.92	Soft
6	62.05	Moderately hard	45.50	Slightly hard	56.30	Slightly hard
7	16.43	Soft	78.90	Moderately hard	54.10	Slightly hard
8	51.68	Slightly hard	33.32	Slightly hard	61.90	Moderately hard
9	93.60	Moderately hard	67.81	Moderately hard	103.30	Moderately hard
10	40.62	Slightly hard	76.84	Moderately hard	98.30	Moderately hard
11			23.97	Slightly hard	33.95	Slightly hard

(A), (B), and (C) are as in Table 3.2.

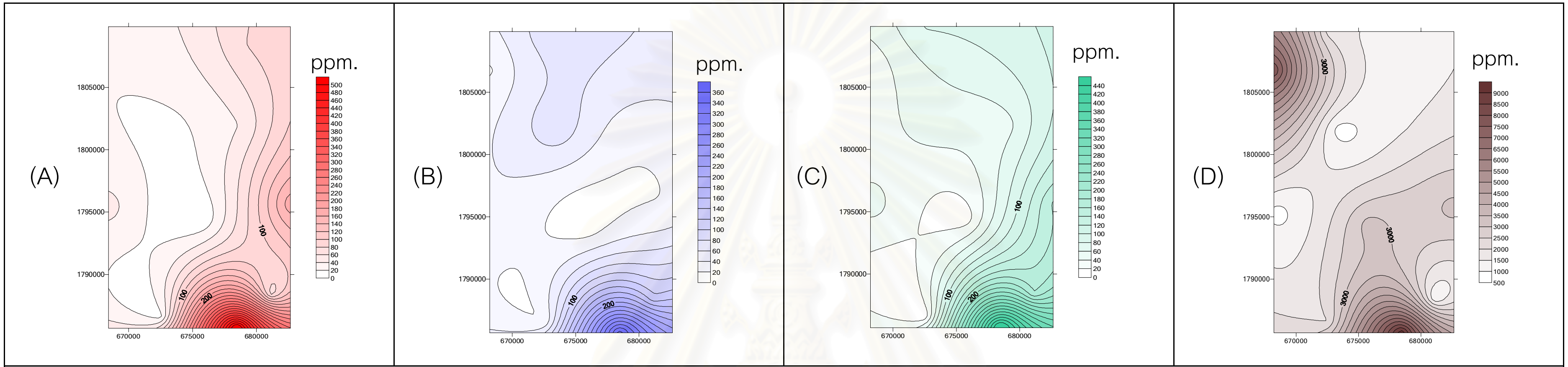


Figure 3.13. Calcium concentration pattern of subsurface water and soil chemical maps. (A) Of water in summer. (B) Of water in rainy season. (C) Of water in winter. (D) Of Soil.

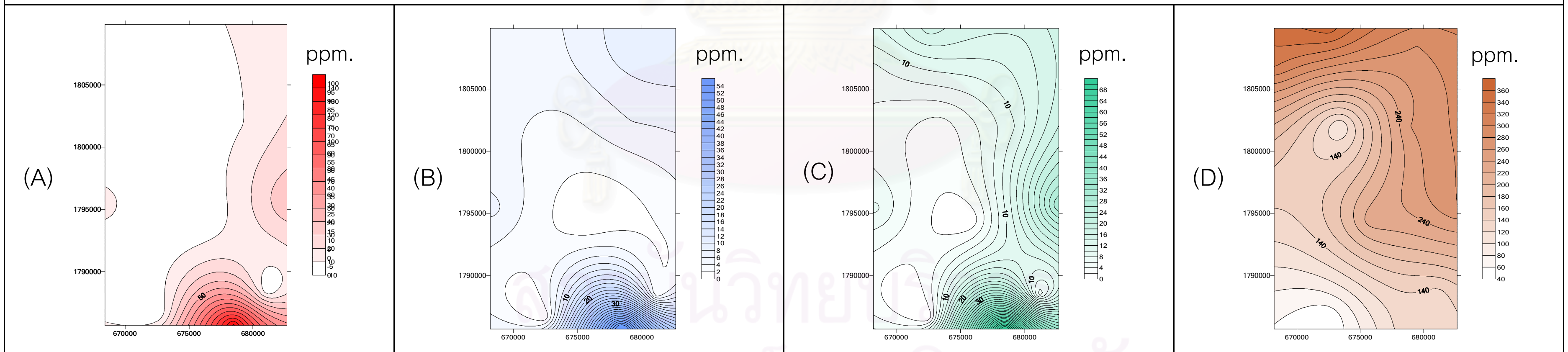
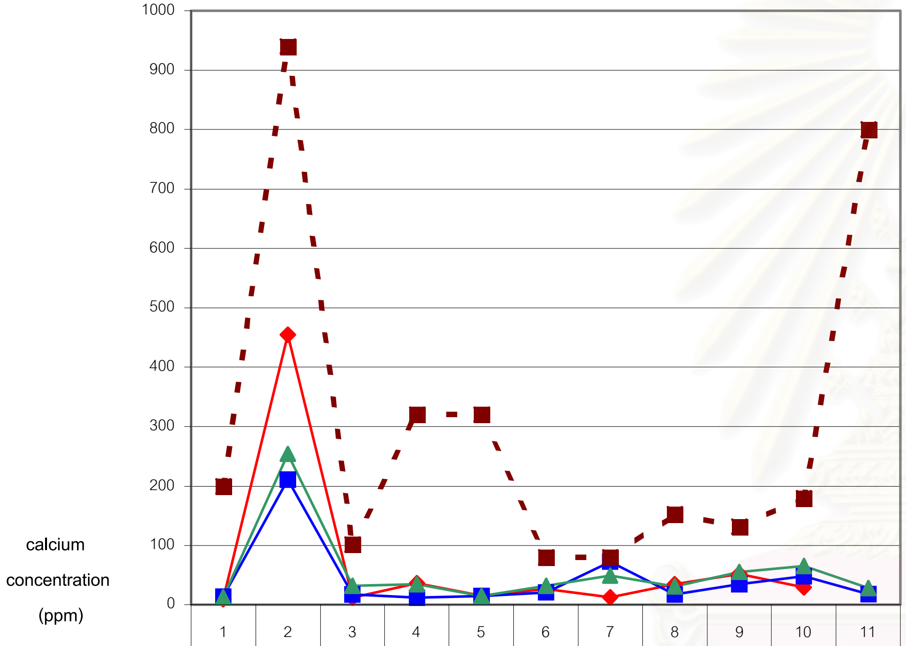
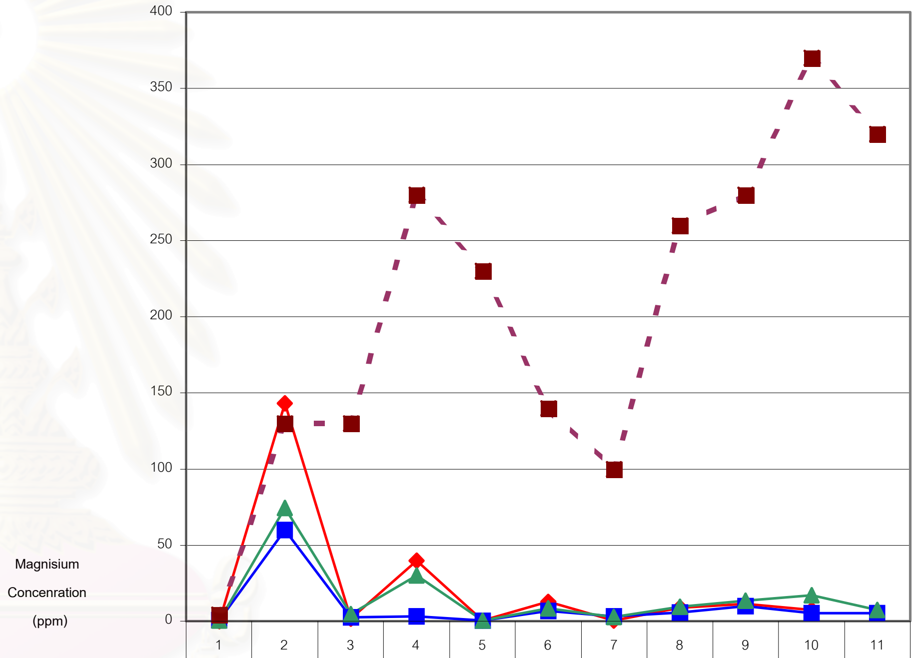


Figure 3.14. Magnesium concentration (ppm.)attern of subsurface water and soil chemical maps. (A) Of water in summer. (B) Of water in rainy season. (C) Of water in winter. (D) Of Soil.



	1	2	3	4	5	6	7	8	9	10	11
Ca (summer)	9.32	455	11.95	36.35	15.74	26.4	12.38	34.6	51.6	29.15	
Ca (rainy)	13.2	210.5	17.5	12.04	14.62	20.7	72.2	17.45	34.85	48.5	18.55
Ca (winter)	12.86	254.5	31.5	34.2	14.46	32.05	48.7	30.6	55.2	65.2	27.75
Ca (soil) * 10	200.0	940.0	102.0	320.0	320.0	80.0	80.0	152.0	132.0	180.0	800.0

Figure 3.15. Comparison of calcium concentration (ppm.) in the study area.



	1	2	3	4	5	6	7	8	9	10	11
Mg (summer)	0.162	143	1.7	39.6	0.259	12.85	0.366	9	11.4	7.38	
Mg (rainy)	0.7	59.75	2.4	3.36	0.245	6.66	3.25	5.72	9.75	5.34	5.42
Mg (winter)	0.253	74.5	4.75	30.1	0.324	8.5	2.9	9.4	13.3	17	7.55
Mg (soil)	4.2	130	130	280	230	140	100	260	280	370	320

Figure 3.16. Comparison of magnesium concentration (ppm.) in the study area.

Chloride (Cl^-)

Chloride is found in all natural waters, but chloride in groundwater is primarily associated with sedimentary rocks, especially evaporites. In groundwater, when chloride is the most dominant anion, sodium is oftenly the predominant cation.

Human influences also have an impact on the amount of chloride found in groundwater. Chlorine is used to clean drinking water by terminating bacteria. Also, Chlorine is used in herbicides, pesticides, drugs, dyes, metals, and plastics. However, leakage from the saline water body is accounted for the most of the elevated chloride level measured in waters.

Chloride concentration water in the study area is as shown in Table 3.11. The soil here was not tested for its chloride content. The chloride pattern in the study area is shown in Figure 3.17. Chloride concentration is high in the north central part of the study area, in Staions 7 and 8. A comparison of chloride concentration by graph is also shown in Figure 3.18.

Table 3.11. The data of water chloride concentration in study area.

Station	Water chloride (Cl^-) concentration (ppm)		
	Summer (A)	Rainy Season (B)	Winter (C)
1	9.29	14.86	13
2	31.58	28.79	31.58
3	14.86	5.57	14.86
4	0	1.86	3.72
5	16.72	7.43	13
6	1.86	0	0
7	37.15	120.74	79.88
8	39.01	23.22	27.86
9	7.43	22.29	6.5
10	7.43	3.72	5.57
11		1.86	0

(A), (B), and (C) are as in Table 3.2.

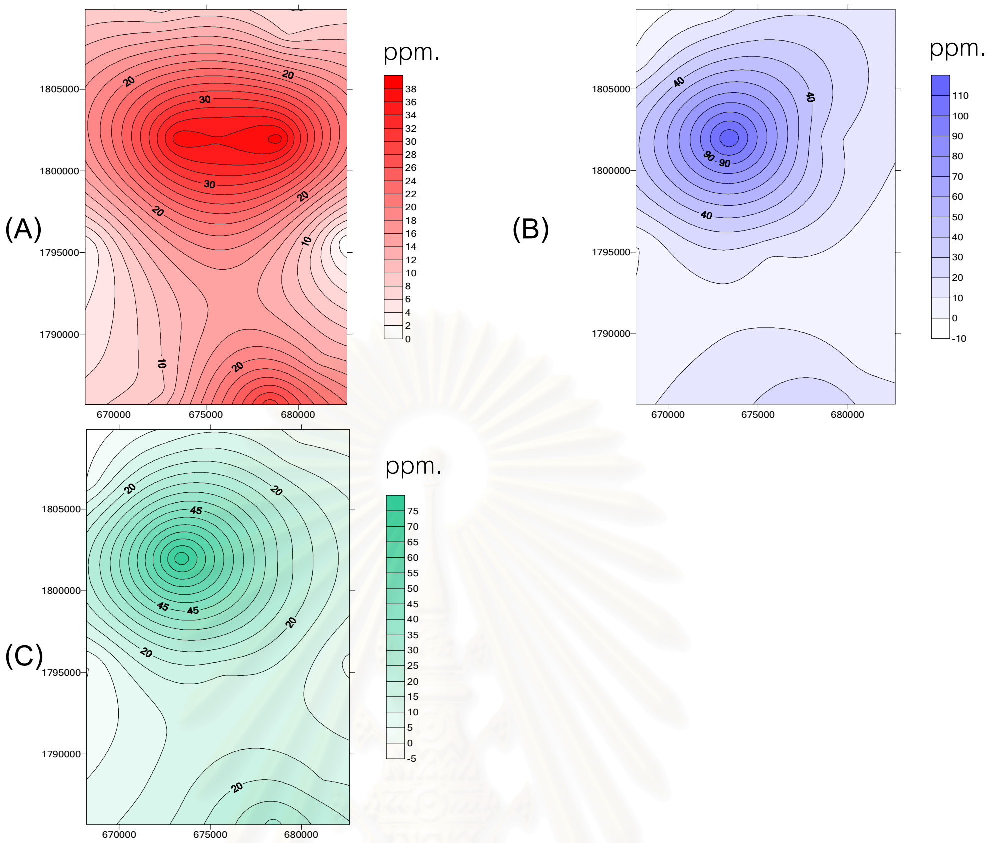
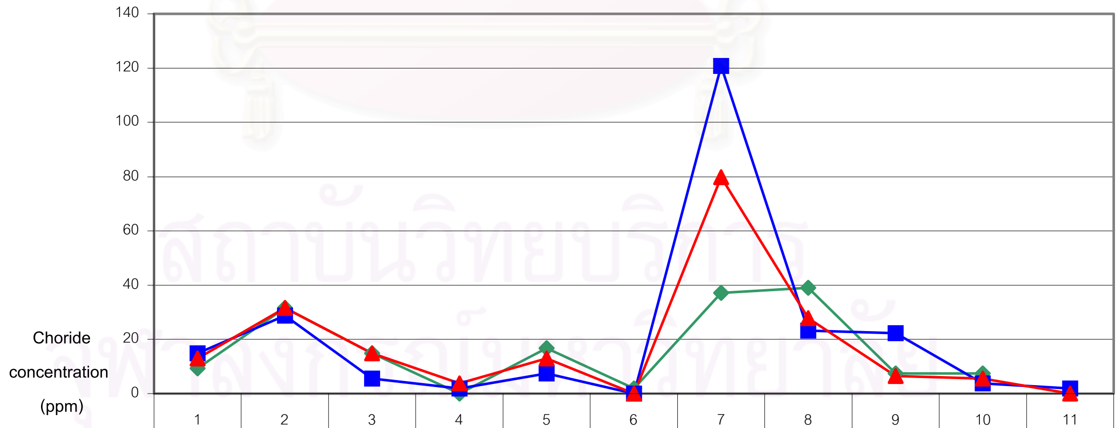


Figure 3.17. Chloride concentration (ppm.)of subsurface water and soil maps. (A) Of water in summer. (B) Of water in rainy season. (C) Of water in winter.



	1	2	3	4	5	6	7	8	9	10	11
Summer	9.29	31.58	14.86	0	16.72	1.86	37.15	39.01	7.43	7.43	
Rainy	14.86	28.79	5.57	1.86	7.43	0	120.74	23.22	22.29	3.72	1.86
winter	13	31.58	14.86	3.72	13	0	79.88	27.86	6.5	5.57	0

Well

Figure 3.18. Comparison of chloride concentration (ppm.) in the study area.

Potassium K^+

Potassium is an alkaline metal closely related to sodium. Potassium is commonly found in the environment, but is rarely found in groundwater above a level of 50 mg/l because potassium binds tightly to the clay fraction of soils. The abundance of potassium in the Earth's crust is as common as that of sodium, but potassium abundance is slightly less.

Potassium concentration in the study area is shown in Table 3.12. The highest potassium concentration in water is at Station 8 or the northwest of study area as shown in Figure 3.19. The potassium pattern of water in general is similary to that of soil but the highest content in soil is at Station 5 (Figure 3.20). The potassium content in water does not change much in the different seasons.

Table 3.12. Potassium concentration in water and soil in the study area.

Station	Water Potassium (K^+) concentration (ppm.)			Soil Potassium (K^+) concentration (ppm.)
	Summer (A)	Rainy Season (B)	Winter (C)	
1	0.639	0.799	0.903	98
2	0.577	0.779	0.481	26
3	0.474	1.952	2.05	28
4	3.25	9.42	2.2	86
5	1.413	1.404	1.511	700
6	4.63	2.83	9.1	25
7	9.695	49.9	28	83
8	111.4	79.6	83.9	112
9	3.04	2.425	1.8	7
10	1.865	4.74	0.7	94
11		4.13	7.55	136

(A), (B), and (C) are as in Table 3.2.

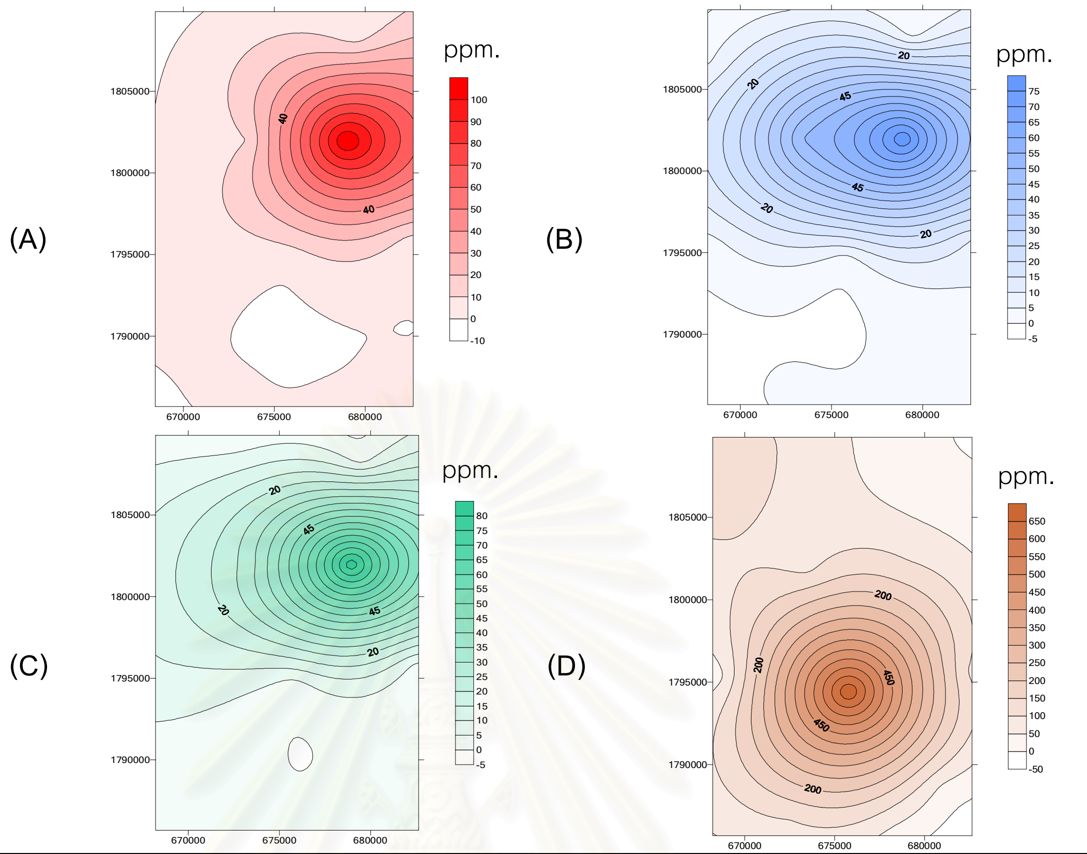
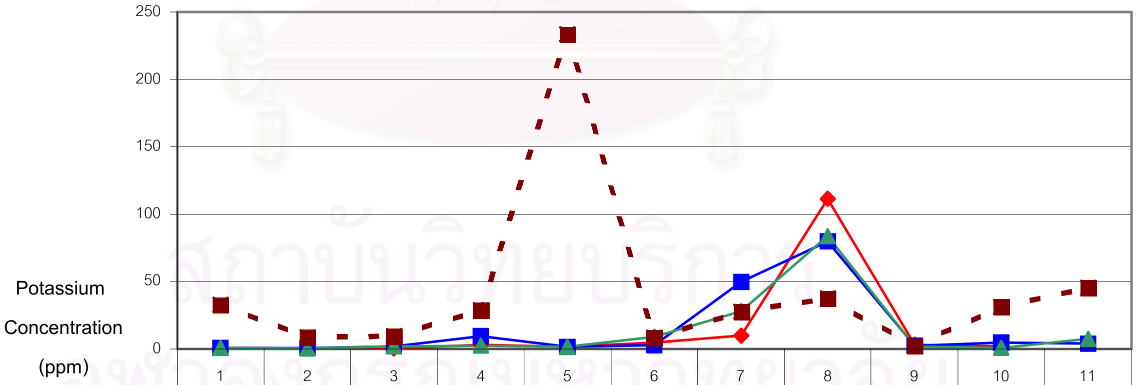


Figure 3.19. Potassium concentration (ppm.) pattern of subsurface water and soil map.
(A) Of water in summer. (B) Of water in rainy season. (C) Of water in winter.
(D) Of soil.



	1	2	3	4	5	6	7	8	9	10	11
Summer	0.639	0.577	0.474	3.25	1.413	4.63	9.695	111.4	3.04	1.865	
Rainy	0.799	0.779	1.952	9.42	1.404	2.83	49.9	79.6	2.425	4.74	4.13
winter	0.903	0.481	2.05	2.2	1.511	9.1	28	83.9	1.8	0.7	7.55
Soil *3	32.7	8.7	9.3	28.7	233.3	8.3	27.7	37.3	2.3	31.3	45.3

Well

Figure 3.20. Comparison of potassium concentration (ppm.) in the study area.

Nitrate (NO^{3-})

Nitrate is commonly introduced into groundwater from decaying organic matter, human and animal wastes, and fertilizers. It is highly soluble in water and is stable over a wide range of environmental conditions. It is easily transported in streams and groundwater. Nitrate is considered a nutrient for plants and microorganism. It stimulates algal growth and growth of other organisms which typically produce undesirable tastes and odors in groundwater.

The amount of nitrate measured in groundwater generally depends on the amounts of rainfall. The nitrate anion is the most common ionic form of nitrogen detected in groundwater. The nitrite and ammonium ions tend to be unstable in groundwater and therefore are less likely to be found.

Nitrate concentration in the study area as shown in Table 3.13. The pattern of nitrate concenbtration varied with seasons and not with soil concentration (Figure 3.21). Here it is higher in rainy season than in other seasons (Figure 3.22), perhaps because of agricultural chemical usage.

Table 3.13. Nitrate concentration of water and soil in the study area.

Station	Water Nitrate (NO^{3-}) concentration (ppm.)			Soil Nitrate (NO^{3-}) concentration (ppm.)
	Summer (A)	Rainy Season (B)	Winter (C)	
1	0.9	0.5	0	0.5
2	2	7.2	7	0.6
3	1.3	0.5	0.4	1
4	0.1	8.6	1.6	0
5	0.8	0.4	0.2	1.2
6	0.2	0.1	0.8	0
7	0.9	10.1	1.4	1.4
8	0.9	14.9	1.2	1.3
9	0.8	0.2	0.6	0.8
10	1.1	0.7	0	3.4
11		1.4	0.1	0.7

(A), (B), and (C) are as in Table 3.2.

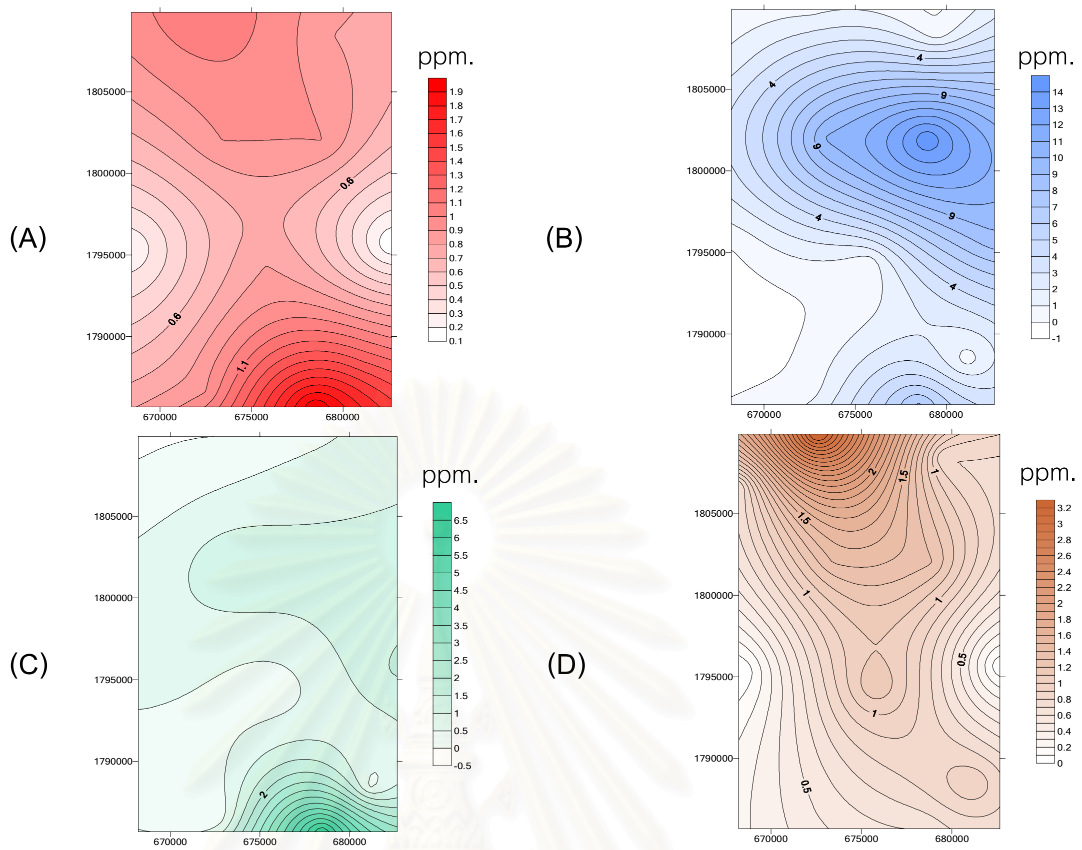
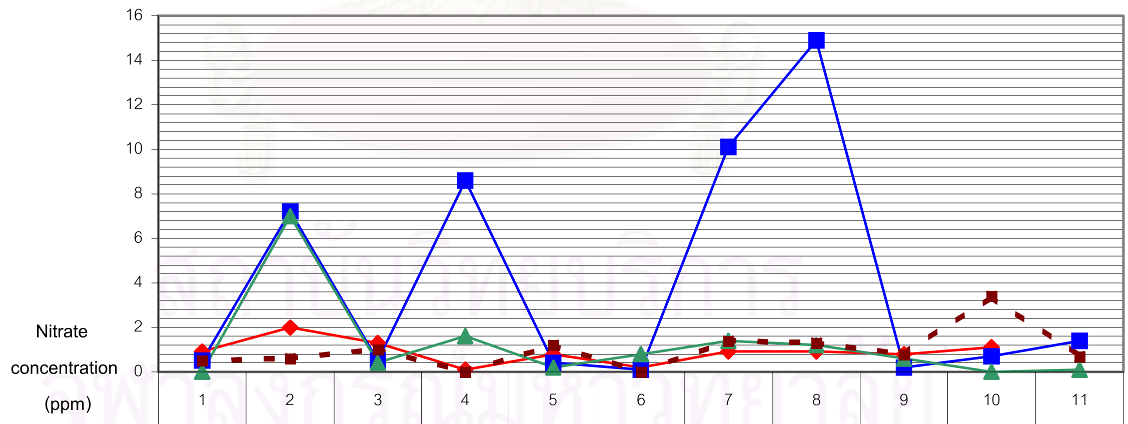


Figure 3.21. Nitrate concentration (ppm.) pattern of subsurface water and soil maps.

(A) Of water in summer. (B) Of water in rainy season. (C) Of water in winter.

(D) Of Soil.



	1	2	3	4	5	6	7	8	9	10	11
Summer	0.9	2	1.3	0.1	0.8	0.2	0.9	0.9	0.8	1.1	
Rainy	0.5	7.2	0.5	8.6	0.4	0.1	10.1	14.9	0.2	0.7	1.4
winter	0	7	0.4	1.6	0.2	0.8	1.4	1.2	0.6	0	0.1
Soil	0.5	0.6	1	0	1.2	0	1.4	1.3	0.8	3.4	0.7

well

Figure 3.22. Comparison of nitrate concentration (ppm.)in the study area.

Sulfate (SO_4^{2-})

Sulfate is a weak alkaline ion that could easily react with most acids. The most common source of sulfate in groundwater is from evaporites. When sulfide minerals are weathered, sulfur is oxidized to become sulfate and the ion is released into solution. Groundwater in semiarid regions tends to be comparatively high in dissolved solids and sulfate is a predominate anion in most of these regions. Sulfates tend to indicate older, trapped groundwater.

The concentrations of sulfate in the study area are shown in Table 3.14. The sulfate study was incomplete so the sulfate concentration pattern was not attempted.

Table 3.14. The data of water sulfate concentration in study area.

station	Water Sulfate (SO_4^{2-}) concentration (ppm.)			Soil Sulfate (SO_4^{2-}) concentration (ppm.)
	Summer (A)	Rainy Season (B)	Winter (C)	
1		-	1	16
2	-	1800	1200	8
3	-	350	100	6
4	-	-	21	14
5	-	-	3	14
6	-	-	8	6
7	-	-	37	10
8	-	-	36	16
9	-	-	19	6
10	-	-	37	8
11		-	34	10

(A), (B), and (C) are as in Table 3.2.

Metals

Metal concentrations above the trace amount level are generally toxic to living things. Trace metals are occurred naturally but they could be potential contaminants with human activities influencing their levels in the environment. Trace amounts (<0.05 mg/L) of Zn, Cu and Mn are presented in most natural waters. Zn and Cu may be presented in higher levels in water in irrigation areas due to the use of galvanised iron, copper and brass in plumbing fixtures and for water storage.

Iron (Fe^{3+})

Iron is the fourth most abundant element, by weight, in the Earth's crust. Natural waters contain variable amounts of iron despite its universal distribution and abundance. Iron in groundwater is normally present in the ferrous or bivalent form ($Fe2^{+}$), forming a clear, colourless solution until it comes into contact with oxygen. Oxygen changes iron to the ferric state (Fe^{3+}) which reacts with alkalinity in the water or exposure to air and forms an insoluble brown ferric hydroxide precipitate.

Iron in water may be presented in varying quantities depending on the geological area and other chemical components of the waterway. Ferrous (Fe^{2+})$^{++}$ and ferric (Fe^{3+})$^{+++}$ ions are the primary forms of concern in the aquatic environment. Other forms may be in either organic or inorganic wastewater streams.

Copper (Cu^{2+})

Copper salts are used in water-supply system to control biological growths in reservoirs and water-supply pipes, and to catalyze the oxidation of manganese. Corrosion of copper-containing alloys in pipe-fitting may introduce measurable amounts of copper into the water in a pipe system.

Zinc (Zn^{2+})

Zinc most commonly enters the domestic water supply from deterioration of galvanized iron and dezincification of brass. In such cases lead and cadmium also may be presented because they are impurities of the zinc used in galvanizing. Zinc in water also may result from industrial waste pollution.

The metal concentrations in this study are shown in Table 3.15. The metals in soil are much higher than in water, commonly 20 –50 times higher. The patterns of metal concentration of iron (Fe^{3+}) are shown in Figure 3.23, Copper (Cu^{2+}) in Figure 3.24, and Zinc (Zn^{-}) in Figure 3.25 respectively. The comparisions of the concentration indifferent seasons of iron (Fe^{3+}), copper (Cu^{2+}), and zinc (Zn^{-}) are shown in Figures 3.26, 3.27 and 3.28 respectively.

The patterns of these three metals do not have a conformable change in each season, so it could mean a lot of factors have influence on the metal concentration.

Table 3.15. Metal concentrations in water and soil in the study area.

station	Concentration of iron (Fe^{3+}) (ppm)				Concentration of copper (Cu^{2+}) (ppm)				Concentration of zinc (Zn^{2+}) (ppm)			
	in Water			In soil	in Water			In soil	in Water			In soil
	summer(A)	rainy season(B)	winter(C)		summer(A)	rainy season(B)	winter(C)		summer(A)	rainy season(B)	winter(C)	
1	0.831	0.571	0.794	46.32	0.005	0.003	0.054	1.382	0.004	0.004	0.024	1.728
2	0.189	0.007	0.012	6.866	0.016	0.013	0.043	1.488	0.035	0.018	0.015	0.384
3	0.034	0.037	0.097	10.608	0.002		0.064	0.748	0.004	0.007	0.009	3.82
4	0.013	0.019	0.155	69.16	0.008	0.1	0.068	1.302	0.002	0.018	0.014	8.68
5	0.014	0.065	0.057	8.892	0.01	0.005	0.073	0.476	0.012	0.003	0.016	4.795
6	0.433	0.408	0.652	41.75	0.006		0.079	0.732	0.003	0.02	0.011	0.412
7	0.005	0.028	0.163	26.705	0.003	0.001	0.072	0.59	0.004	0.016	0.021	2.99
8	0.031	0.356	0.051	42.64	0.004	0.006	0.074	0.812	0.004	0.001	0.007	4.52
9	0.866	0.273	1.415	32.54	0.004	0.08	0.079	0.884	0.003	0.006	0.013	0.696
10	0.046	0.14	0.073	99.48	0.002	0.007	0.087	2.324	0.005	0.028	0.019	3.96
11		0.934	0.068	7.782		-	0.094	1.13		0.002	0.015	0.724

(A),(B), and (C) are as in Table 3.2.

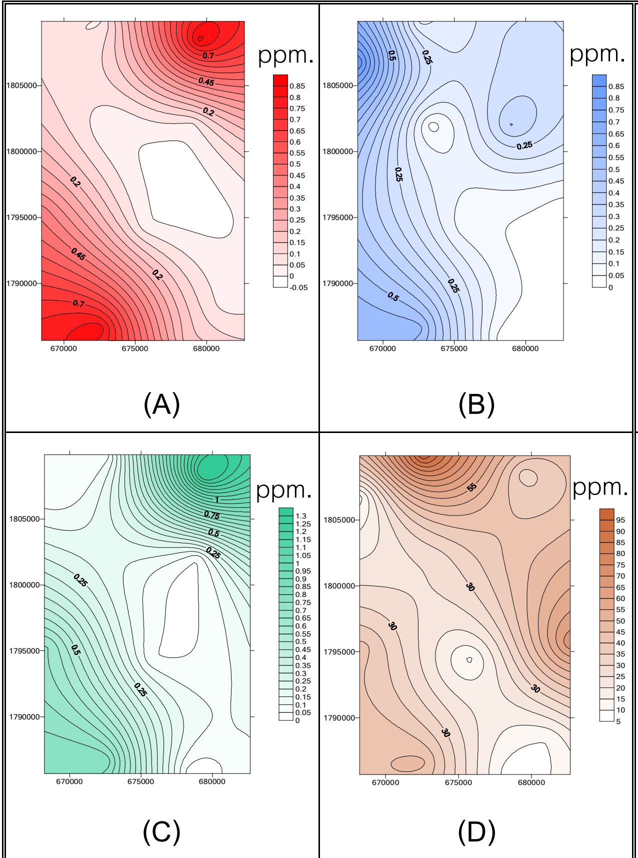


Figure 3.23. Iron concentration pattern of subsurface water and soil maps. (A) Of water in summer. (B) Of water in nainy season. (C) Of water in winter. (D) Of soil.

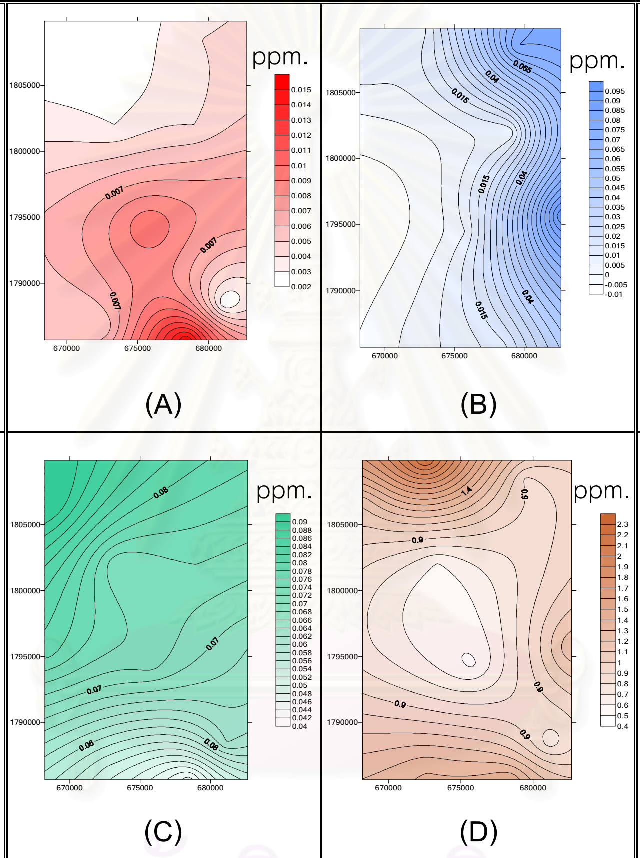


Figure 3.24. Cupper concentration pattern of subsurface water and soil maps. (A) Of water in summer. (B) Of water in nainy season. (C) Of water in winter. (D) Of soil.

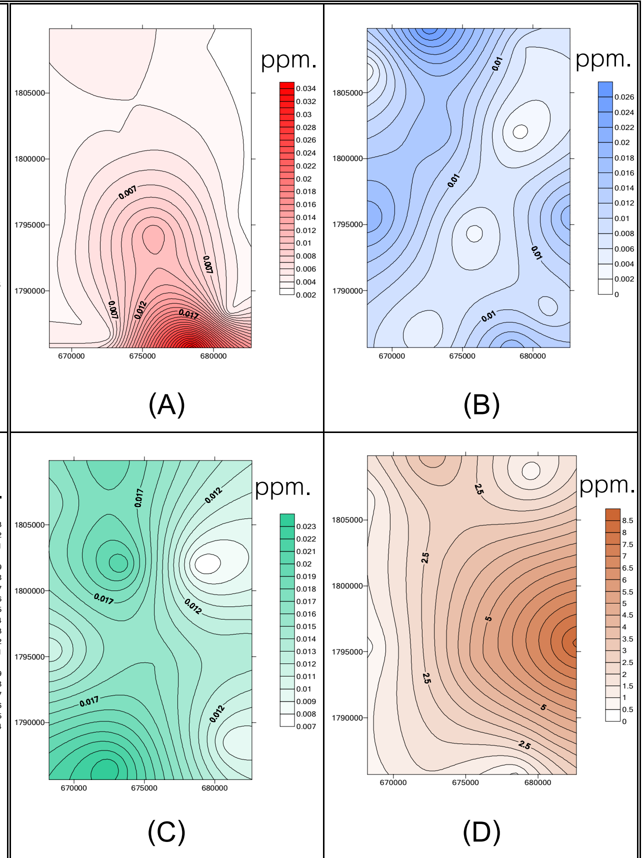
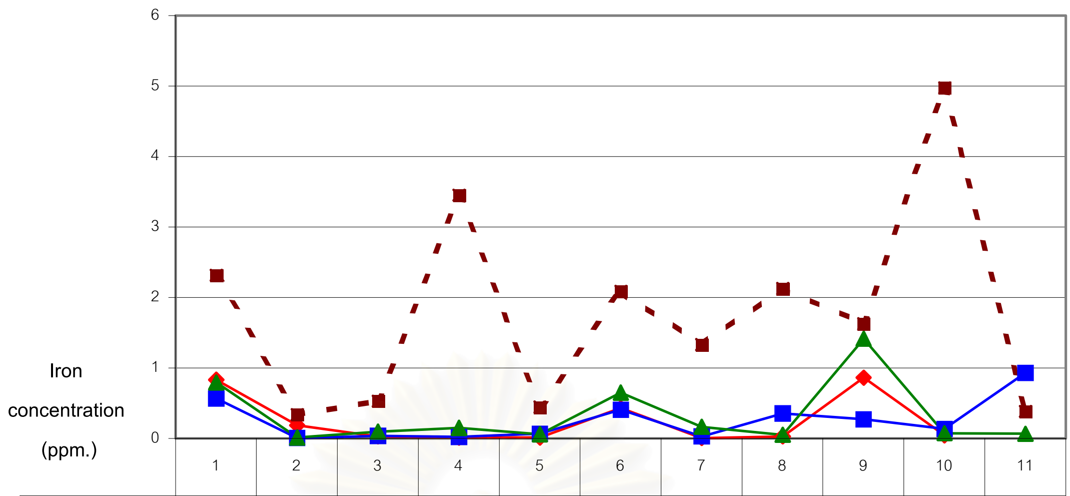


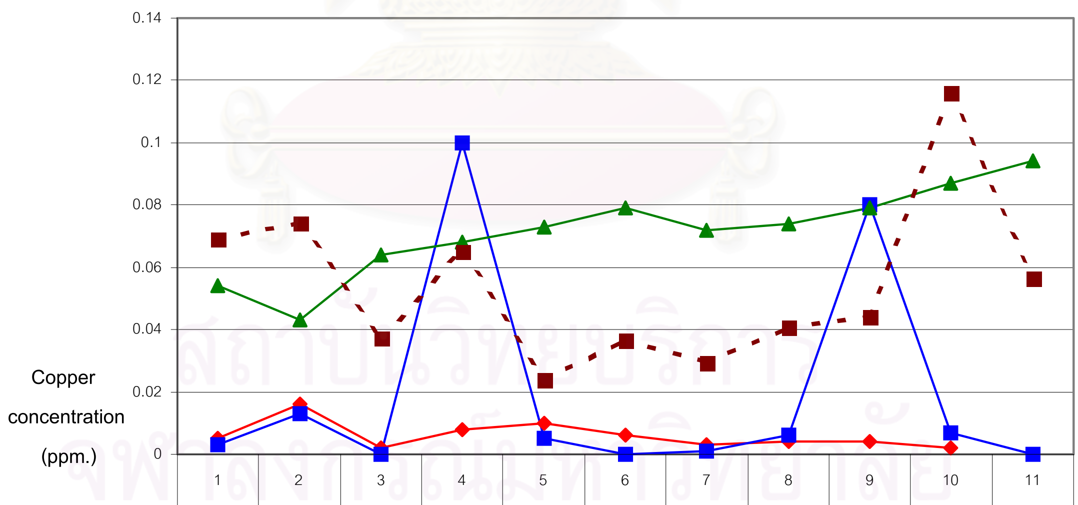
Figure 3.25. Zinc concentration pattern of subsurface water and soil maps . (A) Of water in summer. (B) Of water in nainy season. (C) Of water in winter. (D) Of soil.



	1	2	3	4	5	6	7	8	9	10	11
summer	0.831	0.189	0.034	0.013	0.014	0.433	0.005	0.031	0.866	0.046	
rainy	0.571	0.007	0.037	0.019	0.065	0.408	0.028	0.356	0.273	0.14	0.934
winter	0.794	0.012	0.097	0.155	0.057	0.652	0.163	0.051	1.415	0.073	0.068
soil*20	2.316	0.3433	0.5304	3.458	0.4446	2.0875	1.33525	2.132	1.627	4.974	0.3891

well

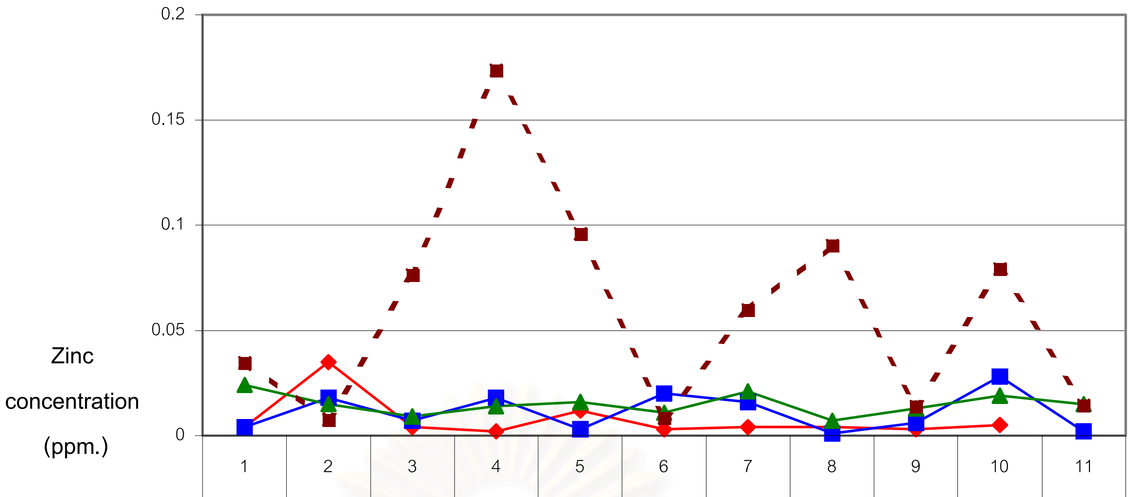
Figure 3.26. Comparison of iron concentration (ppm.) in the study area.



	1	2	3	4	5	6	7	8	9	10	11
summer	0.005	0.016	0.002	0.008	0.01	0.006	0.003	0.004	0.004	0.002	
rainy	0.003	0.013	0	0.1	0.005	0	0.001	0.006	0.08	0.007	0
winter	0.054	0.043	0.064	0.068	0.073	0.079	0.072	0.074	0.079	0.087	0.094
soil*20	0.0691	0.0744	0.0374	0.0651	0.0238	0.0366	0.0295	0.0406	0.0442	0.1162	0.0565

well

Figure 3.27. Comparison of copper concentration (ppm.) in the study area.



	1	2	3	4	5	6	7	8	9	10	11
summer	0.004	0.035	0.004	0.002	0.012	0.003	0.004	0.004	0.003	0.005	
rainy	0.004	0.018	0.007	0.018	0.003	0.02	0.016	0.001	0.006	0.028	0.002
winter	0.024	0.015	0.009	0.014	0.016	0.011	0.021	0.007	0.013	0.019	0.015
soil*50	0.03456	0.00768	0.0764	0.1736	0.0959	0.00824	0.0598	0.0904	0.01392	0.0792	0.01448

well

Figure 3.28. Comparison of zinc concentration (ppm.) in the study area.

Cyanide (CN^-)

Cyanide is an ion composed of carbon and nitrogen (CN^-). The cyanide compounds, usually the sodium-potassium salts, are used in the gold-mine metal extraction and metal finishing and plating industries because of its ability to bind very strongly to metals to form water-soluble complex ions. This same property makes it highly toxic to living things because it stops the normal function of the metal-containing molecules.

Cyanide concentration may be biodegradable by some bacteria to a low concentration, or it can become acclimated to a higher concentration if given enough time. For unacclimated microorganisms in a wastewater treatment plant, however, a cyanide dump by an industry can lead to inhibition or even death.

The cyanide concentration in water in the study area is as shown in Table 3.16. The method to study cyanide concentration in soil is very complicate and very expensive so it was not studied here. The pattern of water concentration is shown in Figure 3.29 and comparison of cyanide in each period is as shown in Figure 3.30.

Table 3.16. Cyanide concentration in water in the study area.

Station	Water Cyanide (CN^-) concentration (ppm)		
	Summer (A)	Rainy Season (B)	Winter (C)
1	0.01	Detection limited	Detection limited
2	0.01	0.028	0.009
3	0.028	0.004	0.027
4	0.037	0.001	0.01
5	0.002	0.001	0.007
6	0.004	0.003	0.001
7	0.001	Detection limited	Detection limited
8	0.003	0.001	Detection limited
9	0.004	0.001	Detection limited
10	0.002	0.001	Detection limited
11		0.008	Detection limited

(A),(B) and (C) are as in Table 3.2.

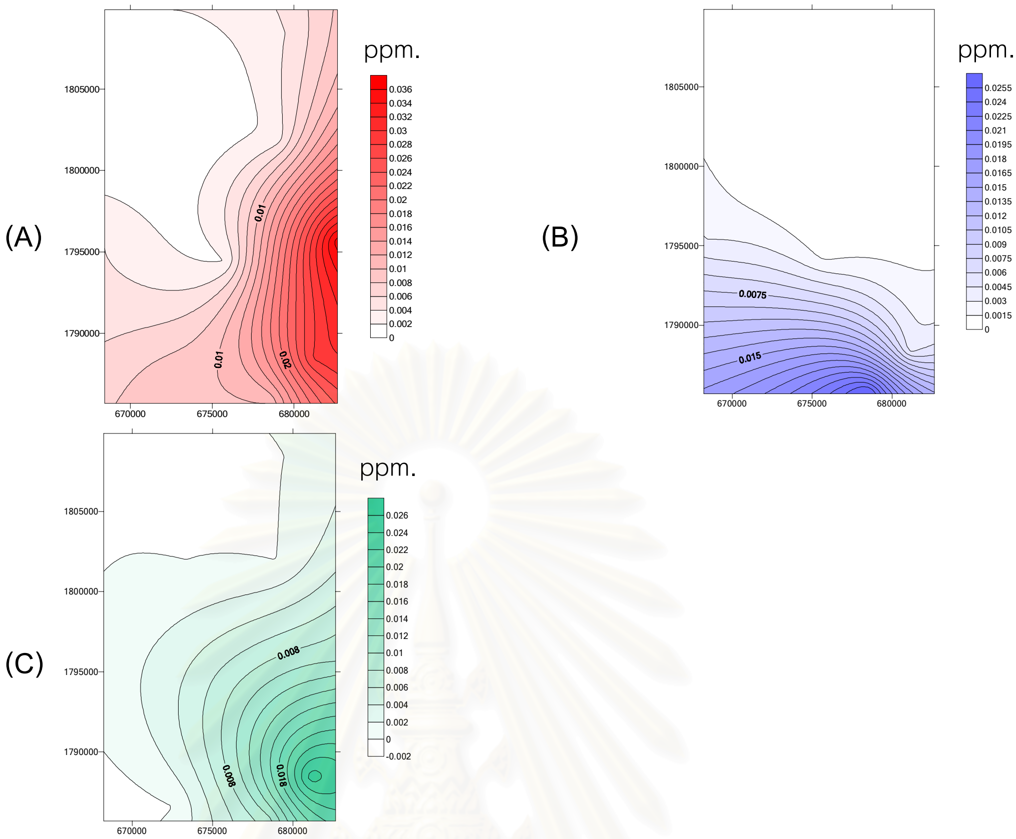
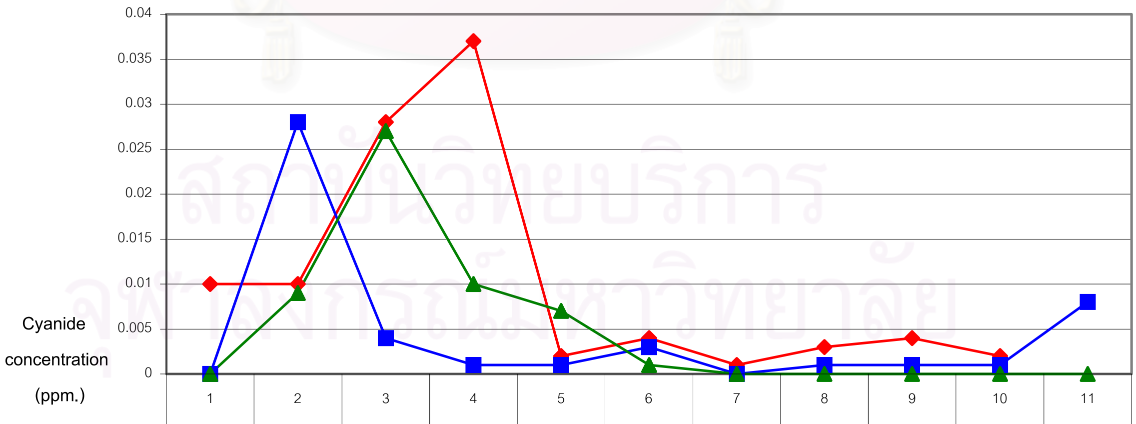


Figure 3.29. Cyanide concentration (ppm.) pattern of subsurface water maps.

(A) Of water in summer. (B) Of water in rainy season. (C) Of water in winter.



	1	2	3	4	5	6	7	8	9	10	11
summer	0.01	0.01	0.028	0.037	0.002	0.004	0.001	0.003	0.004	0.002	
rainy	0	0.028	0.004	0.001	0.001	0.003	0	0.001	0.001	0.001	0.008
winter	0	0.009	0.027	0.01	0.007	0.001	0	0	0	0	0

Well

Figure 3.30. Comparison of cyanide concentration (ppm.) in the study area.

The cyanide pattern is of high concentration to the southeastern corner of the study area at staion 2,3 and 4. The CN^- concentration do not vary with seasons but it is not yet understood of the source of this chemical.

3.3.4 Soil texture

Apart from 11 soil samples which were collected for the determination of chemical and physical chemical properties mentioned in the previous chapters, 15 more soil samples were collected to check the accuracy of soil-group map, and to investigate some physical soil properties in laboratory. The locations of soil sampling were different from those previously mentioned as they were chosen from soil-group map in the study area (Shown in Appendix E). The sampling locations are shown in Figure 3.31 while the study results of soil texture and some others physical properties are shown in Table 3.17.

Table 3.17. Soil texture and others physical properties.

No.	UTM Grid reference		Porosity %	%Organic matter	%Sand	%Silt	%Clay	Texture
	East	North						
ST-1	672520	1786606	51	1.7	54	31	15	sandy loam
ST-2	678458	1785694	50	3.1	50	25	25	sandy clay
ST-3	681139	1788451	62	2.2	48	23	29	sandy clay
ST-4	682642	1795647	40	4.8	64	19	17	sandy loam
ST-5	675773	1794425	45	3.8	70	21	9	sandy loam
ST-6	668437	1795390	33.5	1.3	66	19	15	sandy loam
ST-7	673402	1801985	35	1.4	64	27	9	sandy loam
ST-8	678956	1801961	39	2.8	56	27	17	sandy loam
ST-9	679463	1808480	44.5	1.1	72	15	13	sandy loam
ST-10	672577	1809860	52	2.5	34	37	29	clay loam
ST-11	668220	1806748	50	1.3	52	25	23	sandy clay
ST-12	668226	1806841	40	1.6	46	36	18	loam
ST-13	679607	1806511	37	1	50	28	22	clay loam
ST-14	670594	1793537	37	1.5	56	24	20	sandy clay
ST-15	678343	1794785	42	3.7	72	24	4	sandy loam

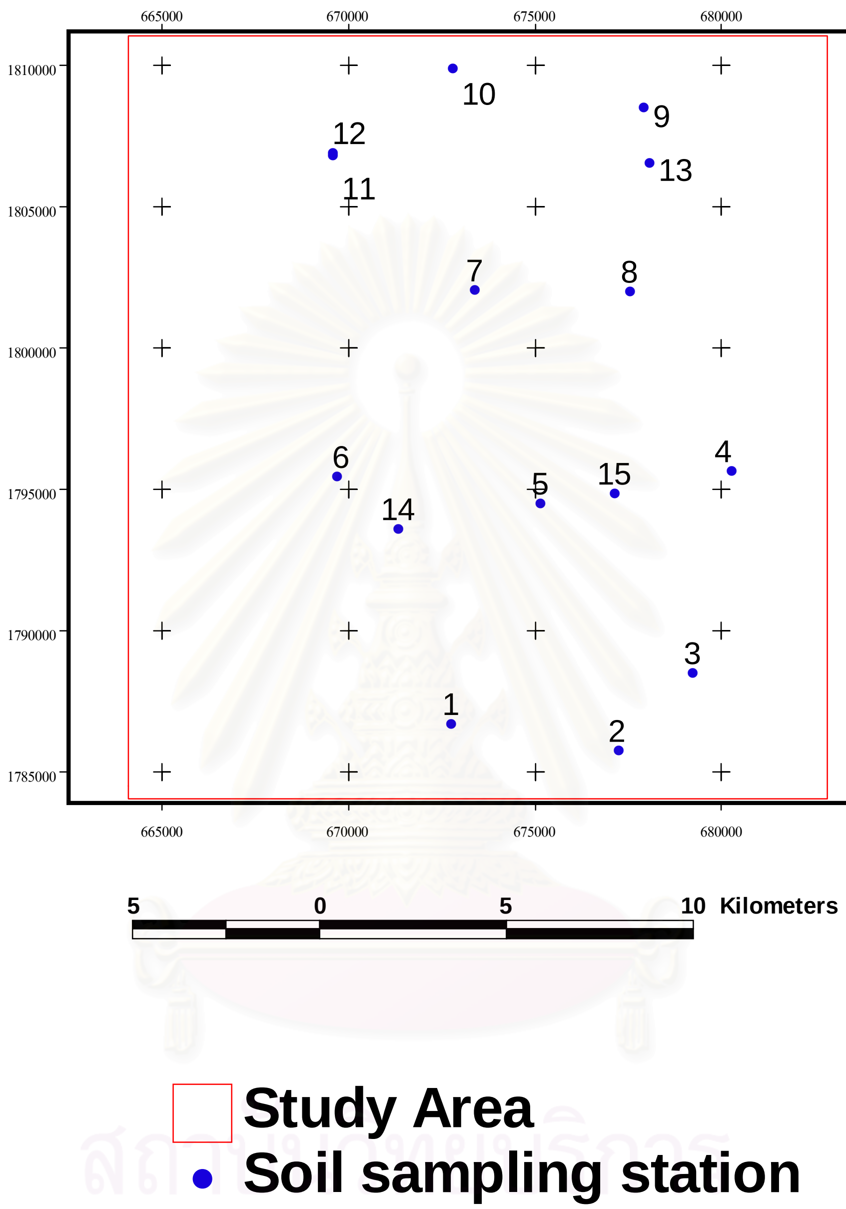


Figure 3.31 Soil sampling locations for physical properties studies.

3.3.4.1 Soil groups in study area

Soil type is a very important factor for calculating the water balance because it affects the infiltration. Soil groups in Thailand were studied by Department of Land Development, Ministry of Agriculture and Cooperatives.

The soil groups and physical properties, or the soil textures, are needed for the consideration of the infiltration rate. The corrected soil textures are based on the data from the Land Development. Department, together with the field observation and laboratorial study to be compiled as soil texture map as shown in Figure 3.32. The improved soil textures were used in calculation of the infiltration rate.

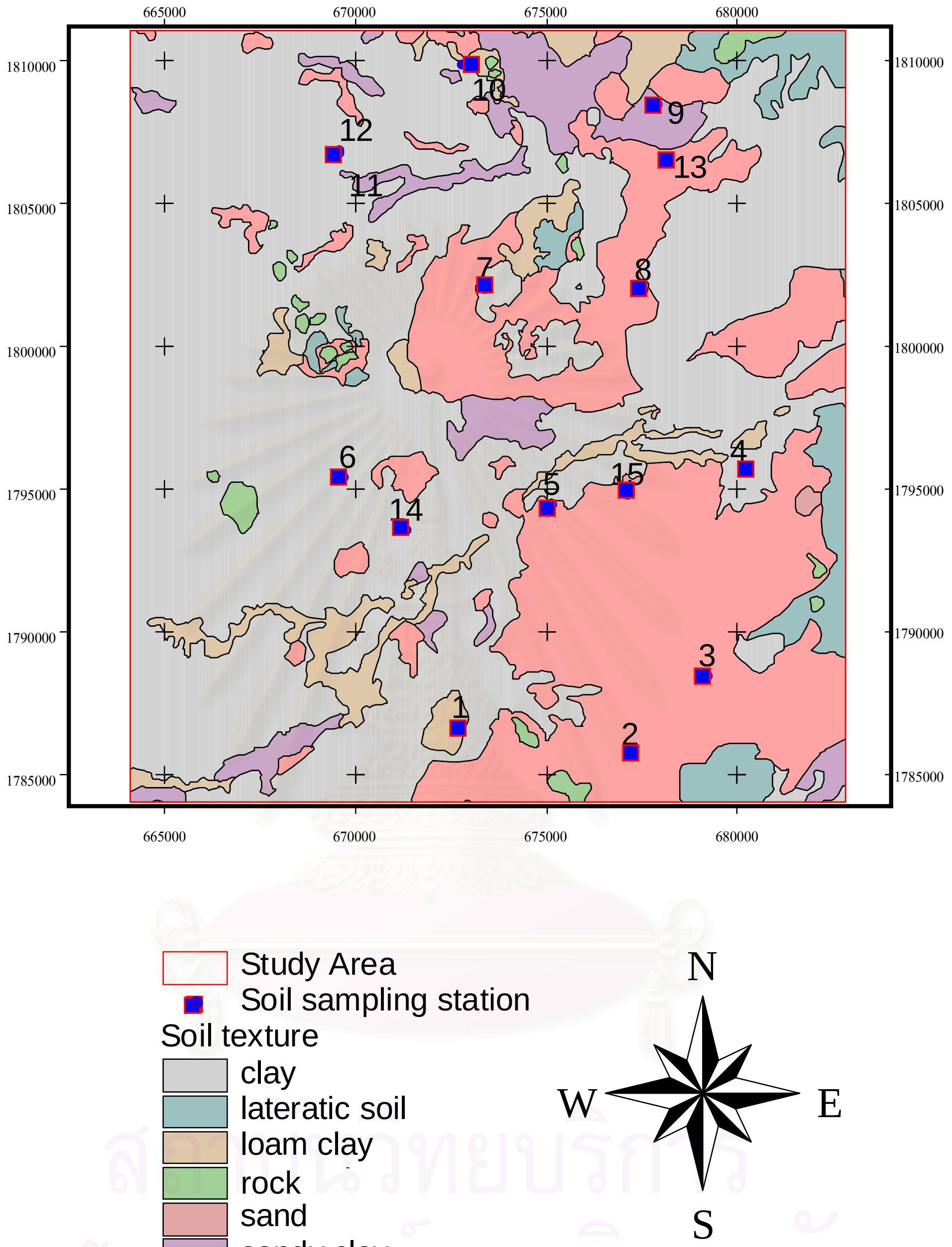


Figure 3.32. Soil map of the study area. The map was based on the soil-group map of the Land Development Department with the field check and laboratorial study of the soil samples done in this study.

3.4 Infiltration

Infiltration is the entry of water into the soil through pores. Understanding infiltration is essential to describe the groundwater recharge component of the hydrologic cycle. Texture and structure determine soil porosity, permeability, and the rate through which water can move into soil. In the event of rain, some part of rain returns to the atmosphere through evaporation or evapotranspiration, some part infitrates into the soil, and the rest stays or flows on ground. This is the surface water balance system.

Infiltration rate is affected by many factors such as vegetation, temperature, soil texture or soil structure, and rainfall duration and intensity. So the rate of infiltration varies in the inhomogeneous soil and vegetation.

Infiltration rate can be determind by infiltrometer. In this research the double ring infiltrometers were used to measure rate of infiltration (Figure 3.33). The concept of double rings infiltrometry is explained in Appendix A.

Figure 3.33 Double rings infiltrometers for testing the infiltration rate.

3.4.1 Infiltration test

(a) Selection of test sites

As the infiltration study is to gain knowledge, on the ability to absorb and transfer downward of the rain water, of the areal ground surface in its natural condition. It is thus essential to keep the study ground surface as it is naturally. As it was noted that in the most part of the area, just before the agricultural season of any field crop, the soil surface was generally covered only with short grass, thus the test sites were selected with this condition. The areas with different types of soil were also selected to gain knowledge on the different rate of infiltration through these soils. It is unfortunately that not every type of soil can be tested in this study due to some limitation of the testing equipments. The infiltration rate in those problematic soils must be obtained by the other means.

(b) Field – test equipments

The study for the infiltration was performed using the double-ring infiltrometers. The equipment were compsoed of 3 sets of double stainless-steel rings, each 25 cm. tall with the diameters of each set of the rings, small inner ring and large outer ring, in cm. as 28/53, 30/55 and 32/57 respectively. The two rings in each set were driven 10 cm. down into the soil by way of pounding evenly on to the top driving steel plate. The water was then pour into the rings, and let it infiltrate into the soil with an open-head. The infiltration was measured from inner ring by which the water moved vertically downward while the water in the outer ring only prevents the sideward movement of the water in the inner ring.

(c) Measurement method

The water was poured into both ring spaces as mentioned above to a height of about 2/3 of that of the exposed part of rings. The level was maintained throughout the study by which the water level in the outer-ring space was only approximately the same, but that in the inner ring space must be accurate, as indicated by the floating level-indicator. Accurate amount of water, in ml., must be recorded for to maintain that inner-ring water level throughout the study procedure, 30 minutes in the present study. The infiltration rate was calculated using an equation below.

$$K = \frac{V_w}{\pi r^2 \times t}$$

K = coefficient of permeability, or infiltration (mm/min)

V_w = amount of water required to retain the initial water level in the inner ring (ml.),

r = radius of the inner ring (mm),

and t = test time (min.).

3.4.2. Infiltration rate in study area

Five test stations were chosen for the infiltrarion study. The selection was done according to the soil types appeared in the area (Figure 3.32). Three tests had been performed at each site concurrently, each test with the different sets of double ring infiltrometers. The study was done on 22 March 2003, and the study results are shown in Table 3.18.

Table 3.18. the result of infiltration rate observation in the study area.

ID	Soil texture	UTM GRID		Infiltration rate (mm/minute)			
		East	North	(1)	(2)	(3)	AVERAGE
1	sandy clay	672520	1786606		0.01		0.01
2	loam	668226	1806841	0.026	0.001	0.008	0.012
3	clay loam	679607	1806511	0.0060	0.0070	0.0064	0.006
4	sandy clay	670594	1793537	0.052	0.011	0.013	0.02
5	sandy loam	678343	1794785	0.024	0.057	0.083	0.0532

(1),(2),(3) are for 3 sets of double ring infiltrometers, from small to large respectively.

Lateratic soil is of a limit for this study because the soils are too hard to drive the rings into to check the rate of infiltation. The missing infiltration rates were referred to those having been performed by American Geological Institute, Soil Science Society of America, USDA Natural Resource Conservation Service publication (1999). Table 3.19 illustrates the infiltration rate study result.

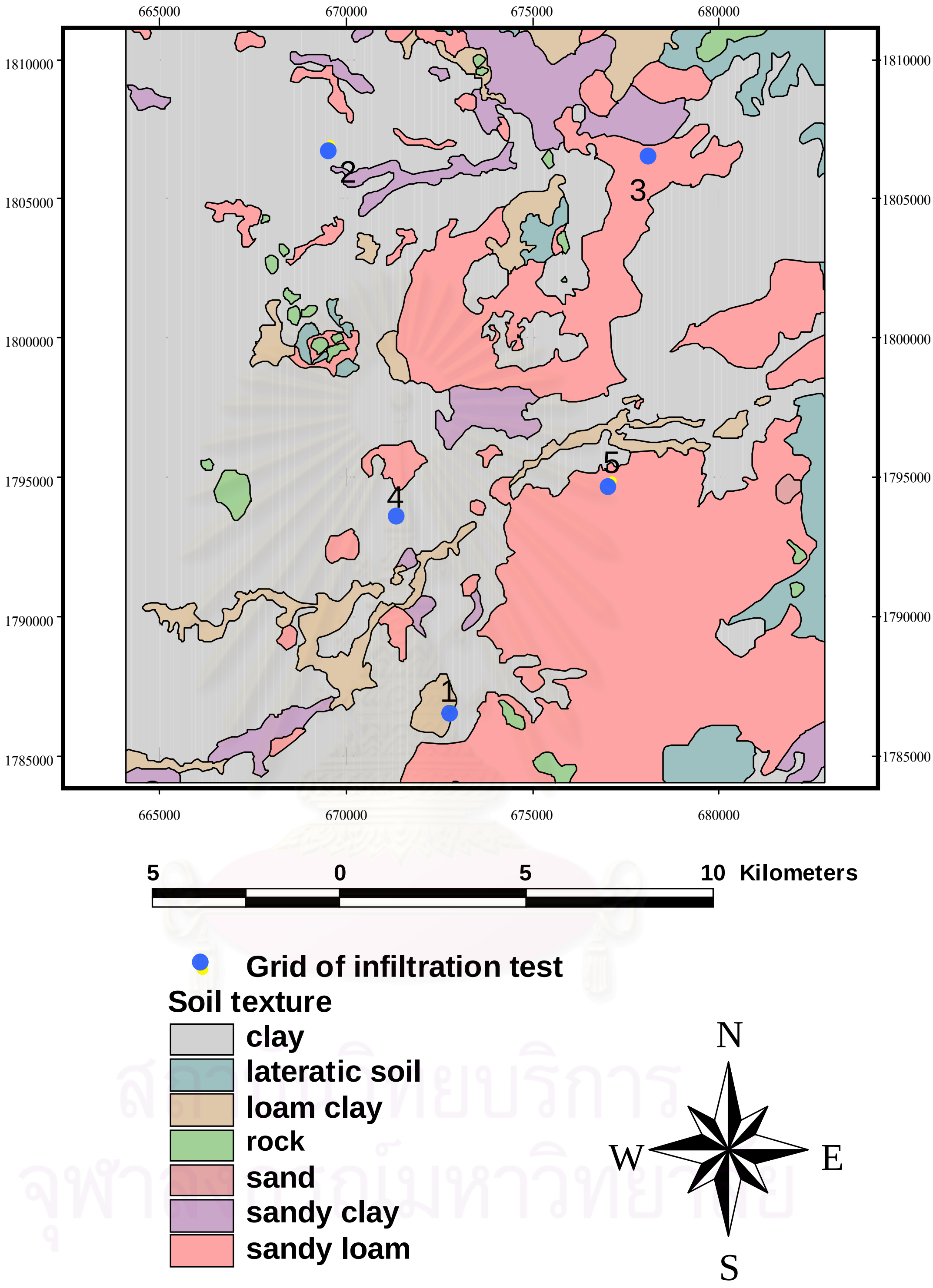


Figure 3.34. The test sites for infiltration and soil texture map.

Table3.19. The infiltration rates used for this study. The rates are according to the field studies done by the present author. Whenever there was no study done, the rate were quoted from American Geological Institute, Soil Science Society of America, USDA Natural Resource Conservation Service publication. (1999).

Rate of in filtration (mm/minute)			
Soil texture	Texas Council of Governments	This field study	Infiltration rate (K) used in this study
Sand	0.033	0.0532	0.0532
Sandy loam	0.042	0.0532	0.0532
Loam sand	0.0083	-	0.0083
Sandy clay	-	0.0015	0.0015
Loam	0.0021	0.0120	0.0120
Silt loam	0.0011	-	0.0011
Sandy clay loam	0.0006	-	0.0006
Clay loam and silty clay loam	0.0004	0.0006	0.0006
Clay	0.0002	-	0.0002

3.4.2 Estimation infiltration

It was noticed in the study that the permeable clay soil layer at the surface only allowed a rapid infiltration for about the first 30 minutes. After then, the infiltration was slow down to almost stop. This could be because the upper permeable layer was underlain by some impermeable layers. So the infiltration rate obtained above is probably true for the upper lying soil layer, perhaps only few ten centimeters thick. The time limit for infiltration is probably because when the permeable layer was saturated, it could accept no more water before there is any means to reduce the soil saturation first. If the rainfall is shorter than 30 minutes, the saturation reduction must be completed before the next rainfall arrives. If longer, the precipitation after 30 minutes must stay above ground, or have to flow as the surface runoff. Also, if the rainfall rate exceeds the infiltration rate, the rain water has to stay above ground or to flow as runoff as well. So the amount of water that infiltrates in the study area in one minute can be calculated by infiltration rate (mm./min.) multiply with the number of the day of rain

Amount of infiltration in one minute (INF)

INF = rate of infiltration (K) (mm^3)

When K = Rate of infiltration

Amount of infiltration one day (INF_{day}) when raining duration is 30 minutes or longer (K_{day})

INF_{day} = rate of infiltration (K) X 30

……….. (1)

Amount of infiltration for period study infiltration (INF_{period})

INF_{period} = INF_{day} X Day of raining

……….. (2)

Considering the statistics of the raining days (Appendix B), 50% of the days have an amount of raining more than 10 mm. and 50% less. Rainfall more than 10 mm. means that the duration of raining is longer than 30 minutes, while rainfall is less than 10 mm. means that the duration of raining is shorter than 30 minutes. But this could pose a problem when calculating for an amount of infiltration by using Equation 2 because the amount of infiltration. Therefore, the calculation of the infiltration rate was done by an average.

With amount of rainfall more than 10 mm, Equation 1 becomes

INF_{day} (more 10 mm.) = rate of infiltration (K) X 30 minutes

……….(3)

50% of all raining days having an amount of rainfall more than 10 mm.,thus

INF_{period} (more 10 mm.) = INF_{day} (more 10 mm.) X 50% Day of raining

..(4)

With amount of rainfall less than 10 mm., supposing an average time of 15 minutes,the equation becomes

$$INF_{day} \text{ (lower 10 mm.)} = \text{rate of infiltration (K)} \times 15 \text{ minutes} \quad \ldots\ldots\ldots(5)$$

50% of all raining days have an amount of less lower than 10 mm, thus

$$INF_{period} \text{ (lower 10 mm.)} = INF_{day} \text{ (lower10 mm.)} \times 50\% \text{ Day of raining} \quad ..(6)$$

So, the approximate amount of infiltration in each period (AVR-INF_{period}) for this study depends on the arerage time and total days of raining. Thus,

$$AVR\text{-}INF_{period} = \text{rate of infiltration (K)} \times 22.5 \text{ minutes} \times \text{Day of raining}$$

The days of raining in the study area for calculating the amount of infiltration in the rainy and dry periods for the year 1975-76, 1988-89 and 2000-01 are as show in Table3-11

Table 3.20. Days of raining in study area for rainy and dry periods in each year.

Station	Raining days					
	1975-76		1988-89		2000-01	
	Rainy	Dry	Rainy	Dry	Rainy	Dry
Muang Phichit	103	9	nd	nd	nd	nd
Chon Dan	63	8	51	5	104	17
Wang Pong	nd	nd	53	4	99	12
Wang Sai Phun	nd	nd	79	4	79	12
Ta Pan Hin	94	12	64	7	84	14
Khao Sai	nd	nd	71	8	70	8

nd = No data

The days of raining are referred to the areal extent in Chapter II (Figure2.11) and the actual days of raining for rainy and dry periods in 1975-76,1988-89 and 2000-01 are from in Figures. 3.35, 3.36 and 3.37 respectively.

(A)
(B)

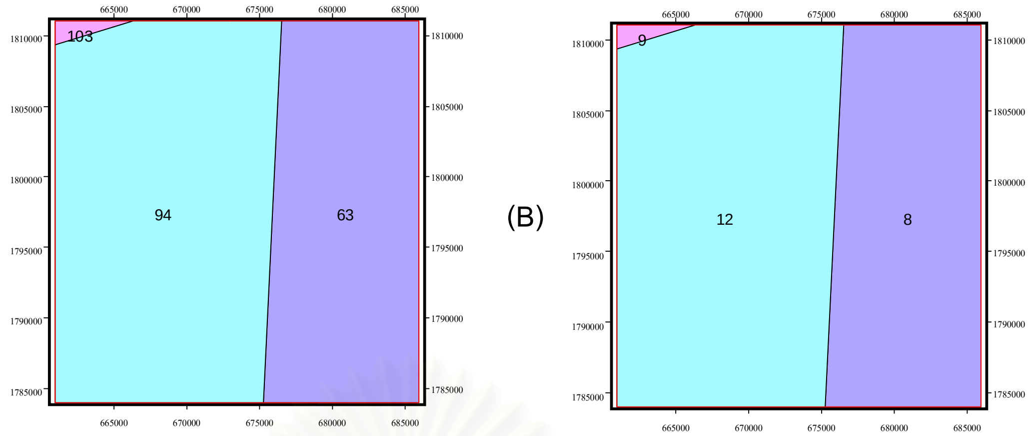


Figure 3.35. Days of raining in 1975-76 in the study area from polygons. (A) Rainy period. (B) Dry period.

(A)
(B)

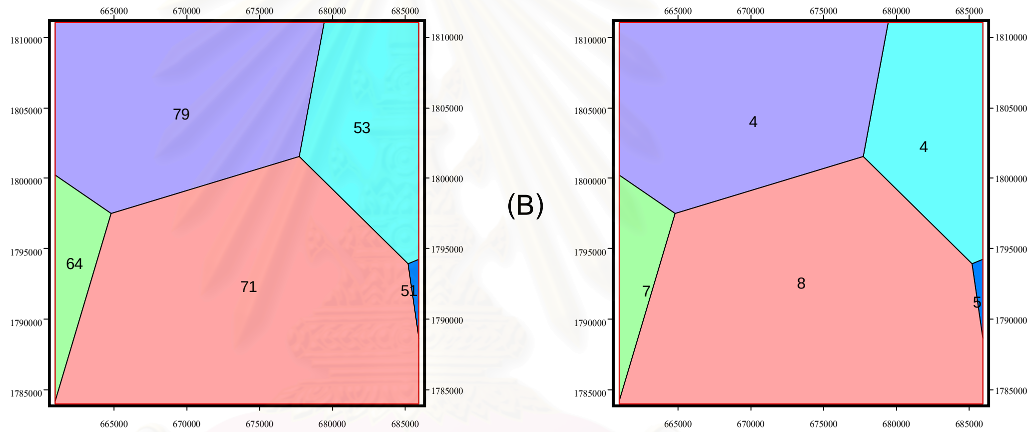


Figure 3.36. Days of raining in 1988-89 in the study area from polygons. (A) Rainy period. (B) Dry period.

(A)
(B)

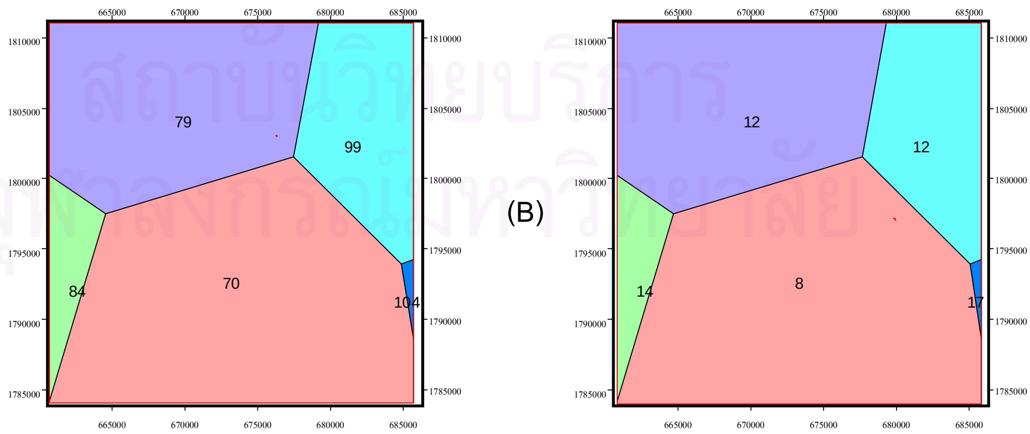


Figure 3.37. Days of raining in 2001-21 in the study area from polygons. (A) Rainy period. (B) Dry period.

3.4.2.1 Estimated of infiltration in the study area

From the calculation, the year-infiltration separated according to the soil types for the rainy and dry periods for 1975-76, 1988-89 and 2000-01 could be totaled in Tables 3.21 to 3.23 respectively.

Table 3.21. Total amount of infiltration in year 1975-76.

Month	Total infiltration in study area x 10^6 (m^3)
May	3.429
Jun.	2.709
Jul.	2.921
Aug.	4.116
Sep.	2.301
Oct.	3.290
Total rainy period 2000	18.767
Nov.	0.176
Dec.	0
Jan.	0.001
Feb.	0
Mar.	0.946
Apr.	0.666
Total dry period 2000 - 01	1.789

Table 3.22. Total amount of infiltration in year 1988-89.

Month	Total infiltration in study area x 10^6 (m^3)
May	3.429
Jun.	2.709
Jul.	2.921
Aug.	4.116
Sep.	2.301
Oct.	3.290
Total rainy period 2000	18.767

Table 3.22. (con't)

Month	Total infiltration in study area x 10^6 (m^3)
Nov.	0.176
Dec.	0
Jan.	0.001
Feb.	0
Mar.	0.946
Apr.	0.666
Total dry period 2000 - 01	1.790

Table 3.23. Total amount of infiltration in year 2000-01

Month	Total infiltration in study area x 10^6 (m^3)
May	3.717
Jun.	3.390
Jul.	3.697
Aug.	3.321
Sep.	3.802
Oct.	2.718
Total rainy period 2000	20.646
Nov.	0.177
Dec.	0.049
Jan.	0.048
Feb.	0.180
Mar.	1.318
Apr.	0.770
Total dry period 2000 - 01	2.543

To consider the infiltration in the study area, amount of infiltration volume is too small for recharge to the groundwater reservoir. The potential of groundwater in the study area are mostly depended on the surface and subsurface flow in study area.

CHAPTER IV
SURFACE WATER

4.1 Overview

In a regular watershed, the water budget for this study is performed on the relationship between subsurface water and surface water, to be considered as the input and output. But in the present study area, which is a small part of Nan basin (Figure.4.1), it is only an open system of water. This means that when water flows in to the study area, it must flow out because the water does not stay here. Unfortunately, the clear data of surface water in flow and out flow and subsurface in flow and out flow for this research could not be obtain. To avoid this complicate problem only the pattern of streams flow and surface storage, not on the amount of water in-flow nor out-flow.

4.2 Surface water

The surface water system in the study area is composed of small streams flowing east to west as shown in Figure 4.2. The drainage pattern could be divided into 2 groups, 1A and 2A, flowing from the east to the northwestern and southwestern corners of the study area respectively. The important streams in Group 1A are Khlong Boosabong, Khlong Kae, Khlong Ban Tak Dad and Khlong Wang Sai Phun in Amphoe Wang Sai Phun. Those in Group 2A are Khlong Rongkok, Khlong Wangdaeng, Khlong Wanghinpleng, Khlong Wangngew, Khlong Muang and Khlong Saiyangrung in Amphoe Thap Khlo. These streams are small, and are dry in the summer.

As the topography does not allow, no large reservoir could be developed along these streams. The way the people conserve water is by constructing small ponds as shown in Figure 4.3. These ponds too are normally dry in the summer when the groundwater table is lower.

Only in the rainy season, the water flows in the streams to Nan river which are are outside of the tudy area to the west. Apart from small ponds mentioned above, the surface water stays in the paddy field temporarily during the crop season (Figure 4.3).

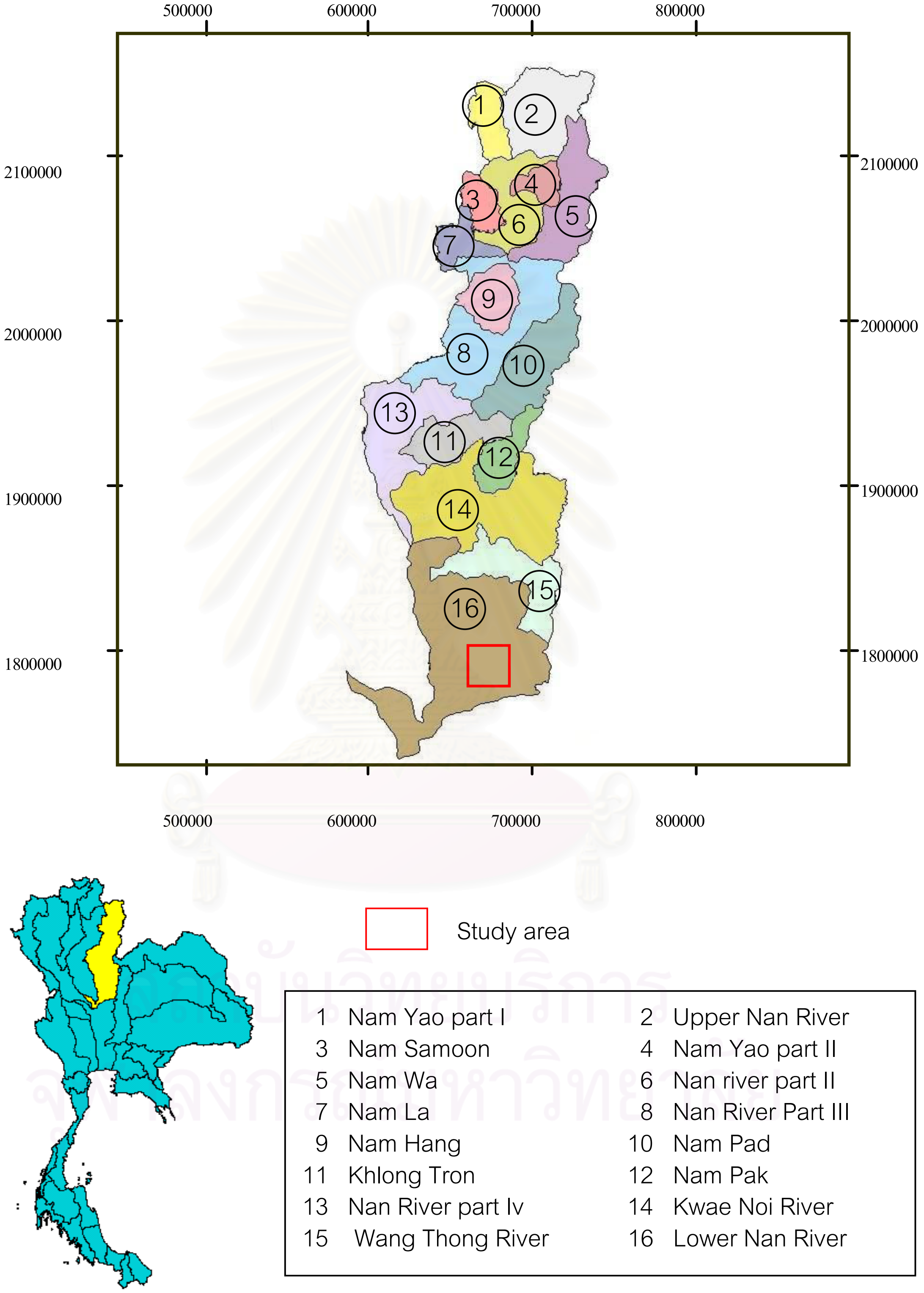


Figure. 4.1. Entire watershed of Nan River with the study area situated in area number 16, Lower Nan River.

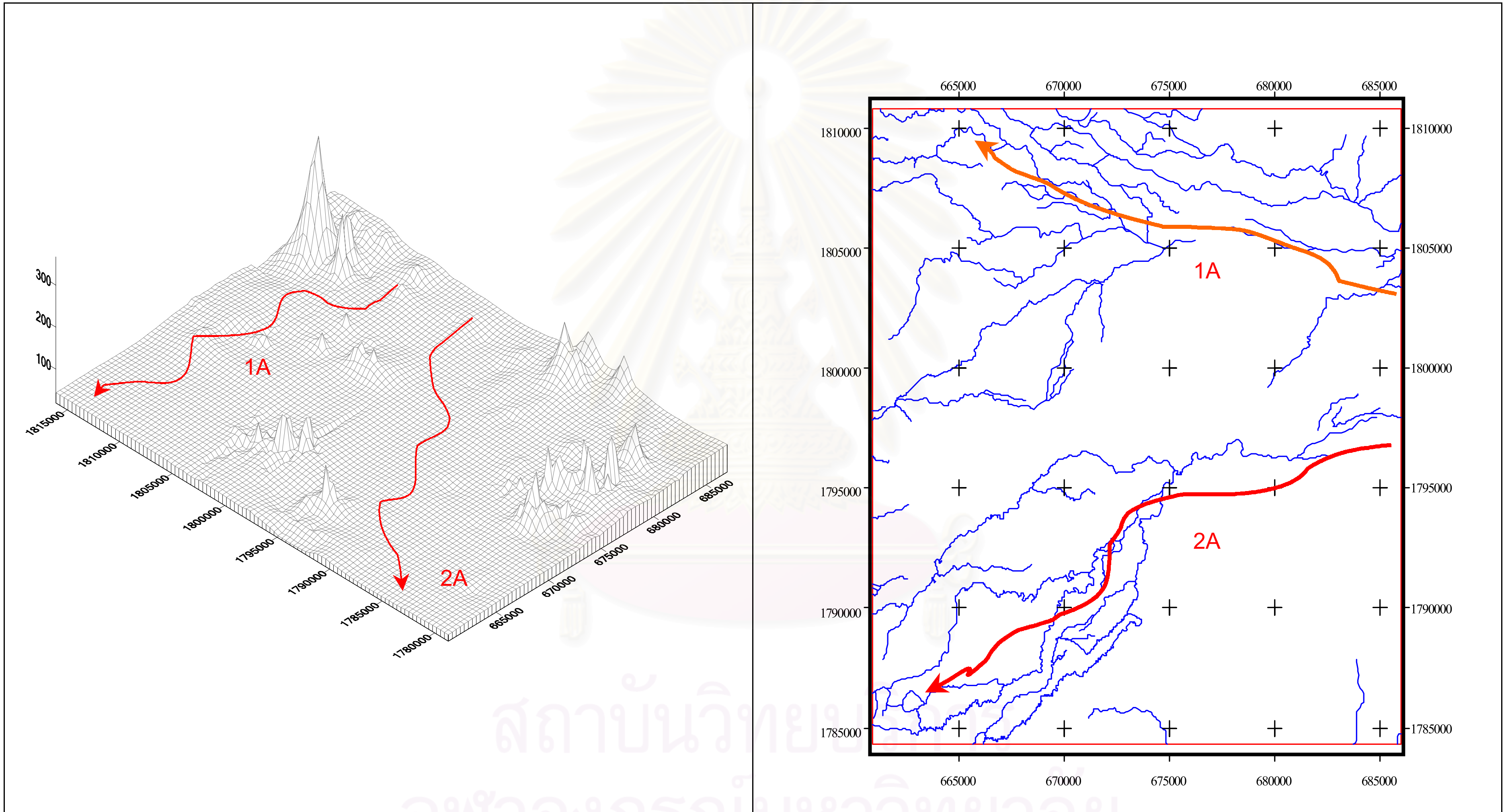


Figure. 4.2. Drainage pattern in the study area . (A) 3-dimensional block diagram of the ground surface, higher elevation to the east and lower to the west. (B) Two groups of small streams, 1A and 2A, flowing from east to the northwest and southwest respectively.

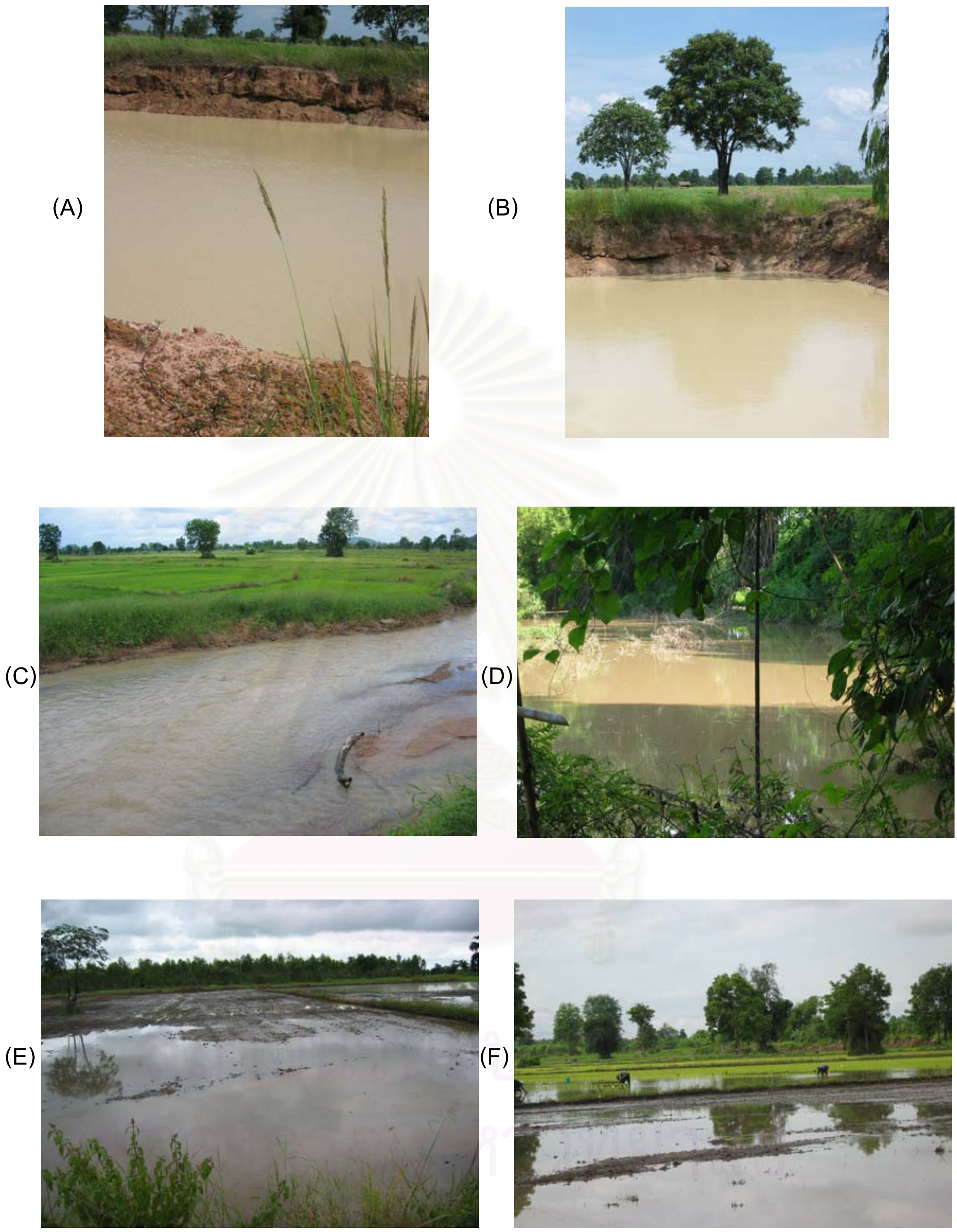


Figure 4.3 Surface water in the study area. (A) and (B), small ponds. (C) and (D), flowing streams in the rainy season, (E) and (F) water stays temporarily in the growing paddy field.

CHAPTER V
WATER BUDGET

5.1 Water budget analysis by GIS

A Water budget model depends on the availability of various information, namely on precipitation, evaporation or evapotranspiration, infiltration, landuses, soil properties, and the surface water flowage. Such information is not readily available in Thailand for a systematic study. Furthermore, the available sources of information such as maps, climatic data, rainfall intensity information, remote sensing information and others are not in a form for a simple creation of model of water balance. The accuracy of the data is also questionable.

To the above mentioned limitation, a Water budget model in this study was attempted using a GIS approach. The GIS information included those data recorded at the locations in or adjacent to the area, essentially those locations with all hydrological processes. The water budget analysis was assumed by using the following equation.

$$\text{Water remaining (R)} = P - (E+ET) - INF$$

where: R - Mean annual water remaining on ground or runoff (mm.);

P - Mean annual precipitation (mm.);

E - Mean annual evaporation in case only evaporation (mm.);

ET - Mean annual evapotranspiration (mm.);

and INF - Mean annual infiltration (mm.);

Using GIS, the meteorological and climatological stations were geo-referenced to the base map, and a spatial analysis of the mean annual precipitation (P) and mean of evaporation (E) was done. The estimated evapotranspiration (ET) was obtained directly from overlaying the digital map of climatological data and landuse map. Infiltration (INF) map was the result of overlaying soil map and precipitation map.

Water remaining (Figure 5.1) on the surface or flow out as the runoff was managed by overlaying all basic data maps including both the gathered secondary data and field investigated data.

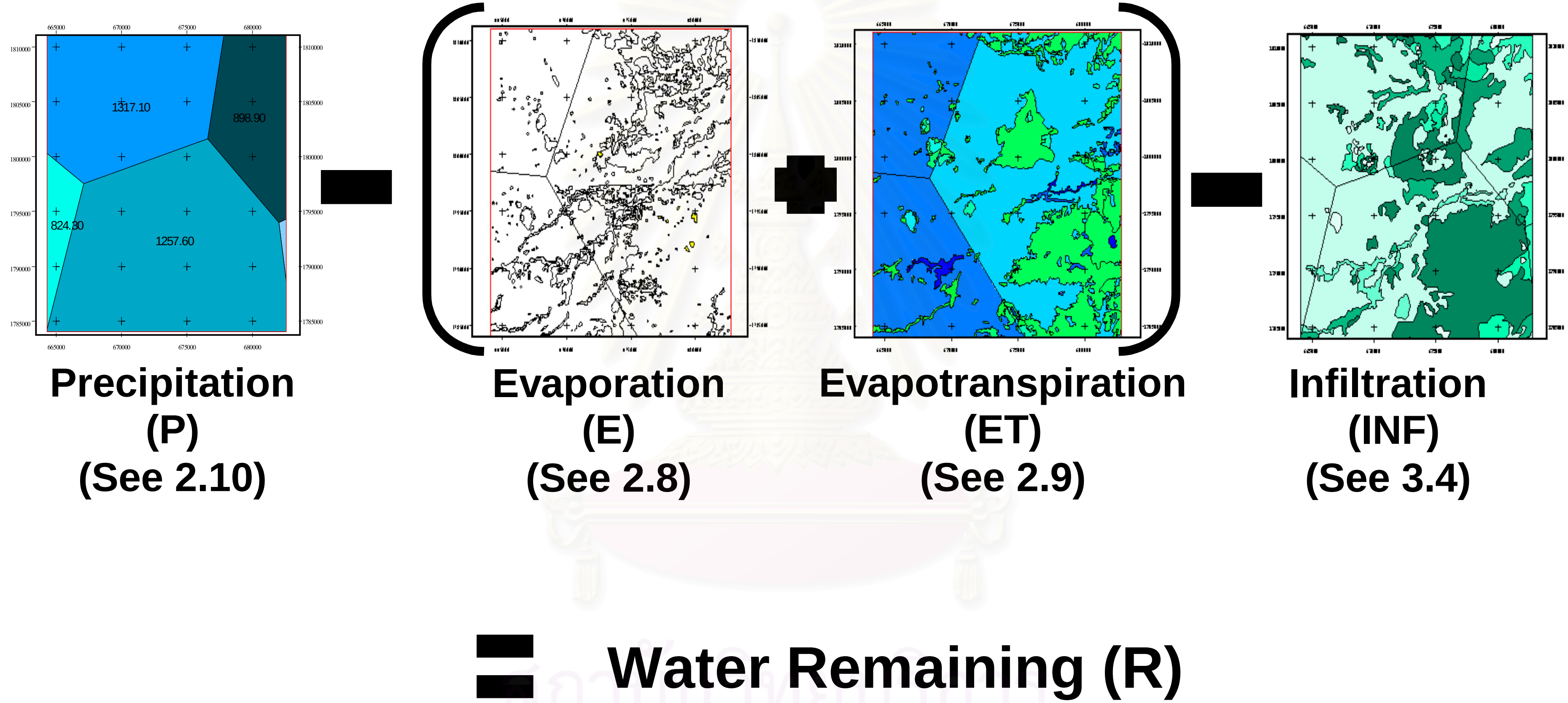


Figure.5.1. Water budget model derived from overlaying of basic data.

5.2 Water budget estimation

The computation of the basic data for the Water budget model was performed by using Arcviews program. The output data of the remaining water in the study area for different periods of time are shown below. They are for the rainy and dry periods of 1975-76, 1988-89 and 2000-01.

5.2.1 Water budget in 1975-76

The output data for Water budget for rainy period and dry period in 1975-76 are shown as the remaining water in the study area, together with the basic water factors used for calculation in Table 5.1.

Table. 5.1. Water budget for rainy period and dry period in 1975-76 .

Month	Water amount in1975-76 x 10^6 (m^3)			
	Rainfall	Evaporation and Evapotranspiration	Infiltration	Remaining water
May	108.425	114.436	3 .429	-9.44
Jun.	115.168	109.431	2.709	3.028
Jul.	116.777	94.504	2.921	19.352
Aug.	193.029	93.37	4.116	95.543
Sep.	144.617	129.756	2.301	12.56
Oct.	131.050	140.008	3.290	-12.248
Rainy period 1975	809.068	681.504	18.767	108.797
Nov.	7.957	89.680	0.176	-81.899
Dec.	7.726	70.793	0	-63.067
Jan.	0	97.128	0.001	-97.129
Feb.	9.703	57.814	0	-48.111
Mar.	7.062	128.803	0.946	-122.687
Apr.	62.649	139.037	0.666	-77.054
Dry period 1975-76	95.100	583.256	1.789	-489.945

The results reveal the amount of remaining water of 108.797 x 10^6 cubic meters in the rainy period. In the dry period, there is drought and a negative value of remaining water of 489.945 x 10^6 cubic meters was obtained.

5.2.2 Water budget in 1988-89

The output data for Water budget for rainy period and dry period in 1988-89 are shown as the remaining water in the study area, together with the basic water factors used for calculation are shown in Table 5.2. The results reveal the amount of remaining water of 13.536 x 10^6 cubic meters in the rainy period. In the dry period, there is drought and a negative value of remaining water of 524.228 x 10^6 cubic meters was obtained.

Table 5.2. Water budget for rainy period and dry period in 1988-89.

Month	Water amount in1988-89 x 10^6 (m^3)			
	Rainfall	Evaporation and Evapotranspiration	Infiltration	Remaining water
May	178.412	118.559	3.429	56.424
Jun.	114.121	169.400	2.709	-57.988
Jul.	90.416	172.209	2.921	-84.714
Aug.	201.838	140.750	4.116	56.972
Sep.	54.899	96.203	2.301	-43.605
Oct.	173.791	84.056	3.290	86.445
Rainy period 1988	813.480	781.177	18.767	13.536
Nov.	1.476	92.807	0.176	-91.507
Dec.	0	75.581	0	-75.581
Jan.	0.226	106.219	0.001	-105.994
Feb.	0	46.819	0	-46.819
Mar.	36.125	143.166	0.946	-107.987
Apr.	25.091	120.766	0.666	-96.341
Dry period 1988-89	62.919	585.357	1.790	-524.228

5.2.3 Water budget in 2000-01

The output data for Water budget for rainy period and dry period in 2000-01 are shown as the remaining water in the study area together with the basic water factors used for calculation are shown in Table 5.3.

Table 5.3. Water budget for rainy period and dry period in 2000-01.

Month	Water amount in 2000-01 x 10^6 (m^3)			
	Rainfall	Evaporation and Evapotranspiration	Infiltration	Remaining water
May	127.212	118.358	3.717	5.137
Jun.	192.110	167.505	3.390	21.215
Jul.	110.382	170.494	3.697	-63.809
Aug.	175.153	141.843	3.321	29.989
Sep.	195.667	80.123	3.802	111.742
Oct.	113.404	82.284	2.718	28.402
Rainy period 2000	913.93	760.608	20.646	132.676
Nov.	6.549	92.807	0.177	-86.435
Dec.	0.960	75.581	0.049	-74.670
Jan.	1.655	106.219	0.048	-104.612
Feb.	4.334	46.819	0.180	-42.665
Mar.	41.706	143.166	1.318	-102.778
Apr.	47.085	120.766	0.770	-74.451
Dry period 2000-01	102.292	585.357	2.543	-485.608

The results reveal the amount of remaining water of 132.676 x 10^6 cubic meters in the rainy period. In the dry period, there is drought and a negative value of remaining water of 485.608 x 10^6 cubic meters was obtained.

CHAPTER VI
CONCLUSION

The water budget in the study area in 1975-76, 1988-89 and 2000-01 are summarized in Table 6.1 below. The water balance is from the amount of precipitation in the study periods subtracted by the amount of evaporation or evapotranspiration and ground infiltration. The infiltration is important in this area as it directly recharges the shallow groundwater layer. Unfortunately, this subsurface layer is not very thick, and perhaps is underlain by a much lower-permeable layer so that the absorption of water is limited only to a short period of time. It is believed that the recharging of deeper aquifers must be occurred predominately elsewhere, perhaps to the northeast and east of this study area, while that from the direct rainfall in the study area is only of a minor portion.

It could be noted from this summary that in the rainy season of the 3 years, which perhaps is true for other rainy seasons also, there are surplus water. Without any mean to conserve, the water thus would flow off, sometimes causing an overbank flooding. On the other hand, in the dry season of these 3 studied years, there are shortages of water. As the remaining water has a negative value, this means that there is no surface water left, and perhaps unsaturated groundwater aquifer as well. The example in 1975,1988, and 2000, the annual remaining water had a negative value. It could be interpreted that even though all remaining water in the rainy season could be conserved, a serious drought or water shortage for the household consumption, not considering the agricultural needs, had occurred. In a normal case of living, the local people could rely their need of water for the household usage on the shallow aquifer during the dry months while waiting for rain in the next rainy season to grow their crops, especially rice which is a high water – consuming crop than many other plants. In the dry season, if one grows any crop that needs watering other than from rain, his crop growing would unavoidably create a conflicting water need with the other needs.

The finding indicates that the needs for water in this area are of a serious problem. In the rainy season, the habitants could grow the water – consuming, traditional crop of rice. On contrary, in the dry season, they could only grow crops which require no

Table 6.1. Water budget in study area.

Year	Period	Water budget x 10^6 (m^3.)		
		Input water	Output water	Remaining water
1975	Rainy	809.068	700.271	108.797
	Dry	95.1	585.045	-489.945
	Total	**904.168**	**1285.316**	**-381.148**
1988	Rainy	813.48	799.944	13.536
	Dry	62.919	587.147	-524.228
	Total	876.399	**1387.091**	**-510.692**
2000	Rainy	913.93	781.254	132.676
	Dry	102.292	587.900	-485.608
	Total	**1016.222**	**1369.154**	**-352.932**

watering other than natural rain, while their household water usage must depend on the subsurface water. Any development plan to be conducted in this area should base on this finding. The plan should include the construction of reservoirs to conserve surplus water in the rainy season, to be used in the dry season, the building of the irrigation system from the water resources elsewhere into here, and the introduction of less water consuming crops to the agrarians. After the gold mining in the area is completed, the mine pits could be turned to be the water storage facility. Also a development program to change the agricultural behavior of the local inhabitants from the usual crop – growing to the livestock raising could be as well reasonable. Meanwhile, any plan to use the groundwater for these purposes might not be very successful as there is not be enough groundwater, shallow or deep, to fulfill such needs.

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APPENDICIES

Appendix A
Field Test Equipments

<u>Introduction</u> Few field test equipments were used to gather data in this study. These include the double-ring infiltrometer, soil pH tester, and tension meter (for natural soil moister determination).

Double-Ring Infiltrometer

General concept

The infiltration rate is the rate at which water enters the soil, and is expressed as volume per unit area per unit time e.g. cm^3/ cm^2/min. or cm/min. The rate of infiltration tends to become constant at the end of certain time. This rate is called the basic infiltration rate. Since the concept is rather vague, one may assume that the basic infiltration rate does not deviate more than 10% if the test is continued for the next hour.

Cumulative Infiltration

The cumulative infiltration is the amount of water infiltrated into the soil at the end of a certain period and is expressed as volume per unit area e.g. cm^3/ cm^2/ or cm.

It is necessary to make note of the measuring time because for comparing two soils or studying the effect of two treatments, the measuring periods should be equal.

Description

The EIJKELKAMP standard double ring infiltrometer used in this study consists of three sets of inner and outer stainless steel cylinders.

Each set of cylinders consists of one large and one small rings. The inner rings have diameters of respectively. 28, 30 and 32 cm, while the accessory outer rings measure 53, 55 and 57 m. The three sets of cylinders permit measurements in treble at the same time.

For accurate measurements it is necessary to drive the ring into the soil. To this end a hammer and steel plates are used (∅ 62 cm. – for large plates; ∅ 37 cm. – for small plates). The plates are provided with a removable handle, that also serves as anvil.

Measurements of the infiltration water are usually made in the inner ring. For that purpose a measuring bridge with float and measuring rod has been devised. The standard set includes three measuring bridges and three floats with measuring rod (for each set of cylinders one measuring unit).

A stopwatch (for accurate registration of the infiltration period) completes the standard double ring infiltrometer.

Procedure

1. Place the inner and outer cylinder(s) on the soil layer(s) to be measured. Hammer the cylinders about 10 cm. into the soil (see Fig. F-1). This has to be done perpendicularly and evenly.
2. After that they have to be filled with water.
3. Next the measuring bridge with float and measuring rod is fixed to the inner ring (with adjustable screws).
4. The downward movement of the float is measured in a certain period.
5. The outcome (in combination with other data as diameter of the rings and height of the water level) enables us to calculate the infiltration capacity of the soil.

Note: During measuring of the infiltration capacity, the water level in the inner and outer cylinders must have equal level.

How to measure

There are 2 different measuring concepts, each has its own advantage and disadvantage to the other.

- Measuring with lowering float and measuring rod.

When the measurement starts with the start of the stopwatch, the float with measuring rod is allowed to lower down with the gradual loss of water in the inner ring through infiltration. After a period of field test, the lowering distance would give the infiltration rate as the lowering distance per unit time.

- Measuring with stable float and measuring rod

In this method, the float and measuring rod is not allowed to lower down with time. Instead, a known volume of water is added into the inner ring to keep the measuring rod to stay at the initial level. In this method, the volume of water added is used in a calculation for the infiltration rate as volume per cross- sectional area (of inner ring) per time. The concept behind this method is that the water volume in the inner ring remains at the same height throughout the test period and thus the gravitation force of the water column which has some influence the infiltration remains the same throughout.

Some factors that influence the infiltration rate

The measurements of the infiltration rate by cylinder infiltrometers is affected by several factors, so that certain standards must be adopted in order to compare the results obtained at different locations, viz.:

1. Surface cover

In general the infiltration rate of bare soil is lower than of covered soil due to the disturbance in the structure of the surface soil when water is poured on cover soil.

2. Depth of fixing

The infiltration rate decreases normally at increasing depth of fixing due to the decrease of lateral movement. This effect tempers off at a depth of about 10 cm which can thus be chosen as depth of fixing.

3. Surface head

The infiltration rate decreases at lower surface head. In order to work under condition more or less comparable with surface irrigation, a surface head of about 10 cm is proposed at the start of the measurement, which may drop to about 5 cm before refilling the infiltrometer.

4. Diameter of the rings

No systematic relation appears to exist between the infiltration rate and the diameter of the infiltrometer. However, in the case of a larger diameter the variability in the measurements decreases as the heterogeneity of the soil, e.g. cracks, has less influence on a larger volume. A diameter of about 30 cm is recommended.

5. Single or double rings

In a homogeneous, non-layered soil the infiltration rate will be essentially a vertical downward movement and no difference will be observed in the performance between a single ring and a double ring infiltrometer.

In a layered soil lateral movement may become important, in which case a double ring infiltrometer will show in its inner ring a lower infiltration rate than a single infiltrometer will do.

In this study, as the infiltration rate to be considered is for the rain water which infiltrates the natural surface soil layer, thus the natural surface of the soil layer was left untouched so the infiltration rate will be that through the natural surface (with grass covers and roots), not through the permeability of the soil layer alone.

Application

Measuring the infiltration capacity of soils for planning of drainage and irrigation projects.

Note

Problems may arise when the rings have to be hammered into very hard soil layers, e.g. very dry clays, concrete soils, and so on. To facilitate this work, a hand operated hydraulic unit for pushing the rings into the soil was constructed. This unit consists of two soil anchors, one adjustable supporting bridge (This bridge connects the soil anchors with each other), one hydraulic hand pump and one hydraulic jack.

Procedure

Screw the soil anchors onto the soil (mostly one has to preauger with an Edelman soil auger). Place the supporting bridge between the anchors. Connect the hand pump and jack to the bridge (at the bottom). Place the ring (with plate) exactly under the jack. By pumping with the hand pump the jack will push the ring into the soil.

“TAKEMURA” Tensiometer

FERTURE

Takemura tension meter used in this study is equipped with vacuum meter to obtain quick, simple and accurate measurement. Furthermore, measurement range is PF 1.0 – 2.6 which is the most important moisture in the soil for growing plant.

READY TO USE

Take off the cover located top of glass tube, fill the water in the glass tube and place the cover. It is recommendable to use distilled water or after boiled water Be sure to fill the water full so that no air remains inside the glass tube. Then water is start passing through white portion of the tube.

HOW TO USE

Because of the white portion is made by glassware, it is not recommendable to insert it directly into the soil to avoid unnecessary damage. In other words, it is advisable to make a hole in the soil beforehand and put it into the hole, and, give a little pressure on the soil so that the white portion of tube and the soil can contact as closely as possible. Please start measuring one hour after fill the water in the glass tube. In case of continuous measurment, please check whether water is full or not from tofrom time. If not, fill the water once again. If cover is taken off, a needle in the mater returns to :0: position, however, it shows again moisture degree in the soil after about one hour.

There are granulation 10,15,20 cm from bottom of the tube where should be located to, root of the plant as nearly as possible.

RECOMMENDABLE MOISTURE CONDITION

PF 1.4 Cucumber (cultivated by sand)

PF 1.5 Tomato (cultivated by sand) , Strawberry

PF 1.8 Carnation

PF 2.0 Leyyuce, Cucumber, Peaman, Eggplant

PF 2.2 - 2.3 Tomato

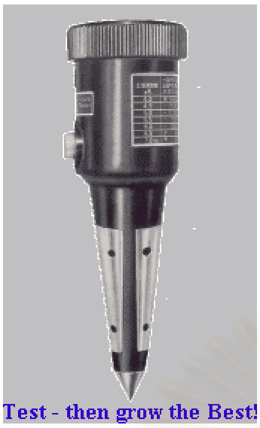
PF 2.4 - 2.5 Celery

CAUTION

1) It can be used semi-perpetually if handling is careful.
2) Water should be away from glass tube, when not used.
3) Please do not move the junction between tube and meter.
4) Keep always clean in the white potion of the tube.
5) Special attention is paid to white portion of the tube in winter because it may be broken when frozen,

It is recommendable to pat slightly the meter when the mater needle does not move.

Soil Tester



How to use

1. Taking the tester out and see that pointer needle points to pH7.
2. The electrode is very sensitive, therefore before and after using wash off dirt and dust on the surface of the electrode and wipe with a dry cloth clean.
3. Insert the tester into soil vertically which is holding about 50-70% moisture and tread down the surrounding soil by foot tightly in order to let contact enough with soil and electrode.

   When soil is dry accurate pH index cannot be detectedin which case it is advisable that water from river or well is properly sprinkled to the above moisture percentage and wait about 2 hours to measure.
4. The pointer needle settle soon (about 3 minutes) and the stabilized position is pH index.
5. In case of measuring humidity, push the button and can get humidity index.
6. After using keep to wash off dirt and dust on the surface of the electrode and wipe with a dry cloth clean.

Care to be Taken in Handling and Measuring

1. When it is desired to put pointer needle to pH7 position, take the lid and glass off and carefully turn the screw on the under part right and left and set correct position. Do not turn strongly.

2. Insert the tester vertically and let the soil contact compactly with the electrode by foot. If the soil does not come in contact completely with metal parts on both of the tester, the pointer needle vacillate left and right and will not settle.

3. Keep the electrode clean and free from rust. When oxidation takes place on surface, sensitivity becomes weakened and the needle will not point to accurate pH and humidity indexes. When rusty, polish with sand-paper or sand before and after using.

4. If high voltage electric pole, etc. be near the soil, avoid to measure in such position since it is probable that the pointer needle will point to higher pH and humidity than the true indexes, in relation to earth electric current, etc.

5. Being designed to harness soil's electricity generating power for its functioning, index comes more or less different depending on pressure by foot and moisture degree, and so it is ideal if average index figure is sought by doing measuring 5-6 rimes.

Appendix B

Climatological data

<u>Introduction</u>

The climatological data were obtained from 6 Metrological Department's stations in and around the study area. The data include number of raining days, daily amount of precipitation, temperature (maximum, minimum, and average) and evaporation. Unfortunately, not all stations recorded all data at the same recording of these stations are varied.

Below is the list of recording stations with station names, province, and geographic and map reference.

Rainfall (mm.)

Station : Chon Daen / Phetchabun (379003)

Year/ month	Monthly total	No. Of rainy day	Daily maximum	Year/ month	Monthly total	No. Of rainy day	Daily maximum	Year/ month	Monthly total	No. Of rainy day	Daily maximum
1975/1	77.2	7	40.4	1978/1	------	ND	------	1981/1	0.0	0	0.0
1975/2	79.0	4	58.4	1978/2	------	ND	------	1981/2	- 4.6 -		
1975/3	83.3	3	56.7	1978/3	------	ND	------	1981/3	136.2	3	96.1
1975/4	262.4	1	262.4	1978/4	------	ND	------	1981/4	46.8	5	18.2
1975/5	143.4	14	36.2	1978/5	------	ND	------	1981/5	253.9	10	63.6
1975/6	144.7	9	43.2	1978/6	------	ND	------	1981/6	176.4	14	70.4
1975/7	149.2	10	45.6	1978/7	------	ND	------	1981/7	294.4	19	41.1
1975/8	349.7	16	86.6	1978/8	------	ND	------	1981/8	113.0	8	49.1
1975/9	103.4	6	33.6	1978/9	------	ND	------	1981/9	120.4	10	60.7
1975/10	259.4	8	88.1	1978/10	------	ND	------	1981/10	59.0	5	16.7
1975/11	9.2	1	9.2	1978/11	------	ND	------	1981/11	54.4	3	20.6
1975/12	0.0	0	0.0	1978/12	------	ND	------	1981/12	0.0	0	0.0
1976/1	------	ND	------	1979/1	4.5	2	3.4	1982/1	0.0	0	0.0
1976/2	------	ND	------	1979/2	86.1	1	86.1	1982/2	1.4	1	1.4
1976/3	------	ND	------	1979/3	------	ND	------	1982/3	77.3	2	40.7
1976/4	------	ND	------	1979/4	------	ND	------	1982/4	46.6	5	33.2
1976/5	------	ND	------	1979/5	------	ND	------	1982/5	257.8	9	102.3
1976/6	------	ND	------	1979/6	------	ND	------	1982/6	271.6	10	57.6
1976/7	------	ND	------	1979/7	------	ND	------	1982/7	115.8	7	40.3
1976/8	------	ND	------	1979/8	------	ND	------	1982/8	187.7	15	43.6
1976/9	------	ND	------	1979/9	------	ND	------	1982/9	384.7	15	62.1
1976/10	------	ND	------	1979/10	------	ND	------	1982/10	182.1	12	65.4
1976/11	------	ND	------	1979/11	------	ND	------	1982/11	32.4	5	16.7
1976/12	------	ND	------	1979/12	------	ND	------	1982/12	2.6	1	2.6
1977/1	0.0	0	0.0	1980/1	- 0.0 -			1983/1	------	ND	------
1977/2	0.0	0	0.0	1980/2	14.9	2	7.6	1983/2	------	ND	------
1977/3	12.8	2	12.6	1980/3	56.5	1	56.5	1983/3	------	ND	------
1977/4	47.7	4	23.1	1980/4	20.3	3	38.1	1983/4	------	ND	------
1977/5	238.2	14	60.6	1980/5	66.9	13	200.6	1983/5	------	ND	------
1977/6	76.6	7	35.4	1980/6	76.2	155	265.5	1983/6	------	ND	------
1977/7	153.2	12	37.3	1980/7	39.3	13	197.8	1983/7	------	ND	------
1977/8	182.4	6	84.2	1980/8	52.6	5	146.1	1983/8	------	ND	------
1977/9	137.4	3	65.2	1980/9	47.1	20	285.1	1983/9	------	ND	------
1977/10	62.9	3	45.2	1980/10	31.1	7	83.9	1983/10	------	ND	------
1977/11	0.0	0	0.0	1980/11	- 4.2 -			1983/11	------	ND	------
1977/12	35.6	1	35.6	1980/12	- 0.0 -			1983/12	------	ND	------

Continued

Station : Chon Daen / Phetchabun (379003)

Year/ month	Monthly total	No. Of rainy day	Daily maximum	Year/ month	Monthly total	No. Of rainy day	Daily maximum	Year/ month	Monthly total	No. Of rainy day	Daily maximum
1984/1	0.0	0	0.0	1987/1	0.0	0	0.0	1990/1	0.0	0	0.0
1984/2	59.5	2	50.3	1987/2	15.2	3	7.5	1990/2	0.0	0	0.0
1984/3	30.3	1	30.3	1987/3	52.0	2	30.6	1990/3	15.7	1	15.7
1984/4	49.1	3	28.3	1987/4	91.3	3	36.9	1990/4	0.0	0	0.0
1984/5	203.1	11	70.4	1987/5	165.7	4	86.2	1990/5	127.9	6	35.6
1984/6	269.7	13	124.6	1987/6	283.8	11	87.5	1990/6	212.3	10	30.5
1984/7	149.4	13	47.4	1987/7	77.9	6	33.5	1990/7	319.4	18	27.5
1984/8	199.8	18	33.7	1987/8	192.3	14	67.0	1990/8	161.3	7	35.4
1984/9	324.3	19	70.0	1987/9	558.3	11	187.2	1990/9	306.2	10	38.6
1984/10	197.1	13	44.5	1987/10	142.3	11	26.4	1990/10	145.0	5	41.3
1984/11	0.0	0	0.0	1987/11	4.8	2	2.9	1990/11	41.9	2	31.5
1984/12	0.0	0	0.0	1987/12	0.0	0	0.0	1990/12	0.0	0	0.0
1985/1	------	ND	------	1988/1	0.0	0	0.0	1991/1	15.4	1	15.4
1985/2	------	ND	------	1988/2	0.0	0	0.0	1991/2	0.0	0	0.0
1985/3	------	ND	------	1988/3	0.0	0	0.0	1991/3	0.0	0	0.0
1985/4	------	ND	------	1988/4	99.5	4	35.6	1991/4	43.0	1	43.0
1985/5	------	ND	------	1988/5	282.1	9	72.6	1991/5	376.7	9	57.4
1985/6	------	ND	------	1988/6	420.2	12	77.9	1991/6	130.1	7	28.2
1985/7	------	ND	------	1988/7	233.6	11	78.9	1991/7	141.8	7	37.2
1985/8	------	ND	------	1988/8	203.8	9	75.3	1991/8	590.9	15	80.3
1985/9	------	ND	------	1988/9	153.9	5	47.3	1991/9	422.1	17	50.7
1985/10	------	ND	------	1988/10	200.0	5	95.7	1991/10	0.0	0	0.0
1985/11	------	ND	------	1988/11	0.0	0	0.0	1991/11	0.0	0	0.0
1985/12	------	ND	------	1988/12	0.0	0	0.0	1991/12	28.5	1	28.5
1986/1	0.0	0	0.0	1989/1	0.0	0	0.0	1992/1	7.2	1	7.2
1986/2	0.0	0	0.0	1989/2	0.0	0	0.0	1992/2	0.0	0	0.0
1986/3	12.5	1	12.5	1989/3	38.6	3	18.3	1992/3	0.0	0	0.0
1986/4	94.9	8	23.2	1989/4	21.9	2	11.4	1992/4	0.0	0	0.0
1986/5	136.5	9	40.3	1989/5	242.5	9	50.5	1992/5	85.7	4	27.5
1986/6	259.0	9	96.9	1989/6	304.3	12	45.8	1992/6	175.6	6	47.8
1986/7	216.6	12	51.6	1989/7	41.4	3	15.6	1992/7	181.1	9	27.6
1986/8	312.7	14	55.7	1989/8	119.0	4	35.6	1992/8	376.9	16	45.7
1986/9	248.5	7	113.9	1989/9	55.3	2	34.7	1992/9	280.5	12	44.7
1986/10	78.3	5	31.4	1989/10	20.5	1	20.5	1992/10	107.8	5	30.6
1986/11	0.0	0	0.0	1989/11	0.0	0	0.0	1992/11	0.0	0	0.0
1986/12	0.0	0	0.0	1989/12	0.0	0	0.0	1992/12	0.0	0	0.0

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Station : Chon Daen / Phetchabun (379003)

Year/ month	Monthly total	No. Of rainy day	Daily maximum	Year/ month	Monthly total	No. Of rainy day	Daily maximum	Year/ month	Monthly total	No. Of rainy day	Daily maximum
1993/1	0.0	0	0.0	1996/1	0.0	0	0.0	1999/1	21.3	2	16.8
1993/2	0.0	0	0.0	1996/2	- 61.1 -			1999/2	5.0	1	5.0
1993/3	28.0	2	27.4	1996/3	14.3	1	14.3	1999/3	5.6	2	3.1
1993/4	39.0	2	28.4	1996/4	253.4	9	50.7	1999/4	226.0	13	49.8
1993/5	150.2	8	31.3	1996/5	171.7	10	50.7	1999/5	301.5	18	60.0
1993/6	98.5	5	25.7	1996/6	215.8	11	43.4	1999/6	133.1	9	46.3
1993/7	156.9	12	25.6	1996/7	87.6	10	27.6	1999/7	244.8	17	47.5
1993/8	333.7	13	87.5	1996/8	193.4	15	29.0	1999/8	292.1	21	52.2
1993/9	200.1	15	35.7	1996/9	312.9	22	53.6	1999/9	361.3	20	40.9
1993/10	0.0	0	0.0	1996/10	86.0	6	41.1	1999/10	237.1	15	41.7
1993/11	0.0	0	0.0	1996/11	110.4	4	84.9	1999/11	65.6	6	20.6
1993/12	0.0	0	0.0	1996/12	0.0	0	0.0	1999/12	0.0	0	0.0
1994/1	0.0	0	0.0	1997/1	0.7	1	0.7	2000/1	0.0	0	0.0
1994/2	0.0	0	0.0	1997/2	0.0	0	0.0	2000/2	63.6	4	50.6
1994/3	81.9	3	32.1	1997/3	7.5	2	5.4	2000/3	3.8	2	2.3
1994/4	0.0	0	0.0	1997/4	123.7	8	55.3	2000/4	104.3	13	19.8
1994/5	124.3	7	35.5	1997/5	82.0	9	23.6	2000/5	402.1	16	126.8
1994/6	269.5	14	42.9	1997/6	105.9	8	30.3	2000/6	360.2	22	69.1
1994/7	251.2	15	45.4	1997/7	187.5	17	36.8	2000/7	184.7	18	39.0
1994/8	330.0	22	45.5	1997/8	112.7	12	31.4	2000/8	244.6	18	51.1
1994/9	266.9	18	60.1	1997/9	246.9	12	54.9	2000/9	448.4	17	180.4
1994/10	92.8	9	30.2	1997/10	167.5	12	42.2	2000/10	125.6	13	23.8
1994/11	0.0	0	0.0	1997/11	6.5	1	6.5	2000/11	0.0	0	0.0
1994/12	- 31.3 -			1997/12	0.0	0	0.0	2000/12	0.0	0	0.0
1995/1	0.0	0	0.0	1998/1	0.0	0	0.0	2001/1	0.0	0	0.0
1995/2	0.0	0	0.0	1998/2	19.2	3	12.3	2001/2	0.0	0	0.0
1995/3	16.3	1	16.3	1998/3	2.3	1	2.3	2001/3	130.7	9	90.0
1995/4	108.5	5	39.6	1998/4	142.7	5	50.0	2001/4	175.7	8	77.9
1995/5	193.3	12	39.6	1998/5	256.6	11	68.2	2001/5	360.4	20	91.4
1995/6	157.3	10	40.0	1998/6	135.2	9	32.2	2001/6	166.8	16	31.0
1995/7	241.7	17	44.1	1998/7	145.0	11	36.2	2001/7	157.6	15	32.5
1995/8	407.4	20	46.1	1998/8	216.4	13	39.7	2001/8	225.5	20	41.5
1995/9	257.2	17	46.8	1998/9	327.4	15	79.2	2001/9	344.1	19	59.7
1995/10	92.6	10	18.5	1998/10	144.4	8	39.2	2001/10	140.3	13	24.4
1995/11	1.7	1	1.7	1998/11	22.2	1	22.2	2001/11	0.0	0	0.0
1995/12	0.0	0	0.0	1998/12	0.0	0	0.0	2001/12	0.0	0	0.0

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Station : Wang Pong / Phetchabun (379009)

Year/ month	Monthly total	No. Of rainy day	Daily maximum	Year/ month	Monthly total	No. Of rainy day	Daily maximum	Year/ month	Monthly total	No. Of rainy day	Daily maximum
1987/1	0.0	0	0.0	1990/1	15.1	1	15.1	1993/1	40.4	1	40.4
1987/2	3.7	1	3.7	1990/2	90.7	4	85.0	1993/2	0.0	0	0.0
1987/3	66.0	3	34.4	1990/3	113.4	6	53.1	1993/3	35.5	3	28.6
1987/4	50.6	5	38.2	1990/4	23.2	3	12.2	1993/4	36.1	4	21.5
1987/5	98.9	10	26.3	1990/5	231.2	13	32.0	1993/5	240.0	16	65.9
1987/6	180.0	16	50.0	1990/6	112.5	13	27.9	1993/6	81.2	7	20.2
1987/7	66.7	11	18.6	1990/7	198.0	14	50.2	1993/7	204.7	12	65.0
1987/8	164.1	20	20.0	1990/8	129.0	10	26.6	1993/8	276.2	14	50.0
1987/9	571.2	22	138.9	1990/9	266.5	14	52.4	1993/9	251.2	22	38.2
1987/10	116.3	8	45.0	1990/10	60.7	7	24.4	1993/10	27.7	4	15.0
1987/11	99.2	6	32.7	1990/11	15.0	1	15.0	1993/11	0.0	0	0.0
1987/12	0.0	0	0.0	1990/12	0.0	0	0.0	1993/12	0.0	0	0.0
1988/1	0.0	0	0.0	1991/1	0.0	0	0.0	1994/1	0.0	0	0.0
1988/2	- 20.5 -			1991/2	0.0	0	0.0	1994/2	39.1	2	27.8
1988/3	6.0	1	6.0	1991/3	11.5	2	7.5	1994/3	113.4	5	45.2
1988/4	104.9	5	50.9	1991/4	34.0	3	27.0	1994/4	67.8	6	40.0
1988/5	155.6	9	47.2	1991/5	207.2	10	48.0	1994/5	241.9	14	61.2
1988/6	149.7	9	50.2	1991/6	158.0	17	65.4	1994/6	282.1	17	52.8
1988/7	135.2	11	37.0	1991/7	141.9	13	49.0	1994/7	279.0	15	54.3
1988/8	214.4	8	50.3	1991/8	689.2	16	388.5	1994/8	384.7	25	44.8
1988/9	53.3	8	22.0	1991/9	295.8	23	62.0	1994/9	228.8	20	76.7
1988/10	190.7	8	32.1	1991/10	80.0	9	21.0	1994/10	111.6	6	50.8
1988/11	0.0	0	0.0	1991/11	0.0	0	0.0	1994/11	0.0	0	0.0
1988/12	0.0	0	0.0	1991/12	20.4	2	17.6	1994/12	66.7	2	34.0
1989/1	0.0	0	0.0	1992/1	17.3	2	12.8	1995/1	21.0	1	21.0
1989/2	0.0	0	0.0	1992/2	0.0	0	0.0	1995/2	0.0	0	0.0
1989/3	15.9	2	14.5	1992/3	0.0	0	0.0	1995/3	16.3	2	13.7
1989/4	8.2	2	6.7	1992/4	0.0	0	0.0	1995/4	21.5	3	13.5
1989/5	340.6	11	176.0	1992/5	53.4	9	32.2	1995/5	172.1	9	67.8
1989/6	186.8	11	39.3	1992/6	219.0	10	53.0	1995/6	269.4	14	108.5
1989/7	128.4	9	38.5	1992/7	192.7	15	39.0	1995/7	375.8	17	78.0
1989/8	110.8	12	48.5	1992/8	336.8	19	56.8	1995/8	387.1	18	87.0
1989/9	258.1	14	53.4	1992/9	324.6	19	64.5	1995/9	268.5	18	42.0
1989/10	138.5	8	50.4	1992/10	99.2	7	43.7	1995/10	236.0	13	47.6
1989/11	27.7	2	26.5	1992/11	0.0	0	0.0	1995/11	3.7	1	3.7
1989/12	0.0	0	0.0	1992/12	5.6	1	5.6	1995/12	0.0	0	0.0

Continued

Station : Wang Pong / Phetchabun (379009)

Year/ month	Monthly total	No. Of rainy day	Daily maximum	Year/ month	Monthly total	No. Of rainy day	Daily maximum
1996/1	0.0	0	0.0	1999/1	16.3	1	16.3
1996/2	63.6	3	53.8	1999/2	0.0	0	0.0
1996/3	14.7	2	10.2	1999/3	0.0	0	0.0
1996/4	158.9	9	46.7	1999/4	143.4	15	52.0
1996/5	259.3	12	68.3	1999/5	277.2	14	90.4
1996/6	276.4	17	59.3	1999/6	340.7	11	100.2
1996/7	63.7	7	17.2	1999/7	356.1	15	60.2
1996/8	369.2	16	48.7	1999/8	327.5	19	50.5
1996/9	346.0	23	46.5	1999/9	206.8	13	70.3
1996/10	91.4	10	28.7	1999/10	228.0	13	60.2
1996/11	99.2	4	47.0	1999/11	8.3	1	8.3
1996/12	3.7	1	3.7	1999/12	0.0	0	0.0
1997/1	3.0	3	2.8	2000/1	0.0	0	0.0
1997/2	6.5	1	6.5	2000/2	72.6	4	30.8
1997/3	64.6	3	37.7	2000/3	0.0	0	0.0
1997/4	131.4	8	32.3	2000/4	144.7	10	30.6
1997/5	105.9	4	52.4	2000/5	355.3	17	47.0
1997/6	80.6	10	43.0	2000/6	486.7	17	95.0
1997/7	227.1	17	43.5	2000/7	212.1	16	38.0
1997/8	175.3	21	39.0	2000/8	273.1	17	44.6
1997/9	299.2	18	57.6	2000/9	294.4	17	94.8
1997/10	191.2	9	68.7	2000/10	185.8	15	43.8
1997/11	27.8	2	26.0	2000/11	0.0	0	0.0
1997/12	0.0	0	0.0	2000/12	0.0	0	0.0
1998/1	0.0	0	0.0	2001/1	0.0	0	0.0
1998/2	16.2	2	9.9	2001/2	0.0	0	0.0
1998/3	0.0	0	0.0	2001/3	52.0	7	16.5
1998/4	47.8	4	23.5	2001/4	79.3	5	27.0
1998/5	150.7	6	59.6	2001/5	268.4	15	70.3
1998/6	88.3	10	36.5	2001/6	198.2	11	30.0
1998/7	207.7	14	36.3	2001/7	141.0	9	45.3
1998/8	447.3	14	56.7	2001/8	345.0	17	71.0
1998/9	536.4	19	63.5	2001/9	306.0	16	66.7
1998/10	144.2	9	33.0	2001/10	79.1	12	19.0
1998/11	34.5	2	26.0	2001/11	5.0	1	5.0
1998/12	0.0	0	0.0	2001/12	0.0	0	0.0

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Station : Muang Phichit / Phichit (386001)

Year/ month	Monthly total	No. Of rainy day	Daily maximum	*Year/ month*	Monthly total	No. Of rainy day	Daily maximum	*Year/ month*	Monthly total	No. Of rainy day	Daily maximum
1975/1	58.7	5	30.5	*1978/1*	0.0	0	0.0	*1981/1*	0.0	0	0.0
1975/2	0.8	1	0.8	*1978/2*	0.0	0	0.0	*1981/2*	0.0	0	0.0
1975/3	12.2	2	11.7	*1978/3*	0.0	0	0.0	*1981/3*	29.1	1	29.1
1975/4	39.7	2	34.4	*1978/4*	2.2	1	2.2	*1981/4*	54.3	6	25.5
1975/5	481.3	20	87.7	*1978/5*	46.7	4	29.7	*1981/5*	177.4	8	80.6
1975/6	147.7	13	31.2	*1978/6*	88.3	7	35.5	*1981/6*	178.2	10	35.5
1975/7	286.6	17	61.2	*1978/7*	373.1	19	68.7	*1981/7*	352.6	15	56.3
1975/8	508.2	22	67.4	*1978/8*	- 197.4 -			*1981/8*	139.5	12	44.5
1975/9	616.8	18	220.7	*1978/9*	277.0	12	53.7	*1981/9*	206.8	15	36.1
1975/10	160.8	13	71.2	*1978/10*	158.0	5	80.5	*1981/10*	59.9	6	30.1
1975/11	10.7	2	8.3	*1978/11*	8.0	1	8.0	*1981/11*	103.2	4	50.7
1975/12	0.0	0	0.0	*1978/12*	0.0	0	0.0	*1981/12*	0.0	0	0.0
1976/1	0.0	0	0.0	*1979/1*	0.0	0	0.0	*1982/1*	0.0	0	0.0
1976/2	51.2	1	51.2	*1979/2*	0.0	0	0.0	*1982/2*	6.9	1	6.9
1976/3	16.4	2	15.7	*1979/3*	0.0	0	0.0	*1982/3*	8.5	1	8.5
1976/4	65.2	4	23.4	*1979/4*	34.9	3	13.8	*1982/4*	110.0	3	50.3
1976/5	286.2	15	80.5	*1979/5*	25.2	5	10.2	*1982/5*	71.5	8	17.9
1976/6	49.5	3	23.8	*1979/6*	254.5	18	50.0	*1982/6*	511.0	11	180.7
1976/7	197.8	19	57.6	*1979/7*	81.9	8	24.5	*1982/7*	168.2	8	61.8
1976/8	320.2	23	49.0	*1979/8*	106.3	10	34.4	*1982/8*	180.3	12	48.7
1976/9	311.1	22	34.6	*1979/9*	229.0	16	48.0	*1982/9*	354.6	17	79.4
1976/10	89.6	9	38.0	*1979/10*	3.9	1	3.9	*1982/10*	163.1	7	60.1
1976/11	25.5	4	13.3	*1979/11*	0.0	0	0.0	*1982/11*	26.9	2	22.6
1976/12	0.0	0	0.0	*1979/12*	0.0	0	0.0	*1982/12*	0.0	0	0.0
1977/1	0.0	0	0.0	*1980/1*	0.0	0	0.0	*1983/1*	0.0	0	0.0
1977/2	0.0	0	0.0	*1980/2*	0.0	0	0.0	*1983/2*	0.0	0	0.0
1977/3	0.0	0	0.0	*1980/3*	0.0	0	0.0	*1983/3*	0.9	1	0.9
1977/4	53.0	4	23.7	*1980/4*	39.0	2	35.5	*1983/4*	9.8	1	9.8
1977/5	167.6	13	47.7	*1980/5*	197.7	9	57.5	*1983/5*	237.2	9	110.5
1977/6	89.5	6	51.7	*1980/6*	167.5	8	43.3	*1983/6*	211.4	10	68.0
1977/7	284.1	13	70.8	*1980/7*	375.1	12	153.2	*1983/7*	274.3	11	63.8
1977/8	308.0	16	50.2	*1980/8*	240.4	11	55.0	*1983/8*	380.1	17	80.1
1977/9	211.3	10	60.5	*1980/9*	532.4	21	94.4	*1983/9*	268.6	16	85.6
1977/10	174.8	7	60.3	*1980/10*	155.7	10	46.3	*1983/10*	250.4	11	45.2
1977/11	0.0	0	0.0	*1980/11*	0.0	0	0.0	*1983/11*	130.5	5	114.5
1977/12	33.3	1	33.3	*1980/12*	0.0	0	0.0	*1983/12*	28.8	3	15.0

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Station : Muang Phichit / Phichit (386001)

Year/ month	Monthly total	No. Of rainy day	Daily maximum	Year/ month	Monthly total	No. Of rainy day	Daily maximum	Year/ month	Monthly total	No. Of rainy day	Daily maximum
1984/1	0.0	0	0.0	*1987/1*	0.0	0	0.0	*1990/1*	0.0	0	0.0
1984/2	10.9	2	5.8	*1987/2*	0.0	0	0.0	*1990/2*	0.0	0	0.0
1984/3	34.8	3	25.6	*1987/3*	36.4	2	22.2	*1990/3*	82.5	5	48.2
1984/4	61.4	3	55.5	*1987/4*	46.4	5	24.1	*1990/4*	19.5	2	18.0
1984/5	95.8	4	85.3	*1987/5*	78.0	5	51.0	*1990/5*	158.4	12	75.0
1984/6	154.1	8	73.4	*1987/6*	79.6	7	27.0	*1990/6*	145.4	9	56.5
1984/7	89.9	9	24.2	*1987/7*	25.1	6	5.4	*1990/7*	151.0	12	32.2
1984/8	177.5	10	53.4	*1987/8*	115.6	13	30.6	*1990/8*	140.8	11	43.3
1984/9	115.2	11	34.5	*1987/9*	315.5	15	110.1	*1990/9*	191.8	13	33.0
1984/10	84.9	8	24.5	*1987/10*	86.4	5	34.4	*1990/10*	94.0	8	31.5
1984/11	0.0	0	0.0	*1987/11*	44.5	3	29.4	*1990/11*	3.4	1	3.4
1984/12	0.0	0	0.0	*1987/12*	0.0	0	0.0	*1990/12*	0.0	0	0.0
1985/1	2.4	1	2.4	*1988/1*	0.0	0	0.0	*1991/1*	0.0	0	0.0
1985/2	2.4	1	2.4	*1988/2*	2.3	1	2.3	*1991/2*	0.0	0	0.0
1985/3	0.0	0	0.0	*1988/3*	14.7	1	14.7	*1991/3*	6.8	1	6.8
1985/4	55.4	5	24.3	*1988/4*	92.7	3	68.4	*1991/4*	26.0	4	9.4
1985/5	95.9	7	50.7	*1988/5*	154.6	12	36.7	*1991/5*	220.1	12	64.4
1985/6	217.7	11	125.6	*1988/6*	104.6	6	37.3	*1991/6*	97.3	12	32.5
1985/7	252.4	9	89.6	*1988/7*	159.9	11	71.2	*1991/7*	59.5	8	21.0
1985/8	213.1	11	75.6	*1988/8*	241.8	17	37.2	*1991/8*	436.9	22	115.1
1985/9	144.6	6	47.1	*1988/9*	108.4	8	37.0	*1991/9*	107.5	8	47.8
1985/10	175.0	9	114.0	*1988/10*	234.9	10	73.5	*1991/10*	145.3	11	35.6
1985/11	71.7	2	40.8	*1988/11*	0.0	0	0.0	*1991/11*	10.0	1	10.0
1985/12	0.0	0	0.0	*1988/12*	0.0	0	0.0	*1991/12*	0.0	0	0.0
1986/1	0.0	0	0.0	*1989/1*	22.0	1	22.0	*1992/1*	0.0	0	0.0
1986/2	0.0	0	0.0	*1989/2*	0.0	0	0.0	*1992/2*	13.0	1	13.0
1986/3	6.1	1	6.1	*1989/3*	60.5	5	37.5	*1992/3*	0.0	0	0.0
1986/4	54.0	4	23.0	*1989/4*	4.5	1	4.5	*1992/4*	0.0	0	0.0
1986/5	127.2	9	26.0	*1989/5*	177.6	10	46.2	*1992/5*	60.2	5	46.0
1986/6	128.0	10	50.2	*1989/6*	144.4	12	29.5	*1992/6*	142.3	5	74.5
1986/7	172.0	8	70.2	*1989/7*	142.8	10	49.7	*1992/7*	156.6	9	73.7
1986/8	142.8	7	71.3	*1989/8*	176.2	13	78.7	*1992/8*	169.0	13	36.3
1986/9	207.5	8	62.3	*1989/9*	339.1	11	115.0	*1992/9*	307.9	20	51.8
1986/10	74.6	4	47.5	*1989/10*	86.7	9	30.8	*1992/10*	64.7	6	16.3
1986/11	0.0	0	0.0	*1989/11*	37.1	3	25.5	*1992/11*	0.0	0	0.0
1986/12	11.8	1	11.8	*1989/12*	0.0	0	0.0	*1992/12*	36.7	1	36.7

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Station : Muang Phichit / Phichit (386001)

Year/ month	Monthly total	No. Of rainy day	Daily maximum	Year/ month	Monthly total	No. Of rainy day	Daily maximum	Year/ month	Monthly total	No. Of rainy day	Daily maximum
1993/1	3.0	1	3.0	*1996/1*	0.0	0	0.0	*1999/1*	31.6	2	20.9
1993/2	0.0	0	0.0	*1996/2*	70.0	3	45.2	*1999/2*	0.0	0	0.0
1993/3	1.0	1	1.0	*1996/3*	12.0	1	12.0	*1999/3*	0.0	0	0.0
1993/4	43.2	3	30.5	*1996/4*	51.3	5	21.2	*1999/4*	126.0	11	17.6
1993/5	153.8	7	56.3	*1996/5*	99.5	8	27.2	*1999/5*	229.1	14	67.4
1993/6	57.7	7	20.0	*1996/6*	83.2	6	28.4	*1999/6*	132.6	8	65.2
1993/7	110.5	11	20.5	*1996/7*	74.9	7	19.5	*1999/7*	230.7	18	25.7
1993/8	203.3	15	48.5	*1996/8*	264.9	9	122.1	*1999/8*	177.7	17	32.7
1993/9	271.8	20	38.5	*1996/9*	213.7	14	97.4	*1999/9*	118.4	13	24.2
1993/10	6.5	2	3.5	*1996/10*	13.2	4	5.8	*1999/10*	272.8	14	76.9
1993/11	0.0	0	0.0	*1996/11*	131.8	4	70.4	*1999/11*	42.1	3	29.7
1993/12	0.0	0	0.0	*1996/12*	0.0	0	0.0	*1999/12*	0.0	0	0.0
1994/1	0.0	0	0.0	*1997/1*	0.0	0	0.0	*2000/1*	0.0	0	0.0
1994/2	0.0	0	0.0	*1997/2*	0.0	0	0.0	*2000/2*	0.0	0	0.0
1994/3	53.2	6	27.5	*1997/3*	30.5	2	21.1	*2000/3*	0.0	0	0.0
1994/4	36.4	2	19.0	*1997/4*	41.2	3	20.4	*2000/4*	33.8	7	6.8
1994/5	287.8	17	67.3	*1997/5*	92.9	7	30.4	*2000/5*	- 218.1 -		
1994/6	179.0	13	66.7	*1997/6*	36.3	4	17.4	*2000/6*	152.3	21	21.4
1994/7	47.9	10	20.9	*1997/7*	57.8	12	20.7	*2000/7*	154.8	22	13.6
1994/8	420.4	20	57.6	*1997/8*	142.4	12	32.0	*2000/8*	102.6	19	11.1
1994/9	200.5	18	36.7	*1997/9*	129.4	6	49.0	*2000/9*	142.1	19	23.6
1994/10	14.1	5	5.2	*1997/10*	60.9	3	52.0	*2000/10*	78.0	9	28.6
1994/11	0.0	0	0.0	*1997/11*	0.0	0	0.0	*2000/11*	0.0	0	0.0
1994/12	55.0	1	55.0	*1997/12*	0.0	0	0.0	*2000/12*	0.0	0	0.0
1995/1	0.0	0	0.0	*1998/1*	17.4	1	17.4	*2001/1*	14.3	2	12.4
1995/2	0.0	0	0.0	*1998/2*	0.0	0	0.0	*2001/2*	0.0	0	0.0
1995/3	0.0	0	0.0	*1998/3*	7.0	2	6.0	*2001/3*	29.1	5	10.6
1995/4	7.7	2	7.2	*1998/4*	70.0	2	45.0	*2001/4*	0.0	0	0.0
1995/5	105.0	10	31.8	*1998/5*	97.9	5	40.0	*2001/5*	59.1	10	16.3
1995/6	143.5	9	46.1	*1998/6*	20.7	5	7.0	*2001/6*	102.7	13	20.9
1995/7	309.6	22	81.5	*1998/7*	142.3	8	59.0	*2001/7*	116.1	15	17.2
1995/8	420.3	22	110.5	*1998/8*	156.2	10	70.4	*2001/8*	206.1	14	34.2
1995/9	260.2	16	77.7	*1998/9*	40.2	4	17.4	*2001/9*	366.5	17	56.2
1995/10	133.1	10	46.7	*1998/10*	11.7	1	11.7	*2001/10*	- 121.9 -		
1995/11	12.1	2	6.3	*1998/11*	31.6	2	20.4	*2001/11*	- 2.0 -		
1995/12	0.0	0	0.0	*1998/12*	21.2	1	21.2	*2001/12*	- 0.0 -		

Continued

Station : Bang Mun Nak / Phichit (386002)

Year/ month	Monthly total	No. Of rainy day	Daily maximum	*Year/ month*	Monthly total	No. Of rainy day	Daily maximum	*Year/ month*	Monthly total	No. Of rainy day	Daily maximum
1975/1	0.0	0	0.0	*1978/1*	0.0	0	0.0	*1981/1*	0.0	0	0.0
1975/2	3.1	1	3.1	*1978/2*	0.0	0	0.0	*1981/2*	0.0	0	0.0
1975/3	0.0	0	0.0	*1978/3*	0.0	0	0.0	*1981/3*	0.0	0	0.0
1975/4	0.0	0	0.0	*1978/4*	9.6	2	8.2	*1981/4*	72.4	5	22.9
1975/5	185.8	12	38.7	*1978/5*	128.3	9	34.9	*1981/5*	204.6	9	97.8
1975/6	168.0	10	47.7	*1978/6*	150.2	11	40.1	*1981/6*	91.3	15	15.5
1975/7	146.2	14	30.2	*1978/7*	360.2	21	62.3	*1981/7*	189.1	21	39.4
1975/8	100.6	13	21.7	*1978/8*	187.7	13	39.9	*1981/8*	199.6	16	29.9
1975/9	238.7	13	54.5	*1978/9*	393.9	17	71.1	*1981/9*	239.6	13	50.9
1975/10	142.8	11	33.9	*1978/10*	80.4	6	41.7	*1981/10*	8.4	3	4.6
1975/11	0.0	0	0.0	*1978/11*	0.0	0	0.0	*1981/11*	106.4	8	47.9
1975/12	0.0	0	0.0	*1978/12*	0.0	0	0.0	*1981/12*	0.0	0	0.0
1976/1	0.0	0	0.0	*1979/1*	0.0	0	0.0	*1982/1*	0.0	0	0.0
1976/2	0.0	0	0.0	*1979/2*	0.0	0	0.0	*1982/2*	0.0	0	0.0
1976/3	0.0	0	0.0	*1979/3*	0.0	0	0.0	*1982/3*	0.0	0	0.0
1976/4	80.2	3	64.9	*1979/4*	0.0	0	0.0	*1982/4*	0.0	0	0.0
1976/5	182.6	12	45.1	*1979/5*	- 48.3 -			*1982/5*	167.4	7	47.1
1976/6	91.4	8	22.3	*1979/6*	175.0	13	43.7	*1982/6*	194.9	14	34.1
1976/7	221.5	12	56.6	*1979/7*	117.9	11	27.7	*1982/7*	36.7	6	27.4
1976/8	158.3	15	46.4	*1979/8*	105.4	10	33.6	*1982/8*	127.1	10	41.9
1976/9	234.7	14	58.5	*1979/9*	290.2	15	62.1	*1982/9*	247.9	19	59.2
1976/10	137.3	8	46.7	*1979/10*	0.0	0	0.0	*1982/10*	316.3	14	44.5
1976/11	21.2	2	11.8	*1979/11*	0.0	0	0.0	*1982/11*	0.0	0	0.0
1976/12	0.0	0	0.0	*1979/12*	0.0	0	0.0	*1982/12*	0.0	0	0.0
1977/1	0.0	0	0.0	*1980/1*	0.0	0	0.0	*1983/1*	0.0	0	0.0
1977/2	0.0	0	0.0	*1980/2*	0.0	0	0.0	*1983/2*	0.0	0	0.0
1977/3	0.0	0	0.0	*1980/3*	12.5	1	12.5	*1983/3*	0.0	0	0.0
1977/4	37.1	2	18.8	*1980/4*	33.4	1	33.4	*1983/4*	40.6	1	40.6
1977/5	69.6	8	29.2	*1980/5*	280.9	13	66.3	*1983/5*	161.6	9	112.6
1977/6	154.1	6	60.7	*1980/6*	135.2	14	28.6	*1983/6*	135.6	11	56.7
1977/7	84.3	11	23.8	*1980/7*	149.2	11	41.7	*1983/7*	165.9	10	74.6
1977/8	252.2	13	47.9	*1980/8*	91.3	9	35.5	*1983/8*	250.8	16	49.2
1977/9	188.3	12	42.7	*1980/9*	275.1	20	37.8	*1983/9*	263.1	18	41.5
1977/10	34.3	3	20.9	*1980/10*	151.1	6	75.4	*1983/10*	224.9	12	44.8
1977/11	0.0	0	0.0	*1980/11*	0.0	0	0.0	*1983/11*	47.5	5	25.9
1977/12	46.3	1	46.3	*1980/12*	0.0	0	0.0	*1983/12*	6.2	3	3.5

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Station : Bang Mun Nak / Phichit (386002)

Year/ month	Monthly total	No. Of rainy day	Daily maximum	Year/ month	Monthly total	No. Of rainy day	Daily maximum	Year/ month	Monthly total	No. Of rainy day	Daily maximum
1984/1	0.0	0	0.0	1987/1	0.0	0	0.0	1990/1	0.0	0	0.0
1984/2	42.9	1	42.9	1987/2	2.0	1	2.0	1990/2	1.8	1	1.8
1984/3	12.1	1	12.1	1987/3	119.0	2	65.0	1990/3	48.2	2	27.8
1984/4	69.1	2	59.6	1987/4	99.5	6	27.5	1990/4	17.3	1	17.3
1984/5	100.7	2	78.8	1987/5	103.7	4	53.5	1990/5	- 172.5 -		
1984/6	133.0	10	38.0	1987/6	78.9	7	35.5	1990/6	127.1	1	10.3
1984/7	128.9	6	39.8	1987/7	171.7	10	49.5	1990/7	124.3	9	66.2
1984/8	80.9	15	15.3	1987/8	63.5	6	30.0	1990/8	106.3	6	34.2
1984/9	119.3	11	50.1	1987/9	241.1	12	114.0	1990/9	123.6	9	36.2
1984/10	173.4	9	82.6	1987/10	129.2	5	57.2	1990/10	88.0	2	64.3
1984/11	0.0	0	0.0	1987/11	66.8	2	38.8	1990/11	4.2	1	4.2
1984/12	0.0	0	0.0	1987/12	0.0	0	0.0	1990/12	0.0	0	0.0
1985/1	28.5	1	28.5	1988/1	0.0	0	0.0	1991/1	0.0	0	0.0
1985/2	0.0	0	0.0	1988/2	0.0	0	0.0	1991/2	0.0	0	0.0
1985/3	0.0	0	0.0	1988/3	0.0	0	0.0	1991/3	0.0	0	0.0
1985/4	46.1	4	25.4	1988/4	68.8	4	36.0	1991/4	10.1	1	10.1
1985/5	184.9	14	52.5	1988/5	148.8	7	84.0	1991/5	92.2	5	34.5
1985/6	152.0	10	45.5	1988/6	84.5	6	23.0	1991/6	122.7	10	50.4
1985/7	193.9	8	83.0	1988/7	177.7	10	35.0	1991/7	120.6	8	40.0
1985/8	121.8	10	32.0	1988/8	137.7	15	28.0	1991/8	288.9	10	120.3
1985/9	206.9	8	44.0	1988/9	130.5	7	43.0	1991/9	281.2	15	68.7
1985/10	247.3	8	93.0	1988/10	281.0	13	55.0	1991/10	0.0	0	0.0
1985/11	57.3	2	45.0	1988/11	0.0	0	0.0	1991/11	0.0	0	0.0
1985/12	0.0	0	0.0	1988/12	0.0	0	0.0	1991/12	0.0	0	0.0
1986/1	0.0	0	0.0	1989/1	0.0	0	0.0	1992/1	10.9	1	10.9
1986/2	5.7	1	5.7	1989/2	0.0	0	0.0	1992/2	0.0	0	0.0
1986/3	0.0	0	0.0	1989/3	74.6	5	32.3	1992/3	0.0	0	0.0
1986/4	71.4	4	47.5	1989/4	18.2	1	18.2	1992/4	0.0	0	0.0
1986/5	318.8	10	123.0	1989/5	91.3	7	33.7	1992/5	0.0	0	0.0
1986/6	57.1	5	18.5	1989/6	100.3	7	27.1	1992/6	86.2	5	77.6
1986/7	119.5	9	42.5	1989/7	32.1	3	22.3	1992/7	58.6	7	38.2
1986/8	128.6	10	37.6	1989/8	44.8	3	29.7	1992/8	187.0	11	78.4
1986/9	36.2	4	24.7	1989/9	169.8	9	37.0	1992/9	223.8	11	68.4
1986/10	97.5	5	30.0	1989/10	128.3	7	30.1	1992/10	77.2	6	18.2
1986/11	0.0	0	0.0	1989/11	20.1	2	15.8	1992/11	0.0	0	0.0
1986/12	0.0	0	0.0	1989/12	0.0	0	0.0	1992/12	6.8	1	6.8

Continued

Station : Muang Phichit / Phichit (386001)

Year/ month	Monthly total	No. Of rainy day	Daily maximum	Year/ month	Monthly total	No. Of rainy day	Daily maximum	Year/ month	Monthly total	No. Of rainy day	Daily maximum
1993/1	0.0	0	0.0	1996/1	0.0	0	0.0	1999/1	0.0	0	0.0
1993/2	0.0	0	0.0	1996/2	0.0	0	0.0	1999/2	0.0	0	0.0
1993/3	35.8	3	21.6	1996/3	15.3	2	12.7	1999/3	0.0	0	0.0
1993/4	47.9	3	26.7	1996/4	90.4	7	29.4	1999/4	186.1	11	59.4
1993/5	82.5	7	20.1	1996/5	257.4	14	64.8	1999/5	310.5	14	54.5
1993/6	44.6	3	18.8	1996/6	133.6	9	57.4	1999/6	181.4	8	44.3
1993/7	20.1	5	12.8	1996/7	68.2	3	34.9	1999/7	126.2	6	38.9
1993/8	78.0	11	17.6	1996/8	254.8	15	44.8	1999/8	112.4	18	42.4
1993/9	286.8	12	72.6	1996/9	190.6	12	32.6	1999/9	241.7	17	34.6
1993/10	30.7	3	26.5	1996/10	198.1	11	52.5	1999/10	220.9	17	57.5
1993/11	0.0	0	0.0	1996/11	183.2	5	68.7	1999/11	5.3	3	2.4
1993/12	0.0	0	0.0	1996/12	0.0	0	0.0	1999/12	0.0	0	0.0
1994/1	0.0	0	0.0	1997/1	0.0	0	0.0	2000/1	0.0	0	0.0
1994/2	4.5	1	4.5	1997/2	0.0	0	0.0	2000/2	0.0	0	0.0
1994/3	42.1	4	25.8	1997/3	0.0	0	0.0	2000/3	0.0	0	0.0
1994/4	42.4	1	42.4	1997/4	30.5	4	10.7	2000/4	61.8	8	15.7
1994/5	220.1	11	44.6	1997/5	64.9	5	36.9	2000/5	106.7	14	45.6
1994/6	124.2	6	69.8	1997/6	- 62.8 -			2000/6	259.9	12	47.8
1994/7	22.8	3	19.8	1997/7	118.2	13	29.6	2000/7	93.0	8	36.8
1994/8	331.2	22	36.2	1997/8	130.7	10	48.9	2000/8	145.1	10	35.5
1994/9	109.3	11	24.8	1997/9	438.8	14	54.8	2000/9	182.1	14	58.7
1994/10	49.4	1	49.4	1997/10	99.6	5	44.5	2000/10	147.4	9	55.7
1994/11	0.0	0	0.0	1997/11	2.8	2	1.6	2000/11	0.0	0	0.0
1994/12	0.0	0	0.0	1997/12	0.0	0	0.0	2000/12	0.0	0	0.0
1995/1	0.0	0	0.0	1998/1	0.0	0	0.0	2001/1	0.0	0	0.0
1995/2	0.0	0	0.0	1998/2	0.0	0	0.0	2001/2	0.0	0	0.0
1995/3	0.0	0	0.0	1998/3	19.9	2	14.7	2001/3	62.5	9	24.6
1995/4	25.4	2	24.8	1998/4	66.9	5	40.7	2001/4	0.0	0	0.0
1995/5	171.1	10	59.7	1998/5	134.5	10	39.5	2001/5	109.8	10	19.2
1995/6	170.3	8	37.2	1998/6	155.1	10	27.4	2001/6	102.5	11	19.7
1995/7	385.3	16	56.4	1998/7	114.9	12	28.9	2001/7	27.4	2	14.8
1995/8	427.9	20	54.9	1998/8	109.2	12	25.7	2001/8	152.6	8	35.9
1995/9	117.5	12	36.4	1998/9	283.6	12	67.4	2001/9	290.6	18	49.3
1995/10	45.2	4	14.7	1998/10	184.9	7	64.7	2001/10	97.5	7	39.2
1995/11	0.0	0	0.0	1998/11	21.9	4	14.6	2001/11	0.0	0	0.0
1995/12	0.0	0	0.0	1998/12	0.0	0	0.0	2001/12	0.0	0	0.0

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Station : Wang Sai Phun / Phichit (386005)

Year/ month	Monthly total	No. Of rainy day	Daily maximum	Year/ month	Monthly total	No. Of rainy day	Daily maximum	Year/ month	Monthly total	No. Of rainy day	Daily maximum
1979/1	0.0	0	0.0	1982/1	0.0	0	0.0	1985/1	13.0	2	11.5
1979/2	0.0	0	0.0	1982/2	0.0	0	0.0	1985/2	17.5	3	8.5
1979/3	0.0	0	0.0	1982/3	16.8	1	16.8	1985/3	0.0	0	0.0
1979/4	- 20.0 -			1982/4	72.1	6	57.3	1985/4	127.5	5	108.0
1979/5	- 48.3 -			1982/5	122.1	10	56.3	1985/5	231.0	8	57.0
1979/6	326.6	15	124.0	1982/6	233.8	18	39.0	1985/6	179.0	13	33.0
1979/7	132.9	11	51.2	1982/7	219.6	13	54.0	1985/7	145.0	14	33.0
1979/8	191.1	15	47.2	1982/8	380.8	19	63.0	1985/8	163.0	19	21.0
1979/9	149.5	18	52.1	1982/9	483.3	21	77.5	1985/9	271.0	15	58.5
1979/10	13.2	2	12.9	1982/10	131.4	9	35.0	1985/10	150.0	11	56.0
1979/11	0.0	0	0.0	1982/11	12.4	2	7.3	1985/11	230.5	4	91.0
1979/12	0.0	0	0.0	1982/12	0.0	0	0.0	1985/12	0.0	0	0.0
1980/1	0.0	0	0.0	1983/1	0.0	0	0.0	1986/1	0.0	0	0.0
1980/2	37.9	2	33.6	1983/2	0.0	0	0.0	1986/2	0.0	0	0.0
1980/3	14.8	2	12.0	1983/3	0.0	0	0.0	1986/3	62.0	1	62.0
1980/4	48.4	4	37.1	1983/4	3.8	1	3.8	1986/4	138.7	3	75.0
1980/5	188.4	16	50.2	1983/5	178.8	11	57.8	1986/5	131.2	9	37.3
1980/6	141.5	21	30.0	1983/6	206.1	13	54.0	1986/6	306.5	11	70.0
1980/7	312.9	22	102.7	1983/7	279.5	16	72.5	1986/7	162.1	8	85.5
1980/8	160.4	10	48.0	1983/8	271.0	20	89.3	1986/8	200.0	12	80.3
1980/9	376.1	18	96.6	1983/9	223.8	21	48.2	1986/9	90.6	5	58.0
1980/10	204.1	12	44.1	1983/10	153.0	14	44.0	1986/10	89.4	7	40.2
1980/11	1.5	1	1.5	1983/11	93.6	3	38.0	1986/11	0.0	0	0.0
1980/12	0.0	0	0.0	1983/12	19.8	2	17.5	1986/12	5.8	1	5.8
1981/1	0.0	0	0.0	1984/1	0.0	0	0.0	1987/1	0.0	0	0.0
1981/2	3.9	1	3.9	1984/2	47.3	3	22.5	1987/2	0.0	0	0.0
1981/3	90.0	2	67.3	1984/3	39.7	4	19.0	1987/3	94.0	4	60.5
1981/4	35.2	3	22.4	1984/4	33.3	4	11.5	1987/4	25.5	8	10.5
1981/5	223.9	13	57.8	1984/5	126.1	10	45.0	1987/5	110.5	5	90.0
1981/6	115.2	15	29.8	1984/6	190.7	12	40.0	1987/6	182.2	6	54.0
1981/7	302.4	19	41.0	1984/7	63.8	6	18.5	1987/7	111.0	6	37.0
1981/8	237.8	15	117.4	1984/8	170.8	18	40.5	1987/8	129.9	15	19.3
1981/9	79.9	11	15.2	1984/9	170.5	17	40.0	1987/9	372.2	20	98.5
1981/10	105.1	10	33.4	1984/10	150.8	12	30.8	1987/10	128.9	5	49.0
1981/11	34.7	7	12.9	1984/11	31.0	1	31.0	1987/11	16.8	1	16.8
1981/12	0.0	0	0.0	1984/12	0.0	0	0.0	1987/12	0.0	0	0.0

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Station : Wang Sai Phun / Phichit (386005)

Year/ month	Monthly total	No. Of rainy day	Daily maximum	Year/ month	Monthly total	No. Of rainy day	Daily maximum	Year/ month	Monthly total	No. Of rainy day	Daily maximum
1988/1	0.0	0	0.0	*1991/1*	0.0	0	0.0	*1994/1*	0.0	0	0.0
1988/2	5.5	2	3.2	*1991/2*	0.0	0	0.0	*1994/2*	1.2	1	1.2
1988/3	0.0	0	0.0	*1991/3*	0.0	0	0.0	*1994/3*	174.0	7	48.0
1988/4	101.0	2	58.0	*1991/4*	19.0	4	10.5	*1994/4*	15.0	1	15.0
1988/5	382.5	15	56.7	*1991/5*	71.1	6	21.4	*1994/5*	209.0	15	35.0
1988/6	177.5	11	83.4	*1991/6*	59.3	11	13.0	*1994/6*	129.0	10	30.0
1988/7	128.3	10	46.7	*1991/7*	105.3	9	30.8	*1994/7*	55.0	15	15.0
1988/8	330.9	19	70.6	*1991/8*	552.9	23	70.4	*1994/8*	223.5	20	32.0
1988/9	112.2	11	25.0	*1991/9*	102.0	11	42.0	*1994/9*	115.0	15	23.0
1988/10	185.7	13	36.8	*1991/10*	56.3	10	20.0	*1994/10*	17.0	4	8.0
1988/11	0.0	0	0.0	*1991/11*	0.0	0	0.0	*1994/11*	0.0	0	0.0
1988/12	0.0	0	0.0	*1991/12*	0.0	0	0.0	*1994/12*	26.0	3	15.0
1989/1	0.0	0	0.0	*1992/1*	0.0	0	0.0	*1995/1*	0.0	0	0.0
1989/2	0.0	0	0.0	*1992/2*	6.5	2	5.0	*1995/2*	0.0	0	0.0
1989/3	115.8	3	60.1	*1992/3*	0.0	0	0.0	*1995/3*	26.0	3	20.0
1989/4	46.4	1	46.4	*1992/4*	5.0	1	5.0	*1995/4*	73.0	5	30.0
1989/5	177.3	9	45.8	*1992/5*	10.5	3	6.5	*1995/5*	116.0	11	28.0
1989/6	211.7	10	62.5	*1992/6*	31.2	5	14.5	*1995/6*	42.0	10	10.0
1989/7	47.4	5	24.0	*1992/7*	124.6	10	35.0	*1995/7*	279.0	19	35.0
1989/8	200.8	16	70.6	*1992/8*	234.0	16	44.0	*1995/8*	314.0	24	28.0
1989/9	166.0	9	48.0	*1992/9*	117.7	20	26.8	*1995/9*	186.0	13	26.0
1989/10	121.0	11	33.0	*1992/10*	62.8	12	22.0	*1995/10*	20.0	3	10.0
1989/11	12.0	1	12.0	*1992/11*	0.0	0	0.0	*1995/11*	10.0	1	10.0
1989/12	0.0	0	0.0	*1992/12*	85.0	1	85.0	*1995/12*	0.0	0	0.0
1990/1	0.0	0	0.0	*1993/1*	0.0	0	0.0	*1996/1*	0.0	0	0.0
1990/2	0.0	0	0.0	*1993/2*	6.0	1	6.0	*1996/2*	90.0	3	45.0
1990/3	87.2	3	52.0	*1993/3*	10.5	2	8.0	*1996/3*	1.0	1	1.0
1990/4	0.0	0	0.0	*1993/4*	21.5	4	11.0	*1996/4*	320.3	8	95.1
1990/5	148.6	11	28.6	*1993/5*	119.8	10	25.0	*1996/5*	169.7	7	80.8
1990/6	89.5	13	24.0	*1993/6*	15.0	5	6.0	*1996/6*	155.5	8	47.0
1990/7	192.7	14	33.2	*1993/7*	186.3	12	40.0	*1996/7*	138.9	12	28.0
1990/8	166.0	11	76.0	*1993/8*	145.0	18	28.0	*1996/8*	309.5	16	56.7
1990/9	258.7	16	40.0	*1993/9*	294.1	15	65.0	*1996/9*	389.7	17	82.8
1990/10	108.8	7	29.0	*1993/10*	45.0	7	16.0	*1996/10*	75.2	6	24.3
1990/11	0.0	0	0.0	*1993/11*	0.0	0	0.0	*1996/11*	159.8	5	44.0
1990/12	0.0	0	0.0	*1993/12*	0.0	0	0.0	*1996/12*	0.0	0	0.0

Continued

Station : Wang Sai Phun / Phichit (386005)

Year/ month	Monthly total	No. Of rainy day	Daily maximum	Year/ month	Monthly total	No. Of rainy day	Daily maximum
1997/1	0.0	0	0.0	2000/1	0.0	0	0.0
1997/2	0.0	0	0.0	2000/2	0.0	0	0.0
1997/3	55.2	2	30.2	2000/3	0.0	0	0.0
1997/4	50.4	3	23.0	2000/4	195.3	10	40.1
1997/5	72.7	4	32.0	2000/5	182.2	10	37.0
1997/6	48.4	6	18.5	2000/6	219.4	14	51.1
1997/7	113.4	13	20.4	2000/7	123.5	14	20.0
1997/8	140.5	15	20.0	2000/8	258.7	9	86.4
1997/9	272.1	12	47.5	2000/9	303.0	19	120.4
1997/10	140.3	10	35.3	2000/10	176.8	13	48.0
1997/11	32.4	1	32.4	2000/11	0.0	0	0.0
1997/12	0.0	0	0.0	2000/12	4.7	1	4.7
1998/1	0.0	0	0.0	2001/1	8.1	1	8.1
1998/2	3.4	1	3.4	2001/2	0.0	0	0.0
1998/3	0.0	0	0.0	2001/3	77.0	6	37.4
1998/4	48.5	3	25.3	2001/4	66.5	4	39.0
1998/5	256.7	8	68.5	2001/5	156.1	13	30.0
1998/6	77.5	7	43.2	2001/6	145.3	11	37.5
1998/7	257.0	10	64.3	2001/7	97.7	12	20.5
1998/8	147.4	11	48.4	2001/8	230.8	17	43.0
1998/9	254.5	16	57.5	2001/9	249.0	12	42.0
1998/10	99.9	8	56.2	2001/10	146.6	10	37.5
1998/11	20.0	2	12.0	2001/11	0.0	0	0.0
1998/12	0.0	0	0.0	2001/12	0.0	0	0.0
1999/1	15.2	1	15.2				
1999/2	0.0	0	0.0				
1999/3	5.4	1	5.4				
1999/4	98.7	7	30.6				
1999/5	201.4	13	40.1				
1999/6	192.8	8	54.5				
1999/7	443.1	14	75.3				
1999/8	284.6	14	59.7				
1999/9	182.6	13	31.3				
1999/10	136.1	11	34.1				
1999/11	45.0	4	19.2				
1999/12	0.0	0	0.0				

Continued

Station : Taphan Hin / Phichit (386006

Year/ month	Monthly total	No. Of rainy day	Daily maximum	*Year/ month*	Monthly total	No. Of rainy day	Daily maximum	*Year/ month*	Monthly total	No. Of rainy day	Daily maximum
1975/1	58.9	6	28.2	*1978/1*	2.6	1	2.6	*1981/1*	0.0	0	0.0
1975/2	33.6	3	24.7	*1978/2*	4.5	2	3.4	*1981/2*	23.8	1	23.8
1975/3	5.8	2	3.1	*1978/3*	0.0	0	0.0	*1981/3*	15.6	2	13.5
1975/4	2.6	2	2.5	*1978/4*	30.9	5	10.7	*1981/4*	83.6	7	49.8
1975/5	167.9	19	49.5	*1978/5*	137.3	12	36.3	*1981/5*	100.4	13	14.5
1975/6	187.6	15	32.0	*1978/6*	160.7	14	31.5	*1981/6*	166.9	14	44.5
1975/7	187.0	15	59.3	*1978/7*	404.6	23	76.8	*1981/7*	257.3	22	33.0
1975/8	238.6	19	34.5	*1978/8*	207.0	20	45.6	*1981/8*	307.9	18	79.2
1975/9	284.0	15	72.3	*1978/9*	218.3	19	47.4	*1981/9*	183.2	14	38.8
1975/10	149.1	11	61.9	*1978/10*	37.6	6	15.4	*1981/10*	42.3	7	17.2
1975/11	13.5	3	6.5	*1978/11*	12.5	1	12.5	*1981/11*	52.4	7	16.6
1975/12	19.3	2	10.7	*1978/12*	0.0	0	0.0	*1981/12*	0.0	0	0.0
1976/1	0.0	0	0.0	*1979/1*	0.0	0	0.0	*1982/1*	0.0	0	0.0
1976/2	8.7	1	8.7	*1979/2*	152.2	2	151.3	*1982/2*	1.7	1	1.7
1976/3	11.2	2	7.6	*1979/3*	0.0	0	0.0	*1982/3*	1.0	2	0.6
1976/4	100.1	4	46.3	*1979/4*	25.1	5	16.6	*1982/4*	16.9	2	16.0
1976/5	124.8	12	24.6	*1979/5*	71.4	12	22.4	*1982/5*	87.0	12	24.0
1976/6	152.0	10	54.3	*1979/6*	258.0	14	104.8	*1982/6*	163.8	16	57.4
1976/7	173.4	11	57.7	*1979/7*	73.1	10	18.9	*1982/7*	252.2	12	71.8
1976/8	324.5	20	44.9	*1979/8*	234.7	19	46.5	*1982/8*	223.0	18	72.8
1976/9	234.3	22	36.2	*1979/9*	254.6	17	85.3	*1982/9*	332.9	20	65.0
1976/10	214.7	17	39.2	*1979/10*	3.3	1	3.3	*1982/10*	103.7	17	21.3
1976/11	24.3	2	17.6	*1979/11*	0.0	0	0.0	*1982/11*	27.4	2	22.0
1976/12	0.0	0	0.0	*1979/12*	0.0	0	0.0	*1982/12*	0.0	0	0.0
1977/1	4.9	2	3.4	*1980/1*	0.0	0	0.0	*1983/1*	4.0	1	4.0
1977/2	0.0	0	0.0	*1980/2*	13.0	1	13.0	*1983/2*	0.0	0	0.0
1977/3	7.5	2	6.8	*1980/3*	3.6	2	2.7	*1983/3*	0.0	0	0.0
1977/4	25.5	5	10.1	*1980/4*	28.5	3	21.2	*1983/4*	16.8	2	15.0
1977/5	68.3	13	19.1	*1980/5*	252.9	16	35.8	*1983/5*	207.5	9	53.6
1977/6	42.5	6	29.7	*1980/6*	164.1	18	50.2	*1983/6*	194.2	12	52.0
1977/7	152.7	17	41.7	*1980/7*	270.4	21	67.4	*1983/7*	242.4	13	61.5
1977/8	296.5	18	66.0	*1980/8*	173.4	15	74.2	*1983/8*	255.5	21	55.3
1977/9	359.1	16	106.2	*1980/9*	305.0	21	68.9	*1983/9*	162.0	19	28.2
1977/10	65.8	10	22.5	*1980/10*	165.8	17	32.2	*1983/10*	110.9	17	21.2
1977/11	0.0	0	0.0	*1980/11*	23.6	1	23.6	*1983/11*	58.9	6	43.4
1977/12	17.6	1	17.6	*1980/12*	0.0	0	0.0	*1983/12*	28.0	4	13.8

Continued

Station : Taphan Hin / Phichit (386006)

Year/ month	Monthly total	No. Of rainy day	Daily maximum	Year/ month	Monthly total	No. Of rainy day	Daily maximum	Year/ month	Monthly total	No. Of rainy day	Daily maximum
1984/1	0.0	0	0.0	1987/1	0.0	0	0.0	1990/1	0.0	0	0.0
1984/2	10.3	3	6.8	1987/2	1.0	1	1.0	1990/2	6.1	1	6.1
1984/3	27.0	4	16.8	1987/3	88.0	3	57.0	1990/3	196.8	5	99.7
1984/4	93.6	7	31.8	1987/4	65.5	5	24.0	1990/4	36.6	2	24.8
1984/5	98.3	12	35.2	1987/5	63.6	3	42.3	1990/5	212.1	9	102.0
1984/6	168.2	15	29.6	1987/6	103.8	7	29.6	1990/6	79.2	8	20.9
1984/7	125.0	15	42.5	1987/7	86.9	6	33.7	1990/7	128.8	17	22.0
1984/8	129.8	18	21.8	1987/8	106.4	11	25.7	1990/8	157.4	16	46.6
1984/9	192.4	18	32.2	1987/9	382.8	18	97.9	1990/9	110.1	15	26.1
1984/10	141.0	10	42.5	1987/10	10.8	2	6.2	1990/10	105.7	8	32.2
1984/11	4.1	3	2.1	1987/11	51.6	7	23.2	1990/11	10.4	1	10.4
1984/12	0.0	0	0.0	1987/12	0.0	0	0.0	1990/12	0.0	0	0.0
1985/1	60.5	2	48.0	1988/1	0.0	0	0.0	1991/1	7.5	1	7.5
1985/2	13.2	1	13.2	1988/2	64.3	2	34.3	1991/2	0.0	0	0.0
1985/3	0.0	0	0.0	1988/3	40.1	1	40.1	1991/3	3.7	1	3.7
1985/4	104.2	6	63.2	1988/4	48.3	4	40.7	1991/4	12.6	2	11.5
1985/5	287.7	13	46.2	1988/5	171.5	10	40.3	1991/5	148.0	6	58.4
1985/6	164.5	15	36.6	1988/6	99.3	11	27.8	1991/6	100.2	13	38.4
1985/7	203.9	14	65.2	1988/7	194.5	10	46.8	1991/7	40.6	11	10.6
1985/8	202.3	12	48.5	1988/8	217.3	15	49.7	1991/8	406.0	22	126.2
1985/9	213.4	10	42.8	1988/9	29.8	5	20.2	1991/9	291.6	20	77.4
1985/10	193.6	6	80.6	1988/10	111.9	13	24.2	1991/10	112.4	9	37.4
1985/11	96.2	3	58.5	1988/11	0.0	0	0.0	1991/11	0.0	0	0.0
1985/12	0.0	0	0.0	1988/12	0.0	0	0.0	1991/12	4.1	2	3.3
1986/1	0.0	0	0.0	1989/1	7.3	1	7.3	1992/1	5.7	1	5.7
1986/2	0.0	0	0.0	1989/2	0.0	0	0.0	1992/2	0.8	1	8.0
1986/3	10.5	1	10.5	1989/3	79.3	5	22.8	1992/3	0.0	0	0.0
1986/4	84.7	9	26.7	1989/4	13.3	1	13.3	1992/4	2.2	1	2.2
1986/5	164.4	9	88.5	1989/5	138.0	13	35.5	1992/5	42.8	4	36.7
1986/6	90.4	8	46.8	1989/6	153.8	15	69.9	1992/6	105.1	9	32.9
1986/7	147.3	13	41.1	1989/7	61.1	14	10.3	1992/7	204.6	12	70.7
1986/8	216.3	16	48.3	1989/8	192.8	14	38.2	1992/8	212.4	16	41.6
1986/9	182.5	8	70.1	1989/9	217.9	14	71.3	1992/9	308.7	20	50.2
1986/10	30.9	5	10.8	1989/10	135.1	10	39.9	1992/10	114.6	11	22.5
1986/11	0.0	0	0.0	1989/11	20.6	2	19.3	1992/11	0.0	0	0.0
1986/12	0.0	0	0.0	1989/12	0.0	0	0.0	1992/12	41.2	1	41.2

Continued

Station : Taphan Hin / Phichit (386006)

Year/ month	Monthly total	No. Of rainy day	Daily maximum	Year/ month	Monthly total	No. Of rainy day	Daily maximum	Year/ month	Monthly total	No. Of rainy day	Daily maximum
1993/1	0.7	1	0.7	1996/1	0.0	0	0.0	1999/1	0.9	1	0.9
1993/2	0.0	0	0.0	1996/2	96.9	2	58.3	1999/2	1.5	1	1.5
1993/3	21.7	4	12.1	1996/3	5.0	1	5.0	1999/3	5.8	1	5.8
1993/4	37.3	4	20.7	1996/4	145.8	8	62.2	1999/4	176.6	11	65.2
1993/5	181.5	12	63.4	1996/5	219.4	11	36.7	1999/5	272.9	16	76.4
1993/6	87.9	7	28.1	1996/6	146.3	12	46.7	1999/6	89.8	12	22.0
1993/7	116.7	10	51.3	1996/7	94.5	11	57.2	1999/7	137.7	15	57.3
1993/8	151.8	12	32.9	1996/8	262.5	16	44.3	1999/8	266.1	22	90.6
1993/9	263.9	16	53.7	1996/9	221.8	24	36.2	1999/9	310.9	20	104.4
1993/10	32.0	7	13.0	1996/10	104.6	10	40.3	1999/10	179.0	17	35.7
1993/11	0.0	0	0.0	1996/11	175.6	7	85.7	1999/11	21.8	6	8.2
1993/12	0.0	0	0.0	1996/12	4.8	1	4.8	1999/12	0.0	0	0.0
1994/1	0.0	0	0.0	1997/1	0.0	0	0.0	2000/1	0.0	0	0.0
1994/2	7.3	1	7.3	1997/2	11.6	1	11.6	2000/2	7.9	3	5.0
1994/3	143.2	7	89.2	1997/3	8.3	3	3.8	2000/3	0.0	0	0.0
1994/4	19.2	2	114.2	1997/4	84.8	5	36.2	2000/4	99.6	10	47.3
1994/5	311.3	17	161.0	1997/5	22.5	6	9.3	2000/5	149.7	13	35.8
1994/6	124.9	12	44.7	1997/6	66.2	7	31.7	2000/6	186.6	15	58.8
1994/7	54.6	14	14.3	1997/7	98.3	13	21.6	2000/7	127.8	15	51.6
1994/8	281.1	19	44.1	1997/8	182.1	15	51.8	2000/8	181.7	16	55.7
1994/9	220.0	20	38.5	1997/9	249.6	18	48.5	2000/9	296.5	12	168.0
1994/10	123.6	7	55.6	1997/10	82.9	8	33.6	2000/10	261.3	13	68.4
1994/11	0.0	0	0.0	1997/11	2.4	2	1.8	2000/11	11.0	1	11.0
1994/12	0.0	0	0.0	1997/12	0.0	0	0.0	2000/12	0.0	0	0.0
1995/1	0.0	0	0.0	1998/1	0.0	0	0.0	2001/1	0.0	0	0.0
1995/2	0.0	0	0.0	1998/2	9.3	3	4.5	2001/2	15.3	3	7.5
1995/3	8.6	1	8.6	1998/3	10.9	1	10.9	2001/3	85.7	9	59.5
1995/4	57.0	4	26.5	1998/4	31.9	5	20.5	2001/4	20.7	1	20.7
1995/5	248.3	10	75.5	1998/5	155.7	10	33.2	2001/5	141.9	13	80.3
1995/6	63.8	9	19.0	1998/6	94.6	5	53.4	2001/6	93.4	14	29.1
1995/7	360.8	22	66.7	1998/7	67.7	11	13.4	2001/7	93.2	13	40.9
1995/8	408.2	24	63.8	1998/8	198.5	17	63.7	2001/8	176.7	18	36.8
1995/9	219.7	21	44.3	1998/9	285.7	13	77.8	2001/9	264.6	13	97.6
1995/10	69.1	6	39.2	1998/10	122.3	9	38.8	2001/10	155.9	15	28.3
1995/11	9.8	3	6.2	1998/11	60.4	3	30.9	2001/11	4.4	2	3.7
1995/12	0.0	0	0.0	1998/12	0.0	0	0.0	2001/12	0.0	0	0.0

Continued

Station : Khao Sai School / Phichit (386008)

Year/ month	Monthly total	No. Of rainy day	Daily maximum	*Year/ month*	Monthly total	No. Of rainy day	Daily maximum	*Year/ month*	Monthly total	No. Of rainy day	Daily maximum
1984/1	0.0	0	0.0	*1987/1*	0.0	0	0.0	*1990/1*	0.0	0	0.0
1984/2	55.0	2	32.0	*1987/2*	0.0	0	0.0	*1990/2*	7.4	1	7.4
1984/3	19.3	3	14.0	*1987/3*	102.2	4	54.3	*1990/3*	131.4	4	60.7
1984/4	256.0	4	130.0	*1987/4*	15.8	2	14.0	*1990/4*	0.0	0	0.0
1984/5	160.0	12	50.0	*1987/5*	29.1	6	7.0	*1990/5*	156.9	10	40.9
1984/6	313.1	15	51.1	*1987/6*	10.5	3	4.0	*1990/6*	123.4	11	56.0
1984/7	154.9	11	40.8	*1987/7*	50.0	3	35.0	*1990/7*	121.3	15	41.0
1984/8	135.9	14	25.7	*1987/8*	60.2	7	15.5	*1990/8*	- 143.5 -		
1984/9	146.6	10	84.5	*1987/9*	350.8	14	93.0	*1990/9*	- 209.5 -		
1984/10	90.9	9	36.0	*1987/10*	68.5	5	23.7	*1990/10*	- 100.4 -		
1984/11	65.8	4	45.0	*1987/11*	67.6	5	37.5	*1990/11*	0.0	0	0.0
1984/12	0.0	0	0.0	*1987/12*	0.0	0	0.0	*1990/12*	- 0.0 -		
1985/1	43.8	2	34.5	*1988/1*	0.0	0	0.0	*1991/1*	0.0	0	0.0
1985/2	0.0	0	0.0	*1988/2*	50.7	3	39.8	*1991/2*	0.0	0	0.0
1985/3	28.2	2	20.5	*1988/3*	1.2	1	1.2	*1991/3*	- 3.7 -		
1985/4	204.1	6	100.8	*1988/4*	83.6	3	36.0	*1991/4*	- 24.1 -		
1985/5	98.0	10	21.8	*1988/5*	232.8	13	55.2	*1991/5*	- 185.9 -		
1985/6	205.7	14	50.2	*1988/6*	173.7	10	80.5	*1991/6*	147.0	10	57.4
1985/7	144.2	9	60.5	*1988/7*	129.9	11	30.0	*1991/7*	193.5	8	90.0
1985/8	282.3	11	60.9	*1988/8*	312.1	16	113.7	*1991/8*	313.4	16	81.8
1985/9	274.6	13	78.5	*1988/9*	75.0	8	16.5	*1991/9*	125.9	14	25.7
1985/10	249.6	7	134.0	*1988/10*	334.1	13	69.8	*1991/10*	87.4	7	27.3
1985/11	70.2	2	66.5	*1988/11*	4.4	1	4.4	*1991/11*	0.0	0	0.0
1985/12	0.0	0	0.0	*1988/12*	0.0	0	0.0	*1991/12*	5.5	1	5.5
1986/1	0.0	0	0.0	*1989/1*	0.0	0	0.0	*1992/1*	7.7	2	4.2
1986/2	0.0	0	0.0	*1989/2*	0.0	0	0.0	*1992/2*	3.5	1	3.5
1986/3	0.0	0	0.0	*1989/3*	24.6	4	12.5	*1992/3*	0.0	0	0.0
1986/4	65.0	5	20.7	*1989/4*	42.6	3	30.0	*1992/4*	1.0	1	1.0
1986/5	114.4	6	44.8	*1989/5*	160.8	8	62.5	*1992/5*	78.0	6	42.2
1986/6	71.3	3	39.8	*1989/6*	172.0	17	28.4	*1992/6*	132.6	8	40.1
1986/7	43.5	3	32.5	*1989/7*	161.5	11	40.1	*1992/7*	- 153.0 -		
1986/8	224.1	14	50.0	*1989/8*	209.3	13	37.0	*1992/8*	- 252.7 -		
1986/9	194.3	7	78.4	*1989/9*	171.0	13	43.0	*1992/9*	- 260.5 -		
1986/10	122.6	5	32.5	*1989/10*	90.7	9	30.3	*1992/10*	121.2	7	28.2
1986/11	14.5	1	14.5	*1989/11*	6.5	2	4.7	*1992/11*	0.0	0	0.0
1986/12	8.2	1	8.2	*1989/12*	- 0.0 -			*1992/12*	20.0	1	20.0

Continued

Station : Khao Sai School / Phichit (386008)

Year/ month	Monthly total	No. Of rainy day	Daily maximum	*Year/ month*	Monthly total	No. Of rainy day	Daily maximum	*Year/ month*	Monthly total	No. Of rainy day	Daily maximum
1993/1	0.0	0	0.0	*1996/1*	0.0	0	0.0	*1999/1*	0.0	0	0.0
1993/2	0.0	0	0.0	*1996/2*	45.9	2	28.5	*1999/2*	0.0	0	0.0
1993/3	70.9	5	53.2	*1996/3*	15.5	1	15.5	*1999/3*	0.0	0	0.0
1993/4	25.1	4	9.7	*1996/4*	63.9	7	14.0	*1999/4*	97.5	8	41.7
1993/5	230.0	14	98.4	*1996/5*	141.2	11	45.5	*1999/5*	180.9	14	45.5
1993/6	33.2	4	17.7	*1996/6*	117.5	10	22.5	*1999/6*	169.9	10	40.6
1993/7	73.9	9	38.3	*1996/7*	61.0	7	27.0	*1999/7*	160.6	10	37.0
1993/8	103.1	10	43.7	*1996/8*	196.3	10	59.8	*1999/8*	133.8	12	34.5
1993/9	- 261.3 -			*1996/9*	172.5	14	32.6	*1999/9*	115.6	8	30.0
1993/10	- 23.7 -			*1996/10*	57.3	8	18.0	*1999/10*	184.9	11	92.0
1993/11	- 0.0 -			*1996/11*	66.0	4	32.5	*1999/11*	59.0	6	21.7
1993/12	- 0.0 -			*1996/12*	0.0	0	0.0	*1999/12*	0.0	0	0.0
1994/1	- 0.0 -			*1997/1*	2.0	1	2.0	*2000/1*	0.0	0	0.0
1994/2	- 8.7 -			*1997/2*	0.0	0	0.0	*2000/2*	46.6	2	42.6
1994/3	- 101.3 -			*1997/3*	2.1	1	2.1	*2000/3*	0.0	0	0.0
1994/4	- 30.1 -			*1997/4*	78.6	6	26.5	*2000/4*	167.1	10	50.0
1994/5	- 232.4 -			*1997/5*	86.4	4	45.7	*2000/5*	141.6	14	24.8
1994/6	- 184.8 -			*1997/6*	39.2	3	22.9	*2000/6*	268.5	11	83.2
1994/7	- 118.4 -			*1997/7*	123.4	13	28.6	*2000/7*	175.0	13	79.0
1994/8	- 328.5 -			*1997/8*	72.0	11	11.0	*2000/8*	261.4	12	72.0
1994/9	- 190.1 -			*1997/9*	148.4	13	22.3	*2000/9*	277.0	12	164.5
1994/10	- 68.1 -			*1997/10*	134.3	7	51.8	*2000/10*	147.7	8	47.3
1994/11	- 0.0 -			*1997/11*	15.5	2	10.0	*2000/11*	18.5	1	18.5
1994/12	40.0	1	40.0	*1997/12*	0.0	0	0.0	*2000/12*	0.0	0	0.0
1995/1	0.0	0	0.0	*1998/1*	0.0	0	0.0	*2001/1*	0.0	0	0.0
1995/2	0.0	0	0.0	*1998/2*	41.1	2	21.0	*2001/2*	11.5	1	11.5
1995/3	28.9	2	18.4	*1998/3*	1.5	1	1.5	*2001/3*	52.5	4	20.0
1995/4	68.0	6	25.5	*1998/4*	55.0	4	26.5	*2001/4*	72.2	2	56.5
1995/5	140.5	12	30.0	*1998/5*	56.7	7	22.4	*2001/5*	168.0	12	42.0
1995/6	20.9	4	10.1	*1998/6*	96.1	10	18.0	*2001/6*	128.7	11	24.0
1995/7	346.1	15	70.5	*1998/7*	112.8	10	38.7	*2001/7*	115.3	10	34.4
1995/8	162.1	17	40.5	*1998/8*	62.4	10	12.5	*2001/8*	175.5	11	45.5
1995/9	188.4	13	30.1	*1998/9*	249.9	11	100.3	*2001/9*	150.2	12	49.0
1995/10	76.3	4	63.8	*1998/10*	92.8	5	39.8	*2001/10*	140.1	10	42.4
1995/11	0.0	0	0.0	*1998/11*	19.0	2	11.0	*2001/11*	4.5	1	4.5
1995/12	0.0	0	0.0	*1998/12*	7.2	1	7.2	*2001/12*	0.0	0	0.0

Continued

Station : Sak Lek / Phichit (386008)

Year/ month	Monthly total	No. Of rainy day	Daily maximum
1999/1	38.4	1	38.4
1999/2	0.0	0	0.0
1999/3	0.0	0	0.0
1999/4	134.1	7	30.3
1999/5	875.1	15	93.7
1999/6	545.0	11	82.7
1999/7	274.4	8	80.7
1999/8	241.1	15	89.4
1999/9	- 168.0 -		
1999/10	- 174.5 -		
1999/11	- 25.9 -		
1999/12	- 0.0 -		
2000/1	0.0	0	0.0
2000/2	0.0	0	0.0
2000/3	0.0	0	0.0
2000/4	210.0	11	40.3
2000/5	189.4	12	32.6
2000/6	203.1	9	49.5
2000/7	133.2	17	21.3
2000/8	267.9	11	83.4
2000/9	272.9	13	95.7
2000/10	167.7	10	39.5
2000/11	0.0	0	0.0
2000/12	0.0	0	0.0
2001/1	59.8	2	40.3
2001/2	12.7	2	9.2
2001/3	75.9	6	54.7
2001/4	20.3	1	20.3
2001/5	365.8	14	52.3
2001/6	172.6	11	57.6
2001/7	97.8	6	36.3
2001/8	432.1	14	63.8
2001/9	187.5	10	41.2
2001/10	94.1	8	21.4
2001/11	0.0	0	0.0

Climatological station

Station	Tha Wang Pha (331401)
	Elevation of station above MSL 235 meters
	Grid reference 689585E 2113865N
Station	Utaradit (351201)
	Elevation of station above MSL 63 meters
	Grid reference 616703E 1948114N
Station	Phisanulok (378201)
	Elevation of station above MSL 45 meters
	Grid reference 634972E 1855868N
Station	Nakhorn Sawan (400201)
	Elevation of station above MSL 34 meters
	Grid reference 624937E 1747019N
Station	Phetchabun (379201)
	Elevation of station above MSL 114 meters
	Grid reference 729543E 1817942N
Station	Lom Sak / Phetchabun (379401)
	Elevation of station above MSL 142 meters
	Grid reference 739446E 7855717N

Evaporation (mm.)

Year/ month	Tha Wang Pha	Utaradit	Phisanulok	Nakhorn Sawan	Phetchabun	Lom Sak	Year/ Month	Tha Wang Pha	Utaradit	Phisanulok	Nakhorn Sawan	Phetchabun	Lom Sak
1975/1	79.1	ND	88.6	108	108.3	94.6	1978/1	85.3	ND	100.3	168.3	136.1	115.2
1975/2	113.8	ND	117.4	161.7	146.8	125.7	1978/2	103.1	ND	90	155.7	134.3	107.9
1975/3	126.1	ND	140.4	211.5	163.2	135.6	1978/3	154.3	ND	147	298	218.4	164.2
1975/4	192	ND	176.4	290.3	239.8	192	1978/4	156	ND	166.2	304.7	214.8	153.7
1975/5	159.3	ND	161.8	195.1	168.6	138.8	1978/5	155.4	ND	157	237.4	161.4	155.9
1975/6	132.7	ND	143.6	211.9	155.6	134.8	1978/6	137.4	ND	140.1	202.8	151.9	134.7
1975/7	110.7	ND	120.9	174.2	138.1	132.5	1978/7	125.8	ND	127.7	157.3	102.4	118
1975/8	120.7	ND	128.3	156.8	139.3	111.1	1978/8	113.7	ND	130.5	154.5	101.1	116.2
1975/9	119.7	ND	110.6	119.3	122.1	120.8	1978/9	110.9	ND	102.6	144.5	95.4	117.5
1975/10	129.8	ND	112	124	136.3	125.6	1978/10	119.3	ND	147.9	148.6	131.6	137.1
1975/11	96.8	ND	105.6	137.2	136.6	122.5	1978/11	111.6	ND	123	155.3	126.4	129.1
1975/12	87.4	ND	96	139.4	162.8	116.6	1978/12	91.7	ND	129.4	154.6	146.5	126.2
1976/1	95.5	ND	98	158.5	151.3	118.1	1979/1	106.9	ND	121	162.9	138.8	132
1976/2	109	ND	105.3	172.9	142.4	109.7	1979/2	109	ND	135.5	209.6	141.3	133
1976/3	132.6	ND	139.6	255.8	199.3	142.3	1979/3	153	ND	204.2	279.9	179.9	169.2
1976/4	162.7	ND	163.5	275.2	245.3	176	1979/4	185.2	ND	206.4	272.7	201.3	181.1
1976/5	147.8	ND	138	192.4	139.5	148.5	1979/5	184.2	ND	199.6	245	166.9	167.8
1976/6	136.2	ND	159	209	157.9	162.7	1979/6	125	ND	165.2	169	114.2	127.4
1976/7	114	ND	133.9	188.4	124.2	131.6	1979/7	143.3	ND	171.4	236.8	157.3	162
1976/8	110.6	ND	99.6	143.6	118.6	103.4	1979/8	118.7	ND	128	173.1	109.9	118.9
1976/9	111.1	ND	105.6	134.5	120.5	126.6	1979/9	130.4	ND	127.2	128.6	116	125.5
1976/10	113.5	ND	113.6	143.4	135.2	122.2	1979/10	114.5	ND	137.5	169.4	147.3	147
1976/11	98	ND	103.3	140.6	130.9	116.8	1979/11	109	ND	139	172.1	151.5	142.6
1976/12	83.5	ND	106.7	145	130.6	116.2	1979/12	94.1	ND	118.1	161.6	141.2	127.4
1977/1	93.4	ND	99.1	167.5	125.5	118	1980/1	87.7	ND	113.4	163.8	130.6	120.3
1977/2	102.3	ND	101.2	174.8	144.3	127.4	1980/2	132.8	ND	139.5	216.3	159.6	151.8
1977/3	116.9	ND	120.4	224.4	189	138.4	1980/3	153.1	ND	183.9	254.1	191.9	168.2
1977/4	156.5	ND	164.9	260.6	196.9	146.2	1980/4	186.1	ND	222.7	313.2	214.2	184.9
1977/5	157.9	ND	158.6	222.4	179.8	159.6	1980/5	181.3	ND	210	262.5	184.3	180.9
1977/6	173.7	ND	175.1	227.4	171.3	165.1	1980/6	144.7	ND	146.3	153.4	113.8	126.8
1977/7	123.4	ND	135.1	205.5	130.9	132.4	1980/7	129	ND	187.1	175.8	122.6	137.9
1977/8	141.1	ND	124.8	169.6	122.3	127.3	1980/8	124.4	ND	141.9	142.7	106	132.9
1977/9	119.9	ND	106.3	132.3	102.6	114.6	1980/9	131.7	ND	113.8	114.7	90.5	116.6
1977/10	116.4	ND	123.5	147.4	155	129.1	1980/10	114.8	ND	122.4	120.1	136.5	128.5
1977/11	132.8	ND	120.9	169.6	145.3	124.7	1980/11	105.5	ND	115.1	121	153.3	130.6
1977/12	79.3	ND	105.6	159	144.5	115.9	1980/12	102	ND	118.2	142.6	154.1	129.6

ND. = No date

Evaporation (mm.) continued

Year/ month	Tha Wang Pha	Utaradit	Phisanulok	Nakhorn Sawan	Phetchabun	Lom Sak	Year/ Month	Tha Wang Pha	Utaradit	Phisanulok	Nakhorn Sawan	Phetchabun	Lom Sak
1981/1	108.9	ND	ND	ND	ND	132.8	1984/1	101.9	115.9	107.1	131.8	113.1	119
1981/2	128.8	ND	ND	ND	ND	139.7	1984/2	116.1	113.3	124	181.7	128.6	130.9
1981/3	185.6	ND	ND	ND	ND	180.9	1984/3	177.4	168.3	180.2	262.1	177.4	162.8
1981/4	201	ND	ND	ND	ND	157.2	1984/4	190	200.3	205.3	253.4	195.2	172
1981/5	152.3	ND	ND	ND	ND	157.4	1984/5	160.1	175.3	198.4	199.8	178.9	173.5
1981/6	132	ND	ND	ND	ND	136.8	1984/6	130.4	133.8	141	195.1	108	141.9
1981/7	117.4	ND	ND	ND	ND	126	1984/7	124	131.6	161	163.2	117	150.9
1981/8	137.2	ND	ND	ND	ND	134.7	1984/8	117.7	115	138.7	142.5	103.7	125.2
1981/9	139.9	ND	ND	ND	ND	124.2	1984/9	116.3	118.2	116.1	123.5	104.2	125.1
1981/10	115.6	ND	ND	ND	ND	134.6	1984/10	110.1	119.9	109.1	115.1	98.6	123.4
1981/11	100.6	ND	ND	ND	ND	116.2	1984/11	101.2	116.7	111.2	122.7	112.4	114.9
1981/12	81.8	ND	ND	ND	ND	122.5	1984/12	95.8	119.7	116	135.1	117.5	126.7
1982/1	97.6	92.1	110.3	143.6	112.8	127.2	1985/1	105.5	112.5	112.6	149.9	107.2	118.7
1982/2	130.2	102.7	125.1	180.9	114.2	120.3	1985/2	136.2	125.4	124.9	201.2	120.6	129.6
1982/3	155.2	147.2	178	248.2	169.7	168.4	1985/3	195	177.2	169.8	258.8	185.8	171.5
1982/4	157.1	171.4	191.1	239.8	181.9	169.9	1985/4	180.5	197.4	182.8	247.4	170.3	175.2
1982/5	172.4	172.3	191.6	229.9	191.6	188.1	1985/5	163.3	157.1	166.1	178.2	138.5	175.4
1982/6	140.2	123.5	155.9	202.2	132.8	166.3	1985/6	124.6	107.3	123.5	153.7	155.5	130.2
1982/7	117.4	107	133.9	188.8	115.6	135.2	1985/7	108.9	116.4	136.6	143	116	133.4
1982/8	105.3	90.3	118.5	149.4	90.6	115.6	1985/8	112.7	114.8	117	157	99.9	116.2
1982/9	112.9	89.7	118.8	128.3	85.6	118.8	1985/9	129.2	129.9	105.3	124.3	117	135.8
1982/10	127.1	116	132.5	131.9	104.1	131.7	1985/10	122.2	123.3	121.2	123.8	100.7	119.6
1982/11	108.1	99.2	115.3	142.3	110.3	133.2	1985/11	87.4	110.4	107.6	119.7	119.9	109.4
1982/12	92.8	92.1	108.3	124.5	101.9	115.4	1985/12	85.8	113.9	110.9	133	114.2	117.6
1983/1	96.1	102.9	108.6	133.5	105.9	120.1	1986/1	92.9	113.8	111.8	146.9	120.1	123.2
1983/2	121.9	122.4	125.1	189.9	123.7	131.3	1986/2	110.2	114.4	115.4	168.8	120	123.7
1983/3	158.1	180.7	182.2	264.5	182.7	182.4	1986/3	143.8	157.6	155.3	225.9	173.1	158.6
1983/4	206.9	203.5	221.2	287.2	207.5	208.1	1986/4	187.9	182.3	167.1	229.3	181.9	162.1
1983/5	202.4	197.1	223.6	247.2	169.5	189.9	1986/5	154.9	144	153.9	168.1	127.3	157.1
1983/6	153.1	146.5	167.9	209.5	157.4	169.1	1986/6	132.5	147.8	157.8	198.5	117	151.4
1983/7	136.2	150.3	154.4	184.3	126.2	147.8	1986/7	119.5	100.3	132.6	176.4	99.4	128.2
1983/8	125.4	115.2	108.4	167.2	106.8	128.1	1986/8	154	142.4	156.1	161.9	115.4	141.3
1983/9	129.7	110.1	116	130.7	158.9	129.9	1986/9	124.4	133.9	147.1	159.5	119.2	147
1983/10	107.6	121.5	123.6	113.9	103.2	120.4	1986/10	112.8	127	131.8	136.7	123.1	137.7
1983/11	97.7	106.1	112.5	116.4	114.5	121.9	1986/11	93.7	113.3	119.1	137	116.4	138
1983/12	80.5	98.3	97.4	129	106.6	114.7	1986/12	93.2	108.4	113.7	138.9	122.8	123.5

Evaporation (mm.) continued

Year/ month	Tha Wang Pha	Utaradit	Phisanulok	Nakhorn Sawan	Phetchabun	Lom Sak	Year/ month	Tha Wang Pha	Utaradit	Phisanulok	Nakhorn Sawan	Phetchabun	Lom Sak
1987/1	98.8	121.2	121	154.1	139.6	143.1	1990/1	94.3	103.2	115.7	140.6	106.9	121.3
1987/2	95.4	125.6	139.5	175.2	134.5	133.7	1990/2	106.6	121.3	139	187.6	119.4	133.4
1987/3	155.3	173.4	178	198.6	144.7	162	1990/3	152.3	174.2	163.8	218.5	148.7	154.2
1987/4	197.7	195	215	237.7	169.9	173.3	1990/4	170.2	182.3	185.4	237.6	159.4	171.4
1987/5	188.4	210.4	239	222.6	166.7	165.1	1990/5	157	178.4	181	208.2	143.6	162.6
1987/6	145.6	132.2	181.2	187.6	124.3	163.9	1990/6	112.7	117.8	148.3	169.4	104.5	125.4
1987/7	117.1	130	159.2	185	114.8	132.6	1990/7	87.9	109.8	138.7	160.7	97.6	119.3
1987/8	144.6	144.7	158.3	157.9	127.6	144.9	1990/8	144.6	143.4	165	178.5	99	134
1987/9	139.8	119.2	132.1	124.2	118.3	125.6	1990/9	136.2	124.3	139.7	132.5	90.8	115.9
1987/10	134.4	130.9	136	123.9	102.5	122.4	1990/10	121.6	129.1	130.5	127.7	103	125.3
1987/11	90.7	117.9	113.5	101.2	92.5	109.1	1990/11	100.5	115.7	127.1	105.9	98.5	121.2
1987/12	87.1	115.5	115.1	122.8	107.3	121.5	1990/12	81.6	119.5	123	125.4	108.6	129.1
1988/1	100.1	126.8	122.9	144.4	112.4	128.9	1991/1	91.1	112.1	125.9	137.3	113.6	135.8
1988/2	121.9	127.4	138.3	175.8	116	124	1991/2	98.7	115.5	124.3	159.6	116.2	136.6
1988/3	166.7	165.6	184.9	235.9	181.3	189.3	1991/3	149.9	163.7	194.1	262.1	162.4	194.4
1988/4	195.1	184	198	202.4	181.3	156.8	1991/4	157.9	186.8	225.5	249.1	164.3	180.9
1988/5	167.7	153.2	162.7	168.1	158.8	150.8	1991/5	170.3	198.2	216.1	227.9	137.1	181.1
1988/6	143.6	133.4	159.8	153.9	131.1	140.4	1991/6	96.6	103.1	142.8	168.6	88.4	139.8
1988/7	134.6	127.4	181.5	171.4	137.8	146.3	1991/7	103.3	120.8	155.3	183.3	89.6	134.8
1988/8	121.3	118.8	137.5	133.1	116	129.1	1991/8	99.6	114.6	140.2	134	60.6	111.2
1988/9	132	126.3	137.3	145.9	128.2	127.9	1991/9	113.5	127.6	126.5	114.8	63.4	121.3
1988/10	114.4	113.2	118.8	108.7	112.5	108.8	1991/10	110.9	125.9	125.3	122.6	98.7	117.4
1988/11	88.7	117	111.5	116.6	153.2	121.3	1991/11	81.4	110.7	115.5	127.5	103.9	119.1
1988/12	91.3	121.5	122.2	128.9	147.1	120.8	1991/12	73.9	108	115.8	132.3	108	118.7
1989/1	114.5	126.8	122.7	152.4	134.9	128	1992/1	76.8	100.1	109.9	130.4	86.4	105.3
1989/2	127.4	122.6	135.4	163.5	143.4	129.9	1992/2	114.9	128.6	142.9	189.5	115.2	143.9
1989/3	171.9	169.6	172.4	218.6	180.6	156.6	1992/3	151.3	152.3	172.9	270.1	160.1	181.3
1989/4	218	214.7	210.8	266.6	218	181.5	1992/4	170.6	183.5	209.9	282.8	201.4	197.6
1989/5	188.4	185	201.5	203.2	175.1	163.9	1992/5	206.3	227	248.1	243.3	171.8	201.9
1989/6	129.7	150.1	146.3	173.8	129.7	128.6	1992/6	140.9	160.7	169.5	179.1	118.6	152.9
1989/7	143.3	141.1	158.2	155.9	126.7	136.8	1992/7	125.6	113.9	148.4	164.4	98.3	130.5
1989/8	119.4	145.4	154.6	160.9	120.5	124.4	1992/8	128.1	124.6	147.8	124.9	85.4	144.8
1989/9	119.3	125.9	125.3	138.1	119.2	123	1992/9	117.2	137.1	146.8	124.8	81.9	119
1989/10	109.7	122.1	142.7	120.7	132.3	121.7	1992/10	101.1	108	122.5	98	102.3	117.6
1989/11	99.4	127.5	125.1	127	137.8	124.2	1992/11	81.9	113.1	116.6	119.2	117.4	133.2
1989/12	86.8	107.3	118.5	131	108.8	115.8	1992/12	75	118.9	121.4	121.1	107.3	123.4

Evaporation (mm.) continued

Year/ month	Tha Wang Pha	Utaradit	Phisanulok	Nakhorn Sawan	Phetchabun	Lom Sak	Year/ month	Tha Wang Pha	Utaradit	Phisanulok	Nakhorn Sawan	Phetchabun	Lom Sak
1993/1	73.2	100.8	109.3	143.7	110.5	129.2	*1996/1*	78	114.9	112.3	122.2	112.1	124.2
1993/2	92.5	113.3	116.7	158.6	120.8	133.1	*1996/2*	84.3	124.2	127.6	144.1	123.4	137.8
1993/3	123.2	143.5	169.4	207	149.2	162.3	*1996/3*	155.3	151	163.4	222.6	143.5	173.3
1993/4	132.1	180	192.9	221.8	160.3	169.2	*1996/4*	116	164.5	171.9	197.2	122	154
1993/5	147.3	180.7	204.4	220.5	150.7	179.6	*1996/5*	144.3	155.6	158.9	168.2	122	147.7
1993/6	128.5	163.3	177.8	194.3	131.2	163.6	*1996/6*	132.6	138.4	134	144.9	109.8	145.6
1993/7	116.3	147.1	150.9	200.1	135.5	172	*1996/7*	107.8	126.9	133.9	157.9	110.4	135.8
1993/8	89.6	107.8	139.3	144.7	106.3	141.4	*1996/8*	94.4	121.6	118.6	140	104.2	122.8
1993/9	124.4	135.8	119.4	119.7	95.8	129.2	*1996/9*	121.4	121.9	102.2	124.2	94.8	118.1
1993/10	114.2	129.4	136.4	126.2	129.4	149.5	*1996/10*	103.6	119	115.4	118	117.5	136.5
1993/11	90.1	134.1	127.8	128.4	139.1	142.4	*1996/11*	82.9	107.6	106	108.5	98.2	116.8
1993/12	86.1	127.9	127.6	130.5	142.1	143.1	*1996/12*	76.7	110.1	118.4	109.2	110.4	126.1
1994/1	83.1	112.3	121.1	151.7	129.5	130.7	*1997/1*	84.8	102.6	115.2	128.6	108	123.4
1994/2	102.1	133.1	134.7	195.4	147.8	149.6	*1997/2*	106.4	118.7	124	151.4	125.3	135.9
1994/3	165.6	150.4	146.8	187.1	141.9	165.7	*1997/3*	145	150.9	150.7	206.5	158	150.7
1994/4	159.8	192.1	190.4	215.3	159.6	189	*1997/4*	146.4	157.4	186.4	187.5	155.2	164.4
1994/5	133.3	147.2	151.6	149.2	126.7	156.3	*1997/5*	155.5	179.4	198.6	208	165.9	188.3
1994/6	110.6	123.2	127.9	134.7	91.1	120.2	*1997/6*	155.4	176.9	194.2	198.2	155	169.6
1994/7	114	120.3	132.1	125.5	107.3	130.7	*1997/7*	110.6	124.4	162.4	155.4	109.3	119.8
1994/8	98.8	96.3	121.5	134.1	83.8	128.3	*1997/8*	114.1	111	115.2	152.2	105.8	134.8
1994/9	109.7	108.3	122.6	120.2	94.1	121.1	*1997/9*	122.6	123.9	111.7	132	103	134.6
1994/10	112.5	135.8	137.9	131.6	118.9	137.6	*1997/10*	101.4	131.7	121.6	120.6	114.7	135.2
1994/11	82.1	120.8	126.8	135.9	124.7	132.1	*1997/11*	84.8	114.9	102.5	114.4	113	132.3
1994/12	86.9	117.2	120.1	134.4	110.1	131.1	*1997/12*	84.3	118.5	111.6	137.1	113.6	132.8
1995/1	86.8	117.2	117.4	148.9	114.8	129.5	*1998/1*	87.5	112.8	107.6	136.1	114.9	124.5
1995/2	96.1	129.6	130.2	184.9	134	139	*1998/2*	105.5	129.8	124	180.5	130.1	135
1995/3	145.6	170.5	179.4	256.2	179.7	182.1	*1998/3*	169.8	178.4	172.8	240.6	175.8	182.7
1995/4	159	200	210.6	260.2	169.3	177.9	*1998/4*	167	171.9	186.1	243.6	178.6	185.8
1995/5	162.7	145.7	173.5	187.5	132.2	159.2	*1998/5*	168.3	187.9	189.1	221.5	161.2	154.7
1995/6	135.2	146.7	136.9	177	127.1	164.3	*1998/6*	134.5	173	174.6	179.3	141.7	162
1995/7	109.3	108.2	128.8	144.4	85.7	124.3	*1998/7*	109.5	124.8	123.5	160.6	120.4	143.2
1995/8	105.8	120	119.6	130.9	90.1	152.6	*1998/8*	136.1	143	125.9	153	113	145.2
1995/9	123.8	113.8	108.1	130.1	92.6	126.2	*1998/9*	134.6	142.5	116	131	106	133.2
1995/10	118.7	129.4	111.4	108.8	104.1	125.8	*1998/10*	105.6	138.6	113.7	120.4	117.6	139.2
1995/11	82.2	113.1	110.7	110.4	115.9	126.6	*1998/11*	87.1	114.7	100.1	111.8	114.6	125.6
1995/12	72.8	112.1	114.6	124.4	122.8	131.9	*1998/12*	83.5	115.7	100.9	116.5	134.7	132

Evaporation (mm.) continued

Year/ month	Tha Wang Pha	Utaradit	Phisanulok	Nakhorn Sawan	Phetchabun	Lom Sak
1999/1	84.3	109.5	99	127.5	132.1	137.4
1999/2	97.5	109.7	106.4	144.6	140.5	137.1
1999/3	143.9	176.2	164.7	212.3	172.9	179
1999/4	146.8	145.3	143.7	160.7	133.8	149.8
1999/5	148.8	134.4	122.9	139.3	111.5	139
1999/6	134.3	121.4	116.3	139.1	109.3	130.2
1999/7	129.6	127.5	123.8	161.4	120.7	142.9
1999/8	99.4	115	108	130.6	94.9	117.8
1999/9	117.8	113.1	108.1	127.7	94.4	109.5
1999/10	94.5	123.5	86.5	102.3	118.4	129.1
1999/11	85.7	109.1	94.7	102	105.6	123.9
1999/12	62.8	108.5	95.1	101.5	137.2	130
2000/1	83.9	124.8	112.7	123	128.1	138.2
2000/2	102.7	119.1	105.9	137.5	125.6	134.4
2000/3	118.6	147.9	147.3	196.1	171.2	180.1
2000/4	146.3	149.5	148.1	159.1	156.2	166.6
2000/5	144.8	150.5	131.3	160.3	133.6	135.7
2000/6	106.7	117.7	106.6	139.1	120.6	125.2
2000/7	117.3	120.1	112	131.4	112.2	130
2000/8	114.8	114.3	105.6	132.5	114.2	133.6
2000/9	109.4	114	96.7	121.9	97.4	124.6
2000/10	109.7	120.5	96	102.8	115.5	136.4
2000/11	85.8	121.8	111.7	111.5	126	129.1
2000/12	80.6	122.3	107	123.8	127.1	134.1
2001/1	88.6	114.2	104.5	130.2	121.9	124.8
2001/2	99.3	118.8	105.4	139.7	124.4	127.1
2001/3	118.7	127.8	118.7	143.3	140.1	137.2
2001/4	147.3	174.4	172.5	230	203.8	190.8
2001/5	118.1	126.9	133	150.9	148.1	151.7
2001/6	123.6	126.8	133.3	143.5	119.4	135.8
2001/7	102.8	110.3	127	148.5	137.5	131.6
2001/8	108.4	132.5	110.5	130.5	108.3	123
2001/9	114.9	109.4	115.6	126.8	110.8	115.8
2001/10	113.4	131	107.7	109.8	121.5	126.8
2001/11	84.3	116.5	106.8	108.8	117.9	126.1
2001/12	78.9	111.5	108.4	124	131.6	131.1

Temperature (°C)

Year/ month	Tha Wang Pha	Utaradit	Phisanulok	Nakhorn Sawan	Phetchabun	Lom Sak	Year/ month	Tha Wang Pha	Utaradit	Phisanulok	Nakhorn Sawan	Phetchabun	Lom Sak
1975/1	ND	23.7	24.6	25.3	23.4	ND	1978/1	ND	24.3	25.4	26.7	24.4	ND
1975/2	ND	25.1	26.4	28.1	25.5	ND	1978/2	ND	26	26.8	27.6	26.2	ND
1975/3	ND	28.5	28.9	30.4	27.6	ND	1978/3	ND	29.6	30.1	31.5	29.4	ND
1975/4	ND	31.4	31.2	32.6	30.4	ND	1978/4	ND	31.6	31.2	31.9	29.4	ND
1975/5	ND	28.6	28.7	29.9	28.1	ND	1978/5	ND	30	29.7	30.3	28.3	ND
1975/6	ND	28	28.3	30	27.4	ND	1978/6	ND	29.1	29.2	29.3	28.2	ND
1975/7	ND	27.4	27.8	29	26.9	ND	1978/7	ND	27.5	27.7	27.8	26.8	ND
1975/8	ND	27.1	27.7	28.5	26.7	ND	1978/8	ND	27.7	27.8	27.8	26.8	ND
1975/9	ND	27.4	27.7	27.5	26.5	ND	1978/9	ND	27.5	27.6	27.2	26.4	ND
1975/10	ND	27.4	27.7	27.9	26.3	ND	1978/10	ND	27.1	27.5	27.4	26.5	ND
1975/11	ND	25.1	25.8	26.3	24.2	ND	1978/11	ND	25.7	26	26.2	25	ND
1975/12	ND	21.1	22	23	20.9	ND	1978/12	ND	23.9	24	24.8	23.4	ND
1976/1	ND	21.2	22.1	23.5	21	ND	1979/1	ND	25.4	25.9	27.5	25.6	ND
1976/2	ND	24.3	25.7	28.2	25	ND	1979/2	ND	26.8	27.9	29.2	26.9	ND
1976/3	ND	28.1	28.6	30.4	27.5	ND	1979/3	ND	28.8	30.2	31.4	28.5	ND
1976/4	ND	30.4	30.4	32.3	29.8	ND	1979/4	ND	30.9	31.2	31.6	29.7	ND
1976/5	ND	28.3	28.5	28.2	27.3	ND	1979/5	ND	31.3	30.2	31.1	29.1	ND
1976/6	ND	28.6	29.2	29.3	28	ND	1979/6	ND	28.8	28.5	29.3	27.7	ND
1976/7	ND	27.8	27.9	28.7	26.9	ND	1979/7	ND	28.8	28.7	30	28.5	ND
1976/8	ND	26.9	27.1	27.1	26.1	ND	1979/8	ND	27.6	27.9	28.5	27.2	ND
1976/9	ND	27.6	28.1	27.5	26.8	ND	1979/9	ND	28.2	27.8	27.9	27.3	ND
1976/10	ND	27.2	27.9	27.8	26.5	ND	1979/10	ND	27.4	27.1	27.6	26	ND
1976/11	ND	25.1	25.6	25.2	23.9	ND	1979/11	ND	25.3	24.9	25.7	24	ND
1976/12	ND	23.7	24.7	25	23.6	ND	1979/12	ND	23.7	23.8	24.8	23.1	ND
1977/1	ND	23.6	24.6	25.9	24	ND	1980/1	ND	23.6	23.9	25.5	23.4	ND
1977/2	ND	24.7	25.5	26.5	24.7	ND	1980/2	ND	26.1	27.2	28.5	26.2	ND
1977/3	ND	27.8	28	29	28	ND	1980/3	ND	29.8	30.2	31.1	29.1	ND
1977/4	ND	30	29.6	31.1	29.2	ND	1980/4	ND	32.1	32.3	33	30.9	ND
1977/5	ND	29.1	29.3	29.6	28.2	ND	1980/5	ND	30.6	30.3	31.7	29.4	ND
1977/6	ND	30.3	30.3	30.8	28.9	ND	1980/6	ND	28.2	28.3	28.5	27.4	ND
1977/7	ND	28.6	28.5	29.5	27.6	ND	1980/7	ND	28.2	28.3	28.7	27.7	ND
1977/8	ND	28.4	28.4	28.7	27.4	ND	1980/8	ND	28.2	28.3	28	27.4	ND
1977/9	ND	27.5	27.9	27.6	26.7	ND	1980/9	ND	27.5	27.6	27.3	26.6	ND
1977/10	ND	27.9	28.3	28.2	26.9	ND	1980/10	ND	27.6	27.6	27.4	26.7	ND
1977/11	ND	25.2	26	26.4	24.2	ND	1980/11	ND	26.4	26.5	26.7	25.6	ND
1977/12	ND	24.3	25.1	25.9	23.8	ND	1980/12	ND	24.7	25	25.2	24.1	ND

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Temperature (°C) continued

Year/ month	Tha Wang Pha	Utaradit	Phisanulok	Nakhorn Sawan	Phetchabun	Lom Sak	Year/ month	Tha Wang Pha	Utaradit	Phisanulok	Nakhorn Sawan	Phetchabun	Lom Sak
1981/1	ND	23	23.2	23.9	22.4	ND	1984/1	ND	23	23.6	24.1	22.5	ND
1981/2	ND	26.1	27	28	26.6	ND	1984/2	ND	27	27.6	28.4	27	ND
1981/3	ND	29.2	29.3	30.1	29.2	ND	1984/3	ND	28.5	28.9	29.9	28.1	ND
1981/4	ND	30.5	30.1	30	29.1	ND	1984/4	ND	31.5	31.1	31.3	30.3	ND
1981/5	ND	29.6	29.5	29.5	28.6	ND	1984/5	ND	30.2	29.7	30	29.2	ND
1981/6	ND	28.1	27.8	28.6	27.3	ND	1984/6	ND	28.4	27.3	29.2	27.5	ND
1981/7	ND	27.6	27.5	27.8	26.9	ND	1984/7	ND	28.2	28.1	27.9	27.3	ND
1981/8	ND	27.5	27.7	27.8	27	ND	1984/8	ND	27.7	27.6	28.2	27.1	ND
1981/9	ND	28.5	28.1	27.9	27.3	ND	1984/9	ND	27.7	27.6	27.6	26.6	ND
1981/10	ND	27.5	27.5	27.6	26.7	ND	1984/10	ND	26.7	27	26.9	25.7	ND
1981/11	ND	26.2	26.1	26.1	25.6	ND	1984/11	ND	25.9	26.3	26.5	25	ND
1981/12	ND	22.6	22.8	23.2	21.9	ND	1984/12	ND	23.7	24.5	25	23.4	ND
1982/1	ND	23.1	23.4	24.1	22.8	ND	1985/1	ND	24.8	25.6	26.4	24.5	ND
1982/2	ND	25.9	27	28.5	26.5	ND	1985/2	ND	26.5	27.7	29	26.8	ND
1982/3	ND	29.6	30.1	30.4	29.6	ND	1985/3	ND	29.3	29.7	30.7	27.8	ND
1982/4	ND	30.5	30	30.4	29	ND	1985/4	ND	30.7	30.8	31.6	29.6	ND
1982/5	ND	30.8	30.4	30.6	29.8	ND	1985/5	ND	29.4	29.4	29.3	28.1	ND
1982/6	ND	28.6	28.6	29.4	28.1	ND	1985/6	ND	27.9	27.8	28.4	27.3	ND
1982/7	ND	28.3	28.1	28.7	27.6	ND	1985/7	ND	27.5	27.8	27.7	26.7	ND
1982/8	ND	27.2	27.2	27.7	26.7	ND	1985/8	ND	27.7	27.7	28.1	27	ND
1982/9	ND	27.7	27.6	27.4	26.4	ND	1985/9	ND	27.9	27.7	27.4	27	ND
1982/10	ND	27.8	27.7	27.6	26.6	ND	1985/10	ND	27.4	27.6	27	26.3	ND
1982/11	ND	26.9	27.3	27.5	26.2	ND	1985/11	ND	25.9	26.8	26.8	25.9	ND
1982/12	ND	22.3	22.6	22.5	21.1	ND	1985/12	ND	23.2	24	24	22.5	ND
1983/1	ND	22.9	23.2	23.9	22.4	ND	1986/1	ND	22.7	23.4	23.6	22.5	ND
1983/2	ND	26.4	27.2	28.5	26.4	ND	1986/2	ND	25.7	26.9	28	26.5	ND
1983/3	ND	29	29.6	30.5	28.8	ND	1986/3	ND	26.8	27.8	29.1	27.7	ND
1983/4	ND	32.6	32.8	32.8	31.8	ND	1986/4	ND	30.1	30.3	31	29.5	ND
1983/5	ND	31	31.2	31	29.6	ND	1986/5	ND	28.6	28.9	28.9	28	ND
1983/6	ND	29.3	29.1	30.1	28.8	ND	1986/6	ND	28.8	29	29.7	28.1	ND
1983/7	ND	29.4	29	29.1	28.3	ND	1986/7	ND	27.9	28.1	28.9	27.1	ND
1983/8	ND	28.4	28.2	28.2	27.3	ND	1986/8	ND	28.5	28.3	28.3	27.8	ND
1983/9	ND	28.1	28.1	28.4	27.1	ND	1986/9	ND	28.1	28.5	28.3	27.3	ND
1983/10	ND	27.8	27.6	27.1	26.6	ND	1986/10	ND	27.8	28	28	27.2	ND
1983/11	ND	24.2	24.5	24.8	23.4	ND	1986/11	ND	25.7	26.2	26.2	25.3	ND
1983/12	ND	22	22.7	23.4	21.7	ND	1986/12	ND	24	24.5	25	24	ND

Temperature (°C) continued

Year/ month	Tha Wang Pha	Utaradit	Phisanulok	Nakhorn Sawan	Phetchabun	Lom Sak	Year/ month	Tha Wang Pha	Utaradit	Phisanulok	Nakhorn Sawan	Phetchabun	Lom Sak
1987/1	ND	24.4	24.9	25.7	24.6	ND	1990/1	21.8	25.3	26.3	27.4	25.6	25.4
1987/2	ND	26.3	27.4	28.1	26.7	ND	1990/2	23.3	26.6	27.8	29.1	27	26.5
1987/3	ND	28.5	28.8	29.2	27.4	ND	1990/3	25.9	28.8	28.7	30	27.6	27.1
1987/4	ND	30.6	31	31.5	29.7	ND	1990/4	28.1	30.5	30.3	31.9	29.6	29.1
1987/5	ND	31.5	31.2	31.1	29.3	ND	1990/5	27.7	29.1	29.6	30.1	28.9	28.5
1987/6	ND	29.3	29.5	30.1	28.6	ND	1990/6	27.5	28.6	28.9	29.7	27.9	27.9
1987/7	ND	28.8	29.1	30.2	28.3	ND	1990/7	26.5	28	28.2	29.2	27.3	27.3
1987/8	ND	28.9	28.9	29	27.8	ND	1990/8	27.6	28.5	28.7	29	27.7	27.7
1987/9	ND	28.3	28.3	27.9	27.2	ND	1990/9	27.1	28	28.2	28.2	27.1	-ND
1987/10	ND	28.2	28.2	27.8	27	ND	1990/10	26.1	27.8	28	27.8	26.9	26.9
1987/11	ND	27.6	27.7	27.5	26.9	ND	1990/11	23.9	26.3	26.9	26.6	25.5	25.5
1987/12	ND	21.8	22.1	22	21	ND	1990/12	20.1	24	24.9	24.9	23.6	23.6
1988/1	ND	24.8	25.4	26	24.5	ND	1991/1	21.3	25.1	26.6	27.5	25.8	25.5
1988/2	ND	27.4	28.2	29.2	27.1	ND	1991/2	21.6	25.5	26.7	27.9	25.8	25.5
1988/3	ND	29.4	30.3	31.4	29.9	ND	1991/3	27.1	29.9	30.8	31.7	29.9	29.2
1988/4	ND	30.8	30.8	30.8	29.8	ND	1991/4	28.9	31.6	31.9	31.9	30.6	29.9
1988/5	ND	29	28.9	28.8	28.1	ND	1991/5	28.3	30.7	30.9	31.4	29.5	29.1
1988/6	ND	29	29	28.8	28	ND	1991/6	27.3	28.4	28.9	29.8	27.8	27.8
1988/7	ND	28.7	28.9	28.5	27.8	ND	1991/7	27.3	28.9	29.2	30	27.9	28
1988/8	ND	28.1	28	28	27.3	ND	1991/8	26.8	27.6	27.9	28.4	26.8	26.7
1988/9	ND	28.8	28.8	28.3	27.9	ND	1991/9	27	28.5	28.9	28.7	27.2	27.3
1988/10	ND	27.6	27.3	27.2	26.4	ND	1991/10	25.8	27.5	27.7	27.6	26.6	26.6
1988/11	ND	24.4	24.7	24.7	24	ND	1991/11	22.3	25.1	25.9	26	24.6	24.4
1988/12	ND	22.9	23.7	23.9	22.7	ND	1991/12	20.3	24	24.8	25.3	23.5	23.4
1989/1	21.3	25	26	26.5	25.4	25.1	1992/1	18.5	22.8	23.9	24.7	22.5	22.3
1989/2	22.8	26	27.1	28.2	26.3	25.8	1992/2	20.5	24.1	25.7	27.8	24.6	24.3
1989/3	26.3	28.4	28.7	29.3	27.9	27	1992/3	25.4	27.9	29	30.7	28.4	27.7
1989/4	29.2	31.3	31.4	32.3	30.4	29.2	1992/4	29.3	31.6	31.9	33.2	31.8	30.5
1989/5	27.8	29.7	30.1	30.4	28.7	28.3	1992/5	30.2	32.3	31.8	31.8	30.1	29.9
1989/6	27.2	28.4	28.4	29.1	27.5	27.3	1992/6	28.3	29.6	29.8	29.6	28.6	28.4
1989/7	27	28.7	28.9	29.1	27.7	27.7	1992/7	27	28.1	28.5	29	27.6	27.4
1989/8	27	28.3	28.2	28.7	27.3	27.3	1992/8	27.2	27.9	28.1	28.3	27.2	27.3
1989/9	26.7	28.1	28.1	28.2	27.2	27	1992/9	26.9	27.8	27.9	28.2	27.1	27.1
1989/10	25.9	27.4	27.5	27.8	26.5	26.4	1992/10	24	26	26.5	26.6	25.7	25.5
1989/11	23.1	26	26.4	26.5	25.2	25	1992/11	21.5	24.3	24.8	25	23.6	23.6
1989/12	18.8	22.6	23.5	23.9	22.4	22.2	1992/12	18.4	22.8	23.7	24.5	23.4	23.2

Temperature (°C) continued

Year/ month	Tha Wang Pha	Utaradit	Phisanulok	Nakhorn Sawan	Phetchabun	Lom Sak	*Year/ month*	Tha Wang Pha	Utaradit	Phisanulok	Nakhorn Sawan	Phetchabun	Lom Sak
1993/1	19.5	23.1	24.4	25.7	23.6	23.6	*1996/1*	19.1	23.4	24.2	25	23.7	23.4
1993/2	20.3	24.1	25.3	27	24.9	24.5	*1996/2*	20.4	24.2	25.2	26	24.2	23.7
1993/3	25.1	28.1	29.1	30.1	28.5	27.7	*1996/3*	25.9	28.3	28.9	30.2	28.1	27.7
1993/4	27	30.3	30.8	31.4	29.6	28.9	*1996/4*	27.7	29.4	29.6	30.4	28.6	28.1
1993/5	27.7	30.1	30.2	31	29.3	28.9	*1996/5*	28.1	29.2	29.1	29	27.9	27.8
1993/6	28	29.6	30	30.6	29.2	29.1	*1996/6*	27.4	28.5	28.6	28.7	28	27.9
1993/7	27.4	29.2	29.3	30.3	28.9	28.4	*1996/7*	27.1	28.7	28.6	28.9	28	27.8
1993/8	26.4	28	27.9	28.5	27.2	27.1	*1996/8*	26.4	27.8	28.3	28.6	27.2	27.2
1993/9	26.6	27.8	28.1	28	26.9	27	*1996/9*	26.7	27.9	27.9	27.7	26.8	26.8
1993/10	25.3	27.7	28	27.9	27	27	*1996/10*	25.9	27.5	28	27.6	26.8	26.7
1993/11	22.4	26	26.7	26.9	26	25.8	*1996/11*	24.1	26.5	27.1	26.9	25.6	25.6
1993/12	19.4	23.7	24.3	24.4	23.5	23.3	*1996/12*	20.7	23.5	24.3	23.9	22.7	22.7
1994/1	20.6	24.7	25.4	26.7	25	24.8	*1997/1*	19.4	23	24.2	24.5	23	23.1
1994/2	23.6	27.8	28.6	30.1	28.3	27.5	*1997/2*	21.6	25.6	26.6	27.6	26	25.9
1994/3	25.9	28	28.3	29.3	27.5	26.9	*1997/3*	25.7	28.3	28.7	29.7	28	27.2
1994/4	28.5	31.1	30.7	31.6	29.6	29.5	*1997/4*	25.7	29.1	29.5	29.6	27.9	27.4
1994/5	27.9	29.5	29.4	29.7	28.5	28.4	*1997/5*	28.8	30.6	30.8	30.6	29.7	29.4
1994/6	27.5	28.2	28.5	28.9	27.4	27.5	*1997/6*	28.8	30.8	30.8	30.6	29.6	29.2
1994/7	26.8	28	28.3	28.7	27.3	27.2	*1997/7*	27.4	28.4	28.5	28.8	27.2	27
1994/8	26.1	27.1	27.4	28	26.6	26.7	*1997/8*	26.8	27.9	28.2	28.8	27.2	27.3
1994/9	27	27.9	28.2	28.3	27.1	27.1	*1997/9*	26.4	27.9	28.2	27.7	26.7	26.8
1994/10	24.4	26.7	26.9	26.8	25.4	25.4	*1997/10*	25.9	28.1	28.4	28.3	27.2	27.2
1994/11	22.1	25.4	26.2	26.6	24.9	24.8	*1997/11*	23.7	26.5	27.3	27.3	26	26.1
1994/12	20.6	24.6	25.2	26.1	24.3	24.4	*1997/12*	22.1	25.5	26.5	26.6	25.3	25.4
1995/1	21	24.7	25.2	26.1	23.9	23.9	*1998/1*	21.4	25.3	26.1	27.1	25.6	25.3
1995/2	20.8	25.2	26	27.8	25.3	24.8	*1998/2*	22.8	26.8	27.9	29.7	27.2	26.3
1995/3	26.7	29.8	29.8	31.1	29.6	29	*1998/3*	27.1	30.2	30.4	31.5	30.5	29.5
1995/4	28.9	32.2	31.6	32.5	30.1	29.4	*1998/4*	28.3	31.3	31.5	32.4	30.8	29.5
1995/5	28.1	29.6	30	30.5	28.4	28.3	*1998/5*	29.4	31.6	31.3	31.3	29.7	29.2
1995/6	28.2	29.1	29.4	29.6	28.7	28.8	*1998/6*	28.9	31.2	30.6	30	29.8	29.4
1995/7	26.9	28.1	28.3	28.6	27	27	*1998/7*	27.7	29	29	29.1	28.3	28
1995/8	26.5	27.6	28	28.1	27.2	27.2	*1998/8*	28	29	28.9	28.9	28.1	27.9
1995/9	26.9	28.1	28.4	28.1	27.3	27.5	*1998/9*	27.2	28.5	28.5	28.4	27.8	27.7
1995/10	26	27.7	28.1	28	26.9	26.9	*1998/10*	26.2	28.4	28.5	28.1	27.5	27.4
1995/11	23.2	25.7	26.4	26.3	25.4	25.3	*1998/11*	23.7	26.5	26.7	26.9	26	25.9
1995/12	18.8	22.7	23.7	23.9	22.9	22.7	*1998/12*	21.9	24.9	25.2	25.3	24.7	24.6

Temperature (°C) continued

Year/ month	Tha Wang Pha	Utaradit	Phisanulok	Nakhorn Sawan	Phetchabun	Lom Sak
1999/1	21.7	25.1	25.2	25.7	25.3	25
1999/2	23.8	26.7	26.8	27.4	27.1	26.7
1999/3	26.1	29.2	29.7	30.5	29.4	28.5
1999/4	28.2	29.5	29.4	29.3	28.2	28.3
1999/5	27.2	27.9	28.4	28.4	27.4	27.2
1999/6	27.5	28.3	28.4	28.8	27.6	27.6
1999/7	27.8	28.6	28.6	28.8	27.7	27.7
1999/8	26.4	27.4	27.9	28.2	26.7	26.8
1999/9	26.9	27.8	28.1	27.9	27	27.1
1999/10	25.8	27.6	27.5	27.3	26.6	26.6
1999/11	23.7	26.2	26.8	26.5	25.7	25.6
1999/12	18.1	21.9	22.5	22.4	21.7	21.5
2000/1	21	24.8	25.3	25.8	25	24.8
2000/2	22	25.3	25.8	26.4	25.8	25.2
2000/3	24.7	27.6	28.4	29.4	28.3	27.5
2000/4	28.2	29.4	29.6	29.4	28.7	28.3
2000/5	26.8	28.5	29	28.9	28	27.7
2000/6	27.3	28.4	28.4	28.5	27.4	27.2
2000/7	27	28.3	28.2	28.4	27.3	27.3
2000/8	27	28.3	28.3	28.5	27.5	27.3
2000/9	26.1	27.3	27.7	27.6	26.6	26.5
2000/10	26.1	27.8	27.8	27.9	27.2	27
2000/11	22.6	25.6	26.2	25.9	24.9	24.8
2000/12	21.5	25.3	25.9	26.1	25.1	24.9
2001/1	21.8	25.5	26.2	27.3	26	25.6
2001/2	22.8	26.3	26.6	28	26.8	26.5
2001/3	25.8	28	28.1	28.9	27.9	27.2
2001/4	29.6	31.3	32.1	32.7	31.4	30.7
2001/5	27.1	28.3	28.8	28.8	28.2	28
2001/6	27.5	28.5	28.8	28.9	27.6	27.7
2001/7	26.7	28.1	28.5	28.9	28	27.6
2001/8	27.2	28.2	28.4	28.6	27.7	27.4
2001/9	26.9	28	28.2	28.3	27.3	27.3
2001/10	26.4	28.1	28.2	28.1	27.4	27.4
2001/11	21.4	24.4	25.1	25	24	23.7
2001/12	21.6	24.9	25.5	25.7	25	24.7

Note: Record data show as “digit numeral”

Estimation of missing data show as “- XX -”

Data not enough to estimate missing show as “ND”

Appendix C

Evapotranspiration calculation methods

Free water evaporation Approach

One of the most widely used approaches for estimating evapotranspiration using meteorological data to estimate potential evapotranspiration and computes actual evapotranspiration is as:

$$ET_p = K_p E_p$$

where: ET = actual evapotranspiration;

E_p = potential evaporation;

and K_p= Crop coefficient

The ET-Water Balance Approach

The water balance approach involves applying the water balance equation to a given water body over a time period Dt, and solving that equation for evaporation E, as follows (units are depth or volume per Dt):

$$ET = P + Qin + Gin - Qout - Gout \pm DS$$

where: P = precipitation

Qin = surface inflow,

Qout = surface outflow,

Gin = groundwater inflow,

Gout = groundwater outflow,

and DS = change in storage over Dt.

Hargreaves' Equation

Hargreaves equation is recommended by Shuttleworth (1993) as one of the few valid temperature-based estimates of potential evaporation, though it was designed for estimating potential evaporation for agricultural systems. It gives an estimate of potential evaporation (mm d^{-1}) which can be averaged to obtain monthly values:

$$E = 0.0023 S_o (T + 17.8)\sqrt{\delta_T}$$

where: T = temperature [° C]

d_T= difference between mean monthly maximum temperature and mean monthly minimum temperature [° C] (i.e. the difference between the maximum and minimum temperature for the given month, averaged over several years)

S_o = the water equivalent of extraterrestrial radiation [mm d^{-1}]

$$S_o = 15.392 d_r (\omega_s \sin\phi \sin\delta + \cos\phi \cos\delta \sin\omega_s)$$

f = latitude of the site (+ in northern hemisphere, - in southern),

w_s= the sunset hour angle [radians]:

$$\omega_s = \arccos(-\tan\phi \tan\delta)$$

d = solar declination on day J (julian day) of the year [radians]:

$$\delta = 0.4093 \sin(\frac{2\pi}{365} J - 1.405)$$

dr= relative distance of the earth from the sun on day J:

$$d_r = 1 + 0.033 \cos(\frac{2\pi}{365} J)$$

Hamon's Equation

One of the simplest estimates of potential evaporation is that of Hamon (1961), being used to estimate seasonal (monthly) or annual values. Following Haith and Shoemaker (1987), Hamon's estimate of potential evaporation is:

$$E = \frac{2.1 H_t^2 e_s}{(T_t + 273.2)}$$

where: E=evaporation, day t [mm day^{-1}]

H_t = average number of daylight hours per day during the month in which day t falls H_t can be calculated by using the maximum number of daylight hours on day t , N_t. which is equal to

$$\frac{24\omega_s}{\pi}$$

where w_s is the sunset hour angle of day t

e_s = saturated vapor pressure at temperature T [kPa]

T_t= temperature, day t [° C] On days when T_t<= 0, Haith and Shoemaker set E=0. Daily values of E are then summed over the period of interest to obtain the monthly or annual estimate.

<u>Penman's equation</u>

Penman's equation (Penman, 1948, 1963; Shuttleworth, 1993) estimates evaporation from the free surface of a body of water (potential evaporation) by considering what is necessary to balance the energy budget at the water surface. The potential evaporation [mm d-1] is a fairly complex function of humidity, windspeed, radiation, and temperature:

$$E_p = \frac{\Delta}{\Delta + \gamma}(R_n + A_h) + \frac{\gamma}{\Delta + \gamma}\frac{6.43(1 + 0.536U_2)D}{\lambda}$$

where: R_n = net radiation exchange at the surface of the water body [mm/d]

A_h = energy advected to the water body (water equivalent) [mm d^{-1}]

D = average vapor pressure deficit (e_s-e) over the estimation period [kPa]. This can be estimated as:

$$D = \left(\frac{e_s(T_{max}) + e_s(T_{min})}{2}\right)\left(1 - \frac{RH}{100}\right)$$

T_{max}, T_{min} = max and min temperatures over the period of estimation [° C]

RH = average relative humidity over the period of estimation (%)

U_2 = wind speed measured at 2m elevation [m s^{-1}] l , a function of temperature, is the latent heat of vaporization of water at temperature T (the surface temperature of the water body, ° C) [MJ kg^{-1}]:

$$\lambda = 2.501 - 0.002361T_s$$

e = the ambient vapor pressure of water vapor in the air [kPa], which can be calculated from the relative humidity and the saturated vapor pressure:

$$e = e_s RH/100$$

RH = relative humidity of the air [percent]

e_s, (T) = is the saturated vapor pressure of water in air at temp. [kPa]:

$$e_s(T) = 0.6108\exp\left(\frac{17.27T}{237.3+T}\right)$$

D (T) = the rate of change of e_s with respect to T [kPa T^{-1}]

$$\Delta(T) = \frac{4098e_s}{(237.3+T)^2} = \frac{2503.06\exp\left(\frac{17.27T}{237.3+T}\right)}{(237.3+T)^2}$$

The **Penman equation**, in its various modifications, is surely very accurate, but is very demanding in terms of input data and elaboration its use is therefore restricted to research, or at best to whole districts.

SCS Blaney-Criddle equation Approach

A few equations can be used to estimate evapotranspiration and it should be based on the data availability to decide the specific approach to be selected. considering the limited meteorological data information, the SCS Modified Blaney-Criddle Equation is for this term project. Following is the Blaney-Criddle Equation:

$$ET = K\sum_{i=1}^{m}\frac{t_i p_i}{100}$$

Where: ET = actual evapotranspiration;

K = monthly growth stage coefficient;

m = month of irrigation

t_i = mean monthly temperature, °F

P_i = percentage of daylight hours of the year occurring during a particular month

or Where t_i = mean monthly temperature, °C

$$ET = 25.4\ K \sum_{i=1}^{m} \frac{(1.8t_i + 32)p_i}{100}$$

Appendix D

Crop Coefficients (K) and Lengths of crop development stages

Note :From office of water Resources Development, Royal Irrigation Department of Thailand

Month	Rucy spontaneum						
	Modified Penman	Blaney-Criddle	E-pan	Thornthwaite	Hargreaves	Radiation	Penman-Monteith
May	0.68	0.98	0.85	0.64	0.78	0.83	0.88
Jun.	0.96	1.32	1.25	0.86	1.07	1.16	1.23
Jul.	0.76	1.15	1.03	0.64	0.94	0.86	1.03
Aug.	0.72	1.04	1.05	0.59	0.83	0.9	0.98
Sep.	0.6	0.87	0.82	0.58	0.72	0.69	0.77
Oct.	0.83	1.2	1.05	0.77	0.99	0.89	1.09
Nov.	0.44	0.53	0.56	0.4	0.51	0.45	0.58
Dec.	0.93	0.95	1.14	1.16	1.01	0.95	1.24
Jan.	0.64	0.64	0.88	0.68	0.69	0.63	0.85
Feb.	0.95	1.05	1.27	1.07	1.02	0.98	1.24
Mar.	0.43	0.5	0.6	0.45	0.45	0.46	0.57
Apr.	0.8	0.9	1.04	0.81	0.94	0.9	1.05
Average	0.73	0.93	0.96	0.72	0.83	0.81	0.96

Week	Rice : HVY						
	Modified Penman	Blaney-Criddle	E-pan	Thornthwaite	Hargreaves	Radiation	Penman-Monteith
1	0.9	1.1	1.23	0.76	0.9	1.29	1.03
2	0.94	1.24	1.21	0.85	0.92	1.38	1.07
3	0.98	1.52	1.27	1.06	1.11	1.35	1.12
4	1.13	1.65	1.55	1.14	1.24	1.57	1.29
5	1.21	1.67	1.55	1.12	1.31	1.77	1.38
6	1.27	1.64	1.89	1.07	1.23	1.88	1.45
7	1.32	2.1	1.87	1.39	1.54	1.78	1.5
8	1.3	1.66	1.86	1.09	1.22	1.87	1.48
9	1.26	1.74	1.72	1.15	1.24	1.77	1.42
10	1.21	1.68	1.42	1.19	1.27	1.73	1.34
11	1.11	1.68	1.48	1.17	1.23	1.51	1.23
12	0.85	1.18	1.29	0.81	0.89	1.15	0.94
13	0.75	1.13	1.13	0.78	0.85	0.63	0.86
Average	1.09	1.54	1.49	1.05	1.15	1.53	1.24

Week	Rice : Khao Dawk Mali 105						
	Modified Penman	Blaney-Criddle	E-pan	Thornthwaite	Hargreaves	Radiation	Penman-Monteith
1	0.6	0.93	0.76	0.75	0.68	0.78	0.66
2	0.7	1.23	0.8	0.84	0.82	1.02	0.79
3	0.86	1.37	1.13	0.92	0.9	1.17	0.97
4	1.05	1.54	1.26	1.26	1.18	1.45	1.18
5	1.2	1.62	1.33	1.07	1.1	1.74	1.35
6	1.3	1.75	1.22	1.13	1.24	1.83	1.51
7	1.39	2.34	1.73	1.61	1.52	1.96	1.61
8	1.42	2.12	1.58	1.76	1.74	1.85	1.64
9	1.4	2.06	1.84	1.75	1.59	1.83	1.62
10	1.36	1.75	1.93	1.19	1.33	1.8	1.6
11	1.32	1.88	1.49	1.32	1.32	1.75	1.55
12	1.24	1.91	1.35	1.38	1.37	1.76	1.46
13	1.1	1.53	1.26	3.13	1.08	1.49	1.28
14	0.92	1.15	0.97	0.82	0.89	1.31	1.08
Average	1.13	1.64	1.31	1.2	1.19	1.53	1.31

Week	Rice : Basmati						
	Modified Penman	Blaney-Criddle	E-pan	Thornthwaite	Hargreaves	Radiation	Penman-Monteith
1	1.11	1.3	1.46	1.55	0.95	1.24	1.22
2	1.18	1.5	1.6	1.72	1.03	1.33	1.3
3	1.23	1.44	1.85	1.45	1.03	1.49	1.36
4	1.27	1.7	1.45	1.71	1.2	1.47	1.45
5	1.29	1.72	1.86	1.38	1.1	1.52	1.47
6	1.3	1.66	1.66	1.59	1.21	1.54	1.49
7	1.3	1.71	1.71	1.65	1.18	1.56	1.49
8	1.3	1.72	1.48	1.56	1.18	1.6	1.48
9	1.28	1.77	1.57	1.14	1.09	1.62	1.46
10	1.26	1.69	1.58	1.34	1.19	1.58	1.44
11	1.22	1.74	1.3	1.2	1.09	1.7	1.36
12	1.17	1.67	1.26	1.18	1.09	1.51	1.23
13	1.06	1.34	1.36	1.01	0.96	1.35	1.11
14	0.88	1.04	1.22	0.82	0.8	1.12	0.93
Average	1.22	1.58	1.5	1.33	1.08	1.48	1.34

Week	Wheat						
	Modified Penman	Blaney-Criddle	E-pan	Thornthwaite	Hargreaves	Radiation	Penman-Monteith
1	0.41	0.62	0.56	0.37	0.47	0.59	0.5
2	0.43	0.56	0.49	0.32	0.45	0.65	0.52
3	0.5	0.66	0.7	0.44	0.6	0.67	0.61
4	0.63	0.74	0.88	0.64	0.79	0.77	0.76
5	0.95	1.11	1.21	1.4	1.04	1.17	1.11
6	1.08	1.35	1.32	2.09	1.06	1.27	1.26
7	1.14	1.41	1.36	2.36	1.15	1.29	1.33
8	1.16	1.48	1.42	2.42	1.17	1.37	1.38
9	1.14	1.38	1.42	2.01	1.13	1.43	1.37
10	1.07	1.28	1.44	1.26	1.04	1.29	1.32
11	0.92	1.13	1.19	1.14	0.93	1.09	1.14
12	0.67	0.69	0.86	0.83	0.66	0.76	0.83
13	0.48	0.58	0.62	0.66	0.52	0.58	0.62
14	0.35	0.45	0.48	0.37	0.4	0.46	0.46
15	0.3	0.42	0.39	0.32	0.34	0.4	0.39
Average	0.75	0.9	0.94	0.87	0.78	0.9	0.91

Week	Maize						
	Modified Penman	Blaney-Criddle	E-pan	Thornthwaite	Hargreaves	Radiation	Penman-Monteith
1	0.5	0.67	0.62	0.53	0.67	0.58	0.63
2	0.57	0.8	0.74	0.48	0.67	0.71	0.72
3	0.68	0.93	0.98	0.5	0.69	0.85	0.86
4	0.89	1.12	1.05	1.03	1.1	0.99	1.13
5	1.12	1.39	1.24	1.48	1.37	1.29	1.35
6	1.26	1.56	1.46	1.77	1.56	1.45	1.52
7	1.33	1.7	1.52	1.55	1.49	1.57	1.61
8	1.35	1.81	1.77	1.43	1.53	1.63	1.63
9	1.34	1.8	1.55	1.42	1.52	1.61	1.58
10	1.3	1.71	1.56	1.07	1.2	1.66	1.5
11	1.2	1.62	1.22	1.07	1.25	1.54	1.38
12	1	1.31	1.07	1.06	1.13	1.26	1.15
13	0.77	1.04	0.66	0.63	0.74	1.07	0.9
14	0.58	0.79	0.61	0.71	0.68	0.72	0.67
Average	0.99	1.31	1.14	1.03	1.13	1.2	1.19

Week	Sweet corn						
	Modified Penman	Blaney-Criddle	E-pan	Thornthwaite	Hargreaves	Radiation	Penman-Monteith
1	0.55	0.66	0.7	0.67	0.58	0.7	0.65
2	0.58	0.84	0.86	0.85	0.72	0.85	0.68
3	0.71	1.03	1.02	1.04	0.85	1	0.84
4	0.84	1.18	1.17	1.22	0.97	1.18	0.99
5	0.96	1.2	1.2	1.37	0.97	1.17	1.16
6	1.01	1.15	1.17	1.39	0.92	1.15	1.22
7	1	1.1	1.14	1.45	0.85	1.14	1.21
8	0.95	0.9	0.95	1.04	0.69	0.94	1.15
9	0.78	0.67	0.71	0.68	0.5	0.66	0.96
10	0.59	0.44	0.48	0.37	0.33	0.44	0.72
11	0.5	0.21	0.25	0.05	0.14	0.17	0.61
Average	0.77	0.85	0.88	0.92	0.68	0.85	0.93

Week	Sorghum						
	Modified Penman	Blaney-Criddle	E-pan	Thornthwaite	Hargreaves	Radiation	Penman-Monteith
1	0.49	0.66	0.69	0.53	0.59	0.59	0.54
2	0.52	0.71	0.72	0.54	0.63	0.63	0.57
3	0.59	0.8	0.68	0.55	0.62	0.74	0.68
4	0.73	1.05	0.95	0.72	0.9	0.9	0.84
5	0.91	1.25	1.09	0.9	1.03	1.13	1.05
6	1.05	1.46	1.4	1	1.17	1.28	1.21
7	1.12	1.61	1.28	0.86	0.96	1.49	1.23
8	1.15	1.65	1.56	1.37	1.39	1.39	1.26
9	1.14	1.67	1.52	1.53	1.59	1.34	1.25
10	1.09	1.64	1.68	1.25	1.36	1.36	1.2
11	0.99	1.44	1.46	1.23	1.3	1.19	1.12
12	0.83	1.2	1.08	0.84	0.94	1.03	0.94
13	0.69	0.95	1	0.78	0.79	0.81	0.78
14	0.61	0.87	0.92	0.79	0.89	0.7	0.69
15	0.57	0.79	0.9	0.79	0.81	0.62	0.65
16	0.55	0.71	0.74	0.7	0.73	0.61	0.62
Average	0.81	1.14	1.1	0.89	0.98	0.97	0.91

Week	Mung bean						
	Modified Penman	Blaney-Criddle	E-pan	Thornthwaite	Hargreaves	Radiation	Penman-Monteith
1	0.49	0.65	0.4	0.29	0.35	0.4	0.58
2	0.74	0.7	0.63	0.51	0.58	0.67	0.87
3	1	0.8	0.88	0.72	0.8	0.93	1.18
4	1.24	1.11	1.12	0.95	0.99	1.2	1.4
5	1.13	1.58	1.36	1.15	1.14	1.45	1.28
6	1.05	1.51	1.2	1.1	1.04	1.37	1.19
7	0.58	0.97	0.82	0.72	0.67	0.9	0.66
8	0.39	0.62	0.5	0.47	0.43	0.58	0.44
9	0.3	0.31	0.22	0.2	0.18	0.25	0.34
Average	0.77	0.92	0.79	0.68	0.69	0.86	0.88

Week	Soy bean						
	Modified Penman	Blaney-Criddle	E-pan	Thornthwaite	Hargreaves	Radiation	Penman-Monteith
1	0.57	0.85	0.65	0.53	0.68	0.72	0.64
2	0.62	0.84	0.7	0.66	0.65	0.74	0.69
3	0.73	1.06	0.89	0.81	0.95	0.89	0.81
4	0.91	1.28	1.08	0.75	0.86	1.15	1.01
5	1.13	1.59	1.3	0.99	1.05	1.48	1.23
6	1.22	1.77	1.32	1.23	1.31	1.51	1.32
7	1.25	1.82	1.64	1.05	1.22	1.22	1.35
8	1.23	1.65	1.58	1.51	1.31	1.43	1.34
9	1.16	1.55	1.41	1.24	1.13	1.42	1.27
10	1	1.35	1.45	1.05	1.2	1.17	1.09
11	0.78	1.05	1.13	0.76	0.85	0.92	0.85
12	0.68	0.86	0.74	0.81	0.8	0.74	0.74
13	0.64	0.82	0.83	0.65	0.62	0.75	0.74
14	0.62	0.78	0.85	0.67	0.6	0.78	0.72
Average	0.89	1.22	1.1	0.91	0.95	1.06	0.99

Week	Sesame						
	Modified Penman	Blaney-Criddle	E-pan	Thornthwaite	Hargreaves	Radiation	Penman-Monteith
1	0.49	0.69	0.64	0.76	0.72	0.56	0.59
2	0.58	0.82	0.68	0.81	0.79	0.67	0.7
3	0.73	1.04	1	0.99	1	0.85	0.85
4	0.96	1.42	1.33	1.21	1.33	1.16	1.11
5	1.06	1.53	1.38	1.48	1.56	1.23	1.23
6	1.1	1.61	1.44	1.47	1.58	1.31	1.28
7	1.11	1.58	1.39	1.36	1.54	1.37	1.24
8	1.08	1.57	1.36	0.93	1.19	1.39	1.21
9	1.01	1.39	1.3	1.14	1.24	1.22	1.13
10	0.88	1.21	1.13	0.8	0.92	1.08	0.98
11	0.63	0.86	0.87	0.89	0.91	0.73	0.71
12	0.49	0.6	0.64	0.49	0.59	0.6	0.55
Average	0.84	1.17	1.09	1.03	1.11	0.99	0.97

Week	Sun flower						
	Modified Penman	Blaney-Criddle	E-pan	Thornthwaite	Hargreaves	Radiation	Penman-Monteith
1	0.56	0.6	0.72	0.62	0.58	0.56	0.68
2	0.6	0.66	0.89	0.61	0.55	0.66	0.73
3	0.62	0.68	0.88	0.77	0.71	0.66	0.75
4	0.64	0.64	0.93	0.78	0.68	0.65	0.78
5	0.66	0.81	0.94	0.69	0.72	0.76	0.81
6	0.69	0.91	0.93	0.6	0.69	0.82	0.85
7	0.73	0.82	0.92	0.82	0.85	0.82	0.9
8	0.77	0.84	0.97	0.88	0.91	0.85	0.95
9	0.83	0.95	1.21	1.14	0.95	0.95	0.97
10	0.9	1.17	1.22	0.8	0.92	1.09	1.06
11	0.94	1.05	1.14	1.09	1.2	1.04	1.1
12	0.98	1.14	1.16	1.09	1.14	1.12	1.03
13	0.8	0.81	0.92	0.98	0.96	0.87	0.92
14	0.7	0.74	0.8	0.9	0.79	0.78	0.8
15	0.63	0.78	0.74	0.72	0.71	0.75	0.72
Average	0.73	0.84	0.96	0.84	0.84	0.83	0.87

Week	Water melon						
	Modified Penman	Blaney-Criddle	E-pan	Thornthwaite	Hargreaves	Radiation	Penman-Monteith
1	0.67	0.73	0.8	0.93	0.58	0.77	1.02
2	0.86	1	1.09	1.25	0.73	0.93	1.14
3	1.21	1.44	1.67	1.75	1.07	1.31	1.6
4	1.44	1.64	1.79	1.9	1.21	1.61	1.9
5	1.59	1.83	1.77	2.23	1.33	1.73	2.1
6	1.48	1.87	1.54	2.07	1.25	1.6	1.9
7	1.35	1.84	1.58	1.92	1.19	1.51	1.73
8	1.12	1.32	1.44	1.6	1.03	1.25	1.44
9	0.8	0.99	0.88	1.04	0.7	0.92	1.03
10	0.6	0.78	0.83	0.63	0.52	0.67	0.75
11	0.52	0.71	0.65	0.52	0.47	0.59	0.65
12	0.41	0.56	0.52	0.41	0.35	0.47	0.52
Average	1.01	1.2	1.18	1.21	0.84	1.08	1.32

Week	Cauliflower						
	Modified Penman	Blaney-Criddle	E-pan	Thornthwaite	Hargreaves	Radiation	Penman-Monteith
1	0.89	1.13	0.77	0.84	1.06	1.02	1.01
2	0.95	1.11	1.04	1.13	1.17	1.04	1.36
3	1	1.18	1.24	1.14	1.12	1.1	1.43
4	1.03	1.21	1.01	1.05	1.14	1.17	1.47
5	1.04	1.22	1.09	1.21	1.29	1.11	1.49
6	1.02	1.18	1.3	2.17	1.16	1.11	1.19
7	1	1.19	1.28	2.08	1.14	1.09	1.17
Average	0.99	1.18	1.09	1.27	1.15	1.09	1.3

Week	Tomato						
	Modified Penman	Blaney-Criddle	E-pan	Thornthwaite	Hargreaves	Radiation	Penman-Monteith
1	0.59	0.66	0.74	0.59	0.66	0.63	0.73
2	0.66	0.73	0.86	0.76	0.82	0.69	0.82
3	0.74	0.83	0.92	0.76	0.83	0.77	0.91
4	0.82	0.92	1.02	0.84	0.9	0.84	1.01
5	0.91	0.96	1.23	1.12	0.98	0.87	1.12
6	0.98	1.03	1.22	1.18	0.96	0.98	1.21
7	1.05	1.13	1.35	1.27	1.05	1.05	1.3
8	1.1	1.16	1.41	1.33	1.03	1.13	1.36
9	1.12	1.23	1.48	1.26	1.15	1.2	1.41
10	1.12	1.2	1.52	1.17	1.14	1.17	1.41
11	1.09	1.2	1.49	1.11	1.11	1.17	1.37
12	1.04	1.15	1.52	0.97	1.02	1.09	1.31
13	0.96	1.08	1.34	0.98	0.98	1	1.22
14	0.85	1	1.25	0.85	0.88	0.92	1.08
15	0.72	0.84	1.3	0.76	0.76	0.78	0.92
เฉลี่ย	0.92	1	1.23	0.97	0.95	0.95	1.15

Week	Chinese Kale						
	Modified Penman	Blaney-Criddle	E-pan	Thornthwaite	Hargreaves	Radiation	Penman-Monteith
1	0.46	0.61	0.61	0.59	0.61	0.56	0.54
2	0.54	0.7	0.7	0.68	0.59	0.63	0.6
3	0.61	0.83	0.72	0.78	0.75	0.74	0.68
4	0.64	0.89	0.85	0.79	0.77	0.77	0.72
5	0.7	0.96	0.8	0.82	0.83	0.85	0.78
6	0.74	1.02	0.86	0.98	0.91	0.91	0.83
7	0.65	0.9	0.73	0.91	0.79	0.8	0.73
8	0.6	0.81	0.67	0.79	0.69	0.74	0.67
Average	0.61	0.84	0.74	0.79	0.74	0.75	0.69

Week	Onion						
	Modified Penman	Blaney-Criddle	E-pan	Thornthwaite	Hargreaves	Radiation	Penman-Monteith
1	0.59	0.79	0.73	0.49	0.64	0.76	0.75
2	0.6	0.76	0.65	0.6	0.74	0.7	0.76
3	0.64	0.75	0.84	0.69	0.73	0.69	0.8
4	0.71	0.82	0.86	0.84	0.84	0.73	0.88
5	0.81	0.92	0.97	1.02	1.02	0.83	1.01
6	0.9	1.03	1.11	1.08	0.98	0.92	1.12
7	0.96	1.09	1.18	1.02	1	1.02	1.21
8	1.04	1.15	1.39	1.15	1.06	1.08	1.32
9	1.07	1.21	1.24	1.16	1.11	1.11	1.38
10	1.08	1.3	1.88	1.08	1.1	1.24	1.41
11	1.09	1.38	1.51	0.96	1.09	1.23	1.4
12	1.07	1.28	1.37	1.21	1.15	1.13	1.37
13	1.04	1.31	1.17	1.06	1.02	1.17	1.33
14	1.01	1.2	1.27	1.2	1.12	1.08	1.29
15	0.95	1.21	1.18	0.97	1	1.11	1.22
Average	0.9	1.1	1.15	0.98	0.99	1	1.15

Week	Shallot						
	Modified Penman	Blaney-Criddle	E-pan	Thornthwaite	Hargreaves	Radiation	Penman-Monteith
1	0.59	0.73	0.76	0.64	0.62	0.65	0.72
2	0.67	0.8	1.07	0.76	0.7	0.7	0.82
3	0.77	0.96	0.99	0.91	0.87	0.87	0.94
4	0.85	1.05	1.18	1.14	1	0.87	1.05
5	0.93	1.12	1.06	1.31	1.03	0.93	1.15
6	0.97	1.1	1.23	1.44	1.02	0.99	1.2
7	0.97	1.07	1.2	1.4	0.97	0.99	1.2
8	0.93	1.03	1.21	1.38	0.95	0.95	1.15
9	0.84	0.9	1.17	0.9	0.79	0.86	1.08
10	0.72	0.79	0.9	0.77	0.7	0.75	0.92
11	0.6	0.69	0.83	0.66	0.63	0.6	0.77
12	0.52	0.57	0.66	0.58	0.53	0.53	0.67
Average	0.78	0.89	1.01	0.95	0.81	0.81	0.97

Week	Bitter gourd						
	Modified Penman	Blaney-Criddle	E-pan	Thornthwaite	Hargreaves	Radiation	Penman-Monteith
1	0.68	0.76	0.68	0.98	0.93	0.69	0.88
2	0.84	0.91	0.89	1.26	1.07	0.86	1.09
3	0.98	1.11	1.04	1.47	1.28	1.02	1.23
4	1.08	1.23	1.1	1.6	1.23	1.15	1.35
5	1.14	1.27	1.43	1.73	1.33	1.19	1.43
6	1.18	1.31	1.52	1.75	1.31	1.26	1.48
7	1.19	1.54	1.49	1.26	1.19	1.49	1.47
8	1.18	1.52	1.41	1.45	1.26	1.34	1.46
9	1.14	1.38	1.32	1.48	1.24	1.24	1.41
10	1.1	1.35	1.2	1.62	1.3	1.2	1.36
11	1.04	1.32	1.16	1.46	1.24	1.19	1.29
Average	1.05	1.23	1.18	1.46	1.22	1.13	1.31

Week	Zinnia flower						
	Modified Penman	Blaney-Criddle	E-pan	Thornthwaite	Hargreaves	Radiation	Penman-Monteith
1	0.25	0.22	0.36	0.36	0.27	0.24	0.36
2	0.42	0.36	0.55	0.5	0.44	0.38	0.58
3	0.56	0.49	0.73	0.61	0.59	0.52	0.77
4	0.68	0.62	0.9	0.71	0.72	0.64	0.93
5	0.79	0.74	1.05	0.8	0.84	0.76	1.07
6	0.88	0.86	1.18	0.87	0.95	0.87	1.18
7	0.95	0.97	1.3	0.92	1.03	0.97	1.27
8	1.01	1.07	1.4	0.97	1.11	1.06	1.33
9	1.05	1.17	1.5	1.01	1.18	1.15	1.38
Average	0.73	0.72	1	0.75	0.79	0.73	0.99

Month	Sugar cane						
	Modified Penman	Blaney-Criddle	E-pan	Thornthwaite	Hargreaves	Radiation	Penman-Monteith
1	0.47	0.56	0.56	0.56	0.6	0.53	0.65
2	0.68	0.83	0.84	0.71	0.83	0.8	0.86
3	0.85	1.04	0.94	0.88	1	1.04	1.13
4	1.03	1.28	1.27	1.06	1.16	1.21	1.35
5	1.2	1.54	1.73	1.18	1.35	1.41	1.56
6	1	1.17	1.5	1.14	1.19	1.06	1.29
7	0.86	0.98	1.23	0.8	1.16	0.96	1.2
8	0.65	0.68	0.74	0.93	0.88	0.63	0.93
9	0.5	0.57	0.48	0.53	0.55	0.53	0.63
10	0.42	0.53	0.45	0.44	0.48	0.48	0.52
Average	0.76	0.9	0.92	0.82	0.91	0.85	1.01

Month	Cotton						
	Modified Penman	Blaney-Criddle	E-pan	Thornthwaite	Hargreaves	Radiation	Penman-Monteith
1	0.71	0.81	0.76	1.13	0.74	0.71	0.88
2	1.03	1.2	1.11	1.96	1.03	1.01	1.19
3	1.08	1.22	1.2	1.26	1.08	1.12	1.34
4	0.98	1.15	1.04	1.18	0.98	1.05	1.15
5	0.75	0.96	0.99	0.77	0.72	0.88	0.85
6	0.55	0.7	0.63	0.54	0.55	0.66	0.62
Average	0.85	1.02	0.96	1.03	0.85	0.92	1.01

Month	Castor bean						
	Modified Penman	Blaney-Criddle	E-pan	Thornthwaite	Hargreaves	Radiation	Penman-Monteith
1	0.7	0.88	0.9	0.77	0.68	0.76	0.76
2	0.79	0.79	0.87	0.88	0.68	0.77	0.86
3	0.82	0.82	0.9	0.93	0.67	0.84	1.01
4	0.84	0.83	1.06	0.93	0.77	0.83	1.02
5	0.81	0.81	0.92	0.9	0.8	0.79	1.01
6	0.73	0.82	0.97	0.82	0.8	0.78	0.89
7	0.6	0.68	0.74	0.67	0.67	0.67	0.7
8	0.41	0.47	0.48	0.45	0.46	0.46	0.47
Average	0.71	0.74	0.82	0.76	0.68	0.72	0.84

Month	Taro						
	Modified Penman	Blaney-Criddle	E-pan	Thornthwaite	Hargreaves	Radiation	Penman-Monteith
1	0.93	1.32	1.08	1.32	1.32	1.08	1
2	1.15	1.59	1.32	1.51	1.57	1.36	1.23
3	2.06	2.72	2.39	2.19	2.52	2.47	2.14
4	2.16	2.84	2.77	1.93	2.3	2.7	2.27
5	1.62	2.17	2.3	1.56	1.84	1.97	1.66
6	1.46	1.77	1.77	1.15	1.39	1.54	1.5
Average	1.52	2.03	1.83	1.63	1.83	1.78	1.63

Month	Lemon 1-3 year						
	Modified Penman	Blaney-Criddle	E-pan	Thornthwaite	Hargreaves	Radiation	Penman-Monteith
Mar.	0.91	1.36	1.15	2.14	1.75	1.09	1.1
Apr.	1.17	1.72	1.49	2.14	2.19	1.44	1.38
May	1.25	1.78	1.6	1.86	2.11	1.57	1.44
Jun.	1.3	1.77	1.68	1.57	1.86	1.64	1.5
Jul.	1.12	1.58	1.66	1.47	1.71	1.4	1.29
Aug.	0.94	1.38	1.31	1.25	1.51	1.19	1.08
Sep.	1.15	1.74	1.6	1.65	1.9	1.45	1.3
Oct.	1.23	1.85	1.9	1.9	2.11	1.51	1.4
Nov.	1.03	1.45	1.59	2.06	1.9	1.18	1.18
Dec.	0.99	1.26	1.17	3.16	1.8	1.1	1.19
Jan.	0.88	1.06	0.99	1.83	1.11	0.95	1.06
Feb.	0.85	1.1	0.98	1.12	1.05	0.94	1.02
Average	1.07	1.49	1.39	1.74	1.71	1.28	1.25

Month	Lemon 3-5 year						
	Modified Penman	Blaney-Criddle	E-pan	Thornthwaite	Hargreaves	Radiation	Penman-Monteith
Mar.	0.97	1.45	1.23	2.28	1.86	1.16	1.17
Apr.	1.25	1.84	1.6	2.29	2.34	1.54	1.47
May	1.31	1.86	1.67	1.95	2.21	1.64	1.51
Jun.	1.38	1.88	1.79	1.66	1.98	1.74	1.59
Jul.	1.17	1.65	1.72	1.53	1.79	1.46	1.35
Aug.	0.99	1.46	1.37	1.31	1.59	1.25	1.14
Sep.	1.18	1.79	1.64	1.69	1.95	1.49	1.33
Oct.	1.25	1.88	1.91	1.94	2.14	1.54	1.42
Nov.	1.06	1.5	1.62	2.12	1.96	1.21	1.21
Dec.	1.07	1.36	1.28	3.41	1.95	1.19	1.28
Jan.	0.96	1.15	1.09	1.99	1.21	1.04	1.16
Feb.	0.92	1.19	1.07	1.21	1.14	1.02	1.11
Average	1.12	1.57	1.47	1.84	1.8	1.35	1.31

Month	Asparagus						
	Modified Penman	Blaney-Criddle	E-pan	Thornthwaite	Hargreaves	Radiation	Penman-Monteith
1	0.62	0.88	0.85	0.66	0.72	0.77	0.68
2	1	1.48	1.32	1.14	1.2	1.23	1.1
3	1.27	1.82	1.76	1.37	1.44	1.56	1.42
4	1.31	1.82	1.6	1.55	1.6	1.55	1.48
5	1.07	1.3	1.23	1.49	1.3	1.14	1.29
6	0.88	1.08	1.06	1.01	1.01	0.98	1.08
7	0.71	0.97	0.92	0.99	0.9	0.81	0.83
8	0.56	0.81	0.69	0.8	0.78	0.65	0.66
9	0.47	0.67	0.6	0.64	0.69	0.55	0.55
10	0.54	0.75	0.64	0.58	0.65	0.65	0.61
11	0.66	0.87	0.77	0.59	0.67	0.83	0.76
12	0.66	0.89	0.84	0.66	0.77	0.81	0.74
Average	0.76	1.06	0.97	0.9	0.94	0.91	0.93

Month	Mango						
	Modified Penman	Blaney-Criddle	E-pan	Thornthwaite	Hargreaves	Radiation	Penman-Monteith
Jun.	1.84	2.35	2.21	1.63	1.51	2.35	2.1
Jul.	2.06	2.62	2.28	1.76	1.7	2.62	2.46
Aug.	2.33	3.13	3.1	2.28	2	2.95	2.53
Sep.	2.07	2.78	2.64	2.35	2.07	2.46	2.28
Oct.	2.12	2.75	2.85	2.48	2.21	2.42	2.29
Nov.	2.29	2.54	2.63	2.68	2.13	2.35	2.5
Dec.	1.54	1.63	1.76	1.79	1.32	1.58	1.9
Jan.	1.44	1.6	1.89	1.65	1.37	1.48	1.69
Feb.	1.29	1.52	1.55	1.52	1.37	1.34	1.61
Mar.	1.04	1.32	1.44	1.2	1.23	1.14	1.27
Apr.	1.06	1.35	1.36	1.23	1.25	1.23	1.24
May	1.04	1.34	1.27	1.22	1.24	1.24	1.19
Average	1.6	1.98	1.99	1.74	1.59	1.82	1.92

Month	Pamelo						
	Modified Penman	Blaney-Criddle	E-pan	Thornthwaite	Hargreaves	Radiation	Penman-Monteith
Dec.	1.44	1.52	1.65	1.6	1.31	1.48	1.74
Jan.	1.32	1.46	1.72	1.42	1.32	1.38	1.62
Feb.	1.19	1.38	1.63	1.44	1.15	1.24	1.45
Mar.	0.91	1.15	1.15	1.05	1.03	1.05	1.12
Apr.	0.87	1.12	1.01	1.01	0.96	1.01	1.02
May	1	1.3	1.28	1.25	1.16	1.17	1.13
Jun.	1.73	2.21	2.09	1.53	1.42	2.21	1.97
Jul.	2.04	2.59	2.23	1.74	1.68	2.59	2.44
Aug.	2.17	2.92	2.92	2.12	1.87	2.74	2.36
Sep.	1.79	2.4	2.28	2.03	1.79	2.12	1.97
Oct.	1.82	2.36	2.43	2.13	1.9	2.08	1.96
Nov.	1.74	1.93	1.98	2.04	1.62	1.78	1.9
Average	1.44	1.76	1.77	1.56	1.41	1.64	1.72

Month	Saccharm spontaneum						
	Modified Penman	Blaney-Criddle	E-pan	Thornthwaite	Hargreaves	Radiation	Penman-Monteith
Dec.	0.69	0.72	0.82	0.68	0.75	0.7	0.91
Jan.	0.6	0.72	0.65	0.62	0.72	0.69	0.79
Feb.	0.66	0.79	0.66	0.7	0.78	0.8	0.87
Mar.	0.62	0.79	0.66	0.68	0.8	0.73	0.83
Apr.	0.79	1.23	0.88	0.77	0.91	0.92	1.03
May	1.06	1.4	1.05	0.86	1.11	1.39	1.37
Jun.	1.07	1.41	1.09	0.88	1.15	1.44	1.37
Jul.	1.24	1.48	1.08	1.1	1.15	1.51	1.53
Aug.	1.09	1.45	1.27	1.17	1.1	1.21	1.33
Sep.	1	1.3	1.24	1.26	1.15	1.05	1.24
Oct.	0.99	1.2	1.01	1.19	1.21	1.07	1.26
Nov.	1.08	1.26	1.01	1.22	1.23	1.11	1.34
Average	0.88	1.1	0.92	0.89	0.99	1.01	1.13

Month	Rose						
	Modified Penman	Blaney-Criddle	E-pan	Thornthwaite	Hargreaves	Radiation	Penman-Monteith
1	0.7	0.96	0.92	0.66	0.72	0.72	0.89
2	0.78	1.05	0.9	0.68	0.72	1.05	0.95
3	1.21	1.28	1.58	1	1.05	1.43	1.46
4	1.25	1.47	1.53	1.08	1.11	1.49	1.49
5	0.93	1.19	1.21	0.87	0.88	0.99	1.16
6	1.04	1.23	1.44	1.02	1.02	1	1.33
7	1.6	1.47	2.17	1.59	1.52	1.32	2.07
8	1.37	1.24	1.74	1.43	1.25	1.09	1.79
9	1.66	1.35	2.43	1.82	1.53	1.31	2.17
10	1.76	1.55	2.65	1.79	1.58	1.48	2.25
11	1.39	1.4	1.94	1.59	1.24	1.42	1.73
12	1.44	1.35	2.05	1.45	1.41	1.25	1.9
Average	1.26	1.29	1.71	1.25	1.17	1.21	1.6

Crop Coefficients (K) for calculate evapotranspiration

From United Nations Food and Agriculture Organization

Crop	Kc ini1	Kc mid	Kc end	Max. Crop Height (m)
a. Small Vegetables				
Broccoli		1.05	0.95	0.3
Brussel Sprouts		1.05	0.95	0.4
Cabbage		1.05	0.95	0.4
Carrots		1.05	0.95	0.3
Cauliflower		1.05	0.95	0.4
Celery		1.05	1.00	0.6
Garlic		1.00	0.70	0.3
Lettuce		1.00	0.95	0.3
Onions, dry		1.05	0.75	0.4
Onions, green		1.00	1.00	0.3
Onions, seed		1.05	0.80	0.5
Spinach		1.00	0.95	0.3
Radishes		0.90	0.85	0.3
b. Vegetables — Solanum Family (*Solanaceae*)				
EggPlant		1.05	0.90	0.8
Sweet Peppers (bell)		1.052	0.90	0.7
Tomato		1.152	0.70-0.90	0.6
c. Vegetables — Cucumber Family (*Cucurbitaceae*)				
Cantaloupe	0.5	0.85	0.60	0.3
Cucumber — Fresh Market	0.6	1.002	0.75	0.3
— Machine harvest	0.5	1.00	0.90	0.3
Pumpkin, Winter Squash		1.00	0.80	0.4
Squash, *zuchini*		0.95	0.75	0.3
Sweet Melons		1.05	0.75	0.4

Crop	Kc ini1	Kc mid	Kc end	Max. Crop Height (m)
Watermelon	0.4	1.00	0.75	0.4
d. Roots and Tubers				
Beets, table		1.05	0.95	0.4
Cassava — year 1	0.3	0.803	0.30	1.0
— year 2	0.3	1.10	0.50	1.5
Parsnip	0.5	1.05	0.95	0.4
Potato		1.15	0.754	0.6
Sweet Potato		1.15	0.65	0.4
Turnip (and Rutabaga)		1.10	0.95	0.6
Sugar Beet	0.35	1.20	0.705	0.5
e. Lugumes (*Leguminosae*)				
Beans, green	0.5	1.052	0.90	0.4
Beans, dry and Pulses	0.4	1.152	0.35	0.4
Chick pea		1.00	0.35	0.4
Fababean — Fresh	0.5	1.152	1.10	0.8
— Dry/Seed	0.5	1.152	0.30	0.8
Grabanzo	0.4	1.15	0.35	0.8
Green Gram and Cowpeas		1.05	0.60-0.356	0.4
Groundnut (Peanut)		1.15	0.60	0.4
Lentil		1.10	0.30	0.5
Peas — Fresh	0.5	1.152	1.10	0.5
— Dry/Seed		1.15	0.30	0.5
Soybeans		1.15	0.50	0.5-1.0
f. Perennial Vegetables (with winter dormancy and initially bare or mulched soil)				
Artichokes	0.5	1.00	0.95	0.7
Asparagus	0.5	0.957	0.30	0.2-0.8
Mint	0.60	1.15	1.10	0.6-0.8
Strawberries	0.40	0.85	0.75	0.2
g. Fiber Crops				

Crop	Kc ini1	Kc mid	Kc end	Max. Crop Height (m)
Cotton		1.15-1.20	0.70-0.50	1.2-1.5
Flax		1.10	0.25	1.2
Sisal8		0.4-0.7	0.4-0.7	1.5
h. Oil Crops				
Castor bean (*Ricinus*)		1.15	0.55	0.3
Rapeseed, Canola		1.0-1.159	0.35	0.6
Safflower		1.0-1.159	0.25	0.8
Sesame		1.10	0.25	1.0
Sunflower		1.0-1.159	0.35	2.0
i. Cereals				
Barley		1.15	0.25	1
Oats		1.15	0.25	1
Spring Wheat		1.15	0.25-0.410	1
Winter Wheat	0.4-0.711	1.15	0.25-0.410	1
Maize, Field *(field corn)*		1.20	0.60-0.351	2
Maize, Sweet *(sweet corn)*		1.15	1.0513	1.5
Millet		1.00	0.30	1.5
Sorghum — grain		1.00-1.10	0.55	1-2
— sweet		1.20	1.05	2-4
Rice	1.05	1.20	0.90-0.60	1
j. Forages				
Alfalfa Hay				
— averaged cutting effects	0.40	0.9514	0.90	0.7
— individual cutting periods	0.4015	1.2015	1.1515	0.7
— for seed	0.40	0.50	0.50	0.7
Bermuda hay				
— averaged cutting effects	0.55	1.0014	0.85	0.35
— Spring crop for seed	0.35	0.90	0.65	0.4

Crop	Kc ini1	Kc mid	Kc end	Max. Crop Height (m)
Clover hay, Berseem				
— averaged cutting effects	0.40	0.9014	0.85	0.6
— individual cutting periods	0.4015	1.1515	1.1015	0.6
Rye Grass hay — averaged cutting effects	0.95	1.05	1.00	0.3
Sudan Grass hay (annual)				
— averaged cutting effects	0.50	0.9014	0.85	1.2
— individual cutting periods	0.5015	1.1515	1.1015	1.2
Grazing Pasture				
- Rotated Grazing	0.40	0.85-1.05	0.85	0.15-0.30
- Extensive Grazing	0.30	0.75	0.75	0.10
Turf grass- cool season16	0.90	0.95	0.95	0.10
- warm season16	0.80	0.85	0.85	0.10
k. Sugar Cane				
Sugar Cane	0.40	1.25	0.75	3
l. Tropical Fruits and Trees				
Banana — 1st year	0.50	1.10	1.00	3
— 2nd year	1.00	1.20	1.10	4
Cacao	1.00	1.05	1.05	3
Coffee — bare ground cover	0.90	0.95	0.95	2-3
— with weeds	1.05	1.10	1.10	2-3
Date Palms	0.90	0.95	0.95	8
Palm Trees	0.95	1.00	1.00	8
Pineapple (multiyear crop)				
— bare soil	0.50	0.30	0.30	0.6-1.2
— with grass cover	0.50	0.50	0.50	0.6-1.2
Rubber Trees	0.95	1.00	1.00	10

Crop	Kc ini1	Kc mid	Kc end	Max. Crop Height (m)
Tea — nonshaded	0.95	1.00	1.00	1.5
— shaded18	1.10	1.15	1.15	2
m. Grapes and Berries				
Berries (bushes)	0.30	1.05	0.50	1.5
Grapes —`Table or Raisin	0.30	0.85	0.45	2
— Wine	0.30	0.70	0.45	1.5-2
Hops	0.3	1.05	0.85	5
n. Fruit Trees				
Almonds, no ground cover	0.40	0.90	0.6519	5
Apples, Cherries, Pears20				
• no ground cover, killing frost	0.45	0.95	0.7019	4
• no ground cover, no frosts	0.60	0.95	0.7519	4
• active ground cover, killing frost	0.50	1.20	0.9519	4
• active ground cover, no frosts	0.80	1.20	0.8519	4
Apricots, Peaches, Stone Fruit				
• no ground cover, killing frost	0.45	0.90	0.6519	3
• no ground cover, no frosts	0.55	0.90	0.6519	3
• active ground cover, killing frost	0.50	1.15	0.9019	3
• active ground cover, no frosts	0.80	1.15	0.8519	3
Citrus, no ground cover				
- 70% canopy	0.70	0.65	0.70	4
- 50% canopy	0.65	0.60	0.65	3
- 20% canopy	0.50	0.45	0.55	2
Citrus, with active ground cover				
- 70% canopy	0.75	0.70	0.75	4
- 50% canopy	0.80	0.80	0.80	3
- 20% canopy	0.85	0.85	0.85	2

Crop	Kc ini1	Kc mid	Kc end	Max. Crop Height (m)
Avocado, no ground cover	0.60	0.85	0.75	3
Conifer Trees24	1.00	1.00	1.00	10
Kiwi	0.40	1.05	1.05	3
Olives (40-60% ground coverage by canopy)	0.65	0.70	0.70	5-7
Pistachios, no ground cover	0.40	1.10	0.45	3-6
Walnut Orchard20	0.50	1.10	0.6519	4-5
o. Wetlands — temperate climate				
Cattails, Bulrushes, killing frost	0.30	1.20	0.30	2
Cattails, Bulrushes, no frost	0.60	1.20	0.60	2
Short Veg., no frost	1.05	1.10	1.10	0.3
Reed Swamp, standing water	1.00	1.20	1.00	1-3
Reed Swamp, moist soil	0.90	1.20	0.70	1-3
p. Special				
Open Water, < 2 m depth or in subhumid climates or tropics		1.05	1.05	0.005
Open Water, > 5 m depth, clear of turbidity, temperate climate		0.6526	1.2526	0.005

Appendix E

Well Lithology

Note : From Department of Ground Water Resources, Ministry of Natural Resources and Environmental, Thailand

CHANGWAT PHETCHABUN		
No. ME0142 (18 m.)	684188 E 1781595 N	Rong Rean Ban Dong Kui m.2 T. Dong Kui A. Chon Dan
0.0 - 4.5 m.	clay	dark brown, silty, low Phrastic, loosely compact
4.5 - 18.2 m.	sand	brown, composed mostly of quartz, feldspars, laterites
No. ME0143 (17 m.)	686773 E 1781506 N	Police Station Dong Kui T. Dong Kui A. Chon Dan
0.0 - 1.5 m.	clay	light brown, silty, Phrastic, compact
1.5 - 3.0 m.	silt	brown, feldspars mottled scatter, loosely compact
3.0 - 13.7 m.	sand	brown, composed of quartz, and feldspars
3.7 - 16.7 m.	gravel	various color, composed of sandstone, feldspars, laterite
No. N0094 (36 m.)	684752 E 1782442 N	Wat Sawang Nate (Ban Dong Kui) T. Dong Kui A. Chon Dan
0.0 - 9.1 m.	clay	brownish gray, silty, calcareous and limonitic
9.1 - 12.1 m.	clay	brown, clayey, composed mostly of quartz.
9.8 - 36.5 m.	andesite	gray, very hard.
12.1 - 19.8 m.	sand	brown, composed mostly of quartz, quartzite, feldspars.
No. N0558 (18 m.)	678500 E 1808800 N	Rong Rean Ban Wang Plub T. Tai Dong A. Wang Pong
0.0 - 6.0 m.	clay	yellowish brown, silty, limonite stained, compacted
6.0 - 18.2 m.	andesite	dark greenish gray, fine grained, very hard, dense, volcanic
No. N0711 (21 m.)	686278 E 1808963 N	Ban Wang Hin Song Tai M.7 T. Wang Hin A. Wang Pong
0.0 - 3.0 m.	gravel	clay + yellow gravel
3.0 - 12.1 m.	clay	yellow clay
12.1 - 21.3 m.	limestone	limestone
No. N0712 (18 m.)	679004 E 1808611 N	Ban Wang Plub m.5 T. Wang Hin A. Wang Pong
0.0 - 6.0 m.	gravel	clay + yellow gravel
6.0 - 7.6 m.	clay	yellow clay
7.6 - 18.2 m.	limestone	gray limestone
No. N0713 (30 m.)	680096 E 1808327 N	Wat Ban Wang Yai T. Wang Hin A. Wang Pong
0.0 - 7.6 m.	gravel	clay + gray gravel

7.6 - 30.4 m.	limestone	gray limestone
No. N0714 (18 m.)	686439 E 1809653 N	Wang Hin Song Ner T. Wang Hin A. Wang Pong
0.0 - 1.5 m.	clay	brown clay
1.5 - 12.1 m.	limestone	gray limestone
12.1 - 18.2 m.	andesite	andesite
No. N0828 (24 m.)	684298 E 1803677 N	Wat Wang Khon T. Tai Dong A. Wang Pong
0.0 - 1.5 m.	clay	light brownish gray, slightly sandy, nonPhrastic, stiff.
1.5 - 9.1 m.	gravel	yellowish brown, composed of quartz, slightly compacted.
9.1 - 24.3 m.	andesitic tuff	gray, aphanitic, fresh to slightly weathered, very hard.
No. N0959 (18 m.)	682105 E 1808895 N	Ban Num Om m.3 T. Wang Hin A. Wang Pong
0.0 - 4.5 m.	clay	light yellowish brown, gravelly, calcareous, high Phrastic.
4.5 - 18.2 m.	sandstone	greenish gray, fine grained
No. N0960 (24 m.)	679420 E 1808280 N	Ban Wang Plub m.5 T. Wang Hin A. Wang Pong
0.0 - 6.0 m.	clay	yellow clay
6.0 - 24.0 m.	limestone	limestone
No. N1020 (24 m.)	686433 E 1807127 N	Ban Bo Thong Pathana m.11 T. Tai Dong A. Wang Pong
0.0 - 6.0 m.	clay	brown clay
6.0 - 24.3 m.	limestone	gray limestone
No. N1022 (24 m.)	679157 E 1808440 N	Ban Wang Plub m.5 T. Wang Hin A. Wang Pong
0.0 - 6.0 m.	clay	yellow clay
6.0 - 24.3 m.	limestone	gray limestone
No. N1055 (24 m.)	683536 E 1781145 N	Rong Rean Ban Dong Kui Tai T. Dong Kui A. Chon Dan
0.0 - 6.0 m.	clay	yellow clay
6.0 - 18.2 m.	gravel	gravel + sand
8.2 - 24.3 m.	limestone	limestone
No. N1056 (42 m.)	679908 E 1799879 N	Ban Thung Na Ngam m.7 T. Tai Dong A. Wang Pong
0.0 - 6.0 m.	clay	yellow clay
6.0 - 42.6 m.	limestone	gray limestone
No. N1057 (36 m.)	680002 E 1808561 N	Ban Wang Yai M.4 T. Wang Hin A. Wang Pong
0.0 - 9.1 m.	clay	yellow clay
9.1 - 36.5 m.	limestone	gray limestone
No. N1094 (30 m.)	682103 E 1803105 N	Wat Ban Cha Nang T. Tai Dong A. Wang Pong

0.0 - 4.5 m.	clay	brown clay
4.5 - 12.1 m.	gravel	clay + brown gravel
12.1 - 30.4 m.	limestone	gray limestone
No. N1095 (30 m.)	682508 E 1802636 N	Ban Rong Tabag m.9 T. Tai Dong A. Wang Pong
0.0 - 4.5 m.	gravel	clay + brown gravel
4.5 - 15.2 m.	clay	yellow clay
15.2 - 25.9 m.	clay	gray clay
25.9 - 30.4 m.	sand	gray clay + gray sand
No. N1097 (18 m.)	685060 E 1805002 N	Ban Wang Kradat M.3 T. Tai Dong A. Wang Pong
10.6 - 18.2 m.	clay	yellow clay
0.0 - 10.6 m.	limestone	gray limestone
No. N1131 (18 m.)	683727 E 1781038 N	Wat Dong Kui Tai T. Dong Kui A. Chon Dan
0.0 - 1.5 m.	clay	brown clay
1.5 - 9.1 m.	gravel	clay + gravel
9.1 - 18.2 m.	sandstone	sandstone
No. N1132 (30 m.)	679488 E 1797581 N	Ban Goot Pan Sadao T. Wang San A. Wang Pong
0.0 - 3.0 m.	clay	brown clay
3.0 - 9.1 m.	laterite	lateritic soil
9.1 - 12.1 m.	clay	brown clay
12.1 - 30.4 m.	limestone	limestone
No. N1133 (30 m.)	679495 E 1797587 N	Ban Goot Pan Sadao T. Wang San A. Wang Pong
0.0 - 4.5 m.	laterite	yellow lateritic soil
4.5 - 15.2 m.	shale	shale
15.2 - 30.4 m.	limestone	limestone
No. N1134 (30 m.)	681030 E 1798360 N	Ban Goot Pan Sadao T. Wang San A. Wang Pong
3.0 - 12.1 m.	sand	red sand
12.1 - 30.4 m.	clay	yellow clay
0.0 - 3.0 m.	limestone	limestone
No. N1135 (24 m.)	682196 E 1802547 N	Ban Wang Cha Nang Ner m.12 T. Tai Dong A. Wang Pong
0.0 - 1.5 m.	clay	yellow clay
1.5 - 15.2 m.	laterite	lateritic soil
15.2 - 24.3 m.	limestone	limestone

No. N1136 (30 m.)	681610 E 1798334 N	Ban Goot Pan Sadao T. Wang San A. Wang Pong
0.0 - 7.6 m.	clay	brown clay
7.6 - 30.4 m.	limestone	limestone
No. N1137 (30 m.)	684041 E 1799229 N	Ban Wang Chae Gloy m.5 T. Wang San A. Wang Pong
0.0 - 4.5 m.	clay	yellow clay
4.5 - 30.4 m.	limestone	gray limestone
No. N1138 (30 m.)	684311E1803794 N	Ban Wang Khon M.6 T. Tai Dong A. Wang Pong
0.0 - 9.1 m.	clay	yellow clay
9.1 - 30.4 m.	limestone	gray limestone
No. N1139 (18 m.)	680907 E 1807315 N	Ban Dong Jarern m.9 T. Wang Hin A. Wang Pong
0.0 - 4.5 m.	clay	brown sandy clay
4.5 - 10.6 m.	gravel	gravel
10.6 - 18.2 m.	limestone	limestone
No. N1140 (18 m.)	679183 E 1808682 N	Ban Wang Plub m.5 4 T. Wang Hin A. Wang Pong
0.0 - 4.5 m.	laterite	brown lateritic soil
4.5 - 9.1 m.	andesite	andesite
9.1 - 18.2 m.	limestone	limestone
No. N1160 (36 m.)	686772 E 1781482 N	Police Station Dong Kui T. Dong Kui A. Chon Dan
0.0 - 18.0 m.	laterite	yellow lateritic soil
18.0 - 36.0 m.	andesite	andesite
No. N1164 (74 m.)	686263 E 1808786 N	Wa Aran Jit Sawang T. Wang Hin A. Wang Pong
10.5 - 73.5 m.	laterite	brown lateritic soil
0.0 - 10.5 m.	limestone	limestone
No. N1191 (48 m.)	685499 E 1784352 N	Wat Noen Sawang m.3 T. Tagoot Rai A. Chon Dan
0.0 - 12.0 m.	clay	yellow clay
12.0 - 48.0 m.	andesite	andestite
No. N1192 (42 m.)	685586 E 1788141 N	Ban Pong Nok Kaew m.7 T. Tagoot Rai A. Chon Dan
0.0 - 12.0 m.	clay	yellow clay
12.0 - 42.0 m.	andesite	andesite
No. N1194 (18 m.)	685229 E 1782116 N	Wat Waree Wong T. Dong Kui A. Chon Dan
0.0 - 4.5 m.	clay	yellow clay
4.5 - 7.5 m.	clay	brown clay

7.5 - 15.0 m.	gravel	gray gravel
15.0 - 18.0 m.	limestone	limestone
No. N1234 (42 m.)	685541 E 1784374 N	Rong Rean Ban Khao Noi m.3 T. Tagoot Rai A. Chon Dan
0.0 - 9.0 m.	laterite	yellow lateritic soil
9.0 - 15.0 m.	clay	yellow clay
15.0 - 21.0 m.	clay	red clay
21.0 - 42.0 m.	andesite	green andesite
No. N1265 (48 m.)	685292 E 1784525 N	Ban Noen Sawang m.2 T. Tagoot Rai A. Chon Dan
0.0 - 6.0 m.	clay	yellow clay
6.0 - 19.5 m.	laterite	clay + black lateritic soil
19.5 - 48.0 m.	andesite	andesite
No. N1266 (54 m.)	685515 E 1784906 N	Ban Noen Sawang m.2 T. Tagoot Rai A. Chon Dan
0.0 - 6.0 m.	clay	yellow clay
6.0 - 16.5 m.	clay	red sandy clay
16.5 - 21.0 m.	laterite	brown rock sald
21.0 - 54.0 m.	andesite	black andesite
No. N1267 (42 m.)	684760 E 1792091 N	Ban Nong Ma m.4 T. Tagoot Rai A. Chon Dan
0.0 - 3.0 m.	laterite	red lateritic soil
3.0 - 7.5 m.	clay	yellow clay
7.5 - 42.0 m.	andesite	andesite
No. N1273 (60 m.)	685761 E 1785363 N	Ban Noen Sawang m.2 T. Tagoot Rai A. Chon Dan
0.0 - 6.0 m.	laterite	yellow lateritic soil
6.0 - 60.0 m.	andesite	andesite
No. TZ0052 (36 m.)	678241 E 1785403 N	Muang Jarern m.11 T. Dong Kui A. Chon Dan
0.0 - 3.0 m.	laterite	lateritic soil
3.0 - 36.0 m.	andesite	andesite
No. TZ0053 (54 m.)	685228 E 1805295 N	Ban Wang Kradat ngearn M.2 T. Tai Dong A. Wang Pong
0.0 - 8.0 m.	clay	yellow clay
8.0 - 10.0 m.	sand	yellow sand
10.0 - 13.0 m.	limestone	gray limestone
13.0 - 36.0 m.	andesite	gray andesite
No. TZ0054 (120 m.)	685900 E 1805708 N	Ban Bo Thong Pathana m.11 T. Tai Dong A. Wang Pong

0.0 - 10.0 m.	laterite	yellow lateritic soil
10.0 - 120.0 m.	andesite	gray andesite
No. TZ0056 (120 m.)	685581 E 1788141 N	Wat Ban Ponh Kaew T. Tagoot Rai A. Chon Dan
0.0 - 4.5 m.	clay	clay + rock sald
4.5 - 120.0 m.	andesite	gray andesite
No. TZ0058 (102 m.)	684545 E 1793806 N	Rong Rean Ban Khao Din m.3 T. Tagoot Rai A. Chon Dan
0.0 - 15.0 m.	clay	brown clay
15.0 - 102.0 m.	andesite	andesite
No. TZ0079 (120 m.)	678879 E 1784402 N	Ban KoMo 28 m.8 T. Dong Kui A. Chon Dan
0.0 - 3.0 m.	clay	brown clay
3.0 - 12.0 m.	clay	yellow clay
12.0 - 24.0 m.	clay	clay + gray limestone
24.0 - 36.0 m.	limestone	gray + black limestone
36.0 - 120.0 m.	andesite	gray + black andesite
CHANGWAT PHICHIT		
No. MC0746 (32 m.)	669396 E 1803219 N	Wat Ban Dai Num Khun T. Nong Phra A. Wang Sai Phun
0.0 – 6.0 m.	clay	brown, clayey, nonPhrastic.
6.0 – 15.2 m.	sand	light brown, silty, very fine sand to coarse sand
15.2 – 30.4 m.	gravel	dark reddish brown, sandy, very fine gravel
30.4 – 32.0 m.	andesite	greenish gray, highly weathered, moderately hard to hard.
No. MC0785 (54 m.)	668741 E 1786971 N	Wat Pa Rayrai M.2 T. Thap Khlo A. Thap Khlo
0.0 – 10.6 m.	sand	Sand
10.6 – 25.9 m.	clay	clay
25.9 – 54.8 m.	andesite	rock sald
No. MC0786 (60 m.)	666400 E 1786800 N	Rong Rean Ban Num Kerng T. Thai Thung A. Thap Khlo
0.0 – 21.3 m.	clay	clay
21.3 – 22.8 m.	sand	sand
22.8 – 45.0 m.	laterite	lateritic soil
45.0 – 60.9 m.	andesite	andesite
No. MC0812 (48 m.)	665900 E 1789100 N	Rong Rean Wat Num Tao T. Thap Khlo A. Thap Khlo
0.0 – 7.6 m.	clay	
7.6 – 30.4 m.	sand	light yellowish brown and yellowish brown

30.4 – 38.0 m.	gravel	yellowish brown, sandy, very fine gravel
38.0 – 48.7 m.	limestone	dark gray, fresh to slightly weathered, hard to very hard.
No. MC0889 (45 m.)	668475 E 1805673 N	Rong Rean Wang Sai Phun Wittaya T. Nong Phra A. Wang Sai Phun
0.0 – 4.5 m.	Clay	clay
4.5 – 10.6 m.	sand	red sand
10.6 – 28.9 m.	laterite	lateritic soil
28.9 – 45.7 m.	andesite	rock sald + clay
No. MD0637 (40 m.)	668465 E 1790131 N	Rong Rean Wat Sai Dong Yang T. Thap Khlo A. Thap Khlo
0.0 – 3.0 m.	clay	grayish brown.
3.0 – 22.8 m.	sand	yellowish brown, sandy.
22.8 – 33.5 m.	clay	yellowish brown.
33.5 – 39.6 m.	andesite	light gray, phaneritic, composed quartz, feldspars, biotite.
No. MD0650 (39 m.)	666528 E 1813796 N	Wat Ban Wang Sang T. Wang Sai Phun A. Wang Sai Phun
0.0 – 4.5 m.	laterite	dark brown, pisolitic, coarse sand to very fine gravel
4.5 – 12.0 m.	clay	yellowish brown, sandy, Phrastic.
12.0 – 22.8 m.	sand	dark yellowish brown, medium sand to coarse sand
22.8 – 33.5 m.	gravel	dark yellowish brown, very fine gravel
33.5 – 39.6 m.	sand	dark yellowish brown, medium sand to coarse sand
No. MD0695 (51 m.)	665957 E 1788985 N	Ban Num Tao M.4 T. Thap Khlo A. Thap Khlo
0.0 – 4.5 m.	laterite	yellowish brown, sandy slightly, slightly Phrastic to Phrastic.
4.5 – 9.1 m.	clay	dark yellowish brown, sandy moderately, Phrastic.
9.1 – 22.8 m.	sand	dark yellowish brown, silty highly, very fine to coarse sand
22.8 – 38.0 m.	gravel	dark yellowish brown, gravelly highly, sandy highly.
38.0 – 51.8 m.	limestone	with white, calcareous highly, completely weathered.
No. MD0699 (68 m.)	660909 E 1793167 N	Ban Nong Pai Lom m.1 T. Wang Loom A. Taphan Hin
0.0 – 7.6 m.	clay	red clay
7.6 – 19.8 m.	laterite	clay + brown lateritic soil
19.8 – 35.0 m.	clay	clay
35.0 – 39.6 m.	laterite	clay + lateritic soil
39.6 – 48.7 m.	sand	sandy clay
No. MD0702 (45 m.)	660800 E 1782700 N	Ban Wang Taloog m.5 T. Thung Po A. Taphan Hin

0.0 – 9.1 m.	clay	olive, sandy, slightly Phrastic.
9.1 – 39.6 m.	clay	light grayish green, sandy, Phrastic.
39.6 – 45.7 m.	gravel	various colors, clayey, fine gravel to medium gravel
No. MD0734 (54 m.)	669428 E 1789126 N	Ban Thap Khlo m.1 T. Thap Khlo A. Thap Khlo
0.0 – 13.7 m.	clay	red clay
21.0 – 33.0 m.	gravel	sand + brown gravel
33.0 – 54.8 m.	gravel	brown gravel
13.7 – 21.0 m.	limestone	limestone
No. MD0735 (72 m.)	664580 E 1812299 N	Citizen Library Nong Porn T. Nong Phra A. Wang Sai Phun
0.0 – 3.0 m.	clay	brown clay
3.0 – 36.5 m.	laterite	red lateritic soil
36.5 – 39.6 m.	gravel	brown gravel
39.6 – 57.0 m.	andesite	gray andesite
57.0 – 59.4 m.	limestone	gray limestone
No. MD0851 (99 m.)	660842 E 1793164 N	Ban Nong Pai Lom m.1 T. Wang Loom A. Taphan Hin
0.0 – 16.7 m.	clay	brown clay
19.8 – 59.4 m.	laterite	lateritic soil + brown clay
16.7 – 19.8 m.	clay	brown clay
59.4 – 100.6 m.	limestone	limestone
No. MD0972 (65 m.)	661400 E 1784700 N	Ban Thung Po m.3 T. Thung Po A. Taphan Hin
0.0 – 10.5 m.	clay	brown clay
10.5 – 15.0 m.	laterite	lateritic soil + sand
15.0 – 22.5 m.	sand	clay + sand
22.5 – 64.0 m.	laterite	rock sald
64.0 – 64.5 m.	sand	clay + sand + rock sald
No. MD0974 (64 m.)	661267 E 1784765 N	Ban Thung Po m.4 T. Thung Po A. Taphan Hin
0.0 – 4.5 m.	gravel	clay
4.5 – 18.0 m.	gravel	clay + gravel
18.0 – 52.5 m.	clay	brown clay
52.5 – 64.0 m.	laterite	rock sald + clay
No. MD0975 (64 m.)	664700 E 1785200 N	Ban Thung Po m.1 T. Thung Po A. Taphan Hin
0.0 – 13.5 m.	clay	black clay

13.5 – 39.0 m.	gravel	clay + gravel
39.0 – 64.0 m.	limestone	gravel + limestone
No. MD1080 (63 m.)	670100 E 1787900 N	Wat Mong Khol Thap Khlo m.2 T. Thap Khlo A. Thap Khlo
9.0 – 15.0 m.	clay	brown clay
15.0 – 63.0 m.	laterite	clay + lateritic soil
0.0 – 3.0 m.	andesite	andesite
No. MD1089 (66 m.)	668800 E 1786900 N	Rong Rean Wat Pa Rayrai T. Thap Khlo A. Thap Khlo
0.0 – 1.5 m.	top soil	top soil
1.5 – 23.0 m.	clay	red clay
23.0 – 66.0 m.	andesite	rock sald + clay
No. MD1097 (80 m.)	662229 E 1790109 N	Ban Wang loom m.9 T. Wang Loom A. Taphan Hin
0.0 – 3.0 m.	top soil	top soil
3.0 – 6.0 m.	laterite	red clay + lateritic soil
6.0 – 9.0 m.	clay	yellow clay
9.0 – 30.0 m.	sand	sand
30.0 – 51.0 m.	laterite	clay + sand
51.0 – 60.0 m.	andesite	andesite
60.0 – 80.0 m.	limestone	limestone
No. MD1098 (150 m.	) 663900 E 1782700 N	Ban Bang Bene M.4 T. Thai Thung A. Thap Khlo
0.0 – 10.0 m.	clay	red clay
10.0 – 50.0 m.	laterite	clay + lateritic soil
50.0 – 96.0 m.	limestone	limestone
96.0 – 150.0 m.	laterite	clay + lateritic soil
No. MD1101 (60 m.)	676300 E 1796200 N	Ban Lum Pra Da m.3 T. Khao Sai A. Thap Khlo
0.0 – 4.5 m.	clay	red clay
4.5 – 7.0 m.	sand	sand
7.0 – 12.0 m.	gravel	gravel
12.0 – 60.0 m.	andesite	andesite
No. MD1102 (60 m.)	674615 E 1794083 N	Ban Rung Thong m.3 T. Khao Sai A. Thap Khlo
0.0 – 1.5 m.	clay	yellow clay
1.5 – 15.0 m.	laterite	lateritic soil + red clay
15.0 – 60.0 m.	andesite	andesite

No. MD1103 (75 m.)	662498 E 1808325 N	Ban Khlong Noi m.3 T. Nong Plong A. Wang Sai Phun
0.0 – 7.5 m.	clay	gray clay
7.5 – 13.5 m.	sand	sand
13.5 – 54.0 m.	laterite	lateritic soil
54.0 – 75.5 m.	limestone	limestone
No. MD1146 (33 m.)	675549 E 1797769 N	Wat Jirapong Wanaram T. Khao Chet Luk A. Thap Khlo
0.0 – 1.5 m.	top soil	top soil
1.5 – 4.5 m.	clay	brown clay
4.5 – 6.0 m.	limestone	limestone
13.5 – 33.0 m.	andesite	andesite
No. MD1160 (81 m.)	670156 E 1790326 N	Thap Khlo Municiple Play ground T. Thap Khlo A. Thap Khlo
0.0 – 1.5 m.	top soil	Topsoil
1.5 – 10.5 m.	clay	brown clay
10.5 – 15.0 m.	sand	sand
15.0 – 39.0 m.	gravel	gravel
39.0 – 81.0 m.	andesite	andesite
No. MQ0153 (45 m.)	666500 E 1806500 N	Rong Rean Ban Yang Sam Ton T. Nong Phra A. Wang Sai Phun
0.0 – 4.5 m.	clay	clay, brown, silty, low Phrastic, moderately compacted.
4.5 – 38.1 m.	sand	sand, light brown.
38.1 – 45.7 m.	limestone	limestone
No. MQ0155 (51 m.)	662970 E 1789285 N	Ban TaNon Mai M.7 T. Thung Po A. Taphan Hin
0.0 – 27.4 m.	clay	clay, brown, Phrastic, well compacted.
27.4 – 30.4 m.	gravel	pebble, brown, gravelly.
30.4 – 45.7 m.	clay	clay, brown, silty, moderately Phrastic, compacted.
45.7 – 51.8 m.	gravel	gravel, brown, pebbly.
No. MQ0258 (42 m.)	668700 E 1804500 N	Rong Rean Ban Nong Lag Khon A. Wang Sai Phun
0.0 – 1.5 m.	top soil	top soil
1.5 – 12.1 m.	sand	brown, gravelly, silty in Phraces, clay: compacted.
12.1 – 33.5 m.	clay	reddish brown, very silty, slightly Phrastic, compacted
33.5 – 42.6 m.	andesite	dark greenish gray, hard, compacted, volcanic
No. MQ0260 (42 m.)	666792 E 1808156 N	Ban Bo Tae m.3 T. Nong Phra A. Wang Sai Phun

0.0 – 12.1 m.	clay	dirty brown, silty, clayey, very fine to coarse grained
12.1 – 30.4 m.	sand	brown, medium to very coarse grained, mostly of quartz
30.4 – 42.6 m.	laterite	various colors, 16 mm. Insizes
No. MQ0261 (30 m.)	672410 E 1806298 N	Ban Dong Khun Tawa m.9 T. Nong Phra A. Wang Sai Phun
0.0 – 1.5 m.	top soil	top soil
1.5 – 6.0 m.	clay	brown, silty, Phrastic, compacted
6.0 – 19.8 m.	laterite	various colors, 15 mm. Insizes
19.8 – 30.4 m.	andesite	dark greenish gray, very hard, dense, volcanic
No. MQ0262 (61 m.)	662529 E 1807959 N	Rong Rean Wat Khlong Noi A. Wang Sai Phun
0.0 – 3.0 m.	top soil	topsoil
3.0 – 7.6 m.	clay	dark brown, very silty, sandy in Phraces, compacted
7.6 – 57.9 m.	sand	dark brown, very silty, sandy in Phraces, compacted
57.9 – 60.9 m.	andesite	green to black, very hard, dense, igneous
No. N0092 (60 m.)	673947 E 1787080 N	Ban Khao Sai m.1 T. Khao Sai A. Thap Khlo
0.0 – 3.0 m.	top soil	blackish and lateritic
3.0 – 10.6 m.	clay	yellowish to reddish, lateritic
10.6 – 21.3 m.	sandstone	sandstone
21.3 – 60.9 m.	limestone	limestone
No. N0129 (24 m.)	672888 E 1786294 N	Ban Khao Sai m.1 4 T. Khao Sai A. Thap Khlo
0.0 – 3.0 m.	laterite	dark brown, loose, 28 mm, in sizes, subrounded, limonitic
3.0 – 7.6 m.	clay	pale grayish brown, gravelly and silty, derived from chert
7.6 – 24.3 m.	limestone	dark gray, cryptocryatalline, massive with calcite veinlets
No. N0134 (48 m.)	660931 E 1784879 N	Wat Ban Thung Po T. Thung Po A. Taphan Hin
0.0 – 21.3 m.	Clay	grayish to yellowish brown
21.3 – 27.4 m.	silt	yellowish brown, slightly compact, lateritic and limonitic
27.4 – 48.7 m.	sand	light brown, coarse sand
No. N0136 (35 m.)	669000 E 1787800 N	BanThap Khlo m.1 T. Thap Khlo A. Thap Khlo
0.0 – 15.2 m.	clay	reddish gray to brown, partially silty and sandy
15.2 – 35.0 m.	laterite	yellowish brown, silty and gravelly
No. N1257 (63 m.)	661851 E 1786446 N	Wat Berng Bang (B.Wang loom) T. Thung Po A. Taphan Hin
0.0 – 18.0 m.	clay	yellow clay
18.0 – 30.0 m.	laterite	yellow lateritic soil

30.0 – 36.0 m.	sand	yellow sand
36.0 – 63.0 m.	gravel	gravel + clay
No. N1259 (36 m.)	671114 E 1813500 N	Ban Noen Hua Loan T. Wang Sai Phun A. Wang Sai Phun
0.0 – 3.0 m.	laterite	red lateritic soil
3.0 – 6.0 m.	clay	yellow clay
6.0 – 36.0 m.	andesite	green + white andesite
No. N1260 (41 m.)	667172 E 1813796 N	Ban Wang Sang m.4 T. Wang Sai Phun A. Wang Sai Phun
0.0 – 22.5 m.	laterite	red lateritic soil
22.5 – 40.5 m.	gravel	clay + brown gravel
No. N1261 (60 m.)	666819 E 1815362 N	Ban Boong Ma Good T. Wang Sai Phun A. Wang Sai Phun
0.0 – 1.5 m.	laterite	clay + yellow lateritic soil
1.5 – 36.0 m.	clay	yellow clay
36.0 – 60.0 m.	andesite	andesite
No. N1262 (48 m.)	673443 E 1809216 N	Rong Rean Khao Khet T. Nong Phra A. Wang Sai Phun
0.0 – 9.0 m.	clay	yellow clay
9.0 – 30.0 m.	sandstone	sandstone
30.0 – 48.0 m.	andesite	andesite
No. N1263 (36 m.)	663914 E 1808300 N	Ban Khlong Noi m.3 T. Nong Plong A. Wang Sai Phun
0.0 – 12.0 m.	clay	yellow clay
12.0 – 14.5 m.	sand	sand + yellow clay
14.5 – 36.0 m.	gravel	clay + yellow gravel
No. N1264 (42 m.)	662500 E 1809200 N	Ban Nong Sano m.10 T. Nong Plong A. Wang Sai Phun
0.0 – 9.0 m.	clay	yellow clay
9.0 – 18.0 m.	sand	yellow sand
18.0 – 30.0 m.	gravel	gravel + yellow clay
30.0 – 42.0 m.	clay	red clay
No. TA0001 (42 m.)	668746 E 1788872 N	Rong Rean Wat Pa Rarai T. Thap Khlo A. Thap Khlo
0.0 – 1.5 m.	top soil	Topsoil
1.5 – 16.7 m.	clay	gray clay
16.7 – 42.6 m.	shale	shale
No. TA0002 (48 m.)	668400 E 1790300 N	Ban Sai Dong Yang m.5 T. Thap Khlo A. Thap Khlo
0.0 – 1.5 m.	top soil	topsoil

1.5 – 3.0 m.	clay	clay
3.0 – 48.7 m.	shale	clay + shale
No. TA0005 (45 m.)	667931 E 1788391 N	Thap Khlo m.1 T. Thap Khlo A. Thap Khlo
0.0 – 1.5 m.	top soil	topsoil
1.5 – 6.0 m.	laterite	clay + laterite
6.0 – 20.0 m.	clay	red clay
20.0 – 45.7 m.	shale	clay + shale
No. TA0006 (60 m.)	667777 E 1788488 N	Thap Khlo m.1 T. Thap Khlo A. Thap Khlo
0.0 – 1.5 m.	top soil	Topsoil
1.5 – 18.0 m.	clay	red clay
18.0 – 36.5 m.	shale	clay + shale
36.5 – 41.1 m.	clay	yellow clay
41.1 – 60.9 m.	shale	shale
No. TA0007 (60 m.)	666100 E 1785800 N	Ban Num Kerng m.13 T. Thai Thung A. Thap Khlo
0.0 – 1.5 m.	top soil	top soil
1.5 – 21.3 m.	laterite	clay + laterite
21.3 – 60.9 m.	shale	shale
No. TA0008 (66 m.)	662400 E 1784700 N	Ban Tay Thung m.1 T. Thai Thung A. Thap Khlo
0.0 – 1.5 m.	top soil	topsoil
1.5 – 9.1 m.	laterite	sand
9.1 – 19.8 m.	sand	clay + sand
19.8 – 38.1 m.	laterite	laterite
38.1 – 58.0 m.	clay	clay
58.0 – 67.0 m.	shale	clay + shale
No. TA0009 (42 m.)	683400 E 1797200 N	PharachadamRee Project Ban Khao Sai A. Thap Khlo
0.0 – 1.5 m.	top soil	Topsoil
1.5 – 4.5 m.	laterite	red clay + laterite
4.5 – 12.1 m.	clay	yellow clay
12.1 – 33.5 m.	laterite	laterite
33.5 – 42.6 m.	shale	shale
No. TA0011 (30 m.)	669300 E 1803200 N	Ban Dai Num Khun m.10 T. Khao Chet Luk A. Thap Khlo
0.0 – 1.5 m.	top soil	topsoil

1.5 – 7.6 m.	clay	yellow clay
7.6 – 12.1 m.	shale	shale
12.1 – 21.3 m.	laterite	laterite
21.3 – 30.4 m.	shale	shale
No. TA0012 (30 m.)	669537 E 1803393 N	Ban Dai Num Khun m.10 T. Nong Phra A. Wang Sai Phun
0.0 – 1.5 m.	top soil	Topsoil
1.5 – 7.0 m.	clay	yellow clay
7.0 – 10.6 m.	shale	sand + shale
10.6 – 30.4 m.	laterite	laterite
No. TA0013 (36 m.)	667445 E 1807000 N	Ban Yang Sam Ton m.2 T. Nong Phra A. Wang Sai Phun
0.0 – 1.5 m.	top soil	topsoil
1.5 – 30.4 m.	clay	clay
30.4 – 36.5 m.	shale	clay + shale
No. TA0026 (17 m.)	674200 E 1783900 N	Ban Khao Pornะ m.7 T. Khao Sai A. Thap Khlo
0.0 – 1.5 m.	top soil	topsoil
1.5 – 3.0 m.	laterite	clay + laterite
3.0 – 9.0 m.	clay	clay + shale
9.0 – 16.7 m.	shale	shale
No. TA0045 (42 m.)	668955 E 1787630 N	Wat Mong KholThap Khlo m.2 T. Thap Khlo A. Thap Khlo
0.0 – 1.5 m.	top soil	topsoil
1.5 – 3.0 m.	clay	clay
3.0 – 15.2 m.	sand	sandy
15.2 – 24.6 m.	laterite	clay + laterite
24.6 – 30.4 m.	shale	clay + shale
30.4 – 35.0 m.	sandstone	sandstone
35.0 – 42.6 m.	andesite	andesite
No. TA0047 (31 m.)	671189 E 1786929 N	Police Station Thap Khlo m.4 T. Khao Sai A. Thap Khlo
0.0 – 1.5 m.	top soil	topsoil
1.5 – 7.0 m.	clay	red clay
7.0 – 16.0 m.	laterite	laterite + clay
16.0 – 19.8 m.	sand	sand
19.8 – 28.9 m.	gravel	gravel + laterite

28.9 – 30.4 m.	andesite	sand + andesite
No. TA0048 (70 m.)	668359 E 1790379 N	Thap Khlo m.10 T. Thap Khlo A. Thap Khlo
0.0 – 1.5 m.	top soil	Topsoil
1.5 – 16.7 m.	laterite	laterite
16.7 – 45.7 m.	shale	shale + clay
45.7 – 70.1 m.	andesite	andesite
No. TA0050 (54 m.)	665400 E 1783200 N	Wat Sri Sachanaram T. Thai Thung A. Thap Khlo
0.0 – 1.5 m.	top soil	topsoil
1.5 – 16.7 m.	clay	red clay
16.7 – 35.0 m.	laterite	sand + laterite
35.0 – 54.8 m.	shale	shale + clay
No. TA0052 (51 m.)	668200 E 1781500 N	Ban Khao San M.8 T. Thai Thung A. Thap Khlo
0.0 – 1.5 m.	top soil	topsoil
1.5 – 6.0 m.	clay	gray clay
6.0 – 24.3 m.	sand	sandy
24.3 – 44.0 m.	laterite	laterite
44.0 – 51.8 m.	sandstone	sandstone
No. TA0053 (69 m.)	662900 E 1785200 N	Ban Tay Thung m.1 T. Thai Thung A. Thap Khlo
0.0 – 1.5 m.	top soil	topsoil
1.5 – 15.2 m.	clay	red clay
15.2 – 30.0 m.	sand	sand
30.0 – 69.0 m.	shale	shale
No. TA0054 (59 m.)	665800 E 1784900 N	Ban Num Kerng m.13 T. Thai Thung A. Thap Khlo
0.0 – 1.5 m.	top soil	topsoil
1.5 – 15.0 m.	clay	red clay
15.0 – 32.0 m.	laterite	clay + laterite
32.0 – 59.0 m.	shale	shale
No. TA0055 (36 m.)	673589 E 1791130 N	Ban Mai Market T. Khao Sai A. Thap Khlo
0.0 – 1.5 m.	top soil	Topsoil
1.5 – 9.1 m.	laterite	Laterite
9.1 – 10.6 m.	shale	shale
10.6 – 36.5 m.	andesite	andesite

No. TC0003 (60 m.)	673850 E 1786200 N	Talad Khao Sai m.10 T. Khao Sai A. Thap Khlo
0.0 – 10.6 m.	laterite	orangish red, very coarse sand to very fine gravel
10.6 – 15.2 m.	silt	light yellowish orange, clayey slightly, loose
15.2 – 22.8 m.	shale	
22.8 – 60.9 m.	andesite	blackish, fresh to slightly weathered, hard to very hard.
No. TC0004 (51 m.)	669089 E 1787860 N	Thap Khlo m.1 T. Thap Khlo A. Thap Khlo
0.0 – 1.5 m.	top soil	topsoil
1.5 – 12.1 m.	clay	red clay
12.1 – 30.4 m.	sand	sandy
30.4 – 51.8 m.	sandstone	sandstone
No. TC0005 (60 m.)	663802 E 1789320 N	Ban Wang loom m.3 T. Wang loom A. Taphan Hin
0.0 10.6 m.	clay	yellow clay
15.0 – 60.9 m.	sand	clay + sand
10.6 – 15.0 m.	shale	clay + shale
No. TC0006 (23 m.)	669210 E 1802500 N	Ban Dai Num Khun m.10 T. Khao Chet Luk A. Thap Khlo
0.0 – 1.5 m.	top soil	topsoil
1.5 – 9.1 m.	clay	yellow clay + sand
9.1 – 12.0 m.	laterite	laterite + sand
12.0 – 21.3 m.	shale	clay + shale
21.3 – 22.7 m.	andesite	andesite
No. TC0017 (87 m.)	671859 E 1786784 N	Ban Khao Sai M.4 T. Khao Sai A. Thap Khlo
0.0 – 2.0 m.	silt	orangish red.
2.0 – 15.2 m.	clay	orangish red, nonPhrastic to slightly Phrastic.
15.2 – 91.4 m.	andesite	light gray, composed of quartz, feldspars, dark minerals
No. TC0018 (27 m.)	674500 E 1783600 N	Ban Khao Phra m.7 T. Khao Sai A. Thap Khlo
0.0 – 6.0 m.	clay	yellowish brown, slightly Phrastic.
6.0 – 12.1 m.	sand	light brownish gray, coarse sand to very coarse sand
12.1 – 24.3 m.	siltstone	light brownish gray, stiff to hard.
24.3 – 28.9 m.	limestone	light brownish gray, soft
No. TC0019 (120 m.)	673200 E 1782900 N	Ban Khao Phra m.7 T. Khao Sai A. Thap Khlo
0.0 – 1.5 m.	top soil	Topsoil
1.5 – 2.0 m.	clay	red clay + laterite

2.0 – 120.0 m.	laterite	laterite + clay
No. TC0021 (56 m.)	673800 E 1786200 N	Ban Khao Sai m.1 T. Khao Sai A. Thap Khlo
0.0 – 1.5 m.	top soil	top soil
1.5 – 7.6 m.	laterite	laterite
7.6 – 10.6 m.	shale	shale
10.6 – 22.8 m.	andesite	andesite
22.8 – 27.4 m.	limestone	limestone
27.4 – 56.4 m.	sandstone	sandstone
No. TC0023 (62 m.)	666500 E 1800400 N	Ban Noen Pwong m.11 T. Khao Chet Luk A. Thap Khlo
0.0 – 3.0 m.	laterite	orangish red, very fine grained, iron oxide cemented.
3.0 – 60.9 m.	andesite	gray
No. TC0025 (48 m.)	668522 E 1799371 N	Ban Khao Loan M.6 T. Khao Chet Luk A. Thap Khlo
0.0 – 1.5 m.	top soil	topsoil
1.5 – 15.2 m.	clay	gray clay
15.2 – 21.3 m.	limestone	limestone
21.3 – 45.7 m.	shale	shale
45.7 – 48.7 m.	andesite	andesite
No. TC0033 (116 m.)	669500 E 1788750 N	Rong Rean Mattayom Thap Khlo T. Khao Sai A. Thap Khlo
0.0 – 1.5 m.	top soil	top soil
1.5 – 16.7 m.	laterite	red clay + laterite
16.7 – 115.8 m.	sandstone	sandstone
No. TC0036 (42 m.)	674593 E 1785871 N	Ban Khao Sai m.4 T. Khao Sai A. Thap Khlo
0.0 – 42.6 m.	limestone	dark gray, nonPhrastic, hard.
No. TC0037 (42 m.)	671800 E 1799500 N	Ban Nong Kanag m.7 T. Khao Chet Luk A. Thap Khlo
0.0 – 1.5 m.	top soil	topsoil
1.5 – 3.0 m.	laterite	laterite + clay
3.0 – 13.7 m.	sand	sandy
13.7 – 42.6 m.	andesite	andesite
No. TC0039 (42 m.)	667800 E 1801700 N	Ban Noen Pwong m.11 T. Khao Chet Luk A. Thap Khlo
0.0 – 1.5 m.	top soil	topsoil
1.5 – 15.2 m.	laterite	red clay + laterite
15.2 – 24.3 m.	sandstone	sandstone

24.3 – 42.6 m.	andesite	andesite
No. TC0040 (42 m.)	673590 E 1801806 N	Ban Khao Din m.3 T. Khao Chet Luk A. Thap Khlo
0.0 – 1.5 m.	top soil	Topsoil
1.5 – 4.5 m.	laterite	red clay + laterite
4.5 – 9.1 m.	clay	yellow clay
9.1 – 12.1 m.	shale	shale
12.1 – 18.2 m.	limestone	limestone
18.2 – 42.6 m.	andesite	andesite
No. TC0042 (36 m.)	674500 E 1786600 N	Rong Rean Ban Khao Sai T. Khao Sai A. Thap Khlo
0.0 – 1.5 m.	top soil	topsoil
1.5 – 4.5 m.	laterite	laterite
4.5 – 6.0 m.	shale	shale
6.0 – 36.5 m.	andesite	andesite
No. TC0044 (39 m.)	675000 E 1789000 N	Ban Wang Hin Pleng m.5 T. Khao Sai A. Thap Khlo
0.0 – 1.5 m.	top soil	topsoil
1.5 – 4.5 m.	laterite	laterite
4.5 – 21.3 m.	shale	shale
21.3 – 39.6 m.	andesite	andesite
No. TC0045 (48 m.)	667541 E 1788706 N	Ban Bo Sai m.7 T. Thap Khlo A. Thap Khlo
0.0 – 1.5 m.	top soil	topsoil
1.5 – 3.0 m.	sand	sand
3.0 – 7.6 m.	laterite	laterite
7.6 – 24.3 m.	clay	yellow clay
24.3 – 35.0 m.	sand	clay + sandy
35.0 – 48.7 m.	shale	shale
0.0 – 1.5 m.	top soil	topsoil
1.5 – 6.0 m.	clay	gray clay
6.0 – 30.4 m.	shale	shale
No. TC0048 (54 m.)	674000 E 1789500 N	Rong Rean Ban Wat Wang Hin T. Khao Sai A. Thap Khlo
0.0 – 1.5 m.	top soil	topsoil
1.5 – 6.0 m.	laterite	red clay + laterite

6.0 – 12.1 m.	sandstone	sandstone
12.1 – 18.2 m.	andesite	andesite
18.2 – 25.9 m.	shale	shale
25.9 – 36.5 m.	limestone	limestone
36.5 – 48.7 m.	andesite	andesite
No. TC0050 (48 m.)	670654 E 1814206 N	Rong Rean Choomchon Ban Noen A. Wang Sai Phun
0.0 – 1.5 m.	top soil	Topsoil
1.5 – 5.0 m.	laterite	laterite
5.0 – 18.0 m.	clay	gray clay
18.0 – 48.0 m.	andesite	andesite
No. TC0063 (36 m.)	670681 E 1791545 N	Ban NongAyToo M.8 T. Thap Khlo A. Thap Khlo
0.0 – 3.0 m.	clay	very dark yellowish brown, Phrastic.
3.0 – 8.0 m.	sand	brownish orange, fine sand to very coarse sand
8.0 – 36.5 m.	gravel	brownish orange, clayey slightly, medium to fine gravel
No. TC0065 (18 m.)	670600 E 1791400 N	Ban NongAyToo M.8 T. Thap Khlo A. Thap Khlo
0.0 – 1.5 m.	clay	very dark yellowish brown, Phrastic.
1.5 – 16.7 m.	sand	brownish orange, fine sand to very coarse sand,
16.7 – 19.8 m.	gravel	brownish orange, clayey slightly, medium to fine gravel
No. TC0066 (78 m.)	663172 E 1784502 N	Ban Tay Thung m.1 T. Thai Thung A. Thap Khlo
0.0 – 12.1 m.	clay	grayish orange, Phrastic.
12.1 – 33.5 m.	sand	yellowish brown, clayey slightly, medium to coarse sand
33.5 – 59.4 m.	clay	yellowish brown, sandy slightly, slightly Phrastic to Phrastic.
59.4 – 78.0 m.	gravel	various colors, sandy slightly, very coarse to fine gravel
No. TC0067 (42 m.)	668100 E 1786100 N	Wat Pa Rayrai M.2 T. Thap Khlo A. Thap Khlo
0.0 – 25.0 m.	clay	reddish brown and grayish orange, sandy slightly
25.0 – 42.0 m.	sand	yellowish brown, fine sand to very coarse sand
No. TC0077 (36 m.)	676200 E 1783500 N	Ban Khao Nok Yoong M.8 T. Khao Sai A. Thap Khlo
0.0 – 3.0 m.	Top soil	topsoil
3.0 – 12.1 m.	gravel	various colors, very fine gravel to medium gravel
12.1 – 24.3 m.	limestone	very dark gray, hard to moderately hard
24.3 – 36.5 m.	sand	very light gray, fine sand to very coarse sand
No. TC0081 (27 m.)	676163E1779630N	Ban Nong Com M.15 T. Thai Thung A. Thap Khlo

0.0 – 27.4 m.	andesite	grayish olive, hard
No. TC0091 (60 m.)	663134 E 1788237 N	Rong Rean Thung Po Wittaya T. Thung Po A. Taphan Hin
0.0 – 19.0 m.	clay	yellowish brown and brown, Phrastic.
19.0 – 49.5 m.	sand	yellowish brown, medium sand to very coarse sand
19.5 – 60.9 m.	gravel	various colors, coarse sand to fine gravel
No. TC0100 (36 m.)	673700 E 1801800 N	Ban Khao Din m.3 T. Khao Chet Luk A. Thap Khlo
0.0 – 1.5 m.	top soil	top soil
1.5 – 7.5 m.	laterite	laterite
7.5 – 27.0 m.	shale	shale
27.0 – 36.0 m.	limestone	limestone
No. TC0102 (30 m.)	668400 E 1800400 N	Ban Khao Loan m.6 T. Khao Chet Luk A. Thap Khlo
0.0 – 1.5 m.	top soil	topsoil
1.5 – 4.5 m.	laterite	laterite
4.5 – 18.0 m.	sandstone	sandstone
18.0 – 30.0 m.	andesite	andesite
No. TC0103 (30 m.)	665200 E 1800200 N	Ban Khao Chet luk m.1 T. Khao Chet Luk A. Thap Khlo
0.0 – 1.5 m.	top soil	topsoil
1.5 – 8.0 m.	clay	red clay
8.0 – 30.0 m.	sandstone	sandstone
No. TC0104 (27 m.)	675500 E 1789000 N	Ban Lam Prada m.3 T. Khao Sai A. Thap Khlo
0.0 – 1.5 m.	top soil	topsoil
1.5 – 6.0 m.	sand	sandy
6.0 – 12.0 m.	shale	shale + clay
12.0 – 18.0 m.	limestone	limestone
18.0 – 27.0 m.	sandstone	sandstone
No. TC0105 (42 m.)	674400 E 1794700 N	Ban Wang Dang m.2 T. Khao Sai A. Thap Khlo
0.0 – 1.5 m.	top soil	Topsoil
1.5 – 12.0 m.	laterite	laterite
12.0 – 18.0 m.	shale	shale
18.0 – 42.0 m.	andesite	andesite
No. TC0106 (33 m.)	674500 E 1799000 N	Ban Wang Hin Pleng m.5 T. Khao Sai A. Thap Khlo
0.0 – 1.5 m.	top soil	topsoil

1.5 – 18.0 m.	laterite	laterite
18.0 – 24.0 m.	sandstone	sandstone
24.0 – 30.0 m.	limestone	limestone
No. TC0123 (60 m.)	664265 E 1784583 N	Ban Tay Thung m.2 T. Thai Thung A. Thap Khlo
0.0 – 1.5 m.	top soil	topsoil
1.5 – 16.5 m.	clay	gray clay
16.5 – 36.0 m.	sand	coarse sand
36.0 – 54.0 m.	shale	clay + shale
No. TC0132 (60 m.)	675400 E 1782400 N	Rong Rean Khao Nok Yoong T. Khao Sai A. Thap Khlo
0.0 – 1.5 m.	top soil	top soil
1.5 – 3.0 m.	laterite	laterite
3.0 – 7.5 m.	clay	clay
7.5 – 15.0 m.	limestone	limestone
15.0 – 21.0 m.	sandstone	sandstone
21.0 – 60.0 m.	andesite	andesite
No. TC0136 (60 m.)	662560 E 1790045 N	Wat Ban Wang loom m.9 T. Wang Loom A. Taphan Hin
0.0 – 4.5 m.	clay	very dark yellowish brown, clayey, composed of clay.
4.5 – 60.9 m.	sand	various colors, sandy, fine sand, angular, poorly sorted
No. TC0162 (44 m.)	677889 E 1789952 N	Ban No.1594 m.11 T. Khao Sai A. Thap Khlo
0.0 – 6.0 m.	Clay	yellowish orange, argillaceous, soft.
6.0 – 44.2 m.	limestone	grayish black, silky luster, composed of siltstone
No. TC0164 (50 m.)	675500 E 1799500 N	Ban Wang Hin Pleng m.5 T. Khao Sai A. Thap Khlo
0.0 – 1.5 m.	top soil	topsoil
1.5 – 7.5 m.	clay	red clay
7.5 – 16.5 m.	limestone	limestone
16.5 – 49.5 m.	andesite	andesite
No. TC0181 (32 m.)	675900 E 1802700 N	Ban Khao Mo m.9 T. Khao Chet Luk A. Thap Khlo
0.0 – 3.0 m.	laterite	top soil red clay laterite
3.0 – 7.5 m.	shale	grae clay shale
7.5 – 18.0 m.	sandstone	sandstone
18.0 – 31.5 m.	limestone	limestone
No. TC0182 (80 m.)	667240 E 1788337 N	Ban Bo Sai m.7 T. Thap Khlo A. Thap Khlo

0.0 – 1.5 m.	top soil	topsoil
1.5 – 3.0 m.	clay	gray clay
3.0 – 18.0 m.	laterite	laterite
18.0 – 48.0 m.	shale	clay + shale
48.0 – 79.5 m.	andesite	andesite
No. TC0184 (36 m.)	660738 E 1808954 N	Ban Khlong Kot m.6 T. Nong Plong A. Wang Sai Phun
0.0 – 1.5 m.	top soil	top soil
1.5 – 4.5 m.	clay	gray clay
4.5 – 24.0 m.	sand	sandy
24.0 – 36.0 m.	gravel	gravel
No. TC0201 (60 m.)	663798 E 1782757 N	Ban Bang Bane m.4 T. Thai Thung A. Thap Khlo
0.0 – 1.5 m.	top soil	topsoil
1.5 – 3.0 m.	clay	gray clay
3.0 – 24.0 m.	sand	sandy
24.0 – 48.0 m.	laterite	laterite
48.0 – 60.0 m.	shale	shale
No. TC0202 (44 m.)	672800 E 1802500 N	Ban Khao Din m.3 T. Khao Chet Luk A. Thap Khlo
0.0 – 1.5 m.	top soil	topsoil
1.5 – 3.0 m.	laterite	laterite
3.0 – 12.0 m.	clay	yellow clay
12.0 – 21.0 m.	andesite	andesite
21.0 – 27.0 m.	limestone	limestone
27.0 – 43.5 m.	andesite	andesite
No. TC0204 (44 m.)	671079 E 1806563 N	Ban Dong Kun Tewa m.9 T. Nong Phra A. Wang Sai Phun
0.0 – 1.5 m.	top soil	topsoil
1.5 – 13.5 m.	sand	sandy
13.5 – 25.0 m.	shale	shale
25.0 – 43.5 m.	limestone	limestone
No. TC0205 (56 m.)	671598 E 1810379 N	Ban Thung Mong m.7 T. Wang Sai Phun A. Wang Sai Phun
0.0 – 1.5 m.	topsoil	topsoil
1.5 – 3.0 m.	clay	gray clay
3.0 – 6.0 m.	laterite	gray clay + laterite

6.0 – 9.0 m.	sand	coarse sand
9.0 – 12.0 m.	shale	shale
12.0 – 37.5 m.	limestone	limestone
37.5 – 55.5 m.	andesite	andesite
No. TC0208 (42 m.)	667300 E 1786500 N	Ban Suan Prig M.3 T. Thap Khlo A. Thap Khlo
0.0 – 1.5 m.	top soil	Topsoil
1.5 – 6.0 m.	clay	gray clay
6.0 – 24.0 m.	sand	sandy
24.0 – 42.0 m.	andesite	andesite
No. TZ0044 (120 m.)	663638 E 1789242 N	Ban Wang loom m.4 T. Wang Loom A. Taphan Hin
0.0 – 25.0 m.	clay	yellow clay
25.0 – 37.0 m.	laterite	clay + yellow laterite
37.0 – 45.0 m.	gravel	gravel + yellow sand
45.0 – 59.0 m.	limestone	gray limestone
59.0 – 120.0 m.	andesite	gray andesite
No. TZ0045 (120 m.)	663918 E 1789263 N	Ban Wang loom m.4 T. Wang Loom A. Taphan Hin
0.0 – 9.0 m.	clay	brown clay
9.0 – 36.0 m.	sand	white sand
36.0 – 60.0 m.	limestone	gray limestone
60.0 – 120.0 m.	andesite	gray andesite
No. TZ0046 (102 m.)	670500 E 1801600 N	Ban Khao Taphan Nak m.2 T. Khao Chet Luk A. Thap Khlo
0.0 – 9.0 m.	clay	clay
9.0 – 18.0 m.	laterite	laterite
18.0 – 24.0 m.	andesite	gray andesite
No. TZ0061 (42 m.)	667700 E 1806700 N	Ban Yang Sam Ton m.2 T. Nong Phra A. Wang Sai Phun
0.0 – 8.0 m.	clay	brown clay
8.0 – 30.0 m.	sand	brown sand
30.0 – 42.0 m.	limestone	gray limestone
No. TZ0062 (56 m.)	664911 E 1811137 N	Ban Nong Phra m.4 T. Nong Phra A. Wang Sai Phun
0.0 – 4.0 m.	clay	brown clay
4.0 – 42.0 m.	laterite	clay + yellow laterite
42.0 – 56.0 m.	limestone	gray limestone

No. TZ0064 (12 m.)	665900 E 1803100 N	Ban Khao Phanompa m.7 T. Nong Phra A. Wang Sai Phun
0.0 – 4.0 m.	andesite	black rock
4.0 – 12.0 m.	sandstone	sandstone + sand
No. TZ0068 (54 m.)	669710 E 1796447 N	Ban Sai Yang Roong m.12 T. Khao Chet Luk A. Thap Khlo
0.0 – 8.0 m.	clay	black clay
8.0 – 18.0 m.	laterite	yellow laterite
18.0 – 54.0 m.	limestone	gray limestone
No. TZ0069 (40 m.)	669998 E 1796686 N	Wat Yang Sam Ton m.12 T. Khao Chet Luk A. Thap Khlo
0.0 – 5.0 m.	clay	black clay
5.0 – 21.0 m.	gravel	clay + yellow gravel
21.0 – 40.0 m.	limestone	clay + gray limestone
No. TZ0070 (50 m.)	666615 E 1808243 N	Ban Bo Tae m.3 T. Nong Phra A. Wang Sai Phun
0.0 – 27.0 m.	sand	yellow sand
27.0 – 30.0 m.	laterite	yellow laterite
30.0 – 50.0 m.	limestone	gray limestone
CHANGWAT PHISANULOK		
No. DC0192 (24 m.)	670319 E 1819790 N	Children office Ban Sai Yoi T. Sai Yoi A. Noen Maprang
0.0 - 7.6 m.	laterite	laterite.
7.6 - 10.6 m.	clay	red clay.
10.6 - 24.3 m.	limestone	limestone
No. MB0091 (18 m.)	677850 E 1809200 N	Rong Rean Ban Wang Kwan T. Sai Yoi A. Noen Maprang
0.0 - 4.5 m.	laterite	clay, brown, lateritic gravel presented, hard, compact
4.5 - 9.1 m.	clay	brown, silty, nonPhrastic, incompact
9.1 - 18.2 m.	sandstone	olive gray, weathered, hard, dense, compact
No. MB0260 (24 m.)	682204 E 1815357 N	Ban Khao Kieo m.5 T. Wang Phlong A. Noen Maprang
0.0 - 9.1 m.	siltstone	reddish brown, weathered, brittle, partially dence.
9.1 - 24.3 m.	andesitic tuff	gray, weathered, hard, dense.
No. MB0319 (30 m.)	679630 E 1815136 N	Rong Rean Ban Wang Phlong A. Noen Maprang
0.0 - 9.1 m.	clay	brown to pale brown, silty, lateritic
9.1 - 30.4 m.	limestone	dark grey, high calcareous, hard
No. MB0339 (24 m.)	676631 E 1806980 N	Rong Rean Ban Mai Khlong A. Noen Maprang
0.0 - 4.5 m.	clay	light brown, silty, sandy, nonPhrastic, compacted.

4.5 - 7.6 m.	gravel	Pebble & gravel, various colors, sandy
7.6 - 15.2 m.	clay	light brown, silty, nonPhrastic, partailly compacted.
15.2 - 18.2 m.	gravel	various colors, gravelly, 47 mm
18.2 - 24.3 m.	andesite	Igneous rock, brown to black, weathered, very hard, dense.
No. MB0583 (27 m.)	674783 E 1806547 N	Ban Thung Yao m.1 T. Wang Phlong A. Noen Maprang
0.0 - 4.5 m.	sand	brownish yellow, clayey, silty, fine sand
4.5 - 27.4 m.	andesitic tuff	yellowish gray and gray, moderately hard to hard.
No. MB0615 (18 m.)	676245 E 1808794 N	Ban Wang Kwan m.2 T. Wang Phlong A. Noen Maprang
0.0 - 9.1 m.	clay	brown and light yellowish brown, sandy, slightly Phrastic.
9.1 - 18.2 m.	andesitic tuff	grayish green, limonite stained, hard.
No. MB0616 (21 m.)	679150 E 1814997 N	Ban Wang Phlong m.4 T. Wang Phlong A. Noen Maprang
0.0 - 3.0 m.	laterite	brown, clayey.
3.0 - 10.6 m.	clay	light yellowish brown, sandy, slightly Phrastic.
10.6 - 21.3 m.	andesitic tuff	purplish gray and greenish gray, fine to medium grained

Appendix F

Soil suit in study area

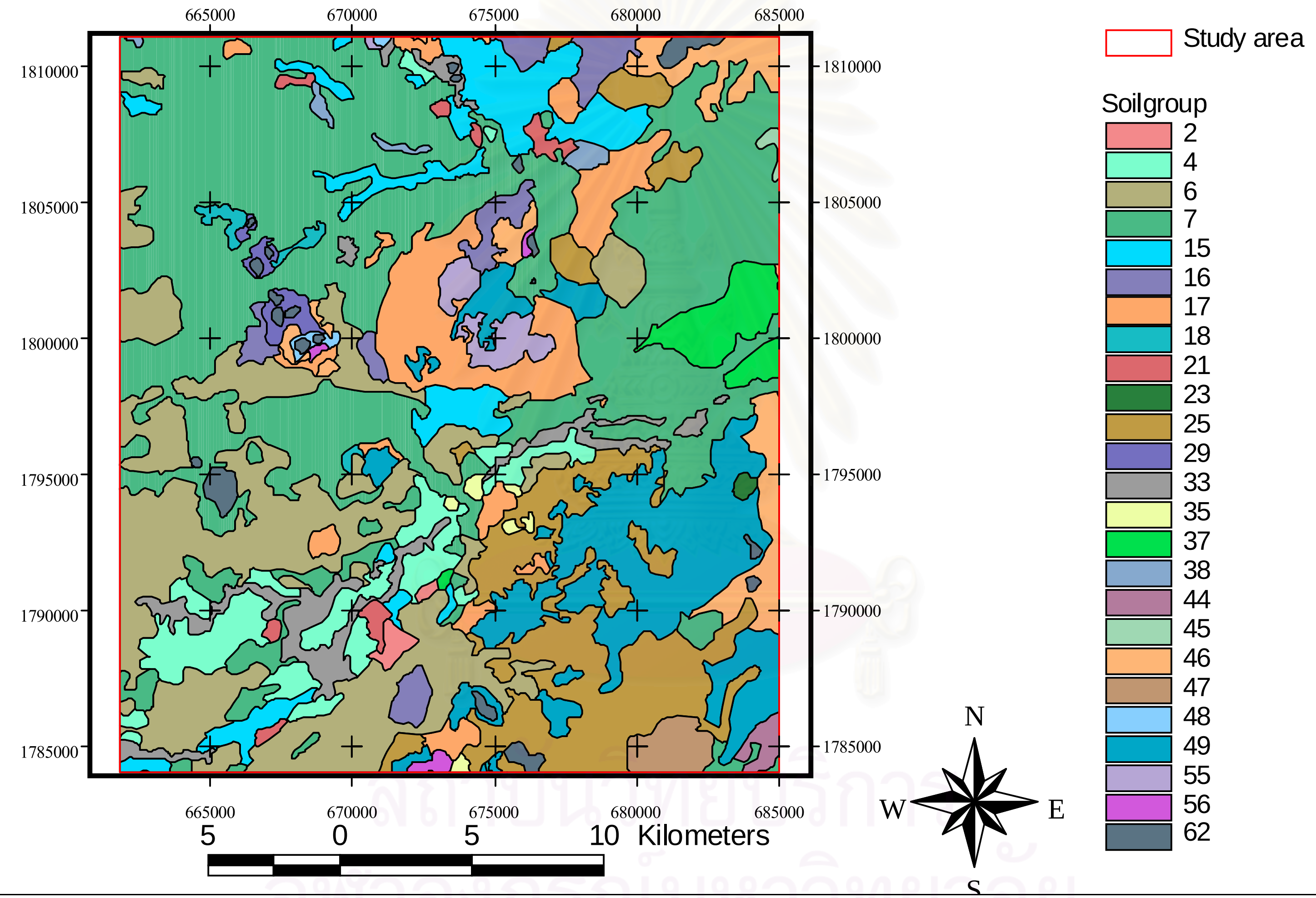
Note : Modified by Limpongstorn (2004) from the data of Department of Land Development, Ministry of Agriculture and Cooperatives, Thailand.

Soil groups in study area, properties, suitability for economic plants, and problems

Soil groups	Texture	Soil depth	Drainage	Fertility	pH	Suitability	Problems	Area (km^2)
2	Clay	Deep	Bad	Medium	4.5-5.5	Rice	High acidity	1.925
4	Clay		Quite bad-bad	Medium	5.5-6.5	Rice	Water detained for 4-5 months	29.479
6	Clay	Very deep	Bad	Low-quite low	4.5-5.5	Rice	Low fertility, high acidity	105.090
7	Clay	Deep	Quite bad	Medium	6.0-7.0	Rice	Water detained for 3-5 months	233.258
15	Sandy clay loam	Very deep	Quite bad	Quite low-medium	6.0-7.5	Rice		34.438
16	Sandy loam	Very deep	Bad	Low-quite low	5.0-6.0		Low fertility	14.072
17	Sandy loam	Very deep	Quite bad	Low	4.5-5.5	Rice	Sandy soil, low fertility	41.217
18	Sandy loam	Deep	Bad	Low	6.0-7.0	Rice	Risk to be starved	2.604
21	Sandy loam	Deep	Medium good-quite bad	Medium	5.5-7.5	Rice /field crop	Water detained for 2-3 months	4.657

Soil groups	Texture	Soil depth	Drainage	Fertility	pH	Suitability	Problems	Area
23	Sandy soil	Deep	Bad-very bad	Low	6.0-7.0	Not suit	Sandy soil	0.657
25	Sandy loam	Shallow	Quite bad	Low	4.5-6.0	Rice/field crop	Too much laterite, low water holding capacity	61.225
29	Clay	Deep	Good	Low	4.5-5.5	Mixed Field crop	Deep groundwater	3.525
33	Sandy loam	Very good	Good-medium good	Medium	6.5-7.5	Many plants	Risk to be starved	19.854
35	Sandy loam	Deep	Good	Low	4.5-5.5		Sandy soil	1.862
37	Sandy loam	Deep	Medium good	Low	4.5-5.5		Low fertility	12.555
38	Sandy loam	Deep	Medium good	Medium	5.0-7.0	Field crop	Sandy soil	2.626
44	Sandy clay loam	Deep	Very good	Very low	5.5-7.0	Grassland	Very sandy	0.213
45	Lateritic soil	Very shallow	Good	Low	4.5-5.5	Rubber tree	Shallow soil	0.632
46	Lateritic soil	Shallow	Good	Low	4.5-7.0	Grassland	Too much laterite	21.05
47	Lateritic soil	Shallow	Good	Low-medium	5.0-7.5	No suit	High erosion	5.47

Soil groups	Texture	Soil depth	Drainage	Fertility	pH	Suitability	Problems	Area
48	Sandy loam	Very shallow		Low	5.0-7.0	Grassland	High erosion	0.904
49	Sandy loam	Shallow-very shallow	Good	Low	5.0-6.5	No suit	Too much laterite	62.542
55	Clay	Medium deep	Good-medium good	Medium	6.0-7.5	Mixed field crop, grassland	High erosion	7.004
56	Sandy loam	Medium deep	Good	Low	5.0-6.0	Field crop	High erosion	1.39
62	Mountainous soil	Its properties and fertility depend on parent rocks that have rubble and rocks scatter mostly.				Forest	High erosion	6.967
Total								677.136



Soil type in study area