

**STUDY OF HYDROGEOCHEMISTRY AND  
GROUNDWATER FLOW IN THA CHIN-MAE KLONG BASIN  
FOR GROUNDWATER QUALITY MANAGEMENT**



**BANJONG PROMCHAN**

**A THESIS SUBMITTED IN PARTIAL FULFILLMENT  
OF THE REQUIREMENTS FOR  
THE DEGREE OF MASTER OF SCIENCE  
(TECHNOLOGY OF ENVIRONMENTAL MANAGEMENT)  
FACULTY OF GRADUATE STUDIES  
MAHIDOL UNIVERSITY  
2012**

**COPYRIGHT OF MAHIDOL UNIVERSITY**

Copyright by Mahidol University

Thesis  
entitled  
**STUDY OF HYDROGEOCHEMISTRY AND  
GROUNDWATER FLOW IN THACHIN-MAEKLONG BASIN  
FOR GROUNDWATER QUALITY MANAGEMENT**

*Banjong Promchan*  
.....  
Mr. Banjong Promchan  
Candidate

*P. Suw.*  
.....  
Assoc. Prof. Parkorn Suwanich, Ph.D.  
Major advisor

*B. Prapagdee*  
.....  
Assoc. Prof. Benjaphorn Prapagdee,  
D.Tech.Sc.  
Co-advisor

*Aranya Fuangwasdi*  
.....  
Ms. Aranya Fuangwasdi, Ph.D.  
Co-advisor

*A. Mutchimwong*  
.....  
Asst. Prof. Auemphorn Mutchimwong,  
Ph.D.  
Acting Dean  
Faculty of Graduate Studies  
Mahidol University

*Sura Pattanakiat*  
.....  
Assoc. Prof. Sura Pattanakiat, Ph.D.  
(Forestry)  
Program Director  
Master of Science Program in  
Technology of Environmental  
Management  
Faculty of Environment and Resource  
Studies  
Mahidol University

Thesis  
entitled  
**STUDY OF HYDROGEOCHEMISTRY AND  
GROUNDWATER FLOW IN THACHIN-MAEKLONG BASIN  
FOR GROUNDWATER QUALITY MANAGEMENT**

was submitted to the Faculty of Graduate Studies, Mahidol University  
for the degree of Master of Science (Technology of Environmental Management)

on  
April 28, 2012



*Banjong Promchan*

Mr. Banjong Promchan  
Candidate

*O. Lorphensri*

Ms. Oranuj Lorphensri, Ph.D.  
Chair

*P. Suwanich*

Assoc.Prof. Parkorn Suwanich, Ph.D.  
Member

*Aranya Fuangswad*

Ms. Aranya Fuangswad, Ph.D.  
Member

*B. Prapagdee*

Assoc.Prof. Benjaphorn Prapagdee,  
D.Tech.Sc.  
Member

*A. Mutchimwong*

Asst. Prof. Auemphorn Mutchimwong,  
Ph.D.  
Acting Dean  
Faculty of Graduate Studies  
Mahidol University

*K. Bhaktikul*

Assoc.Prof. Kampanad Bhaktikul, Ph.D.  
(Civil and Environmental Engineering)  
Dean  
Faculty of Environment and Resource  
Studies  
Mahidol University

## ACKNOWLEDGEMENTS

The success of this thesis can be succeeded by the scholarship from Department of Groundwater Resources (Groundwater Development Fund) and by partial scholarships of the Faculty of Environment and Resource Studies, Mahidol University.

I would like to thank for Associate Professor Dr. Parkorn Suwanich, Dr. Aranya Fuangsawasdi, Dr. Oranuj Lorphenstri and Associate Professor Dr. Benjaphorn Prapagdee who are guidance, supervision and consult to make this thesis complete. Miss Kittima Phakomgruksa who is the excellent coordinator.

I would like to express deep sincere gratitude to my family who give life love warmth advice assistance and support all my life until this second.

I would like to thank executive boss and colleagues for supporting. Also, I thank everybody in Bureau of Groundwater Conservation and Restoration, Department of Groundwater Resources.

Finally, very special thank to Mrs. Anchalee Pongsatitpat, Miss Theparree Jungsatapatchai, and others of my friend who are always assistance and encouragement especially when I was discouraged.

Banjong Promchan

STUDY OF HYDROGEOCHEMISTRY AND GROUNDWATER FLOW IN THA CHIN-MAE KLONG BASIN FOR GROUNDWATER QUALITY MANAGEMENT

BANJONG PROMCHAN 5036337 ENTM/M

M.Sc. (TECHNOLOGY OF ENVIRONMENTAL MANAGEMENT)

THESIS ADVISORY COMMITTEE: PARKORN SUWANICH, Ph.D. (POPULATION EDUCATION), BENJAPHORN PRAPAGDEE, D. TECH. SC. (ENVIRONMENTAL TOXICOLOGY, TECHNOLOGY AND MANAGEMENT), ARANYA FUANGSWASDI, Ph.D. (ENVIRONMENTAL MANAGEMENT)

ABSTRACT

The Department of Groundwater Resources has studied and collected a large number of groundwater samples in Tha Chin-Mae Klong Basin to analyze their chemical composition. However, most data are in numerical and table forms representing various parameters which lead to a difficulty for perception and utilization. Thus, this study aimed to obtain hydrogeochemical characteristics of each aquifer by analyzing and interpreting such data. A computer program was employed to conduct Piper diagram, Durov diagram, Stiff diagram, X-Y scatter plot (ion ratio analysis), and Wilcox diagram (Sodium Adsorption Ratio analysis) in order to comprehend the hydrogeochemical characteristics and groundwater evolution. According to the study, it can be concluded that there are four main groups of groundwater including: 1) Ca-HCO<sub>3</sub>, Ca-Na-HCO<sub>3</sub> and Na-HCO<sub>3</sub> group which is common in young-age groundwater, high terrain or recharge area, i.e. the western area from Ratchaburi to Chainat and some parts of the centre, 2) Ca-HCO<sub>3</sub>-Cl, Na-HCO<sub>3</sub>-Cl and Ca-Na-HCO<sub>3</sub>-Cl group which is found in groundwater that has migrated far from the recharge area. It is generally freshwater but brackish to salt water in some areas. 3) Ca-Na-Cl, Ca-Cl and Na-Cl group which is found in groundwater with a great distance migration in discharge area such as the southern part of the study area, and 4) SO<sub>4</sub> group which is distributed in certain areas, particularly Phra Pradaeng aquifer, assumed to be a result of seawater contamination, dissolution of sulfate or sulfide minerals, or human activities. According to the hydrochemical analysis along the groundwater flow path from West to East, Na<sup>+</sup> is primarily a product of Plagioclase weathering. Ca<sup>2+</sup> and Mg<sup>2+</sup> are products of carbonate minerals' dissolution. There is also mixing of groundwater, ion exchange, and alteration of water types as follows:

- Recharge area (West of Lao Khwan) => Discharge area (West of Chao Phraya Basin): Rainwater => Ca-HCO<sub>3</sub> => Na-Ca-HCO<sub>3</sub> => Ca-Na-HCO<sub>3</sub> => Ca-Na-Mg-HCO<sub>3</sub> => Ca-Na-Mg-HCO<sub>3</sub>-Cl-SO<sub>4</sub>.

- Recharge area (Tha Maka) => Discharge area (Sai Noi, Pathum Thani): Rainwater Ca-HCO<sub>3</sub> => Ca-Mg-HCO<sub>3</sub> => Ca-Mg-Na-HCO<sub>3</sub> => Na-HCO<sub>3</sub>-Cl => Ca-Na-Mg-Cl.

The following three areas of categorized groundwater types were delineated for groundwater quality management: (i) where groundwater quality is high to very high (mostly groundwater types in Group 1). Preventive measures are required for these areas, (ii) where groundwater quality is moderate to high (mostly groundwater types in Group 2). There should be measures taken for groundwater quality monitoring and (iii) in contaminated areas (mostly groundwater types in groups 3 and 4). Remediation measures and groundwater utilization control are necessary. Groundwater quality for agriculture mostly is proper to average, except in the coastal area.

KEY WORDS: HYDROGEOCHEMISTRY / HYDROGEOCHEMICAL FACIES / GROUNDWATER FLOW SYSTEM / THA CHIN-MAE KLONG BASIN

162 pages

การศึกษาอุทกธรณีเคมีและการไหลของน้ำบาดาลบริเวณแอ่งท่าจีน-แม่กลอง เพื่อการจัดการคุณภาพน้ำบาดาล  
 STUDY OF HYDROGEOCHEMISTRY AND GROUNDWATER FLOW IN THACHIN-MAEKLONG BASIN FOR  
 GROUNDWATER QUALITY MANAGEMENT

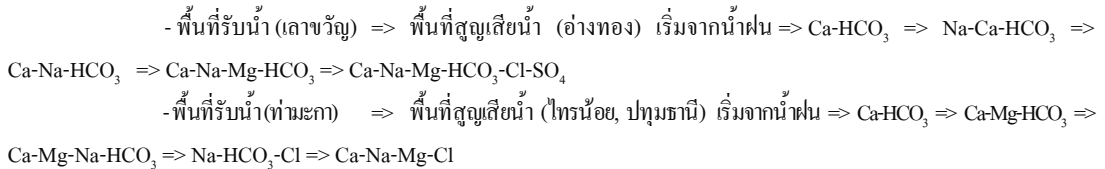
บรรจง พรหมจันทร์ 5036337 ENTM/M

วท.ม.(เทคโนโลยีการบริหารสิ่งแวดล้อม)

คณะกรรมการที่ปรึกษาวิทยานิพนธ์: ปกรณ์ สุวานิช, Ph.D. (POPULATION EDUCATION), เบญจภรณ์ ประภักดิ์, D. Tech. Sc. (ENVIRONMENTAL TOXICOLOGY, TECHNOLOGY AND MANAGEMENT), อรัญญา เพ็องสวัสดิ์, Ph.D. (ENVIRONMENTAL MANAGEMENT)

บทคัดย่อ

กรมทรัพยากรน้ำบาดาลได้มีการศึกษาและเก็บตัวอย่างน้ำบาดาล เพื่อทำการวิเคราะห์องค์ประกอบทางเคมีของน้ำบาดาลในแอ่งท่าจีน-แม่กลองเป็นจำนวนมาก แต่ข้อมูลส่วนใหญ่จะอยู่ในรูปตารางและตัวเลข ซึ่งพารามิเตอร์ต่างๆ มีค่อนข้างมาก ยุ่งยากต่อการเข้าใจและการนำไปใช้ประโยชน์ในการบริหารจัดการ การศึกษาครั้งนี้ เป็นการนำข้อมูลดังกล่าวมาทำการวิเคราะห์ และแปลความหมาย คุณลักษณะทางอุทกธรณีเคมีของแต่ละชั้นน้ำ โดยใช้โปรแกรมคอมพิวเตอร์สำเร็จรูป เพื่อให้มีความเข้าใจลักษณะอุทกธรณีเคมี และวิวัฒนาการของน้ำบาดาล ด้วยวิธีการพล็อตแผนภูมิไปเปอร์ แผนภูมิคูรอฟ แผนภูมิสทิฟ วิเคราะห์การดูดซับอนุโมลโซเดียม (SAR) พล็อตกราฟ X-Y และการวิเคราะห์อัตราส่วนไอออน ผลการศึกษาสรุปได้ว่า ลักษณะชนิดของน้ำบาดาล แบ่งออกเป็น 4 กลุ่มน้ำหลัก ได้แก่ 1) กลุ่ม  $\text{Ca-HCO}_3$ ,  $\text{Ca-Na-HCO}_3$  และ  $\text{Na-HCO}_3$  มักพบในน้ำบาดาลเกิดใหม่และมีอายุน้อย พื้นที่รับน้ำฝนมีสภาพภูมิประเทศเป็นที่สูงอยู่บริเวณด้านตะวันตกของขอบแอ่ง ตั้งแต่จังหวัดราชบุรี ไปจนถึงชัยนาท และบางส่วนในตอนกลางของพื้นที่ 2) กลุ่ม  $\text{Ca-HCO}_3\text{-Cl}$ ,  $\text{Na-HCO}_3\text{-Cl}$  และ  $\text{Ca-Na-HCO}_3\text{-Cl}$  พบในน้ำบาดาลที่มีการเคลื่อนที่มาจากพื้นที่เติมน้ำ คุณภาพน้ำจัดเป็นส่วนใหญ่ อาจมีกร่อยถึงเค็มในบางพื้นที่ 3) กลุ่ม  $\text{Na-Cl}$ ,  $\text{Ca-Cl}$  และ  $\text{Ca-Na-Cl}$  พบในน้ำบาดาลที่มีการเคลื่อนที่มาเป็นระยะทางไกลมากๆ พบในพื้นที่สูญเสียน้ำทางตอนใต้ของพื้นที่ศึกษา และ 4) กลุ่ม  $\text{SO}_4$  พบน้อยมาก กระจายตัวเฉพาะในชั้นน้ำพระประแดง สันนิษฐานว่า อาจมาจากการปนเปื้อนจากน้ำทะเล เกิดจากการละลายของกลุ่มแร่ซัลไฟด์ ซัลเฟต หรือเกิดจากกิจกรรมของมนุษย์ ผลวิเคราะห์กระบวนการอุทกเคมีตามแนวตะวันตกไปทางตะวันออก พบว่า  $\text{Na}^+$  ส่วนใหญ่เกิดจากการผุพังของแร่เพลจิโอเคลส (plagioclase) ส่วน  $\text{Ca}^{2+}$ ,  $\text{Mg}^{2+}$  เกิดจากกระบวนการละลายของแร่คาร์บอเนต นอกจากนี้ ยังมีการผสมกันของน้ำบาดาลทำให้เกิดการแลกเปลี่ยนไอออน การเปลี่ยนแปลงชนิดน้ำจากพื้นที่รับน้ำฝนไปยังพื้นที่สูญเสียน้ำ มีดังนี้



ในด้านการจัดการคุณภาพน้ำบาดาล สามารถทำได้โดยแบ่งออกเป็น 3 เขตพื้นที่ ได้แก่ (i) บริเวณที่น้ำบาดาลมีคุณภาพดีถึงดีมาก (ส่วนใหญ่เป็นกลุ่มน้ำหลักที่ 1) พื้นที่นี้ควรใช้มาตรการป้องกันเป็นหลัก (ii) บริเวณที่น้ำบาดาลมีคุณภาพปานกลางถึงดี (ส่วนใหญ่เป็นกลุ่มน้ำหลักที่ 2) บริเวณนี้ควรมีมาตรการติดตามเฝ้าระวังอย่างใกล้ชิด และ (iii) บริเวณที่พบว่ามีกร่อยปนเปื้อน (ส่วนใหญ่เป็นกลุ่มน้ำหลักที่ 3 และ 4) จำเป็นต้องมีมาตรการการฟื้นฟู และการควบคุมการใช้น้ำบาดาลให้อยู่ในปริมาณที่ปลอดภัย สำหรับคุณภาพน้ำบาดาลเพื่อการเกษตรส่วนใหญ่มีความเหมาะสมดีถึงปานกลาง ยกเว้น บริเวณใกล้ชายฝั่งทะเลมีคุณภาพไม่เหมาะสม

## CONTENTS

	<b>Page</b>
<b>ACKNOWLEDGEMENTS</b>	<b>iii</b>
<b>ABSTRACT (ENGLISH)</b>	<b>iv</b>
<b>ABSTRACT (THAI)</b>	<b>v</b>
<b>LIST OF TABLES</b>	<b>ix</b>
<b>LIST OF FIGURES</b>	<b>x</b>
<b>CHAPTER I INTRODUCTION</b>	<b>1</b>
1.1 Background and statement of problem	1
1.2 Objectives	2
1.3 Conceptual Framework	3
1.4 Scope and limitations of the study	4
1.5 Expected results	5
1.6 Methodology	6
<b>CHAPTER II LITERATURE REVIEWS</b>	<b>7</b>
2.1 Groundwater Hydrogeochemistry	7
2.2 Geography and Geomorphology	26
2.3 Principle of groundwater management	41
2.4 The Relevant Research	42

## **CONTENTS (cont.)**

	<b>Page</b>
<b>CHAPTER III RESEARCH METHODOLOGY</b>	<b>46</b>
3.1 Data collection and database preparation	46
3.2 Data Presentation in Map	48
3.3 Analysis of Groundwater Flow System	48
3.4 Wells Selection for Hydrochemical Analysis and Data Determination	48
3.5 Hydrogeochemical Analysis of Groundwater	50
3.6 Analysis of Groundwater Resources Management from the Study	52
<b>CHAPTER IV RESULTS AND DISCUSSION</b>	<b>58</b>
4.1 Hydrochemical analysis of groundwater	59
4.2 Flow Path Selection and Flow Direction	66
4.3 Groundwater Flow System (GFS)	76
4.4 Hydrochemical Facies Analysis	82
4.5 Hydrogeochemical Process along Kanchanaburi – Anghong Flow Path (A-A’)	94
4.6 Hydrogeochemical Process along Kanchanaburi (Thamaka) – Pathum thani Flow path (B-B’)	97
4.7 Groundwater Quality Management applied according to the Research and Analysis	101
<b>CHAPTER V CONCLUSION AND RECOMMENDATIONS</b>	<b>105</b>
5.1 Conclusion	105
5.2 Recommendations for further study	108

**CONTENTS (cont.)**

	<b>Page</b>
<b>REFERENCES</b>	<b>109</b>
<b>APPENDICES</b>	<b>112</b>
Appendix A List of classification of water types for aquifer layer I-V	113
Appendix B Piper Diagram of Aquifer Layer I-V	133
Appendix C Map of Hydrogeochemical Facies Distribution of Aquifer Layer I-V	138
Appendix D Wilcox Diagram of Aquifer Layer I-V	143
Appendix E Map of Stiff Diagram Distribution of Layer I-V	148
Appendix F Stiff diagrams of each well for aquifer Layer I-V	153
Appendix G Details of wells selected along Principle Flow Paths	160
<b>BIOGRAPHY</b>	<b>162</b>

## LIST OF TABLES

<b>Table</b>		<b>Page</b>
2-1	General classification of water sodium hazard based on SAR values	18
2-2	Effect of sodium expressed as sodium adsorption ratio (SAR) on crop yield and quality under non-saline conditions	19
2-3	Summary of the ratios and parameters used to determine both the source rock and chemical reactions	24
2-4	Average annual and monthly values of Maeklong and Thachin Basins	26
3-1	Summary of hydrochemical facies associated with nine numbered fields on the Durov diagram	53
4-1	Stiff Diagram types in study area	60
4-2	Change in velocity along flow path	69
4-3	GFS in Tha Chin-Mae Klong Basin	79
4-4	Comparison of ions ratio along Kanchanburi – Ang Thong flow path (hydrogeologic cross section A-A')	83
4-5	Comparison of ions ratio along Kanchanburi – Pathum thani flow path (hydrogeologic cross section B-B')	84
4-6	Analysis on Hydrogeochemical Process along Kanchanaburi (Lao Kwan) – Angthong Flow Path (A-A')	96
4-7	Analysis on Hydrogeochemical Process along Kanchanaburi – Pathum Thani Flow path (B-B')	99

## LIST OF FIGURES

<b>Figure</b>		<b>Page</b>
1-1	Diagram of conceptual frame work	3
1-2	Diagram of methodology flow chart	6
2-1	Ions exchange and phenomena on ground surface caused by groundwater flow systems	9
2-2	Hydrogeochemical cycle of groundwater	12
2-3	Different water types classified by using Piper diagrams	14
2-4	Piper plots of waters from different rocks	15
2-5	Expand Durov diagram with subdivisions processes demonstrated	16
2-6	Stiff diagrams of waters from difference rocks	18
2-7	Simple scatter plot of Sodium Hazard (SAR) on the Y-axis vs. Salinity Hazard (Conductivity) on the X-axis (Aquachem 5)	19
2-8	X-Y plot of major ions	21
2-9	Weathering flow chart illustrating logic of water quality interpretation using simplified mass balance technique	23
2-10	Topographic map of the study area	28
2-11	Geomorphological Map of the Study Area	30
2-12	Geologic map of the study area, modified from DGR	35
2-13	Hydrogeological Map of the Study Area	40
2-14	Principle of groundwater management in universal	41
3-1	An example of Piper diagram which can classify groundwater into 4 types	52
4-1	Steady state flow direction	72
4-2	Particle Tracking of steady state flow direction	74
4-3	Flow Path and Groundwater Flow System on Cross Section A-A'	80
4-4	Flow Path and Groundwater Flow System on Cross Section B-B'	81

## LIST OF FIGURES (cont.)

<b>Figure</b>		<b>Page</b>
4-5	X-Y Plot of ions in Kanchanburi – Angthong flow path (hydrogeologic cross section A-A')	85
4-6	X-Y Plot of ions in Kanchanburi – Pathum thani flow path (hydrogeologic cross section B-B')	86
4-7	(a-g) Piper Diagram of hydrogeochemical Process along cross section A-A'	87
4-8	(a-j) Piper Diagram of hydrogeochemical Process along cross section B-B'	89
4-9	(a-g) Durov Diagram of hydrochemical changes on cross section A-A'	92
4-10	(a-j) Durov Diagram of Hydrochemical changes on cross section B-B'	93
4-11	Map of categorization groundwater types for groundwater quality management	103
4-12	Map of SAR distribution of the study area	104

## **CHAPTER I**

### **INTRODUCTION**

#### **1.1 Background and statement of problem**

Water Resources in Thailand are acquired from two main sources: surface water and groundwater. Currently, groundwater has been used in various sectors including agriculture, industries and domestic consumption. High rate of population growth and leapfrog economic development have an influence on increasing demand of water for exploitation; while, the surface water supply is limited. Thus, the development of groundwater is necessary in order to serve those activities. The groundwater can be used as a supplementary water resource because of its good quality, its inexpensive cost, and its usability.

Groundwater resources in the Tha Chin and Mae Klong Basin cover an area of 44,313 km<sup>2</sup> (1). Water from unconsolidated aquifers, covering an area of 12,296 km<sup>2</sup>, has been widely used in sugarcane farms and dry-season rice cultivation as well as several industries. In addition, the aquifers of the downstream basin areas in Ratchaburi, Nakhon Pathom, Samut Sakhon and Samut Songkhram Provinces contain both salt and fresh water layers since these areas encounter saltwater intrusion and were flooded by seawater and overexploitation by pumping a large amount of the groundwater in the area, particularly by industrial plants without an appropriate control, could therefore lead to saltwater intrusion into fresh water aquifers.

In the study area, there is a large number of groundwater quality data from the Department of Groundwater Resources (DGR). However, the data are generally stored in numeral and table forms and include a lot of parameters. This resulted in the difficulty to remember and recognize, and the inconvenience to utilize for management.

Therefore, it is necessary to study the hydrogeochemistry and groundwater flows in the Tha Chin- Mae Klong Basin. The analysis of groundwater quality data should have been processed by computer programs and correlated with the

groundwater flow system in the study area in order to increase the comprehension on the hydrogeological condition, the chemical pattern, the groundwater origin, and the vulnerability of aquifer systems. The results are interpreted and presented in a simple form for the appropriated purpose of groundwater management.

## 1.2 Objectives

1.2.1 To manipulate a large number of chemical analysis data of groundwater samples into simplified figures for increasing the convenience and comprehension on interpretations and utilizations

1.2.2 To identify and classify the hydrogeochemistry of five aquifers in the Tha Chin-Mae Klong Basin.

1.2.3 To analyze groundwater flow system in each aquifer and correlate the flow system with the groundwater types of the Tha Chin-Mae Klong Basin.

1.2.4 To determine the appropriated approaches for groundwater quality management in the study area.

### 1.3 Conceptual Framework

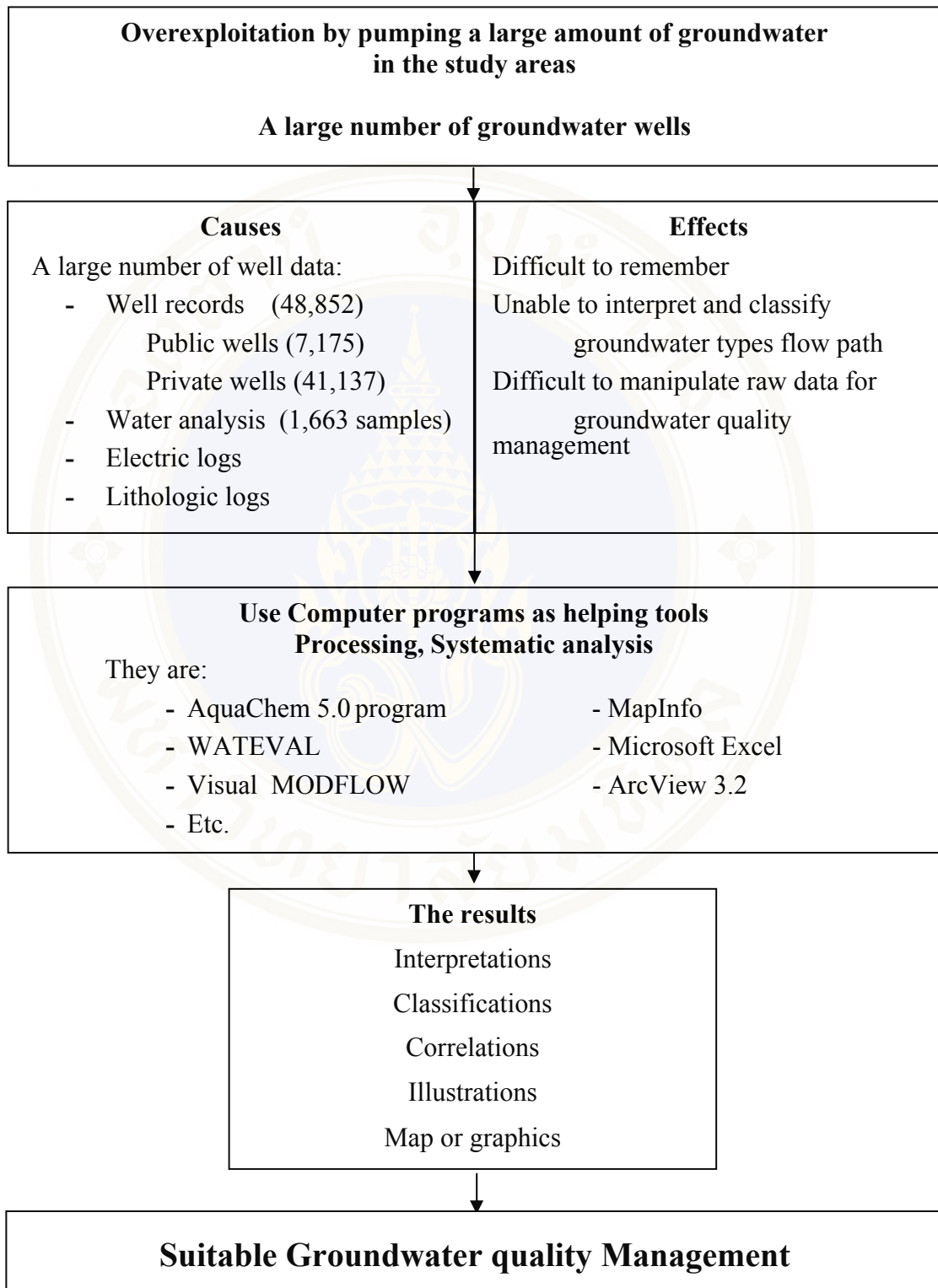


Figure 1-1: Diagram of conceptual frame work

## 1.4 Scope and limitations of the study

1.4.1 The study areas are located in the central part of Thailand, on the west of Chao Phraya River. The areas cover some parts of the Tha Chin-Mae Klong Basin in Kanchanaburi, Ratchaburi, Samut Songkhram, Samut Sakhon, Nakhon Pathom, Nonthaburi, Ayutthaya, Suphan Buri, Ang Thong and Chai Nat Provinces. The areas are approximately 12,300 km<sup>2</sup> (1).

1.4.2 Visual MODFLOW program version 4.2 (2) was utilized to simulate groundwater flow.

1.4.3 All data used in this study is secondary data including the hydrogeologic data from DGR such as aquifer layers, well records, hydrogeologic cross sections, and water analysis.

1.4.4 The criteria for data selection. (3)

- 1) The chemical analysis should include the following major ions: Na<sup>+</sup>, K<sup>+</sup>, Ca<sup>2+</sup>, Mg<sup>2+</sup>, HCO<sub>3</sub><sup>-</sup>, CO<sub>3</sub><sup>2-</sup>, Cl<sup>-</sup>, and SO<sub>4</sub><sup>2-</sup>.
- 2) The sum of cations in meq/L should equal the sum of anions in meq/L. The charge balance must be less than ± 5%.
- 3) The sum of major ions would be used instead of the Total Dissolved Solids (TDS) in case that the TDS in groundwater sample is not measured
- 4) The latest analysis data would be selected if there are more than one chemical analysis data the samples of those wells had analyzed more than one time.
- 5) Selected wells must possess groundwater chemical analysis data and lithologic logs.
- 6) The selected wells must contain the slotted casing or screen only in a single aquifer.

#### 1.4.5 Software and computer applications

- 1) AquaChem 5.0 (4)
- 2) WATEVAL Version 8.10L 9/94 (5)
- 3) Microsoft Excel and Surfer 8 (6)
- 4) ArcView GIS Version 3.2 (7)
- 5) MapInfo Profesional Version 7.0 (8)
- 6) CorelDraw 12

### 1.5 Expected results

1.5.1 The comprehension on types of groundwater in the Tha Chin-Mae Klong Basin which would facilitate the interpretation of the groundwater origins and the processes of the hydrogeochemical evolution in the study area.

1.5.2 The capability to simplify a large number of groundwater analysis data, which are difficult to remember and interpret, by presenting them in form of graphs or cluster types of groundwater.

1.5.3 Hydrogeochemical types of water are beneficial for predicting trend of groundwater quality changes.

1.5.4 The groundwater flow system of each aquifer in the Tha Chin-Mae Klong Basin.

1.5.5 The appropriate approaches for groundwater quality management in the study area.

## 1.6 Methodology

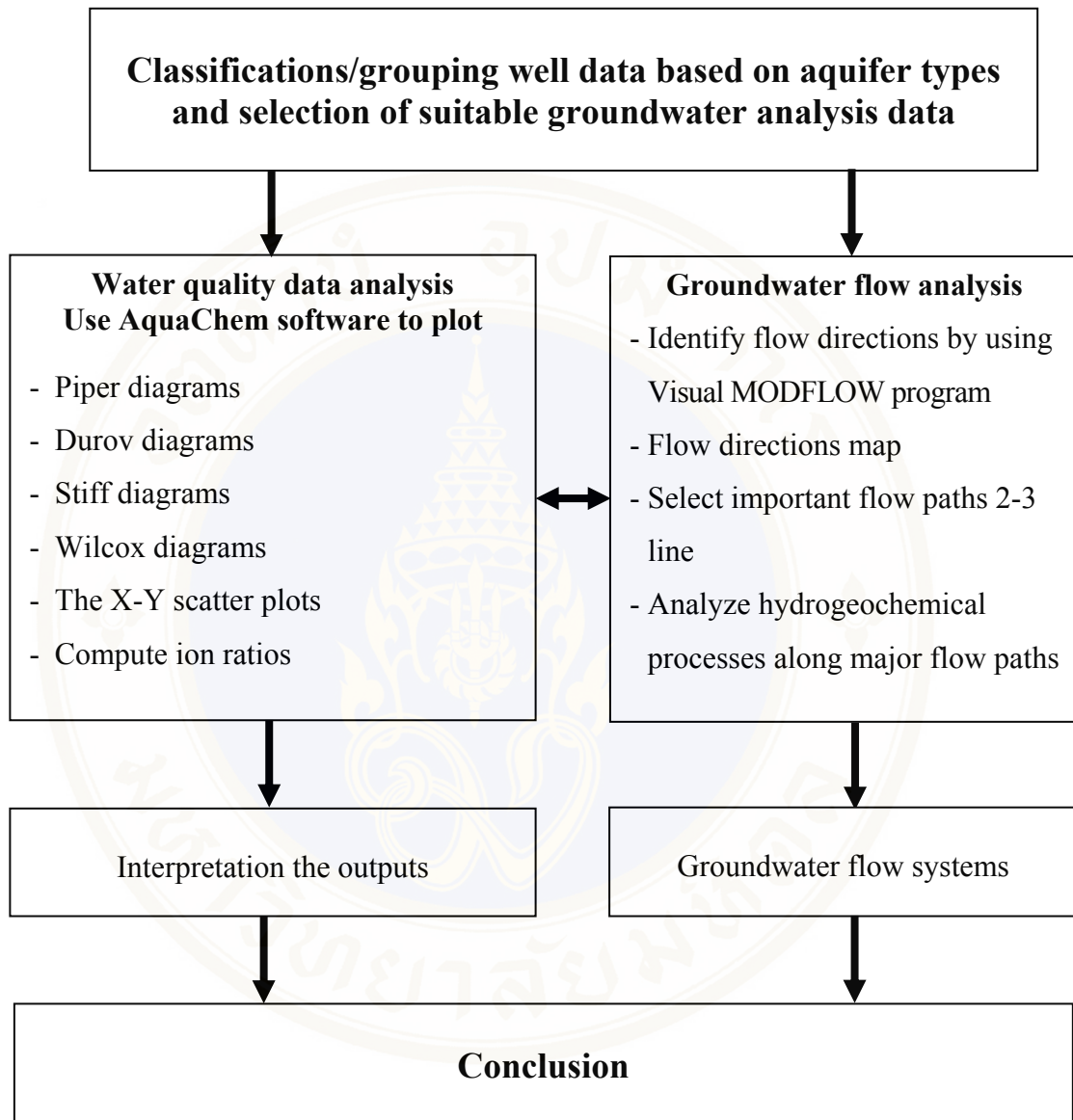


Figure 1-2: Diagram of methodology flow chart

## **CHAPTER II**

### **LITERATURE REVIEWS**

Groundwater, hydrogeology, and morphology are the fundamental knowledge for hydrogeochemistry analysis. These items include:

1. Groundwater Hydrogeochemistry
2. Geography and Geomorphology of study area
3. Groundwater resources management
4. Secondary documents concerning

#### **2.1 Groundwater Hydrogeochemistry**

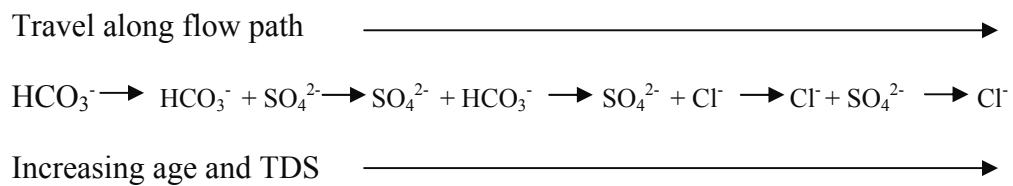
##### **2.1.1 Factors controlling groundwater quality**

The four main factors that control characteristics of chemical constituents of groundwater are as follows:

- 1) Flow paths and distance
- 2) Geology
- 3) Hydrology
- 4) Human activities

###### **2.1.1.1 Controlled by flow paths and distance**

According to “Chebotarev sequence” (9), the quantity of total dissolved solids (TDS) and anions in groundwater are increasing by distance and age along flow path (10) (11) (12). Groundwater tends to evolve chemically with residence time. And that the end point of the chemical evolution is the water that has the composition of seawater. You can see the following formula:



Regarding groundwater flow systems, it is basically found that there are low TDS, high oxygen, low acids, low bases and high cations content in recharge areas. A high quantity of bicarbonates that present in groundwater is caused by carbon dioxide and carbonate minerals in soils. The reaction between carbon dioxide and water to form a weak acid called carbonic acid,  $\text{H}_2\text{CO}_3$ , according to the following reaction:  $\text{CO}_2 + \text{H}_2\text{O} \rightarrow \text{H}_2\text{CO}_3$ . When groundwater travels distant from the origin,  $\text{SO}_4$  in water presents increasingly caused by the solution of gypsum and anhydrite. However, the sulfate does not occur in all flow system. In deep flow system also found Cl predominantly since the sulfate and carbonate were precipitated during movement along the flow paths and long residence time in the deep level. In addition, There are low tritium, high TDS, low young age carbon, high sulfate and high chloride in discharge areas (13). (Figure 2-1)

The change of groundwater chemistry may be caused by the mixing of others water due to the alteration of rock texture, hydraulic conductivity, geologic structure, infiltration, and leakage of each aquifer. The mixing of water results in the difference of dilution and the saturation of mineral, isotope and ions content in groundwater. The summary of figure 2-1 is:

**Recharge area:** dissolution, hydration, oxidation, and high level of  $\text{Ca}^{2+}$ ,  $\text{Mg}^{2+}$ ,  $\text{HCO}_3^-$ ,  $\text{CO}_3^{2-}$ ,  $\text{SO}_4^{2-}$ , and  $\text{Cl}^-$  in groundwater.

**Midline area:** dissolution, precipitation, sulfate reduction, ion exchange and high level of TDS,  $\text{Na}^+$ ,  $\text{Ca}^{2+}$ ,  $\text{Mg}^{2+}$ ,  $\text{HCO}_3^-$ ,  $\text{CO}_3^{2-}$ ,  $\text{SO}_4^{2-}$ , and  $\text{Cl}^-$  in groundwater.

**Discharge area:** precipitation, reduction and high level of TDS,  $\text{Na}^+$ ,  $\text{SO}_4^{2-}$ , and  $\text{Cl}^-$  in groundwater

In groundwater flow system, change of chemistry in groundwater can be defined as;

- 1) **Local flow system** : Low TDS, high  $\text{HCO}_3^-$ ,  $\text{Ca}^{2+}$ ,  $\text{Mg}^{2+}$
- 2) **Intermediate flow system** : TDS increases, Cl-Sulphate reaction occurs
- 3) **Regional flow system** : TDS,  $\text{SO}_4^{2-}$ , and Cl increase,  $\text{HCO}_3^-$  decreases

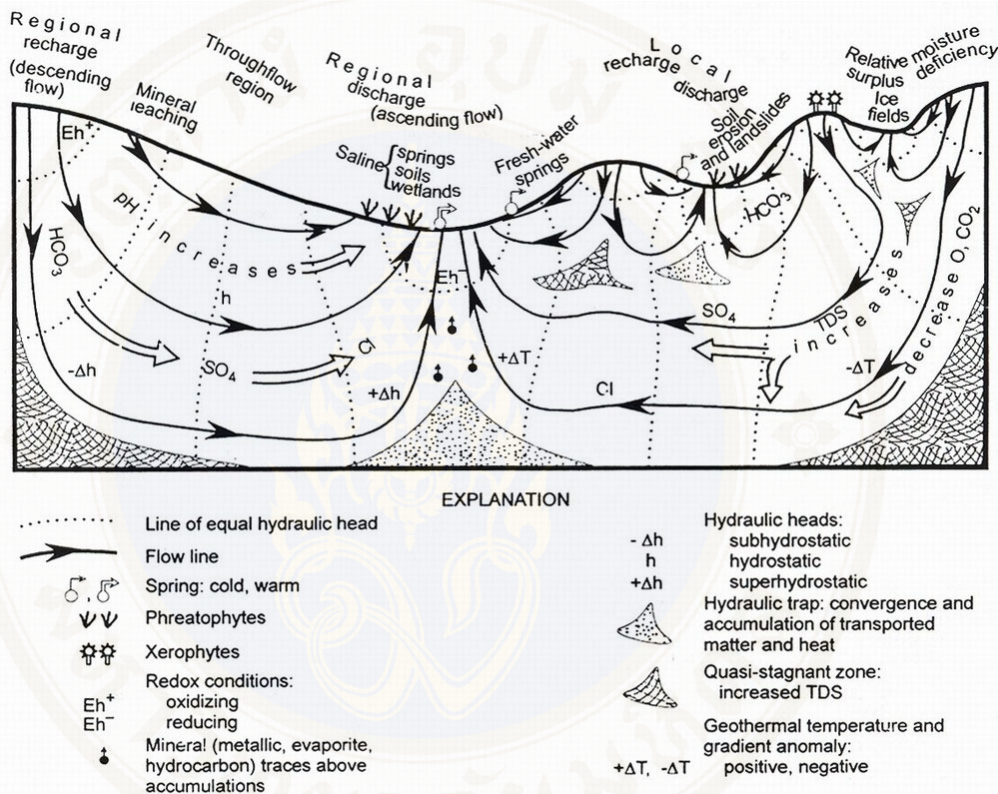


Figure 2-1: Ions exchange and phenomena on ground surface caused by groundwater flow systems. (13)

### 2.1.1.2 Geologic features Control

Lithology influences to chemical elements of groundwater directly (9) (12). Groundwater flow through several aquifer layers that means groundwater pass many types of minerals and chemical reactions, or non-homogeneous aquifer, such as in different areas of limestone may contain carbonate minerals in different quantity and variety, or sandstones in different areas may have different cementing minerals (13). Variety of rock causes different elements in groundwater.

Dissolution process will affect entire quantity value higher according to the direction of groundwater flow especially in unconsolidated aquifer which is composed of high soluble mineral such as gypsum, anhydrite or halite. Total dissolved solid (TDS) of carbonate group of this aquifer will be dependent increment since reduction of dissolved carbon dioxide (3) or even size of sediment and permeability coefficient will affect the residence time that water will remain in stone and make reaction with stones and minerals. If sediment is small size and less permeability coefficient, residence time will be high. But if aquifer cracks, time and surface area for reactions between water and mineral resources will be decreased.

The geologic material such as clay does not only cause direction change of groundwater flow but also changes of hydro-chemistry due to the sort of clay mineral will perform infiltration as semi-permeable membrane which are accumulated for some types of ions at clay area that water pass. Additionally, cation exchange between  $\text{Ca}^{2+}$  and  $\text{Mg}^{2+}$  in water with  $\text{Na}^+$  in clay minerals are also caused residence time increment.

#### **2.1.1.3 Hydrology control**

Hydrology is the one factor that preliminary controls hydro-chemistry and reactions in groundwater (13) such as accumulated for some types of ions in soil layer: namely  $\text{Cl}^-$ ,  $\text{SO}_4^{2-}$ ,  $\text{Na}^+$  and  $\text{Ca}^{2+}$  from precipitation or evaporation of water in soil layer or accumulated due to wind blow when rain or water pass this area and meets sufficient quantity, these ions will be leached down to groundwater.

Dissolution of salt or various minerals depend on other factors, such as temperature,  $\text{O}_2$ ,  $\text{CO}_2$ , pressure, pH, alkali ion, degree of saturation and redox coefficient which will determine whether the reaction occurs and access steady stage.

#### **2.1.1.4 Influence because of human activities**

Human activity is the other factor that important to chemical changes in groundwater such as groundwater contamination because of wastewater or sewage from industries, basement oil tank, even agricultural activities will add  $\text{NO}_3^-$ ,  $\text{SO}_4^{2-}$ ,  $\text{Cl}^-$ , with groundwater due to eliminate weeds, the use of pesticides, fertilizer, animal manure, irrigation, leakage of leachate, which will impact chemical changes in groundwater directly (3).

Groundwater abstraction one of human activity that causes changes chemical property of groundwater: they are leakage of water into confine aquifer, changes of groundwater flow path, inducement surface waters into groundwater sources and saltwater intrusion into fresh water aquifers.

### **2.1.2 Hydrogeochemistry process in groundwater**

Groundwater at the recharge areas will change chemical elements through groundwater flow up to discharge areas (15). The element has been changed because of complete hydrogeochemistry process in groundwater for 12 processes. Figure 2-2 illustrates the concept of hydrogeochemistry process from precipitation into recharge areas and discharge areas (13).

- 1) Acid-base reaction
- 2) Dissolution
- 3) Calcite precipitation
- 4) Redox reaction
- 5) Ion exchange
- 6) Reverse ion exchange
- 7) Sulfate reduction
- 8) Dedolomitization
- 9) Filtration
- 10) Mixing
- 11) Biogenic reactions
- 12) Gas dissolution and ionizations

For more details, please see “Water Quality: Analysis and Interpretation” (3), “Physical and Chemical Hydrogeology” (15) and, “Groundwater as a Geologic agent: and overview of the causes, processes, and manifestations” (13).

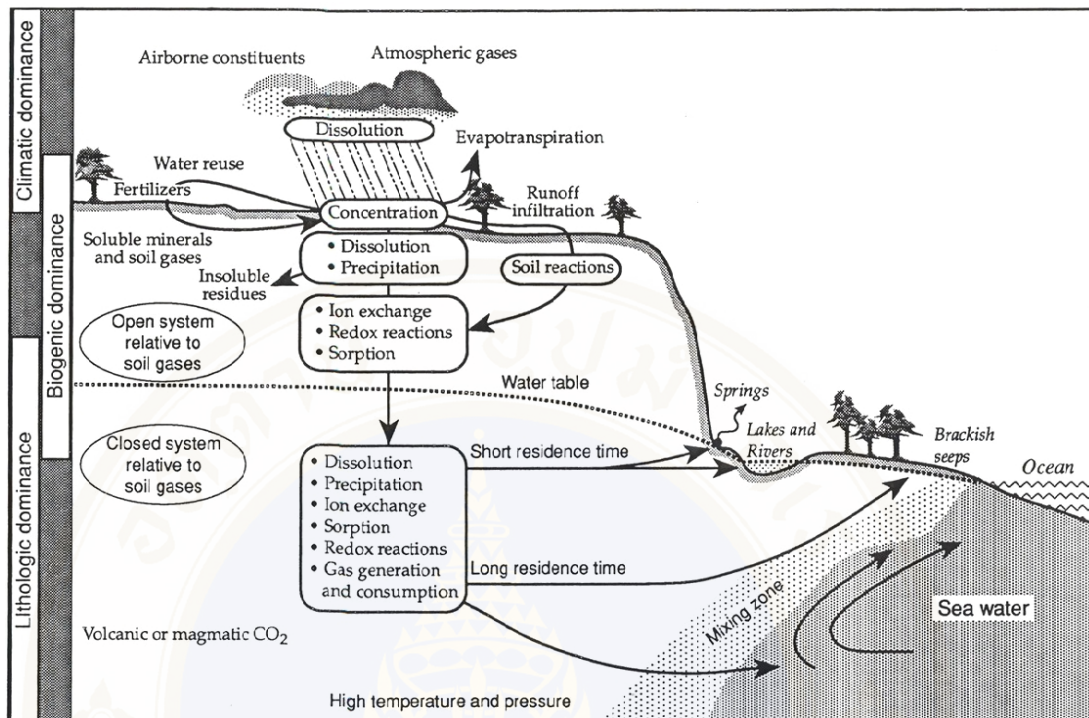


Figure 2-2: Hydrogeochemical cycle of groundwater (13)

### 2.1.3 Analysis and interpretation of hydrogeochemistry

The approved result of chemical analyses of groundwater sample will be hydrochemically analyzed to determine water types and groundwater quality of each aquifer using AquaChem 5.0 program and Sodium Adsorption Ratio (SAR) analysis.

In this study, six following approaches are used for the analysis and interpretation of groundwater quality:

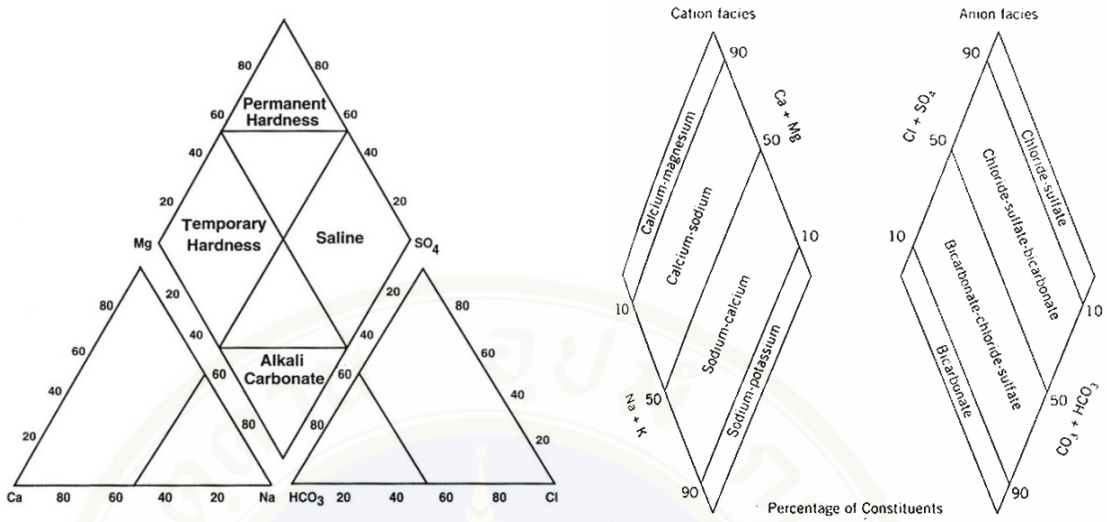
- 1) Piper diagrams
- 2) Durov diagrams
- 3) Stiff diagrams
- 4) Analysis of SAR by plotting on Wilcox diagrams
- 5) X-Y plots
- 6) Ion ratio comparisons

### 2.1.3.1 Piper Diagrams

Piper diagrams (3) are a combination of anion and cation triangles that lie on a common baseline. Adjacent sides of the two triangles are then 60 degrees apart. A diamond shape between them is used to replot the analyses as circles whose areas are proportional to their TDS. The position of an analysis that is plotted on a Piper diagram can be used to make a tentative conclusion as to the origin of the water represented by the analysis. However, the bicarbonate to silica ratio must also be considered when making this deduction.

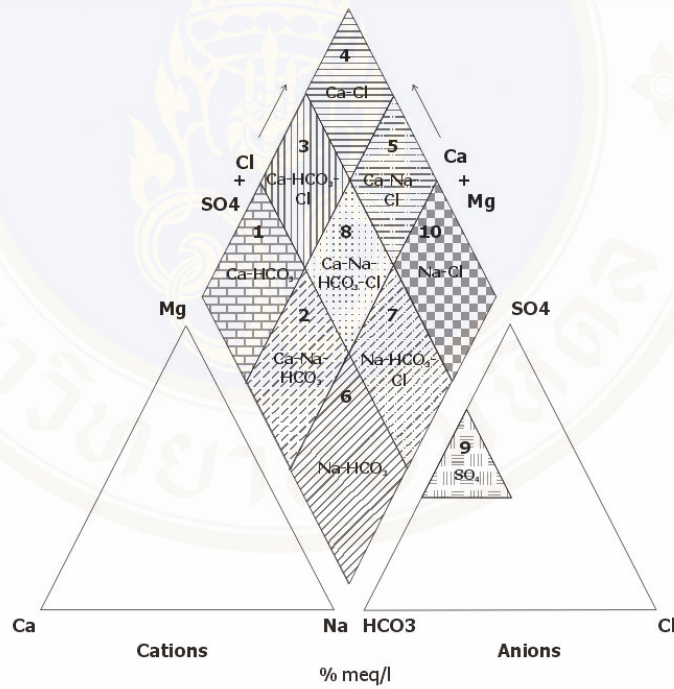
Hydrochemical facies (14) are used to describe the bodies of groundwater, in an aquifer, that differ in their chemical composition. The facies are function of the lithology, solution kinetics, and flow patterns of the aquifer (10).

The diamond part of a Piper diagram may be used to characterize different water types (3). Piper divided water into four basic types according to their placement near the four corners of the diamond. Water sample plotted at the top of the diamond is high in  $\text{Ca}^{2+} + \text{Mg}^{2+}$  and  $\text{Cl}^- + \text{SO}_4^{2-}$ , which results in an area of permanent hardness. The water sample plotted near the left corner, the region of water of temporary hardness, is rich in  $\text{Ca}^{2+} + \text{Mg}^{2+}$  and  $\text{HCO}_3^-$ . Water sample plotted at the lower corner of the diamond is primarily composed of alkali carbonates ( $\text{Na}^+ + \text{K}^+$  and  $\text{HCO}_3^- + \text{CO}_3^{2-}$ ). Water sample lying near the right-hand side of the diamond may be considered saline ( $\text{Na}^+ + \text{K}^+$  and  $\text{Cl}^- + \text{SO}_4^{2-}$ ). These divisions are shown in Figure 2-3. Groundwater from aquifers within different rock types are shown in Figure 2-4.



a. Water types according to Piper (17)

b. Water types according to Back (10)



c. Water types according to Galloway & Kaiser (18)

Figure 2-3: Different water types classified by using Piper diagrams

**WATER QUALITY FROM AQUIFERS COMPOSED OF DIFFERENT ROCKS**

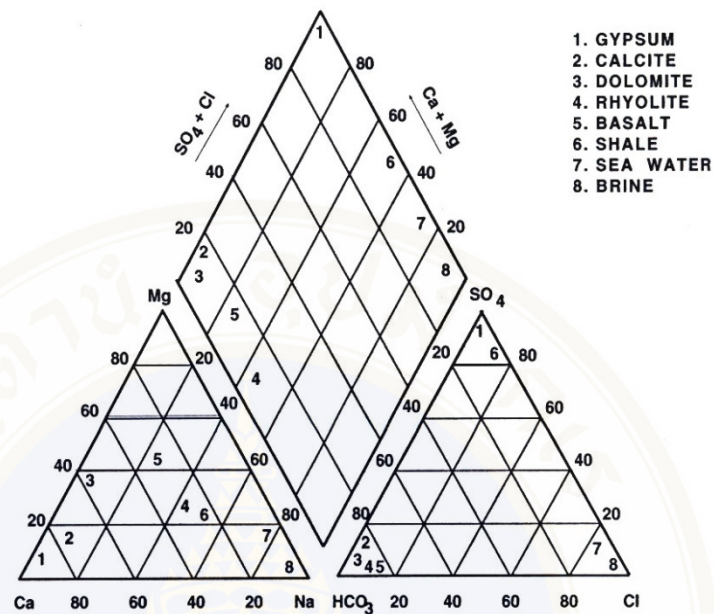


Figure 2-4: Piper plots of waters from different rocks (3)

**2.1.3.2 Durov diagram.**

A Durov diagram (16) can be used to identify different water types (hydrochemical facies) in groundwater system like the Piper diagram. The significance of the nine fields on the expanded Durov diagram can be discussed with respect to Figure 2-5 as follows:

1)  $\text{HCO}_3^-$  and  $\text{Ca}^{2+}$  dominant, frequently indicates recharging waters in limestone, sandstone, and many other aquifers.

2)  $\text{HCO}_3^-$  dominant and eight  $\text{Mg}^{2+}$  dominant or cations indiscriminant, with  $\text{Mg}^{2+}$  dominant or  $\text{Ca}^{2+}$  and  $\text{Mg}^{2+}$  important, indicates waters often associated with dolomites; where  $\text{Ca}^{2+}$  and  $\text{Na}^+$  are important partial ion exchange may be indicated.

3)  $\text{HCO}_3^-$  and  $\text{Na}^+$  dominant, normally indicates ion-exchanged waters although the generation of  $\text{CO}_2$  at depth can produce  $\text{HCO}_3^-$  where  $\text{Na}^+$  is dominant under certain circumstances. Winograd and Farlekas, 1974, cited in (16).

4)  $\text{SO}_4^{2-}$  dominant or anions indiscriminant and  $\text{Ca}^{2+}$  dominant,  $\text{Ca}^{2+}$  and  $\text{SO}_4^{2-}$  dominant frequently indicates a recharge water in lavas and

gypsiferous deposits; otherwise a mixed water or a water exhibiting simple dissolution may be indicated.

5) No dominant anion or cation indicates waters exhibiting simple dissolution or mixing.

6)  $\text{SO}_4^{2-}$  dominant or anions indiscriminant and  $\text{Na}^+$  dominant, is a water type not frequently encountered and indicates probable mixing influences.

7)  $\text{Cl}^-$  and  $\text{Ca}^{2+}$  dominant, is rarely encountered unless cement pollution is present in a well; otherwise the waters may result from reverse ion exchange of  $\text{Na}^+$  -  $\text{Cl}^-$  waters.

8)  $\text{Cl}^-$  dominant and no dominant cation indicates that the groundwater may be related to reverse ion exchange of  $\text{Na}^+$  -  $\text{Cl}^-$  waters.

9)  $\text{Cl}^-$  and  $\text{Na}^+$  dominant frequently indicate end - point waters. The Durov diagram does not permit much distinction between  $\text{Na}^+$  -  $\text{Cl}^-$  waters.

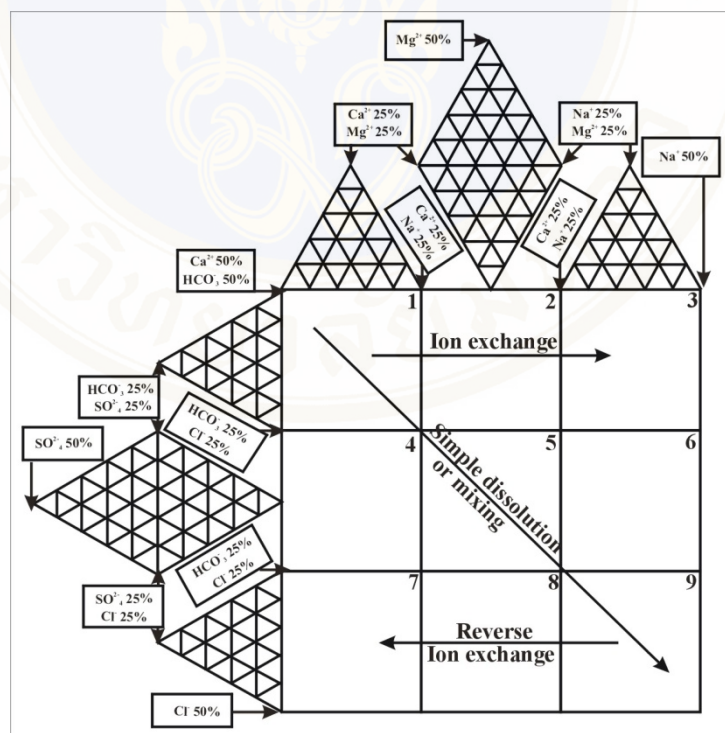


Figure 2-5: Expand Durov diagram with subdivisions processes demonstrated. (16)

### **2.1.3.3 Interpretation chemical analysis on Stiff diagrams.**

A stiff diagram uses four parallel, horizontal axes extending on each side of a vertical, zero axis. Four cations and four anions can thus be plotted on the left and right of the vertical axis, respectively. Concentrations are in meq/l. The resulting points are connected to give an irregular polygonal pattern. The size of the pattern is approximately equal to the total ionic content. Classically, the pairs are sodium-chloride, calcium-bicarbonate, magnesium-sulfate, and iron-carbonate. Usually the iron-carbonate line is small or nonexistent. In some computer programs, such as the author's WATEVAL (5), it is not drawn at all. In addition, the diagrams may be drawn using either a linear or a log meq/l scale.

The log plot is useful for wide ranges of water compositions without having to change the scale. This diagram may also be used to evaluate the source-rock deduction described above, if silica is represented by a line of appropriate length. Stiff diagrams of waters from aquifers of different rock types are shown in Figure 2-6. In the diagrams the axes are log meq/l. (3)

### **2.1.3.4 Analysis of Adsorption Sodium Ratio (SAR) by plotting on Wilcox diagram.**

The sodium hazard can be expressed based on the sodium adsorption ratio (SAR) by the US Salinity Laboratory. This index quantifies the proportion of sodium ( $\text{Na}^+$ ) to calcium ( $\text{Ca}^{2+}$ ) and magnesium ( $\text{Mg}^{2+}$ ) ions in a sample. Calcium will flocculate (hold together), while sodium disperses (pushes apart) soil particles. This dispersed soil will readily crust and have water infiltration and permeability problems. General classifications of irrigation water based upon SAR values are presented in Table 2-1 (19). Figure 2-7 shows diagram adopted from US salinity laboratory. Table 2-2 shows effect of sodium expressed as sodium adsorption ratio (SAR) on crop yield and quality under non-saline conditions (20).

Diagram US salinity laboratory (21) is a simple scatter plot of Sodium Hazard (SAR) on the Y-axis vs. Salinity Hazard (Conductivity) on the X-axis. This diagram is used in interpreting the analysis of irrigation water. Water can be grouped into 16 classes. The Conductivity is plotted by default in a log scale. Diagram is based on the integrated effect of EC and SAR, in which EC is taken as salinity hazard and SAR is taken as alkalinity hazard.

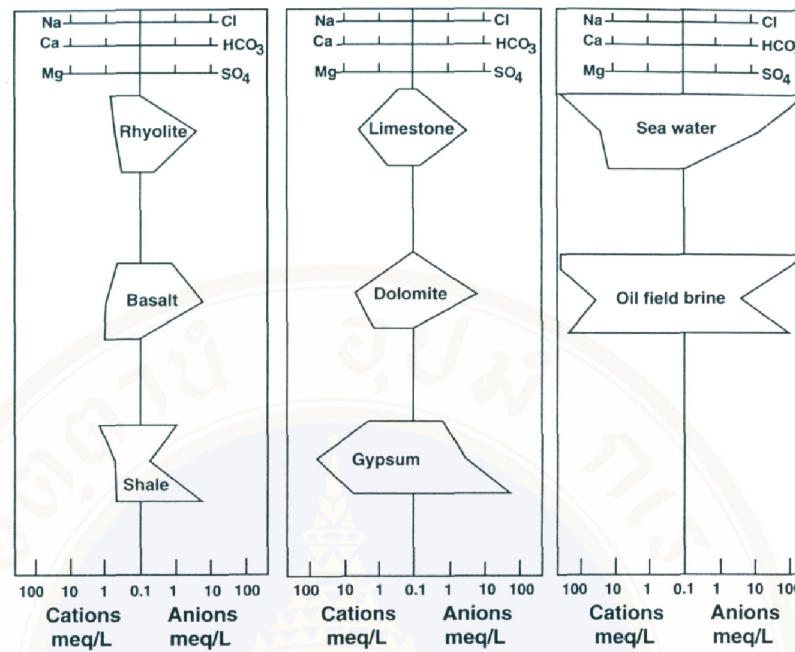


Figure 2-6: Stiff diagrams of waters from different rocks (3).

Table 2-1: General classification of water sodium hazard based on SAR values.

SAR values	Sodium hazard of water	Comments
1-9	Low	Use on sodium sensitive crops must be cautioned.
10-17	Medium	Amendments (such as gypsum) and leaching needed.
18-25	High	Generally unsuitable for continuous use.
≥26	Very High	Generally unsuitable for use.

Table 2-2: Effect of sodium expressed as sodium adsorption ratio (SAR) on crop yield and quality under non-saline conditions (20).

irrigation water SAR	Level of tolerance	Crop	Leaf tip burn, leaf scorch
2-8	Very sensitive	Fruits, nuts, citrus, avocado	Leaf tip burn, leaf scorch
8-18	Susceptibility	Peeling fruits, beans	Stunted growth
18-46	Moderate tolerant	Clover, oats, rice	Stunted growth, possible sodium toxicity, possible calcium or magnesium deficiency
46-102	Tolerant	Wheat, barley, tomatoes, tall wheat grass, crested grass	Stunted growth

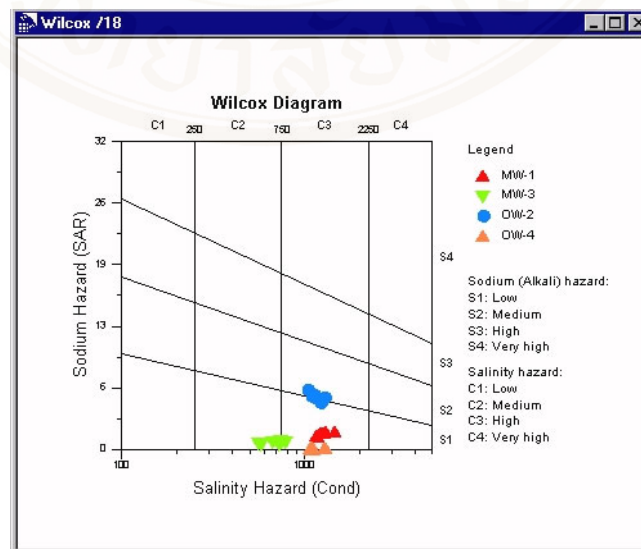


Figure 2-7: Simple scatter plot of Sodium Hazard (SAR) on the Y-axis vs. Salinity Hazard (Conductivity) on the X-axis (Aquachem 5)

**Class and Status for irrigation(21):**

C1: ( $EC < 250$  ( $\mu\text{sm/cm}$ )) Low salty water. It can be used for each type soil and plant.

C2: ( $250 < EC < 750$  ( $\mu\text{sm/cm}$ )) Medium salty water. It is suited for all plants. But natural drainage should be good.

C3: ( $750 < EC < 2250$  ( $\mu\text{sm/cm}$ )) High salty water. It should require drainage. Some plants tolerate.

C4: ( $EC > 2250$  ( $\mu\text{sm/cm}$ )) Very high salty water. Soil should be permeable and drainage should be rich. In addition, plants tolerating salinity should be chosen.

S1: Low sodium content water. It can be used in each soil type.

S2, S3: Medium and high sodium content water. It may be dangerous for soil. That is why soluble matters should be leached and organic matters should be added to soil.

S4: Very high sodium content water. It is unsuitable for irrigation.

**2.1.3.5 Hydro-chemical analysis of groundwater by X-Y plots**

*X-Y* plots are the most simple and obvious initial approach to the interpretation of hydrochemical data. With modern computer graphical facilities such plots can rapidly be compiled for a large number of *X-Y* relationships which will allow a preliminary assessment of those parameters that may assist in interpretation. Plots of single ion relationships and those ion ratios that may prove meaningful can easily be established. Ratios considered include  $\text{Ca}^{2+} : \text{Mg}^{2+}$ ,  $\text{Ca}^{2+} : \text{Na}^+$ ,  $\text{Na}^+ : \text{Ca}^{2+} + \text{Mg}^{2+}$ ,  $\text{HCO}_3^- : \text{Cl}^-$ ,  $\text{SO}_4^{2-} : \text{Cl}^-$ ,  $\text{Cl}^- - \text{Na}^+ : \text{Cl}^-$ , etc. See Figure 2-8

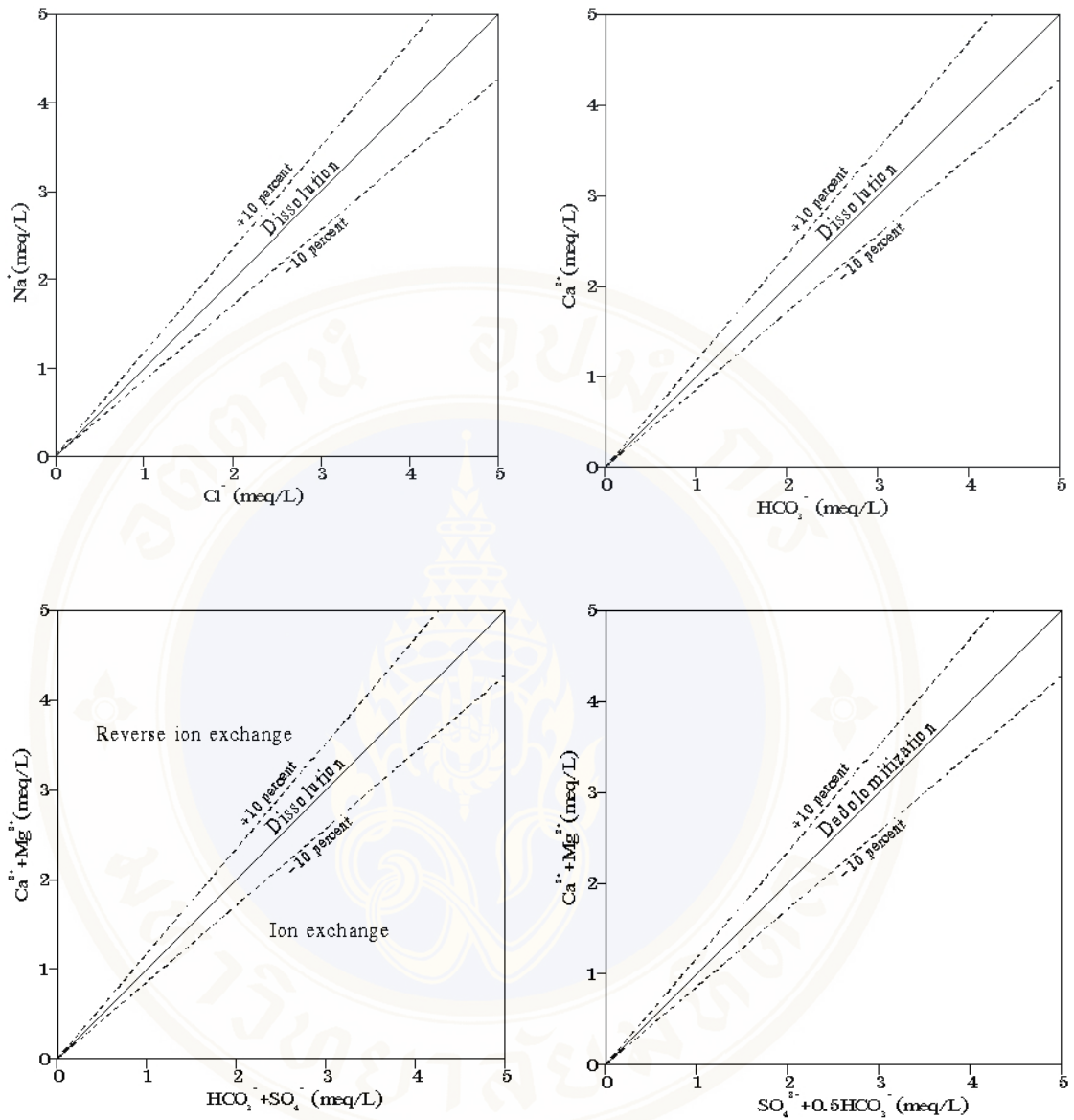


Figure 2-8: X-Y plot of major ions (16)

### 2.1.3.6 Hydrochemical analysis of groundwater by ion ratio comparison.

The analysis of groundwater quality by ion ratios comparison is derived from a simplistic mass balance approach to water quality data to determine type of water and hydrochemical process (3). There are 7 steps as follows.

1) If the pH of the water is less than about 5-6, be cautious in applying the following steps as acid waters may not be able to be interpreted in this way. The primary reason why low pH causes an interpretation problem is that at low pH values, significant quantities of clay minerals may dissolve and release anomalously high silica (and alumina) to the water.

2) Concentration of the element usually expressed in meq/L except silica in neutral is mmol/L.

3) Sum the cations and the anions separately, omitting silica. Their totals should be within about 5% of each other; if not, proceed with caution or do not continue.

4) Compare the chloride and sodium contents. The primary source of chloride was assumed that directly from halite dissolution or indirectly from ocean via rainfall. On the other hand, sodium can be derived from others sources (dissolution of albite-plagioclase, and ions exchange). Thus, if chloride higher than sodium, then there is either an analytical error or the composition of the water is derived from brines where reverse ion exchange or reverse softening has occurred (such as in oil field brines). In the latter case, one would expect the dissolved solid content of the water to be high- at least over 500 mg/l.

5) Compare the sulfate and calcium contents. The primary source of sulfate is assumed that directly from gypsum (or anhydrite) dissolution or from the acid-base neutralization of water by limestone or dolomite. If sulfate is higher than calcium, then the inference is that calcium has been removed from solution, most likely by the precipitation of calcite or ion exchange reactions.

6) Compare silica with non halite sodium ( $\text{Na}^+ + \text{K}^+ - \text{Cl}^-$ )

7) Compare silica with non halite sodium ( $\text{Na}^+ + \text{K}^+ - \text{Cl}^-$ )

In this study, step 6 and 7 were not performed since there were no  $\text{SiO}_2$  in analytical data. In short, the process of various elemental ratios comparison and source rocks deduction summary are shown as figure 2.9 and table 2.3

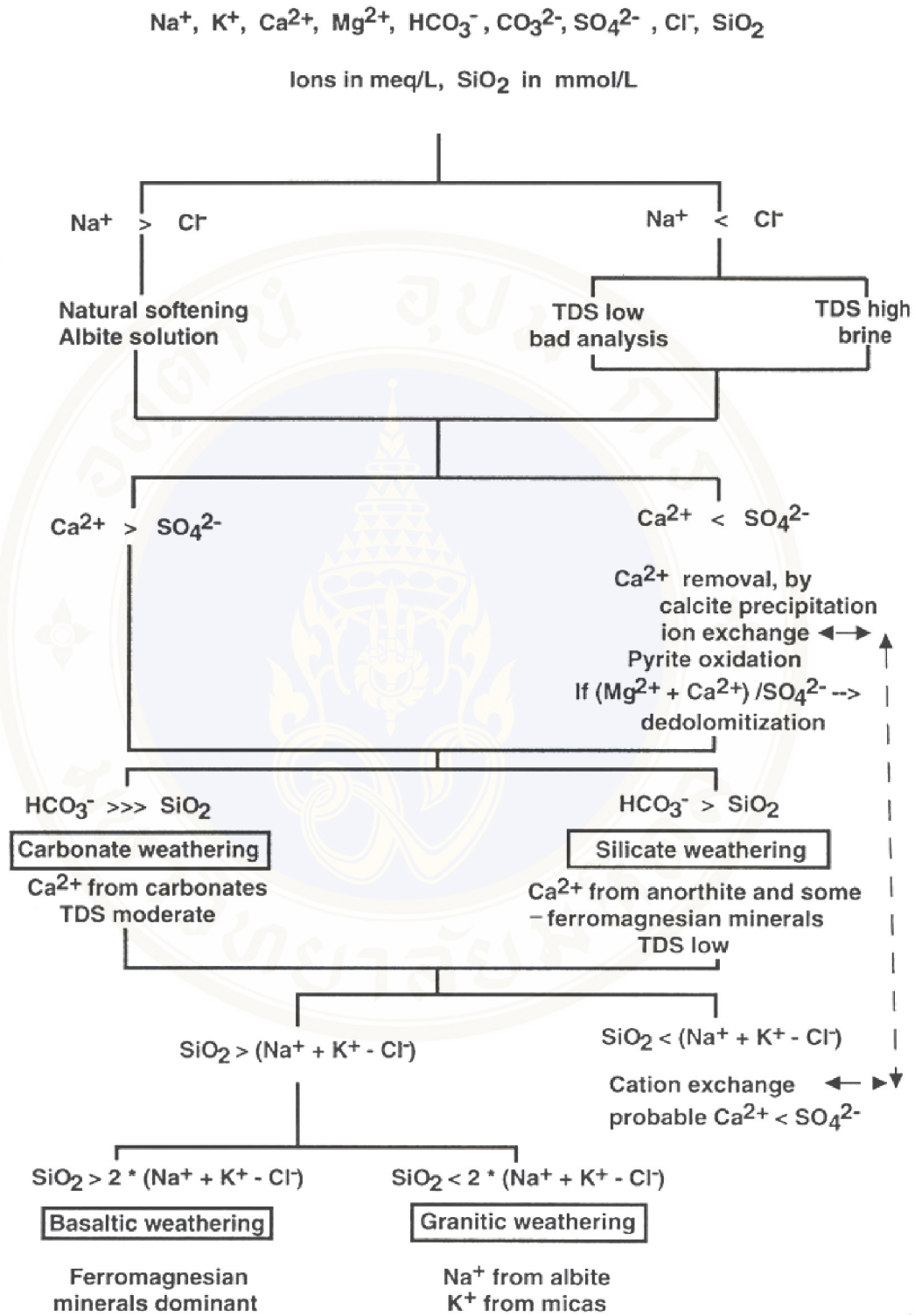


Figure 2-9: Weathering flow chart illustrating logic of water quality interpretation using simplified mass balance technique (3).

Table 2-3: Summary of the ratios and parameters used to determine both the source rock and chemical reactions (3).

Parameter	Value	Conclusion
$\text{SiO}_2$ (mmol/l)	> 0.5	Volcanic glass or hydrothermal waters possible
$\frac{\text{HCO}_3^-}{\text{SiO}_2}$	> 10 > 5 and < 10 < 5	Carbonate weathering Ambiguous Silicate weathering
$\frac{\text{SiO}_2}{\text{Na}^+ + \text{K}^+ - \text{Cl}^-}$	< 1 > 1 and < 2 > 2	Cation exchange Albite weathering Ferromagnesian minerals
$\frac{\text{Na}^+ + \text{K}^+ - \text{Cl}^-}{\text{Na}^+ + \text{K}^+ - \text{Cl}^- + \text{Ca}^{2+}}$	> 0.2 and < 0.8 < 0.2 and > 0.8	Plagioclase weathering possible Plagioclase weathering unlikely
$\frac{\text{Na}^+}{\text{Na}^+ + \text{Cl}^-}$	> 0.5 = 0 < 0.5 TDS > 500 < 0.5 TDS < 500 > 50 < 0.5 TDS < 50	Sodium source other than halite - albite ion exchange Halite solution Reverse softening, seawater Analysis error Rainwater
$\frac{\text{Mg}^{2+}}{\text{Ca}^{2+} + \text{Mg}^{2+}}$	$\frac{\text{HCO}_3^-}{\text{SiO}_2} > 10$ = 0.5 < 0.5 > 0.5  $\frac{\text{HCO}_3^-}{\text{SiO}_2} < 5$ > 0.5 < 0.5	Carbonate weathering Dolomite weathering Limestone-dolomite weathering Dolomite dissolution, calcite precipitation, or seawater Silicate weathering Ferromagnesian minerals Granitic weathering

Table 2-3: Summary of the ratios and parameters used to determine both the source rock and chemical reactions (3). (cont.)

Parameter	Value	Conclusion
$\frac{\text{Ca}^{2+}}{\text{Ca}^{2+} + \text{SO}_4^{2-}}$	= 0.5 < 0.5 pH < 5.5 < 0.5 neutral > 0.5	Gypsum dissolution Pyrite oxidation Calcium removal-ion exchange or calcite precipitation Calcium source other than gypsum carbonates or silicates
$\frac{\text{Ca}^{2+} + \text{Mg}^{2+}}{\text{SO}_4^{2-}}$	> 0.8 and < 1.2	Dedolomitization
TDS	> 500 < 500	Carbonate weathering or brine or seawater Silicate weathering
$\frac{\text{Cl}^-}{\text{Sum anions}}$	> 0.8 TDS > 500 > 0.8 TDS < 100 < 0.8	Seawater, or brine, or evaporates Rainwater Rock weathering
$\frac{\text{HCO}_3^-}{\text{Sum anions}}$	> 0.8 < 0.8 sulfate high < 0.8 sulfate low	Silicate or carbonate weathering Gypsum dissolution Seawater or brine
Langelier index	Positive 0 Negative	Oversaturated with respect to calcite Saturated with respect to calcite Undersaturated with respect to calcite
Conclusion	Aquifer Mineralogy	Saturated with respect to calcite
Conclusion	Reactions	Undersaturated with respect to calcite

**Remark:** Units are usually in meq/L except SiO<sub>2</sub> is in mmol/L

## 2.2 Geography and Geomorphology

### 2.2.1 Meteorology

1) **Temperature** Influenced by the southwest and northeast monsoons, the area consists of three seasons namely dry season from May to October, cold season from November to mid-February and hot season from mid-February to early May. The basin is also influenced by occasional tropical depression. Basing on the temperature data from 1975-2005 collected from the Thai Meteorological Department's six weather stations in the Tha Chin-Mae Klong Basin and nearby areas namely Bangkok, Don Muang, Suphan Buri, Lop Buri, Kanchanaburi and Phetchaburi, the average annual and monthly values of significant weather variables of the two basins are shown in the table below.

Table 2-4: Average annual and monthly values of the Maeklong-Thachin Basin

Weather factors	Average monthly ranges		Annual average	
	Tha Chin	Mae Klong	Tha Chin	Mea Klong
Temperature, (°C)	24.9-30.5	24.9-31.2	28.3	28.0
Relative Humidity (%)	59.0-82.0	60.0-82.0	73.3	73.0
Wind Speed (Knot)	1.0-6.5	1.1-5.4	3.2	2.3
Cloud cover (0-10)	2.5-8.7	3.0-8.7	6.3	6.0
Pan evaporation (mm.)	121.2-195.0	122.6-215.8	1,822.3	1,862.5

2) **Evapotranspiration (ETp)** The evaporation is measured by the Penman-Monteith method based on temperature data from six weather stations namely Bangkok, Don Muang, Suphan Buri, Lop Buri, Kanchanaburi and Phetchaburi. The lowest rate of 110.58 mm is in September while the highest of 183.57 mm is in March. The average annual evaporation is 139.88 mm, and the overall annual rate is 1,678.61 mm.

3) **Evaporation (E)** The evaporation is rather low during rainy season and high during hot season. The analysis during the 30-year period (from 1975-2003) and the collection of evaporation data from four weather stations show

that the maximum rate is in March (128.67 mm), the minimum in September (77.41 mm), the average annual rate is 98.07 mm and the overall annual evaporation is 1,176.83 mm.

#### **4) Rainfall**

According to data on the average annual and monthly rainfall at 76 stations from 1976-2006, the variation is between 675 and 1,232 mm, with high amount of rainfall in the coastal areas of Samut Sakhon Province. In addition, after the testing of reliability of the average monthly rainfall data of representative stations and the evaluation of the average annual rainfall in the project area with Thiessen weight factor, the average annual rainfall in the project area is 965.85 mm, with the highest rainfall of 222.68 mm in September and the lowest of 3.96 mm in January.

### **2.2.2 Topography**

Based on hydrogeological significance, the topography of the Tha Chin-Mae Klong Basin can be categorized into four types. (Figure 2-10).

**1) Flood Plain and Tidal Flat** Ranging in elevation from 0-15 m above MSL, the areas are floodplain deposits consisting of fluvial delta, delta brackish sediments and delta marine sediments.

**2) Low Terrace** Ranging in elevation from 5-50 m above MSL, the area is the deposit of clay, silt, sand and gravel from the ancient time which have transformed into gravel and laterite. In addition to these sediments, the area also consists of old Alluvial Fan of Don Chedi and young Alluvial Fan of Kamphaeng Saen or Mae Klong. Generally, those alluvial fans consist of gravel, sand and fine sand, which have transformed into laterite on the surface, blocking the underlying layer of laterite soil.

**3) High Terrace** Ranging in elevation from 50-150 m above MSL, the area is terrace deposits consisting of thick laterite that blocks the underlying layer of sand, silt, and silt and gravel.

**4) Mountain Bed Rocks** Ranging in elevation of over 150 m above MSL, the area is the boundary of the Tha Chin-Mae Klong Basin.

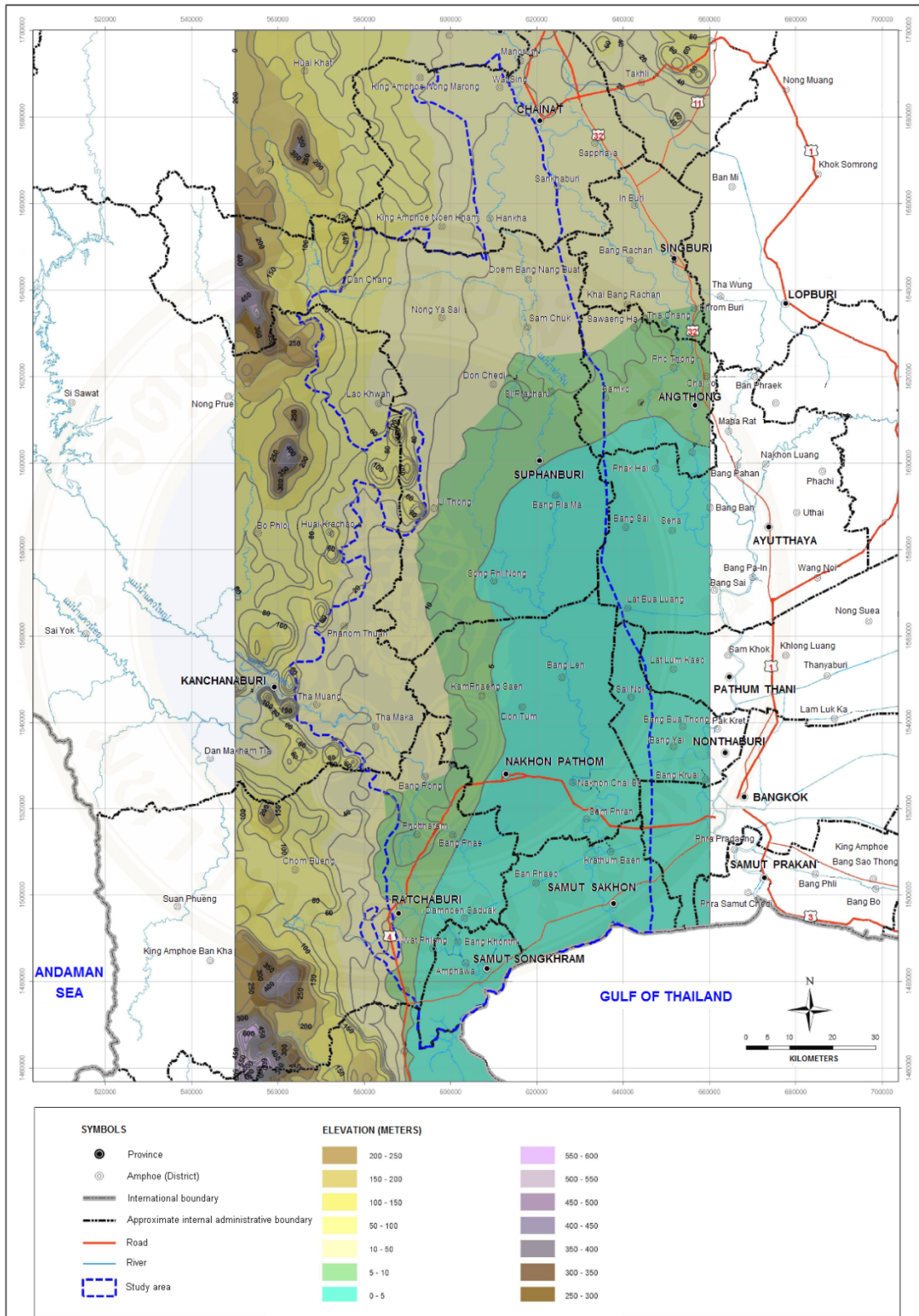


Figure 2-10: Topographic map of the study area (1)

### 2.2.3 Geomorphology

According to Thiramongkol (1983) and Charupingsakul (1990), the landforms, the sedimentation and the sedimentation period of the lower central plains as the deposits of fluvial and marine quaternary sediments are categorized into several kinds as follows: (Figure 2-11)

**1) Structural Terraces (Late Tertiary or Miocene-Pleistocene)** Ranging in elevation from 30-120 m above MSL, the landform consists of decayed round limestone and loamy marl. In deeper levels, Fresh limestone with thickness ranges of 10-100 m can be found.

**2) Peneplain (Pilo-pleistocene)** Ranging in elevation from 10-100 m above MSL, the height of the alluvium is approximately 30 m. Most area of the peneplain is covered with laterite cap with thickness ranges of 3-4 m (for laterite transformed from metamorphic rock) or 4-5 m (for laterite transformed from weathered granite). The sediment consists mostly of quartz fraction and decayed feldspar, which will gradually transform into clay and laterite.

**3) High Terrace (Pliocene-Early Pleistocene)** Ranging in elevation from 30-150 m above MSL, the western terrace is larger than the eastern one. With the height of approximately 30 m, the humps slope towards the heart of the plains with the degree of 10. The sedimentation consists mostly of rather thick laterite surface that covers layers of sand, silty gravel and laterite.

**4) Middle Terrace (Middle Pleistocene)** Found in both sides of the plains, the eastern terrace lies along with structural terrace limestone and peneplain. The terrace consists mostly of clay, silt, sand and gravel covered by laterite surface of 1 m. thick, which consists of laterite fractions of 10-30 cm and ancient clay or sandy clay layers. The sedimentation of the terrace is of Middle Pleistocene period.

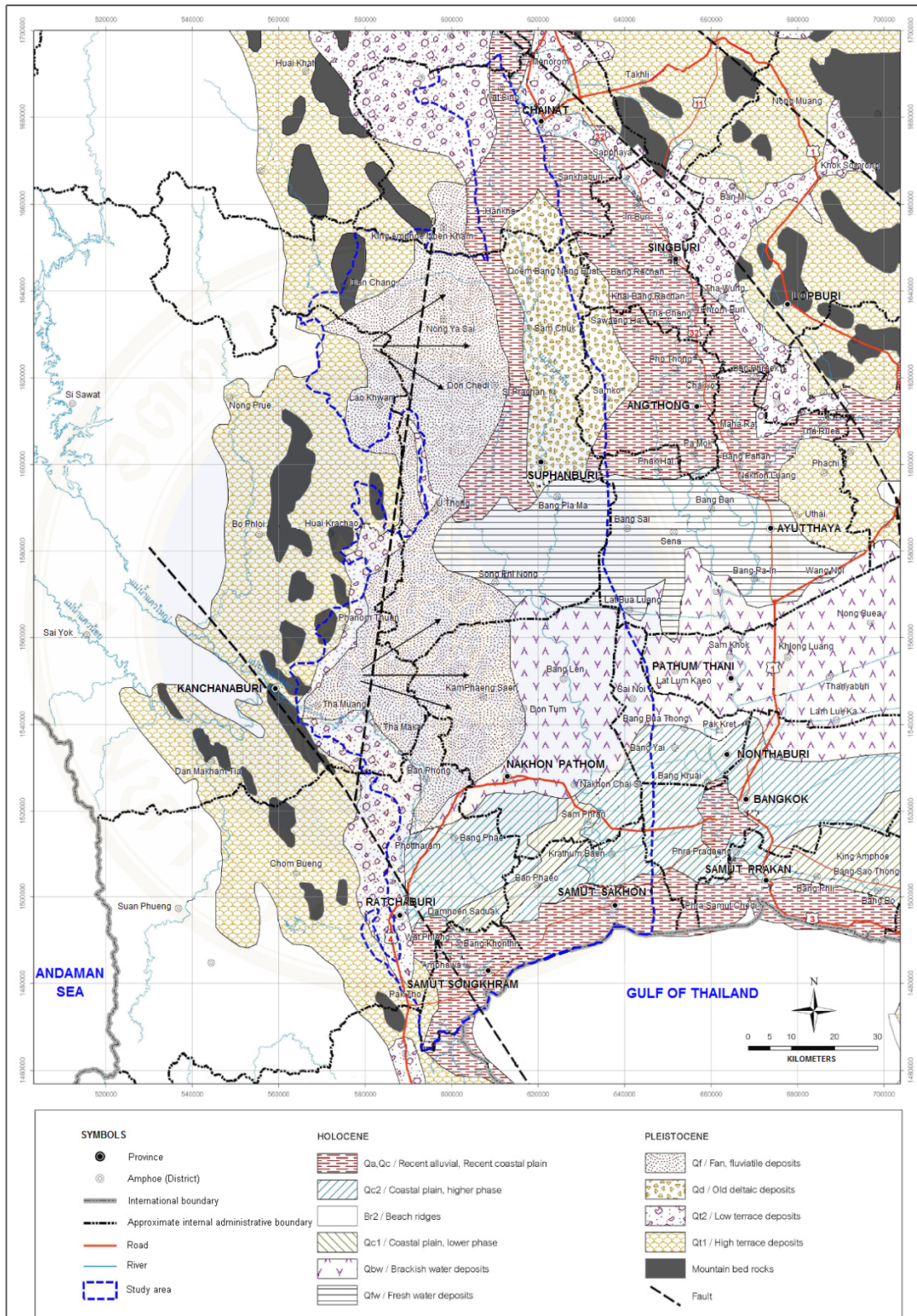


Figure 2-11: Geomorphological Map of the Study Area (1)

**5) Old Alluvial Fan (Middle Pleistocene)** Found in the western side, the landform includes Nong Chang Fan and Don Chedi Fan. Located in the west of Uthai Thani and Chai Nat Provinces, Nong Chang Fan ranges in elevation from 20-100 m MSL. Meanwhile, Don Chedi Fan ranges in elevation from 5-45 m above MSL. The topography of the landform is slightly undulating formed by the erosion of water channel. The sedimentation consists of the alternated clay, silt, sand and gravel; the upper layer consists mostly of fine and coarse sands that cover thin laterite and thick clay layers. The sedimentation of the fan is of Middle Pleistocene period.

**6) Young Alluvial Fan (Middle-Late Pleistocene)** Ranging in elevation from 5-20 m above MSL, the landform is slightly undulating. It is found that the thickness of the fan is more than 80 m. The fan consists mostly of the alternated gravel and sand, silt and silt, sand and clay layer on the top, which is covered by laterite. The sedimentation of the fan is of Middle-Late Pleistocene period.

**7) Delta of Fluvial Sediments (Late Pleistocene)** Ranging in elevation from 6-18 m above MSL, the landform slopes from the north to the south for approximately 3 degree. Found in northern part of Chai Nat Province and southwards, the delta consists of sediments of silty clay and sandy loam layers with thickness ranges of 2-4 m. The sediments have passed weathering process for a long time and have transformed into laterite soil. Calcareous modules bed with a thickness of approximately 2 m can be commonly found in the lower part of the delta; it is assumed that the bed has been formed for a long time under tropical temperature of Late Pleistocene period.

**8) Delta of Brackish Sediments (Late Pleistocene)** Ranging in elevation from 4-12 m above MSL, the delta has been formed in the same period of the fluvial delta. Covering areas in the north of Ang Thong and Ayutthaya Provinces, the delta is about 3-meter high and is sloping from the north to the south for approximately 3 degree. The delta consists of sediments of black-gray and black clay that have passed weathering process for a long time that yellow-brown dots can be found. Also commonly found in the sediment are manganese and iron gravels, Jarosite formed in brackish water. Found in the area of Ayutthaya and Bangkok, the deposits—or Stiff Clay—are currently supporting the Bangkok Soft Clay.

### 9) **Barrier Beach/Tidal Flat Marine Clay (Holocene)**

Ranging in elevation from 3-6 m above MSL, barrier beach, the upper sand sediment of stiff clay, can be found in the boundaries between Nakhon Pathom, Samut Sakhon and Samut Songkhram Provinces. The landform consists mostly of white and reddish brown silt and sand layers with stain and Jarosite dots, shell and wood fragments and clay layer. Meanwhile, ranging in elevation from 2-3 m MSL, tidal flat marine clay consists mostly of silty clay with stain, manganese and Jarosite dots transformed by the sea water. Both landforms are of Holocene period.

**10) Floodplain Deposits (Late Holocene)** Ranging in width from 10-15 km, the landform can be found along with major rivers namely the Chao Phraya, Noi, Tha Chin, Bang Pakong and Mae Klong Rivers. The deposits consist of natural levee and back swamp of 1-meter sand and fine sand layers, which can be as thick as 3 m. Aged in Late Holocene period, the landform does not contain any iron or manganese stains.

#### 2.2.4 Geology of study area(22)

Generally, the geology in the area consists of hard rock of different periods found mostly in the western boundaries of the lower central basin, which are the origin of deposits in the basin; and quaternary deposits which consists of loamy and partly-hard deposits of gravel, sand, silt and clay, which are formed by natural processes of erosion, transportation and basin deposition: see Figure 2-12.

**1) Hard Rocks** Ranging from the oldest period of Precambrian period to the earliest period of Jurassic period, the rocks found in the boundaries of the Tha Chin-Mae Klong Basin are **Gneiss (PЄ)** dated in Precambrian Period and is found in the north of Kanchanaburi Province, in the form of layer; **Marble (ЄO)** dated between Cambrian and Ordovician periods and is found in the north of Dan Chang District and the west of U-Thong District in Suphan Buri Province, in the form of white marble and quartz-mica schist layers; **Thung Song limestone (O)** dated in Ordovician period and is found in the west of Chai Nat and Suphan Buri Provinces, in the form of dirt-gray and pink marble and argillaceous limestone with dolomite and fossil components as well as mudstone layer;

**Metamorphic Rock (SD)** dated between Silurian and Devonian periods and is found in vast fields or single mountains in the west of Chai Nat, Sing Buri, Suphan Buri and Kanchanaburi Provinces, in the form of carbon and quartz phyllite; **Sedimentary Rock (CP<sub>K-1</sub>, CP<sub>K-2</sub>, both categorized in the Kaeng Krachan Formation or CP<sub>K</sub>)** dated between Carboniferous and Permian periods and is found in the west of Ratchaburi Province, in the forms of Khao Phra Formation (CP<sub>K-1</sub>, consisting of shale, sandstone and dark-grey gravel shale) and Khao Chao Formation (CP<sub>K-2</sub>, consisting of mudstone, tuffaceous sandstone and rhyolitic tuff); **Sedimentary Rock (Pr, Ps)** dated in Permian period and is found in the west of Kanchanaburi and Ratchaburi Provinces, in the form of long mountain ranges and limestone hill knots of Ratchaburi Formation (Pr, consisting of limestone, dolomitic limestone and chert with fossil components); **Sandstone (T)** dated in Jurassic period and is found in the northwest-southeast mountain ranges in the west of Ratchaburi Province, in the form of Umphang Formation (Ju, consisting of mudstone, silt stone, sandstone and limestone with bivalves fossil).

**2) Quaternary Deposits** Found in basin boundaries and low plains (Figure 2-12), the geology can be categorized into Colluviums (**Qc, Plio-Ple**) dated between late Tertiary and early Pleistocene periods and is found in the wide range in Suphan Buri, Kanchanaburi and Ratchaburi Provinces, in the form of laterite and colluvium sediment layers and decayed granite and metamorphic rock zones; **High Terrace Deposits (Qt or Qht, Plio-E-Ple)** dated between Pliocene and Early Pleistocene periods and are found in the west of Chai Nat and Suphan Buri Provinces, consisting of gravel layer that tops sand and pebbly silt layers; **Middle Terrace Deposits (Qt<sub>2</sub>, M-Ple)** dated in Middle Pleistocene period are found in the west of Chai Nat and Suphan Buri provinces, consisting of gravel and sand layers; **Old Alluvial Fan (Qf<sub>1</sub>, M-Ple) of Don Chedi Fan** dated in Middle Pleistocene period and is found in the form of coarsening upward sequence of hard rock-sand-thick sand-clay and silt layers formed by branches of Suphan Buri River in Pleistocene periods, which are now existing in the form of Krasiao and Chara Streams; **Young Alluvial Fan (Qf<sub>2</sub>, M-L-Ple) or Kamphaeng Saen or Mea Klong Fan** dated in Middle-Late Pleistocene period and covers areas in the west of Song Phi Nong District in Suphan Buri Province and Kamphaeng Saen District in Nakhon Pathom Province and the east of Mueang and

Tha Maka Districts in Kanchanaburi Province, consisting mostly of gravel-sand-silt layers topped by laterite layer of more than 80-meter thick; **Delta of Fluvial Sediments (Q<sub>df</sub>, L-Ple)** dated in the Late Pleistocene period and is covering a wide area from the north of the City of Chai Nat to the southern boundary of Ang Thong Province, consisting of clayish silt and sandy loam layers with brown and laterite dots and thickness range of 2-4 m and is supported by bed of calcareous with thickness of 2 m; **Delta of Brackish Sediments (Q<sub>db</sub>, L-Ple)** dated in the Late Pleistocene periods and is covering a wide area from the north of Ayutthaya Province southwards to parts of Suphan Buri, Nakhon Pathom and Ratchaburi Provinces until the mouth of the Gulf of Thailand, consisting of black grayish black clay and Jarosite formed in brackish water under tropical temperature; **Floodplain Deposits (Q<sub>a</sub>)** dated in Holocene periods and is found in a wide area along with major river channels in Tha Chin-Mae Klong Basin, consisting of natural levees and deposits of sand and silt with thickness ranges of 1-3 m and with almost no iron and black manganese stain; **Barrier Beach** dated in Holocene period and consists of sand and silt layers with jarosite and iron stain spots, shell and wood fragments as well as white-reddish brown clay layers in some areas; **Tidal Flat Marine Clay (Q<sub>tf</sub>, Holo)** dated in Holocene period and consists of silty clay layers with rust dots, black gray-black manganese and Jarosite disseminated.

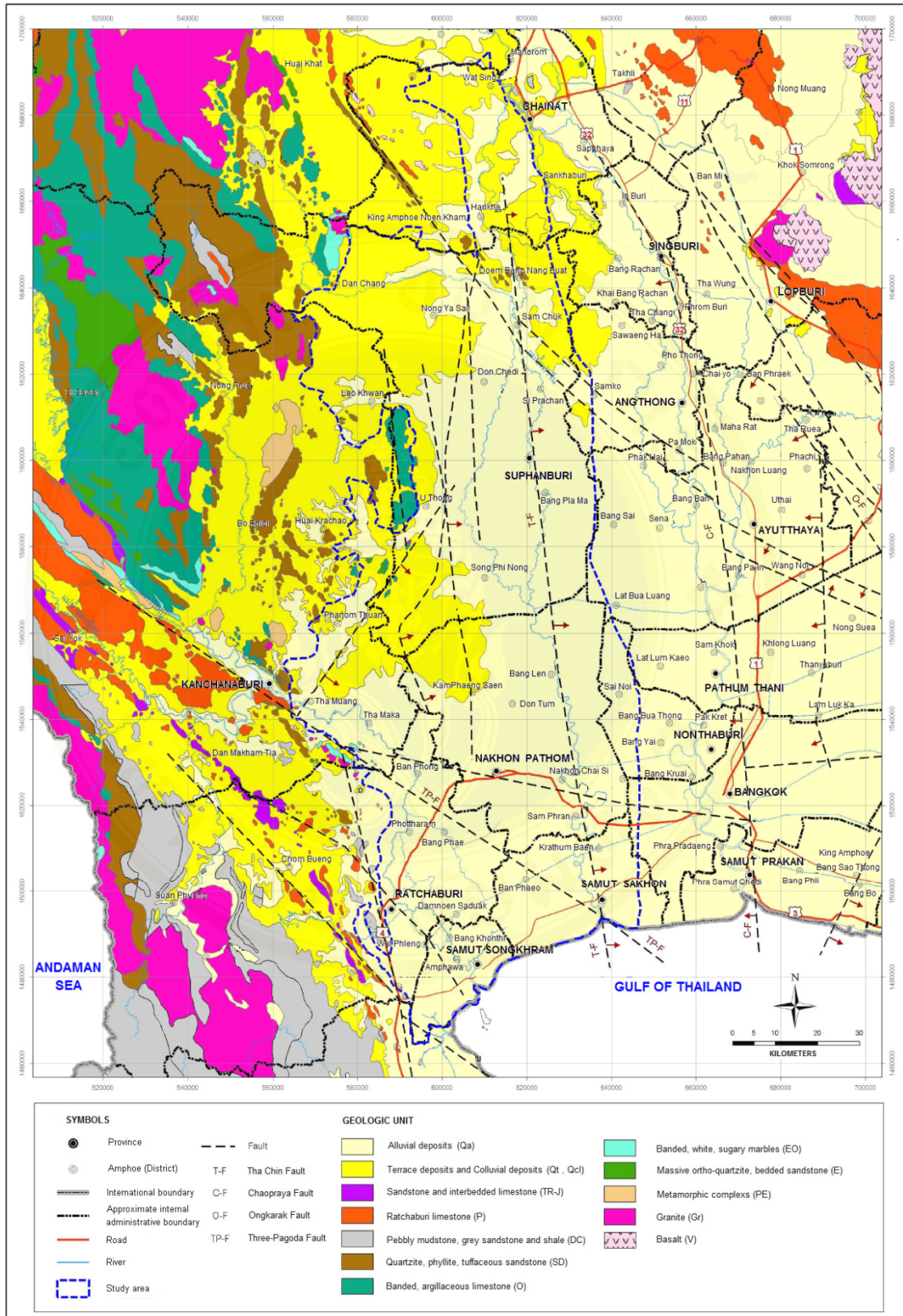


Figure 2-12: Geologic map of the study area, modified from the Department of Mineral Resources (22)

### 2.2.5 Hydrogeology(1)

1) **The Tha Chin Basin Area** Hydrogeological characteristics of loamy aquifers in each province in the area can be summarized as follows: (Figure 2-13)

**Chai Nat Province** consists of 1) alluvial aquifers (Qa) spreading along both sides of the Tha Chin River, with average depth of 20-60 m (can be as deep as 80 m in some parts), 10-150 cu m/h yield and good water quality, and 2) low terrace aquifers (Qlt) spreading vertically along the Qfd aquifers in Wat Sing, Nong Mamong and Hankha Districts on the west of Tha Chin River, with average depth of 20-40 m, 1-50 cu m/h yield and good water quality.

**Suphan Buri Province** (23) consists of 1) alluvial aquifer (Qa) spreading in Doem Bang Nang Buat, Sam Chuk, Si Prachan, U Thong and some parts of Mueang Districts in Suphan Buri Province, with average depth of 20-60 m (can be as deep as 80 m in some parts), 10-30 cu m/h yield (up to 50 in some areas) and good water quality, although brackish water can still be found particularly in the south of Mueang and U Thong Districts, 2) old alluvial fan (Qaf1) or Don Chedi Fan, found in Dan Chang and Nong Ya Sai Districts, with average depth of 10-50 m, not more than 5 cu m/h yield and good water quality, and 3) low terrace (Qlt) spreading in various areas such as in Dan Chang District, north of Suphan Buri Province, with average depth of 100-130 m, not more than 5 cu m/h yield and good water quality. In addition, two Qlt aquifers found in Mueang, Bang Pla Ma and Song Phi Nong Districts of Suphan Buri Province are with average depths of 70-120 m (equivalent to Phra Pa Daeng Aquifer) and 130-150 m (equivalent to Nakhon Luang Aquifer), and both aquifers are of more than 50 cu m/h yield and good-very good water qualities

**Nakhon Pathom Province** consists of 1) alluvial aquifer (Qa) with average depths of 0-20 m for sea clay aquifer and 20-60 m for groundwater layer of more than 100 cu m/h yield but of brackish-salt water quality and is equivalent to Bangkok Aquifer, 2) young alluvial fan (Qaf2) or Kamphaeng Saen Fan, found in Kamphaeng Saen, Don Tum and Bang Len Districts, consisting of sand and sandy clay layers with average depth of 60-80 m, 10-50 cu m/h yield, brackish water quality due to the influence of saltwater layer on the top and is equivalent to Phra Prdaeng Aquifer, 3) low terrace (Qlt2) with average depth of 60-120 m, good fresh water quality (although the water can be brackish in some area) and is equivalent to Phra

Padaeng Aquifer, 4) low terrace (Qlt1) with average depth of 120-220 m, good fresh water quality and is equivalent to Nakhon Luang Aquifer, and 5) high terrace (Qht) spreading in almost all districts in Nakhon Pathom Province with average depth of 220-300 m and is equivalent to Nonthaburi Aquifer, although there is still not so many development of groundwater resources in the area.

**Samut Sakhon Province** consists of 1) alluvial aquifer (Qa) with average depth of 30-50 m (can be as deep as 60 m in some parts), more than 100 cu m/h yield, salt water quality and is equivalent to Bangkok Aquifer, 2) low terrace (Qlt2) with average depth of 70-90 m, 50 cu m/h yield and brackish-salt water quality (although freshwater can be found in some area) and is equivalent to Phra Padaeng Aquifer, 3) middle terrace (Qlt1) with average depth of 140-150 m, more than 100 cu m/h yield, fresh water quality in the middle part and brackish in the west and the east, and is equivalent to Nakhon Luang Aquifer 4) high terrace (Qht) with average depth of 150-200 m, 150-300 cu m/h yield, fresh water quality (although brackish can be found in the eastern part) and is equivalent to Nonthaburi Aquifer, 5) semi-consolidated aquifer (E-Ple?) with average depth of 200-250 m, low yield, fresh water quality and is equivalent to Sam Khok Aquifer, 6) semi-consolidated aquifer (E-Ple?) with average depth of 275-350 m, low yield, brackish-salt water quality and is equivalent to Phayathai Aquifer, 7) semi-consolidated aquifer (E-Ple?) with average depth of 350-400 m, 20-30 cu m/hr yield, fresh water quality and is equivalent to Thon Buri Aquifer, and 8) consolidated and semi-consolidated aquifers (E-Ple?) with average depth of 420->500 m, 20-30 cu m/h yield, fresh water quality and is equivalent to Pak Nam Aquifer. In addition, the aquifers in this province are topped by sea clay and the development of underground resources has been done in all eight aquifers.

**2) The Mae Klong Basin Area** Previous studies show that there are at least four unconsolidated aquifers supporting the eastern side of the Mae Klong Basin. These aquifers support the whole basin area and slope down from the boundary to the heart of the basin along with the Mae Klong River, except for the lower eastern edges, which are the boundary of Samut Songkhram and Ratchaburi Provinces, slope towards the east. The aquifers top the consolidated stone layer on the west of the basin while connecting the aquifers in the Tha Chin Basin on the east and the south; they slope to the southeast, which indicates a groundwater divide. The

eastern part of the basin has high groundwater potential and is significant for the assessment of groundwater, while the western part has lower groundwater potential and is less important for the assessment. In addition, the topography of the western part is mostly ledge hills and single mountains supported by thin unconsolidated aquifers and shallow consolidated aquifers.

The aquifers in the area can be categorized into five types (24).

**(1) Alluvial Aquifer (Qfd)** consists of the deposits of flood plains in the current areas of the Mae Klong River. The aquifer expands in the narrow channel along with the river from the City of Kanchanaburi to the City of Ratchaburi, with average thickness of 10-20 m and is equivalent to Bangkok Aquifer.

**(2) Young Alluvial Fan Aquifer (Qf2)** found on the northeast of the basin in Kamphaeng Saen District, Nakhon Pathom Province, the aquifer underlie the alluvial aquifer and is overlain by brackish clay, with average thickness of 90 m, clear coarsening upward structure and depositional sequence and is equivalent to Bangkok Aquifer

**(3) Old Alluvial Fan Aquifer (Qf1)** underlies the Qf2 aquifer. It does not appear on the surface level; with average thickness of 70 m. The aquifer is equivalent to Phra Padaeng Aquifer

**(4) Middle Terrace Aquifer (Qt2)** underlies the Qfd aquifer. It lies on a narrow channel of approximately 5-km wide on the west of the basin, next to the flood plain and covers the boundary of the high ledge; with average thickness of 100 m. The aquifer is equivalent to Nakhon Luang Aquifer

**(5) High Terrace Aquifer (Qt1)** underlies the Qt2 aquifer. It is found in the west of the basin; with average thickness of more than 100 m. The aquifer in single mountain areas can be thinner as the supporting consolidated rock in the shallow level, and is equivalent to Nonthaburi Aquifer

### **3) Aquifer Classification**

In this study order to classify the aquifers as well as to measure their depth, thickness and positions, hydrogeological cross section of 12 lines have been made in both east-west and north-south directions.

At the depth of not exceeding 350 m, the aquifers can be classified into four aquifers namely I, II, III, and IV. Aquifers V and VI, which are in the depth of exceeding 350 m, have limited numbers of groundwater. Aquifer layers I – IV have been compared with the existing aquifers in the Chao Phraya delta as categorized by the Department of Groundwater Resources, which can be summarized as follows(1):

1. Aquifer I is comparable to Bangkok Aquifer (BK)
2. Aquifer II is comparable to Phra Pradaeng Aquifer (PD)
3. Aquifer III is comparable to Nakhon Luang Aquifer (NL)
4. Aquifer IV is comparable to Nonthaburi Aquifer (NB)
5. Aquifer V is the layer more deeper than Nonthaburi Aquifer

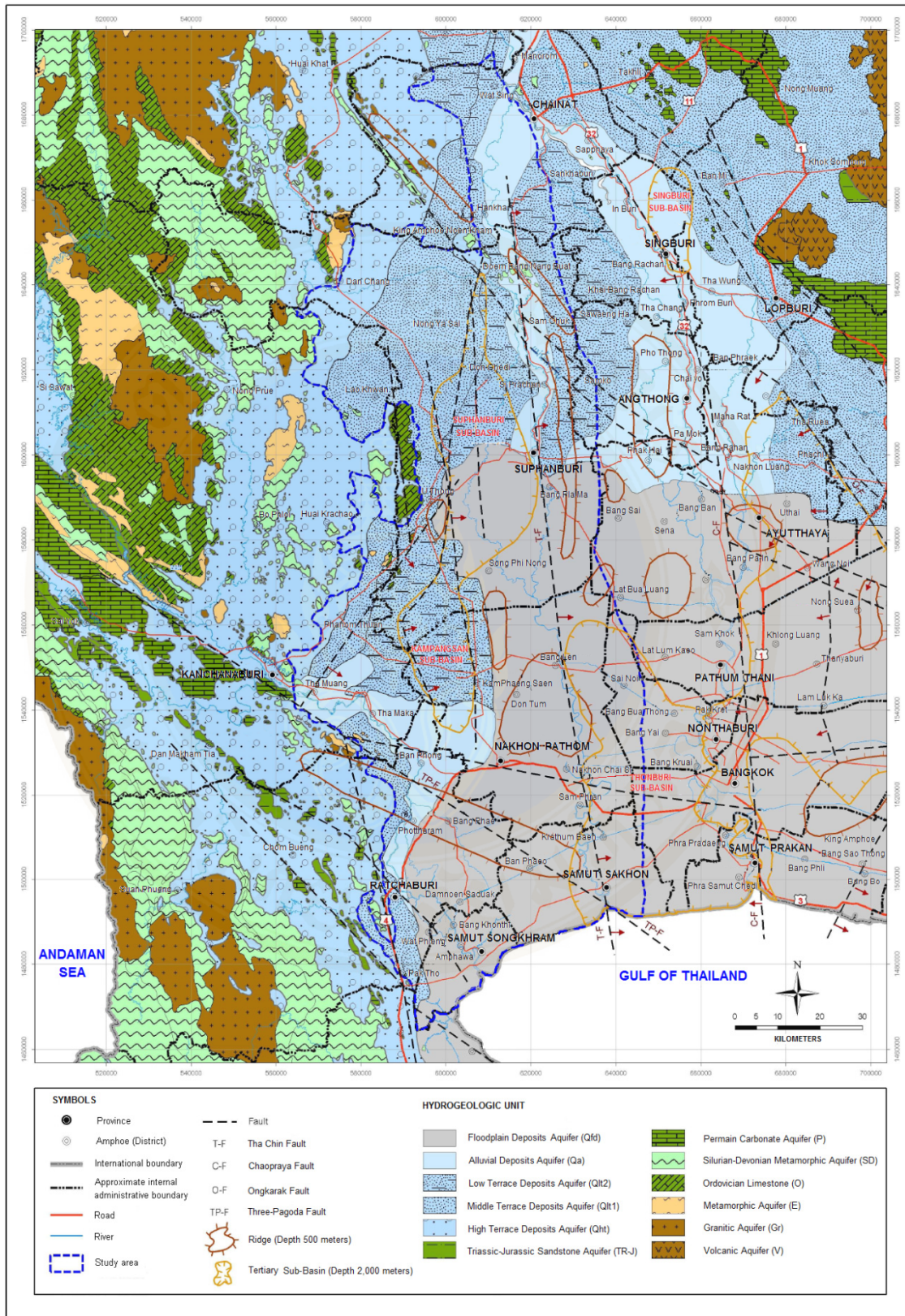


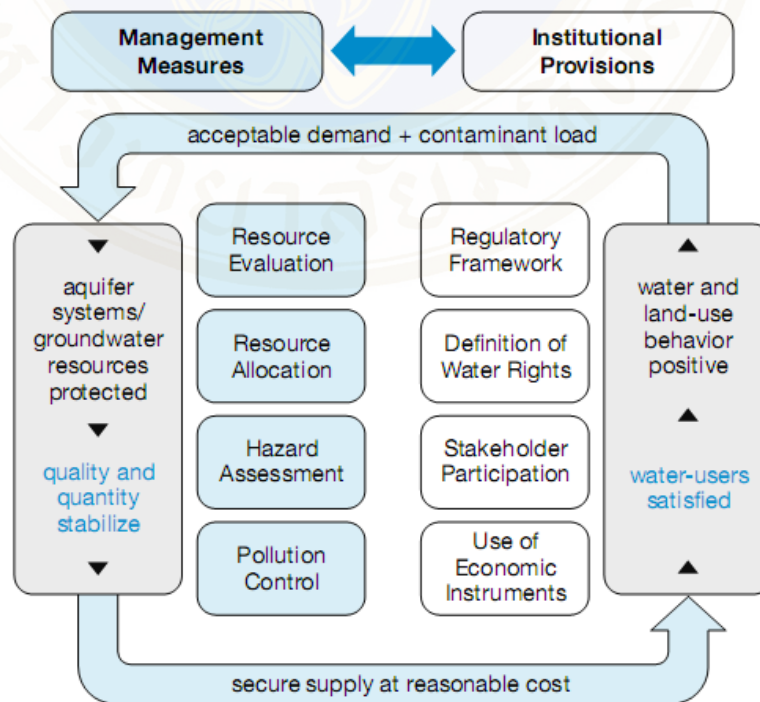
Figure 2-13: Hydrogeological Map of the Study Area (1)

### 2.3 Principle of groundwater management

Groundwater resource management is the maintenance of groundwater balance in terms of quantity and quality. Groundwater usage that not considers principle management is groundwater usage that not keeps natural balance. It results in an effect on groundwater such as continuous decrease of groundwater level, invasion of salt water and subsiding of land etc. The maintenance of groundwater balance is practicable by using resource systematically; management of groundwater user (demand-side management) and management of groundwater resource (supply-side management).

Principle of groundwater management in universal standard can be divided into 2 parts (25) as follows: (Figure 2-14)

- 1) Management measure; e.g. Resource evaluation, Resource allocation, Hazard assessment, and Pollution control
- 2) Institutional provisions will go together with management measure; e.g. regulatory framework, definition of water rights, stakeholder participation, and economic instruments.



Sources: (25)

Figure 2-14: Principle of groundwater management in universal

Groundwater resource management should be operated regarding the necessity and status of suitable groundwater development (25).

## 2.4 The Relevant Research

**Srisuk** (26) has evaluated potential source of groundwater in Konkaen province and categorized the hydrogeology of Konkaen Basin into three systems including Huai Yai, Chonnabot and Hin Tank by learning flow system and hydro-chemistry process of groundwater flow path by analyzing contour map, head, and main flow direction of groundwater. The water chemistry derives by plotting ion in the Piper diagram and personalizing chemical by format (18), then recognizing groundwater flow system, selecting path flow of groundwater flow system to analyze hydrochemical processes of groundwater by creating graphs to compare and analyze the elements and the ratio of ions of rain water and groundwater from recharge areas to discharge area including calculating saturated index value. The study found that total dissolve solid varies according to ion quantity and change according to the path of groundwater flow. Major ions in recharge areas has the similar pattern i.e.  $\text{Ca}^{2+} \text{Na}^+ > \text{Mg}^{2+} > \text{K}^+$  and  $\text{HCO}_3^- > \text{Cl}^- > \text{SO}_4^{2-}$ , while in discharge area,  $\text{Na}^+ > \text{Ca}^{2+} > \text{Mg}^{2+} > \text{K}^+$  and  $\text{Cl}^- > \text{SO}_4^{2-} > \text{HCO}_3^-$  and unsaturated with gypsum mineral, anhydrite and halite. Analyzed results of groundwater flow system and hydrochemical process (27) are as follows:

**Huai Yai Flow system** has 67 percent area as discharge areas which underlain by sedimentary rock of Khorat group. Main aquifer contains sandstone, siltstone and shale of Phu Phan category, mudstone interbedded with siltstone and sandstone of Mahasarakam category, and sand sediment and gravel. Flow direction starts at recharge areas and flows into watershed area at north, west and south portions. Regional flow in the system is controlled by topography and fracture. Recharge areas have chemical types of water as Ca-HCO<sub>3</sub> and Ca-Na-Cl with an average of TDS less than 1000 mg/L in more than 60% of the flow system area. The major hydrochemical processes of Huai Yai flow system are the dissolution of calcite, dolomite and silica minerals in recharge areas, the dissolution of evaporated minerals; carnallite, sylvite,

halite, anhydrite and gypsum, the reverse process of ion exchange, the process of sulfate reduction, and the combination of groundwater in discharge area.

**Chonnabot Flow System** has 64 percent area as recharge areas. Main aquifer contains Khokkruad and Mahasarakam aquifer. Flow direction has range from highest area through formation of rock layer and plunge line of geosynclines. Chonnabot flow system has chemical form of water as Ca-HCO<sub>3</sub> and Ca-HCO<sub>3</sub>-Cl that was found at recharge areas. The average TDS is less than 700 mg/L. The major hydrochemical processes are the dissolution of calcite and silica minerals in recharge areas, the dissolution of evaporated minerals, and the diffusion of halite in Mahasarakam group.

**Hin Tank Flow System** is underlain by Phu Thok aquifer. It contains orange-red and purple-red fine to medium fine sandstone, well size, very thick formation, cross-bedding appearance interbedded with siltstone and mudstone. Many of fracture zones have been found from artesian well bored at Ban Nong Krai Noon. The bottom of Phu Thok category is underlain by rock salt of the Mahasarakam category at the average depth of 200-250 m. Scope of Hin Tank Flow System can be divided by 4 faults which are mostly normal and horizontal fault found along streams and major rivers such as Pong river, Chi river, Huai Than and Huai Kud Cheuk located in west, north, east and south direction, respectively. Regional flow in the system is controlled by topography and fracture. Recharge areas have chemical types of water as Ca-HCO<sub>3</sub> while discharge areas contain chemical types of water as Na-Cl with an average TDS higher than 500 mg/L. The major hydrochemical processes compose of the dissolution of calcite, dolomite and silica minerals in recharge areas, the dissolution of evaporated minerals, and the diffusion of halite in Mahasarakam group. The excess TDS of 1,100 mg/L crystallize calcite.

**Anchalee, Rungruang and Arunee** (28) have studied groundwater flow system in Amphoe Kham Thale Sor, Nakhon Ratchasima province to learn groundwater flow system in the study area, hydrochemical facies, factors that control and affect spread brine in the area, and groundwater flow model. The field survey includes hydrogeology, water level and EC measurement, and groundwater sampling to analyze chemical facies. In addition, result of applying Visual MODFLOW program to analyze groundwater flow system. According to the study, the study area is

underlain by four hydrogeologic units: unit of sedimentary rock, unit of shale rock, unit of clay rock and rock salt, and siltstone and carbonate conglomerate. The distribution of hydrochemical facies of groundwater contained eight facies such as calcium-bicarbonate, calcium-bicarbonate-chloride, sodium-chloride, calcium chloride, sodium-bicarbonate-chloride, calcium-sodium-chloride, calcium-sodium-bicarbonate-chloride, and sodium-bicarbonate. Results of groundwater flow system classification and chemical types of groundwater are as follows:

### **1) Local flow system**

Local flow system is the groundwater flow system in shallow zone that affects change of flow pattern, EC, and groundwater level in the study area. Local flow system in this study is in the depth range of 20-50 meters with distance of flow 2-15 kilometers. The system includes:

1.1) None Ka local flow system: the approximate depth of flow system is 35-44 meters. The approximate flow distance is 5-10 kilometers. Chemical type changes from  $\text{Ca-HCO}_3 \rightarrow \text{Ca-HCO}_3\text{-Cl}$ .

1.2) Mai Don Tiew local flow system: the approximate depth of flow system is 30-37 meters. The approximate flow distance is 2-5 kilometers. Chemical type changes from  $\text{Ca-Cl}$ .

1.3) Kum Phaya local flow system: the approximate depth of flow system is 20-30 meters. The approximate flow distance is 7-10 kilometers. Chemical type changes from  $\text{Ca-HCO}_3 \rightarrow \text{Na-HCO}_3\text{-Cl}$ .

1.4) Nong Nam Sai local flow system: the approximate depth of flow system is 50-60 meters. The approximate flow distance is 10-15 kilometers. Chemical type changes from  $\text{Na-HCO}_3\text{-Cl} \rightarrow \text{Na-Cl}$ .

1.5) Sa Kud local flow system: the approximate depth of flow system is 50-60 meters. The approximate flow distance is 8-10 kilometers. Chemical type changes from  $\text{Na-HCO}_3\text{-Cl} \rightarrow \text{Na-Cl}$ .

### **2) Intermediate flow system**

Intermediate flow system in the study is in the depth range of 60-200 meters with the distance of flow 16-20 kilometers. The system includes:

2.1) Mai Don Tiew intermediate flow system: the approximate depth of flow system is 80-90 meters. The approximate flow distance is 16-20 kilometers. Chemical type changes from  $\text{Ca-HCO}_3 \rightarrow \text{Na-Cl}$ .

2.2) Lam Ta Khong intermediate flow system: the approximate depth of flow system is 200-220 meters. The approximate flow distance is 16-20 kilometers. Chemical type changes from  $\text{Ca-HCO}_3 \rightarrow \text{Ca-HCO}_3\text{-Cl} \rightarrow \text{Ca-Cl} \rightarrow \text{Na-Cl}$ .

2.3) Khok Mai Dang intermediate flow system: the approximate depth of flow system is 100-120 meters. The approximate flow distance is 16-20 kilometers. Chemical type changes from  $\text{Ca-HCO}_3 \rightarrow \text{Na-HCO}_3\text{-Cl} \rightarrow \text{Na-HCO}_3 \rightarrow \text{Na-Cl} \rightarrow \text{Na-HCO}_3$ .

### **3) Regional flow system**

Regional flow system in the study is in the depth over 200 meters with the distance of flow over 20 kilometers. The system includes:

3.1) Lam Nam Mun regional flow system is the groundwater flow from outside into inside system. The approximate depth of flow system is 260-280 meters. The approximate flow distance is 40-50 kilometers. Chemical type is Na-Cl.

3.2) Lam Chiang Krai regional flow system: the approximate depth of flow system is 280-320 meters. The approximate flow distance is 20-30 kilometers. Chemical type changes from  $\text{Ca-HCO}_3 \rightarrow \text{Na-HCO}_3\text{-Cl} \rightarrow \text{Na-HCO}_3 \rightarrow \text{Na-Cl} \rightarrow \text{Na-HCO}_3 \rightarrow \text{Na-Cl}$ .

## CHAPTER III

### RESEARCH METHODOLOGY

The study of hydrochemical conditions of artesian water of unconsolidated aquifers in the Tha Chin-Mae Khlong Basin will analyze the groundwater quality from wells which are installed in each aquifer. The purpose of the study is to determine hydrogeochemistry processes and history of aquifer. The process of the study contains:

#### 3.1 Data collection and database preparation

Secondary data is obtained from the reports, academic documents and articles of the Government and private sectors as follows:

- 1) General data about the study area.

Data Layers	Data Sources
1.1 Study area boundary	Department of Groundwater Resources
1.2 Boundary of Sub-district, District, Province	Topographic map scale 1:50,000, Royal Thai Survey Department, Ministry of Interior
1.3 Village location	Topographic map scale 1:50,000, Royal Thai Survey Department The Ministry of Interior
1.4 Area of Sub-district, District, Province	Topographic map scale 1:50,000, Royal Thai Survey Department The Ministry of Interior
1.5 Transportation route	Topographic map scale 1:50,000, Royal Thai Survey Department

<b>Data Layers</b>	<b>Data Sources</b>
1.6 Contour line, point	Topographic map scale 1:50,000, Royal Thai Survey Department
1.7 River and waterway	Topographic map scale 1:50,000, Royal Thai Survey Department Royal Irrigation Department
1.8 Surface water source	Topographic map scale 1:50,000, Royal Thai Survey Department Royal Irrigation Department

## 2) Geologic information contains

<b>Data Layers</b>	<b>Data Sources</b>
2.1 Distribution of lithologic units	Department of Mineral Resources
2.2 Geologic structure	Department of Mineral Resources
2.3 Geologic cross section	Department of Mineral Resources
2.4 Soil profiles and lithologic logs	Department of Groundwater Resources

## 3) Hydrogeologic information contains

<b>Data Layers</b>	<b>Data Sources</b>
3.1 Boundary of aquifers	Department of Groundwater Resources
3.2 Wells	Department of Groundwater Resources
3.3 Groundwater quality	Department of Groundwater Resources
3.4 Characteristic of aquifers	Department of Groundwater Resources
3.5 Groundwater level	Department of Groundwater Resources
3.6 Cross section of aquifers	Department of Groundwater Resources

### 3.2 Data Presentation in Map

ArcView version 3.2 is a Geographic Information System (GIS) program developed by the Environmental Systems Research Institute Inc. (ESRI). This program is utilized to display data and retrieve data or analyzed results in a numerical or graphic form.

### 3.3 Analysis of Groundwater Flow System

In this step, the numerical model of groundwater flow system, developed by DGR(1), is updated and determine the main direction of groundwater flow using MODPATH module in the Visual MODFLOW program.

The MODPATH program was developed by United State Geological Survey (USGS) to calculate the motion paths of the particles in three dimensions (3D) using simulated results of groundwater flow in the steady-state or transient condition from the Visual MODFLOW program. Flow direction analysis is calculated based on the assumption that the flow speed and direction variations are linear and have the same direction within a grid cell.

### 3.4 Wells Selection for Hydrochemical Analysis and Data Determination

#### 3.4.1 The criteria for hydrogeochemical analysis in selected wells:

- 1) The chemical analysis should include major ions i.e.  $\text{Na}^+$ ,  $\text{K}^+$ ,  $\text{Ca}^{2+}$ ,  $\text{Mg}^{2+}$ ,  $\text{HCO}_3^-$ ,  $\text{CO}_3^{2-}$ ,  $\text{Cl}^-$ , and  $\text{SO}_4^{2-}$ .
- 2) The sum of cations in milliequivalents per liter (meq/L) should equal the sum of anions in meq/L. The charge balance must be less than  $\pm 5\%$ .
- 3) The sum of major ions would be used instead of the Total Dissolved Solids (TDS) in case that the TDS in groundwater sample is not measured.

4) The latest analysis data would be selected if there are more than one chemical analysis data the samples of those wells had analyzed more than one time.

5) Selected wells must possess groundwater chemical analysis data and lithologic logs.

6) Selected wells must contain the slotted casing or screen only in a single aquifer.

In order to obtain the proper hydrogeochemical characteristics, the groundwater quality data must be collected from wells that meet the standard of artesian well. The slotted casing or screen should be installed only in a single aquifer. The well should be sealed with clay or cement, no leakage from other aquifer. In addition, the distribution of artesian wells must cover study area. Wells should be developed in groundwater layers that represent the aquifers in the study area. The reliability of the analysis results for groundwater quality should be examined. Typically, for a proper data, the sum of cations must equal the sum of anions in units of meq/L (3). The charge balance can be calculated by the following steps:

Step 1 Convert the concentration unit from mg/l to meq/l by dividing the concentration by molecular mass or atomic mass and multiplied by the value of the charge as the following equation:

$$\text{meq/l} = \frac{\frac{mg}{l} * \text{valency}}{\text{Formula wt.}} \quad (3.1)$$

Step 2 Replace the value from the equation 3.1 in the following formula:

$$\text{Charge balance (\%)} = \frac{(\Sigma \text{ cation} - \Sigma \text{ anion})}{(\Sigma \text{ cation} + \Sigma \text{ anion})} * 100 \quad (3.2)$$

An error of the charge balance must be less than 5 percent (3)

### 3.4.2 Classification of wells based on aquifers

The whole selected well data should be determined in to 5 groups according to groundwater aquifer which classified by Department of Groundwater Resources. Namely: (1)

- Aquifer I is comparable to Bangkok Aquifer (BK)
- Aquifer II is comparable to Phra Pradaeng Aquifer (PD)
- Aquifer III is comparable to Nakhon Luang Aquifer (NL)
- Aquifer IV is comparable to Nonthaburi Aquifer (NB)
- Aquifer V is the layer deeper than Nonthaburi Aquifer (NB)

## 3.5 Hydrogeochemical Analysis of Groundwater

The approved results of groundwater chemical analysis will be analyzed to determine the hydrochemical facies and groundwater quality of each aquifer using the AquaChem 5.0 program and the Sodium Adsorption Ratio (SAR) analysis. Hydrochemical analysis and interpretation of groundwater quality can be conducted by using the following methods:

- 1) Hydrochemical analysis of groundwater by Piper diagram.
- 2) Hydrochemical analysis of groundwater by Durov Chart
- 3) Hydrochemical analysis of groundwater by Stiff Chart
- 4) Analysis of Sodium Adsorption Ratio (SAR) by plotting on Wilcox diagram.
- 5) Hydrochemical analysis of groundwater by plotting XY graph.
- 6) Hydrochemical analysis of groundwater by ion ratio comparison.

### 3.5.1 Plotting chemical analysis data on a Piper diagram

Piper (17) found that plotting chemical elements of water on the Piper diagram can classify (ground) water as follows:

- 1) Hydrochemical facies (water types)
- 2) Crystallizations or dissolution
- 3) Water mixing
- 4) Ion exchange

### 3.5.2 Hydro-chemical analysis of groundwater by Durov Chart

Hydrochemical facies of groundwater is derived from major ion analysis by Expanded Durov diagram associated with groundwater flow system (16).

### 3.5.3 Hydrochemical analysis of groundwater by Stiff Chart

This method is a type of groundwater element plot using at least three pairs of cation and anion. The graph, looks like the polygons, indicates the approximate sum of ions. The pairs of ions used in this plot are sodium vs. chloride, calcium vs. bicarbonate, magnesium vs. sulfate, and iron vs. carbonate. In general, the level of iron and carbonate is very low or non-detection. The unit of cation and anion is milliequivalent per litre.

### 3.5.4 Analysis of Sodium Adsorption Ratio (SAR)

Sodium Adsorption Ratio can be calculated from the following equation:

$$SAR = \frac{Na^+}{\sqrt{(Ca^{2+} + Mg^{2+})}} \quad (3.3)$$

The concentration of constituent ions is milliequivalent per litre (meq/L)

### 3.5.5 Hydrochemical analysis of groundwater by plotting X-Y graph

X-Y plot is the most simple and initial approach to interpret the hydrochemical data (16). The plot represents the correlation of each pair of ions.

### 3.5.6 Hydrochemical analysis of groundwater by ion ratio comparison

The purpose of this method is to determine the type of aquifers and the hydrochemical process (3). The analysis consists of 7 steps:

1. If the pH of the water is less than 5 to 6, be cautious in applying the following steps as acid waters may not be able to be interpreted in this way.
2. Concentration of the elements must be in the unit of meq/L except silica which is neutral and must be in the unit of mmol/L.

3. The error of charge balanced, derived from concentration values of the cation and anion except silica, must be less than 5%

\* If the condition does not meet the criteria 1-3, the next step cannot be proceeded.

4. Compare the quantity of sodium and chloride.

5. Compare the quantity of sulfate and calcium.

6. Compare the proportion of bicarbonate and silica.

7. Compare the silica with non-halite sodium ( $\text{Na}^{++} \text{K}^{+} - \text{Cl}^{-}$ ).

In this study, step 6 and 7 were not performed since there were no  $\text{SiO}_2$  in analytical data.

### 3.6 Analysis of Groundwater Resources Management from the Study

The results of data analysis and interpretations in the study areas are able to carry out any of groundwater quality management in the suitable measure and activity. It is shown in brief as follows:

#### 3.6.1 Piper diagram

A Piper diagram is used to assess hydrochemical facies.

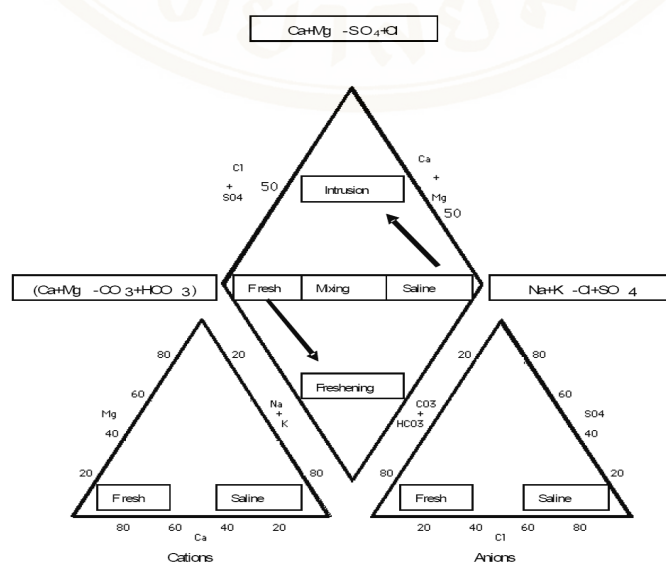


Figure 3-1: An example of Piper diagram which can classify groundwater into 4 types: After: Appelo & Postma, 1993, cited in (32).

Type I (Ca+Mg-CO<sub>3</sub>+HCO<sub>3</sub>) facies = Fresh water

Type II (Na+K-Cl+SO<sub>4</sub>) facies = Saline water

Type III & IV (Ca+Mg-SO<sub>4</sub>+Cl) and (Na+K-HCO<sub>3</sub>) facies = mixing water

### 3.6.2 Durov diagram

A Durov diagram can be used to identify different water types (hydrochemical facies) in groundwater system like the Piper diagram.

According to Figure 2-5, the nine numbered fields in the central plotting square are identified and explained in Table 3-1 (33). If plotted samples along a groundwater flow line show a clear trend from one facies to another, then it is possible to infer the predominant processes affecting the evolution of groundwater chemistry.

Table 3-1: Summary of hydrochemical facies associated with nine numbered fields on the Durov diagram that shown in Figure 2-5

Field number	Predominant facies	Typical occurrences of these facies in real aquifers
1	Ca-HCO <sub>3</sub>	Shallow, fresh groundwater in recharge areas in a wide range of aquifer types.
2	Mg- HCO <sub>3</sub>	Typical of “leading-edge” of seawater intrusion into shallow unconfined aquifer.
	Mg-Ca- HCO <sub>3</sub>	Shallow, fresh groundwater in aquifer composed (at least in part) of dolomite.
3	Na- HCO <sub>3</sub>	Shallower portions of regional confined aquifers: water deduced to have been affected by ion exchange.
4	Ca-SO <sub>4</sub>	Gypsum-bearing sedimentary aquifer and groundwater affected by oxidation of pyrite and other sulfide minerals.
5	No clear facies	Normally the result of mixing of two or more different facies.

Table 3-1: Summary of hydrochemical facies associated with nine numbered fields on the Durov diagram that shown in Figure 2-5 (cont.)

Field number	Predominant facies	Typical occurrences of these facies in real aquifers
6	Na-SO <sub>4</sub>	Rare; can result from mixing of ancient Na-rich groundwater with pyrite oxidation waters also formed by intensive evaporation of waters which have previously lost their Ca and HCO <sub>3</sub> to calcite precipitation.
7	Ca-Cl	Associated with the invasion of shallow, fresh aquifers by seawater less commonly, can form by dissolution of the very rare evaporite mineral tachyhydrite(CaCl <sub>2</sub> ).
8	Mg-(Na)-(Ca)-Cl	Mixing of fresh and saline waters; possible influence also of reverse ion exchange.
9	Na-Cl	Influence of seawater, ancient saline groundwater, or dissolution of halite (NaCl)

In addition, according to Frank van Weert et al. in Global Overview of Saline Groundwater Occurrence and Genesis (34), and in Piper and Durov diagram, term of managing saline groundwater, can be divided actions and measures into 8 types in summary as follows:

1) Groundwater abstraction optimization

Coastal aquifers are prone to lateral seawater intrusion and up-coning, inland movement of the groundwater wells.

2) Barriers

Another group of measures is aimed at physically blocking the movement of salts. In various areas in the world tidal creeks, river estuaries and other sea inlets enormously enlarge the length of the coastline and thus the contact area between the coastal aquifers and seawater.

### 3) Aquifer Storage and Recovery (ASR)

A different approach in fighting salinization especially in areas of later seawater intrusion and upcoming is the artificial recharging of aquifers with fresh groundwater. The recharge increases the groundwater pressure often reversing the pressure gradient caused by coastal groundwater abstraction.

### 4) Reduce water-logging induced salinization

Water-logging induced salinization occurs in areas with shallow groundwater tables and high evaporation rates. The evaporation acts as a fractionation process. When the saline water evaporates, basically only water molecules and volatile constituents change into the gaseous phase. The dissolved solutes remain behind in the non-evaporated water increasing the TDS content

### 5) Saline effluent, transport, treatment disposal

Drainage effluent from intensive cropping irrigation areas, industrial effluent and domestic wastewater may contain very high salt contents. Uncontrolled disposal or release of these waters may lead to introducing salts into the groundwater system.

### 6) Desalinization of saline (ground) water

Desalination processes separate dissolved solutes from brackish and saline feedwater by means of phase-change processes (distillation and freezing) or membrane processes (reversed osmosis, electrodialysis, nano- and ultra-filtration).

### 7) Groundwater abstraction reduction

A straightforward measure to decrease the process of salinization from lateral seawater intrusion and up-coning is by limiting the amount of abstracted groundwater. In order to do this, water demand management should be adopted.

### 8) Salt tolerant crops

Groundwater salinity is also managed by adjusting groundwater use to lower groundwater quality levels. In many agricultural areas where only marginal quality water is available and where soil conditions are negatively affected by salinity, farmers are still able to grow crops profitably by changing to more salt-tolerant crops. The crop adaptation is often accompanied by nutrients augmentation (in fertilizers) and soil quality improvement (e.g. adding gypsum sulphuric acid and iron pyrite to reduce the negative effects of soil sodicity).

### 3.6.3 Stiff plots

The Stiff plot belongs to the group of pattern plots (29). It is constructed by plotting the concentration of three or more anions and three or more cations in the unit of milliequivalents per liter. In term of groundwater quality management, stiff plots can be used to evaluate the change in water quality at a single location over a period of time. In addition, they can be used to evaluate the change in water quality as the water passes through different geologic formations or different subsurface conditions. The examples of stiff diagrams of waters from difference rocks are shown in Figure 2-5.

### 3.6.4 Sodium Adsorption Ratio (SAR) and Wilcox diagrams

#### 3.6.4.1 Sodium Adsorption Ratio (SAR)

According to the US Salinity Laboratory of the Department of Agriculture (USDA) (21), in term of groundwater management, the classification of irrigation waters with respect to SAR is based primarily on the effect of exchangeable sodium on the physical condition of the soil. Sodium-sensitive plants may, however, suffer injury as a result of sodium accumulation in the plant tissue when exchangeable sodium values are lower than those effective in causing deterioration of the physical condition of the soil. There were classified into four levels as fallow:

Low sodium water (S1) can be used for irrigation on almost all soils with little danger of the development of harmful levels of exchangeable sodium. However, sodium sensitive crops, such as stone-fruit trees and avocados may accumulate injurious concentration of sodium.

Medium sodium water (S2) in fine-textured soils of high cation exchange capacity, especially under low leaching conditions, unless gypsum is present in the soil, presents appreciable sodium hazard, but may be used on coarse textured or organic soils which have good permeability.

High sodium water (S3) may produce harmful levels of exchangeable sodium in most soils and will require special soil management-good drainage, high leaching, and organic matter additions. Gypsiferous soils may not develop harmful levels of exchangeable sodium from such waters. Chemical

amendments may be required for replacement of exchangeable sodium except that amendments may not be feasible with waters of very high salinity.

Very high sodium water (S4) is generally unsatisfactory for irrigation purposes, except at low and perhaps medium salinity. Application of gypsum or other amendments may render this water feasible. Application of gypsum also increases the crust conductivity property of the soil.

#### 3.6.4.2 Wilcox diagram

Wilcox diagram is a simple scatter plot of SAR on the Y-axis vs. Salinity Hazard (Conductivity) on the X-axis. This diagram is used in interpreting the analysis of irrigation water (21). Water can be grouped into 16 classes. This diagram classified groundwater for irrigation purposes based on per cent of sodium and specific conductance (EC). Eaton (30) recommended the concentration of residual sodium carbonate to determine the suitability of water for irrigation purposes. The USDA adopted certain techniques based on which the suitability of water for agriculture is explained. In term of groundwater management, The Wilcox diagram is indicated water suitability to irrigation (i.e. very good to good, good to permissible, permissible to doubtful, doubtful to unsuitable and unsuitable).

## CHAPTER IV

### RESULTS AND DISCUSSION

The study of Hydrogeochemistry and Groundwater Flow in the Tha Chin-Mae Klong Basin for Groundwater quality Management consists of multiple aspects, including hydrochemical analysis and numerical modeling. Both primary and secondary data were utilized regarding various methods. Hydrochemical analysis were undertaken in order to better understand the quality and evolution of groundwater. The numerical groundwater models were constructed to simulate the groundwater flow in steady state. The results from all processes in previous chapter are presented here in Chapter 4 and will be discussed in this chapter as well. They can be divided and summarized into 7 subjects as follows:

- 4.1 Hydrochemical analysis of groundwater
- 4.2 Flow path selection and flow direction
  - 4.2.1 Flow path selection
  - 4.2.2 Groundwater flow direction
- 4.3 Groundwater flow system (GFS)
  - 4.3.1 Intermediate flow system (IFS)
  - 4.3.2 Regional flow system (RFS)
- 4.4 Hydrochemical facies analysis
  - 4.4.1 Hydrochemical analysis by ion ion ratio comparison.
  - 4.4.2 Hydrochemical analysis by plotting XY graph.
  - 4.4.3 Hydrochemical analysis by Piper diagram.
  - 4.4.4 Hydrochemical analysis by Durov Chart.
- 4.5 Hydrogeochemical process along Kanchanaburi (Lao Kwan) – Angthong flow path (A-A')
- 4.6 Hydrogeochemical process along Kanchanaburi (Tha Maka) – Pathum Thani flow path (B-B')

#### 4.7 Groundwater Quality Management applied according to the Research and Analysis.

### 4.1 Hydrochemical analysis of groundwater

According to the data collection and database preparation on the research methodology in Chapter 3, wells selection for hydrogeochemical analysis, classification of aquifers and data determination in chapter 3.4 (see page 48) are categorized and applied to the 1,175 wells (1401 samples) with AquaChem 5.0 program by plotting on Piper diagram, Wilcox diagram and Stiff diagram. For more details on the results of water type classification of each aquifer in the study area are given in Appendix A.

4.1.1 The results of this study and analysis in terms of groundwater aquifers are classified into 5 layers (1) as follow:

- 1) Aquifer layer I is comparable to Bangkok Aquifer (BK)
- 2) Aquifer layer II is comparable to Phra Pradaeng Aquifer (PD)
- 3) Aquifer layer III is comparable to Nakhon Luang Aquifer (NL)
- 4) Aquifer layer IV is comparable to Nonthaburi Aquifer (NB)
- 5) Aquifer layer V is deeper layer than Nonthaburi Aquifer

Hydrogeochemical analysis of groundwater in the Tha Chin-Mae Klong Basin is in the results of the following research methods:

1. By Piper diagram (see Appendix B)

There are 10 hydrochemical facies that can be classified into 4 different groups:

Group 1: Ca- HCO<sub>3</sub>, Ca-Na-HCO<sub>3</sub> and Na-HCO<sub>3</sub>

Group 2: Ca-HCO<sub>3</sub> -Cl, Na-HCO<sub>3</sub>-Cl and Ca-Na-HCO<sub>3</sub>-Cl

Group 3: Ca-Na-Cl, Ca-Cl and Na-Cl

Group 4: SO<sub>4</sub> (existed in aquifer layer II only)

Map of hydrochemical facies distribution is displayed on Appendix C.

## 2. By Plotting Wilcox diagram for the Irrigation (Appendix D)

Water types found are mostly of C<sub>2</sub>-S<sub>1</sub>, C<sub>2</sub>-S<sub>2</sub>, C<sub>3</sub>-S<sub>1</sub>, and C<sub>3</sub>-S<sub>2</sub>. These water types are appropriate and quite in good quality (21), nonetheless, they are not decent for the irrigation in certain areas.

## 3. By Stiff diagram for change in water quality evaluation (Appendix E)

There are 7 water types according to table 4-1 that can be divided into 3 groups following:

Group 1: Ca-CO<sub>3</sub> (Type 1 and 2)

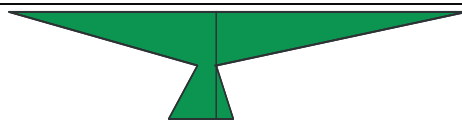
Group 2: Na-CO<sub>3</sub> (Type 3 and 4)

Group 3: Cl (Type 5, 6 and 7)

Table 4-1: Stiff Diagram types in study area.

Type	Stiff diagram	Water type	TDS
1		Ca-HCO <sub>3</sub>	Low
2		Ca-HCO <sub>3</sub>	Low (2>1)
3		Na-HCO <sub>3</sub>	Low
4		Na-HCO <sub>3</sub>	Medium
5		Ca-Cl	Medium
6		Na-Cl	Medium

Table 4-1: Stiff Diagram types in study area. (cont.)

Type	Stiff diagram		Water type	TDS
7	Na+K Ca Mg		Cl HCO <sub>3</sub> +CO <sub>3</sub> SO <sub>4</sub>	Na-Cl High

The results of the stiff diagram of each well of hydrochemical analysis on aquifer layer I to layer V are given in Appendix F.

#### 4.1.2 The Tha Chin-Mae Klong Basin hydrochemical analysis:

##### Aquifer Layer I (BK)

Due to the hydrochemical analysis on various 94 samples of water by the research method of Piper diagram, the map of hydrochemical facies distribution, Wilcox diagram and Stiff diagram, the results are given in Appendices B1, C1, D1, and E1 respectively, which imply that there is dissolved calcite process from other sources rather than decayed Halite- Albite in the northwest of Don Chedi district and U-thong district in Suphan Buri province. The Ion exchange found in the southwest border between Ratchaburi province and Kanchanaburi province, in the middle of which the plagioclase calcite rocks are passed by underground water; and brine is contaminated in Song Phi Nong district of Suphan Buri province.

There are 3 main groups of hydrochemical facies as follows:

1. Calcium-Bicarbonate(Ca-HCO<sub>3</sub>) and Calcium-Sodium-Bicarbonate(Ca-Na-HCO<sub>3</sub>)

This group is young aged and found in the upper aquifer and in high land or in recharge areas. This water type is mainly fresh water. Ca- HCO<sub>3</sub>, Ca-Na-HCO<sub>3</sub> and Na-HCO<sub>3</sub> are found in the west of research areas: from Ratchaburi province upto Chainat province and Suphan Buri province.

2. Calcium-Bicarbonate-Chloride(Ca-HCO<sub>3</sub>-Cl)and Sodium-Bicarbonate-Chloride (Na-HCO<sub>3</sub>-Cl)

This group is found in the discharge areas of Suphan Buri, Phra Nakhon Si Ayutthaya, Nakhon Pathom, Samut Songkram, Samut Sakhon and Ratchaburi, which is partially contact to saline aquifers.

### 3. Calcium-Sodium-Chloride (Ca-Na-Cl) and Sodium-Chloride (Na-Cl)

This group is found in Kamphaeng Saen, Don Tum, Nakhon Chai Si of Nakhon Pathom Province, Amphoe Muang and Bang Pla Ma district of Suphan Buri Province. There is combination of water types and in certain areas found the saltwater intrusion.

According to the hydrogeochemical analysis for agriculture by plotting Wilcox diagram of aquifer layer I, the majority of water is decent for the agriculture activities, except that in Amphoe Muang, Bang Pla Ma, U-thong, Suphan Buri, Kamphaeng Saen, Don Tum, and Nakhon Pathom, in which found Sodium and the salinity hazard in high quantity and the low quality water for the irrigation.

#### **Aquifer Layer II (PD)**

After the hydrogeochemical analysis on 467 water samples, the results are displayed as Appendices B2, C2, D2, and E2 respectively. The dissolved Calcite and Halite, including the contamination by brine are found.

There are 4 main groups of hydrochemical facies as follows:

#### 1. Calcium-Bicarbonate (Ca-HCO<sub>3</sub>) and Calcium-Sodium-Bicarbonate (Ca-Na-HCO<sub>3</sub>)

This group is young aged, weakly acidic, and found in new groundwater, high land or recharge areas. This water type is mainly fresh water. Ca-Na-HCO<sub>3</sub> and Ca-HCO<sub>3</sub> are found in the west of research areas: from Kanchanaburi, in certain part of Suphan Buri, upto Chainat.

#### 2. Calcium-Sodium-Bicarbonate-Chloride (Ca-Na-HCO<sub>3</sub>-Cl)

This type is found in groundwater that is far from the recharge areas which is mainly fresh water and part of that between brackish water to brine. This water type is found in the discharge area of Ratchaburi, Nakhon Pathom, and some part of Samut Songkhram.

#### 3. Calcium-Sodium-Chloride (Ca-Na-Cl)

This type is found in groundwater that moves gradually away from the recharge areas and is found with the salinity. This water type is found in the discharge areas of the east of the research areas: some part of Suphan Buri, Phra Nakhon Si Ayutthaya, Pathum Thani, and Nonthaburi.

#### 4. Sulphate (SO<sub>4</sub>)

This type is found in the discharge areas and in the middle of the research areas: some part of Suphan Buri and Nakhon pathom. This water type is a result of dissolved Sulphate, brine or agrochemical activities.

The analysis by plotting Wilcox diagram on aquifer layer II indicates that 10% of water samples are not appropriate to the agricultural activities. This water type is found in Nong khaem, Hankha, Chainat, Kamphaeng Saen, Nakhon Pathom, Don Chedi, Sam Chuk, Amphoe Muan Suphan Buri, Song phi Nong, and Suphan Buri province.

#### **Aquifer Layer III (NL)**

The result of the hydrochemical analysis on 448 water samples is displayed as Appendices B3, C3, D3, and E3 respectively. The dissolution of Calcite and Dolomite is found, as well as the contamination by sea water intrusion.

There are 3 main groups of hydrochemical facies as follows:

1. Calcium-Sodium-Bicarbonate (Ca-Na-HCO<sub>3</sub>)

This type is young aged and weakly acidic as a result of the ground depth. Thus, this water type is rare, found in the plain recharge areas of the central part and the west of research areas: from Nakhon Pathom to Suphan Buri province.

2. Sodium-Bicarbonate-Chloride (Na-HCO<sub>3</sub>-Cl) and Calcium-Sodium-Bicarbonate-Chloride (Ca-Na-HCO<sub>3</sub>-Cl)

This group is found in ground water that is far from the recharge areas. This water type is mainly fresh water and partially between brackish water and brine. This groundwater is found in the discharge areas of the central part and the south of the research areas: Suphan Buri, Phra Nakhon Si Ayyuthaya, Nakhon Pathom, Samut Songkhram, Samut Sakhon and Ratchaburi, which is partially contact to saline aquifers.

3. Calcium-Sodium-Chloride (Ca-Na-Cl) and Sodium-Chloride (Na-Cl)

This group is found in groundwater that is far from the recharge areas, as a result of salinity advection. This water type is found in the

discharge areas in the east of the research areas: some parts of Phra Nakhon Si Ayyuthaya, Pathum Thani and Samut sakhon.

The hydrogeochemical analysis on Aquifer Layer III and the one of Aquifer Layer II indicates that approx 95% of water in both layers is applicable to agricultural activities, whereas the other 5% of that is the opposite, found in Phasi Charoen in Bangkok, Lao Khwan district in Kanchanburi, Nong khaem district, Wat Sing district in Chainat, Don Tum district, Kamphaeng Saen district in Nakhon Pathom, Ban Phaeo district, Amphoe muang in Samut Sakhon, Amphoe muang Suphan Buri and Song phi Nong district in Suphan Buri.

#### **Aquifer Layer IV (NB)**

The result of the hydrochemical analysis on 159 samples of water is displayed as Appendices B4, C4, D4, and E4 respectively. The dissolved Calcite is found, as well as the contamination by sea water intrusion.

There are 3 main groups of hydrochemical facies as follows:

1. Calcium-Bicarbonate( $\text{Ca-HCO}_3$ ), Calcium-Sodium-Bicarbonate ( $\text{Ca-Na-HCO}_3$ ), and Sodium-Bicarbonate ( $\text{Na-HCO}_3$ ).

This group is found in the plain areas of the central part and the west of research areas: from Nakhon Pathom to Suphan Buri province.

2. Sodium-Bicarbonate-Chloride ( $\text{Na-HCO}_3\text{-Cl}$ ) and Calcium-Sodium-Bicarbonate-Chloride ( $\text{Ca-Na-HCO}_3\text{-Cl}$ )

This group is found in groundwater that is far from the recharge areas. This water type is mainly fresh water and partially between brackish water and brine. This ground water is found in the discharge areas of the central part and the south of the research areas: Suphan Buri, Phra Nakhon Si Ayutthaya, Nakhon Pathom, Samut Songkram, Samut Sakhon and Ratchaburi, which is partially contact to saline aquifers.

3. Calcium-Sodium-Chloride ( $\text{Ca-Na-Cl}$ ) and Sodium-Chloride ( $\text{Na-Cl}$ )

This group is found in ground water that is far from the recharge areas, as a result of salinity advection. This water type is found in the discharge areas in the east of the research areas: partial Ayuthaya and Nakhon pathom.

The hydrogeochemical analysis by plotting Wilcox diagram on aquifer layer IV indicates that 10% of 206 water samples contain high level of salinity and sodium hazard. This water type covers Bangkok, Nakhon Pathom, Nonthaburi, Pathum Thani, and Suphan Buri.

#### **Aquifer Layer V (deeper layer than NB)**

The result of the hydrochemical analysis on 16 samples of water is displayed as Appendices B5, C5, D5, and E5 respectively. The dissolved Calcite-Albite-Halite is found, as well as the saltwater intrusion.

There are 3 main groups of hydrochemical facies as follows:

1. Calcium-Sodium-Bicarbonate ( $\text{Ca-Na-HCO}_3$ ) and Sodium-Bicarbonate ( $\text{Na-HCO}_3$ )

This group is found in the research areas: partial Ratchburi, Samut Songkhram and Suphan Buri province.

2. Sodium-Bicarbonate-Chloride ( $\text{Na-HCO}_3\text{-Cl}$ )

This type is found in ground water that is far from the recharge areas. This water type is mainly fresh water and partially between brackish water and brine. This ground water is found in the discharge areas of the south of the research areas: Samut Sakhon.

3. Sodium-Chloride ( $\text{Na-Cl}$ )

This type is found in ground water that is far from the recharge areas, as a result of salinity advection. This water type is found in the discharge areas in the central part of the research areas: partial Phra Nakhon Si Ayutthaya.

The database of this hydrogeochemical analysis by plotting Wilcox diagram on Aquifer Layer V is quite a few, as a result of the depth of the layer. This water type is ranged between quite decent and very suitable for the agricultural activities. There found only 1 water sample: well MK5-3(Suan Luang, Kratum Ban District Samut Sakhon Province) that needs to be improved and is applicable to certain agricultural activities.

## 4.2 Flow Path Selection and Flow Direction

The study of hydrogeochemical process leads to the comprehension of the flow path process that is a fundamental subject of the study on the contamination in groundwater.

The study process consists of the principle flow path selection which is the outcome of the study on flow direction map and hydrogeologic cross section. The hydrochemical process is assumed that continuously occurs and be related along the principle flow path. Then, the wells in research areas are selected for the analysis of hydrogeochemical process.

### 4.2.1 Flow Path Selection

In this study are selected 2 Principle Flow Paths (Figure: 4-1 and Figure 4-2), of which each flow path is in hydrogeologic setting.

#### 4.2.1.1 Kanchanaburi – Ang Thong Flow Path (A - A')

Figure: 4-1(a) and 4-1(b)

This flow path prolongs 74.4 Km, directing from the west to the east: from the recharge area to the discharge area: Lao Khwan district (172 m.AMSL) to Chao Phraya Basin (10 m.AMSL). The flow path through aquifers is shown as the following diagram:

The flow path through aquifers is shown as the following diagram:

Metamorphic aquifer  $\implies$  Colluvial aquifer  $\implies$  Alluvial aquifer.

TDS in Recharge areas: 532 mg/L

TDS in Discharge areas: ~ 400 - 500 mg/L (highly found in shallow wells)

Hydrochemical alteration along A-A' flow path (from recharge area to discharge area):

$\text{Ca-HCO}_3 \implies \text{Ca-Na-HCO}_3 \implies \text{Ca-Na-Mg-HCO}_3 \implies \text{Na-Ca-Mg-HCO}_3\text{-Cl-SO}_4$

The cluster of wells selected for the hydrogeochemical analysis: MK3-181, MK2-198, MK2-199, MK3-275, MK4-74, MK3-410, MK3-358, MK3-87, MK2-276, MK3-330, MK3-350, and MK3-468.

#### 4.2.1.2 Kanchanaburi - Pathum Thani Flow Path (B - B')

This flow path prolongs 82.2 Km, directing from the west to the east: from the recharge area to the discharge area: Tha Maka district (82 m AMSL) to Plain of Sai Noi district of Pathum Thani (3 m AMSL).

The flow path through aquifers is shown as the following diagram:

Metamorphic aquifer  $\implies$  Colluvial aquifer  $\implies$  Alluvial aquifer

TDS in Recharge areas: 195 mg/L

TDS in Discharge areas: ~ 500 - 600 mg/L (highly found in deep wells)

Hydrogeochemical flow path from recharge areas - discharge areas:

$\text{Ca-HCO}_3 \implies \text{Ca-Na-HCO}_3 \implies \text{Ca-Na-Mg-HCO}_3 \implies \text{Na-HCO}_3\text{-Cl} \implies \text{Na-Ca-Cl} \implies \text{Ca-Na-Mg-Cl} \implies \text{Na-Ca-HCO}_3$

The cluster of wells selected for the hydrogeochemical analysis:

MK3-198, MK1-20, MK1-4, MK2-55, MK2-3, MK2-71, MK3-58, MK3-87, MK1-54, MK2-177, MK3-200, MK2-273, MK3-107, MK4-33.

The details of the clusters of wells selected along 2 Principle Flow Paths are given in Appendix G.

#### 4.2.2 Flow Direction

Ground water flow path directs from recharge areas to discharge areas: from the west to the east of Ang Thong and Plain of Chao Phraya River as shown of Figure: 4-1 to 4-2. The research methods need Particle Tracking for the experiments of Flow path and velocity.

The results are as the following Table 4-2 and hydrogeologic cross section A-A', B-B':

#### 4.2.2.1 Hydrogeologic cross section A - A'

Direction from the west - the east: from Lao Khwan, Kanchanburi – Ang Thong.

This flow path consists of 3 main parts:

- 1) Recharge areas => Discharge areas: Lao Khwan => Pho Thong  
Maximum velocity:  $3 \times 10^{-2}$  m/s  
Depth: ~ 270 - 290 m  
Distance: ~ 60 - 70 km
- 2) Recharge areas => Discharge areas: Nongyasai => Pho Thong  
Maximum velocity:  $2 \times 10^{-1}$  m/s  
Depth: ~ 230 - 260 m  
Distance: ~ 50 - 60 km
- 3) Recharge areas => Discharge areas: Si Prachan => Pho Thong  
Maximum velocity:  $1.2 \times 10^{-2}$  m/s  
Depth: ~ 70 - 90 m  
Distance: ~ 20 - 30 km

#### 4.2.2.2 Hydrogeologic cross section B - B': (Figure 4-1)

Direction from the west - the east: from the recharge areas in Tha Maka, Kanchanburi, Kamphaeng Saen, Don Tum, Bang Len, Nakhon Pathom - Discharge areas in Sai Noi, Nonthaburi.

This flow path consists of 3 main parts:

- 1) Recharge areas => Discharge areas: Don Tum => Sai Noi  
Maximum velocity:  $5.9 \times 10^{-1}$  m/s  
Depth: ~ 80 - 100 m  
Distance: ~ 30 - 40 km
- 2) Recharge areas => Discharge areas: Kanchanburi => Sai Noi  
Maximum velocity:  $3 \times 10^{-2}$  m/s  
Depth: ~ 130 - 140 m  
Distance: ~ 50 - 60 km
- 3) Recharge areas => Discharge areas: Tha Maka => Sai Noi  
Maximum velocity:  $3 \times 10^{-1}$  m/s  
Depth: ~ 200 - 230 m  
Distance: ~ 70 - 80 km

Table 4-2: Change in velocity along flow path

Row	Location		Velocity (m/s)				Media	Plot of velocity changes along flow path
	Eastings	Northings	Elevation (m MSL)	V <sub>x</sub>	V <sub>y</sub>	V <sub>z</sub>		
37	595358	1626000	-22.70	5.97E-07	-1.58E-05	7.87E-05	8.62E-05	
	595474	1626000	46.84	2.27E-04	-2.16E-03	-2.78E-06	2.17E-03	
	595513	1626000	-5.96	-1.85E-03	-1.32E-02	-1.93E-06	1.33E-02	
	606181	1626000	-211.13	-2.40E-05	-3.76E-04	-5.27E-06	3.77E-04	
	611573	1626000	-228.26	-8.49E-06	-2.69E-05	-1.21E-04	1.25E-04	
	621773	1626000	-236.05	-1.52E-03	-1.36E-03	-5.39E-06	2.04E-03	
	645502	1626000	-249.28	1.34E-05	-2.77E-05	-2.10E-04	2.12E-04	
	657025	1626000	-257.46	1.93E-01	-4.59E-03	-2.22E-05	1.93E-01	
37	582543	1626000	37.89	-2.24E-05	-1.30E-04	-1.64E-07	1.32E-04	
	585037	1626000	30.80	-8.25E-07	-1.04E-05	-8.00E-05	8.07E-05	
	590735	1626000	17.14	5.22E-03	-3.86E-02	-1.17E-06	3.90E-02	
	593440	1626000	-17.52	8.27E-07	-1.50E-05	-6.01E-05	6.19E-05	
	594621	1626000	-43.51	3.13E-04	-1.89E-03	-2.27E-06	1.92E-03	
	595750	1626000	-70.03	5.47E-06	-2.41E-05	-2.59E-05	3.58E-05	
	601737	1626000	-198.17	7.82E-05	-3.83E-04	-4.21E-06	3.91E-04	
	607278	1626000	-244.64	-3.42E-06	-2.86E-05	-1.02E-04	1.06E-04	
617269	1626000	-250.16	-5.15E-03	-2.06E-02	-7.77E-06	2.13E-02		
644498	1626000	-255.15	-1.10E-05	-2.71E-05	-1.95E-04	1.97E-04		
656996	1626000	-260.40	8.99E-03	-4.27E-03	-7.25E-06	9.95E-03		

Table 4-2: Change in velocity along flow path (cont.)

Row	Location		Elevation (m MSL)	Velocity (m/s)				Media	Plot of velocity changes along flow path
	Eastings	Northings		$V_x$	$V_y$	$V_z$	$V_{total}$		
37	630059	1626000	-111.93	5.47E-04	-1.49E-03	-3.33E-06	1.59E-03		
	630226	1626000	-133.62	7.76E-06	-1.66E-05	-8.31E-05	8.51E-05		
	630365	1626000	-192.57	1.44E-04	-2.64E-04	-4.88E-06	3.00E-04		
	630393	1626000	-221.50	1.08E-05	-2.09E-05	-1.15E-04	1.18E-04		
	631533	1626000	-277.67	2.39E-03	-9.95E-03	-4.66E-06	1.02E-02		
	631980	1626000	-316.04	5.30E-03	-1.12E-02	-1.02E-05	1.24E-02		
	639681	1626000	-403.36	9.45E-06	-2.86E-05	-1.92E-04	1.94E-04		
	643018	1626000	-417.82	3.68E-03	-7.66E-03	-3.16E-06	8.50E-03		
78	610733	1544000	-20.44	8.75E-02	-1.59E-02	-2.47E-05	8.90E-02		
	629871	1544000	-42.13	1.77E-02	-7.86E-03	-7.13E-06	1.94E-02		
	635674	1544000	-53.85	1.35E-05	-5.27E-06	-6.88E-05	7.03E-05		
	647632	1544000	-103.09	7.04E-02	-3.01E-02	-2.45E-05	6.77E-01		
	657069	1544000	-125.37	5.93E-01	-1.17E-02	-4.12E-05	5.93E-01		
	592898	1544000	-69.40	3.36E-02	1.89E-02	-8.62E-06	3.86E-02		
78	629224	1544000	-121.16	1.37E-05	1.46E-06	-5.31E-05	5.48E-05		
	629486	1544000	-161.78	2.23E-04	1.97E-05	-4.67E-06	2.24E-04		
	642622	1544000	-214.19	1.70E-03	-7.38E-04	-1.06E-06	1.85E-03		
	656903	1544000	-178.15	9.44E-03	7.03E-05	-2.15E-06	9.44E-03		
	629224	1544000	-161.78	2.23E-04	1.97E-05	-4.67E-06	2.24E-04		

Table 4-2: Change in velocity along flow path (cont.)

Row	Location		Elevation (m MSL)	Velocity (m/s)				Media	Plot of velocity changes along flow path
	Eastings	Northings		V <sub>x</sub>	V <sub>y</sub>	V <sub>z</sub>	V <sub>total</sub>		
78	574893	1544000	14.27	-1.05E-04	1.71E-03	-2.66E-06	1.72E-03	Gravel, sand, and clay	
	576642	1544000	-49.08	1.54E-01	2.69E-01	1.07E-06	3.10E-01	Gravel, sand, and clay	
	586902	1544000	-122.53	9.17E-04	1.10E-03	-8.62E-06	1.43E-03	Gravel, sand, and clay	
	595762	1544000	-167.99	3.31E-05	1.64E-05	-1.87E-04	1.90E-04	Clay	
	612026	1544000	-271.52	4.51E-04	-7.90E-05	-7.74E-06	4.58E-04	Gravel, sand, and clay	
	656912	1544000	-187.43	4.55E-03	7.70E-05	8.23E-06	4.55E-03	Gravel, sand, and clay	
78	610896	1544000	-151.84	3.07E-03	-1.87E-04	-7.79E-06	3.08E-03	Gravel, sand, and clay	
	611783	1544000	-174.34	2.52E-05	-3.28E-06	-1.53E-04	1.55E-04	Clay	
	612086	1544000	-212.00	4.51E-04	-7.90E-05	-7.79E-06	4.58E-04	Gravel, sand, and clay	
	618124	1544000	-288.57	7.81E-03	-6.73E-04	-3.95E-06	7.84E-03	Gravel, sand, and clay	
	645890	1544000	-424.52	1.99E-03	-6.30E-04	-9.51E-08	2.08E-03	Gravel, sand, and clay	
	656495	1544000	-303.76	-1.54E-04	2.60E-03	1.05E-05	2.60E-03	Gravel, sand, and clay	
657036	1544000	-265.67	2.49E+00	-9.84E-02	7.47E-05	2.49E+00	Gravel, sand, and clay		

Remarks: Row 37 = AA' , Row78 = BB'

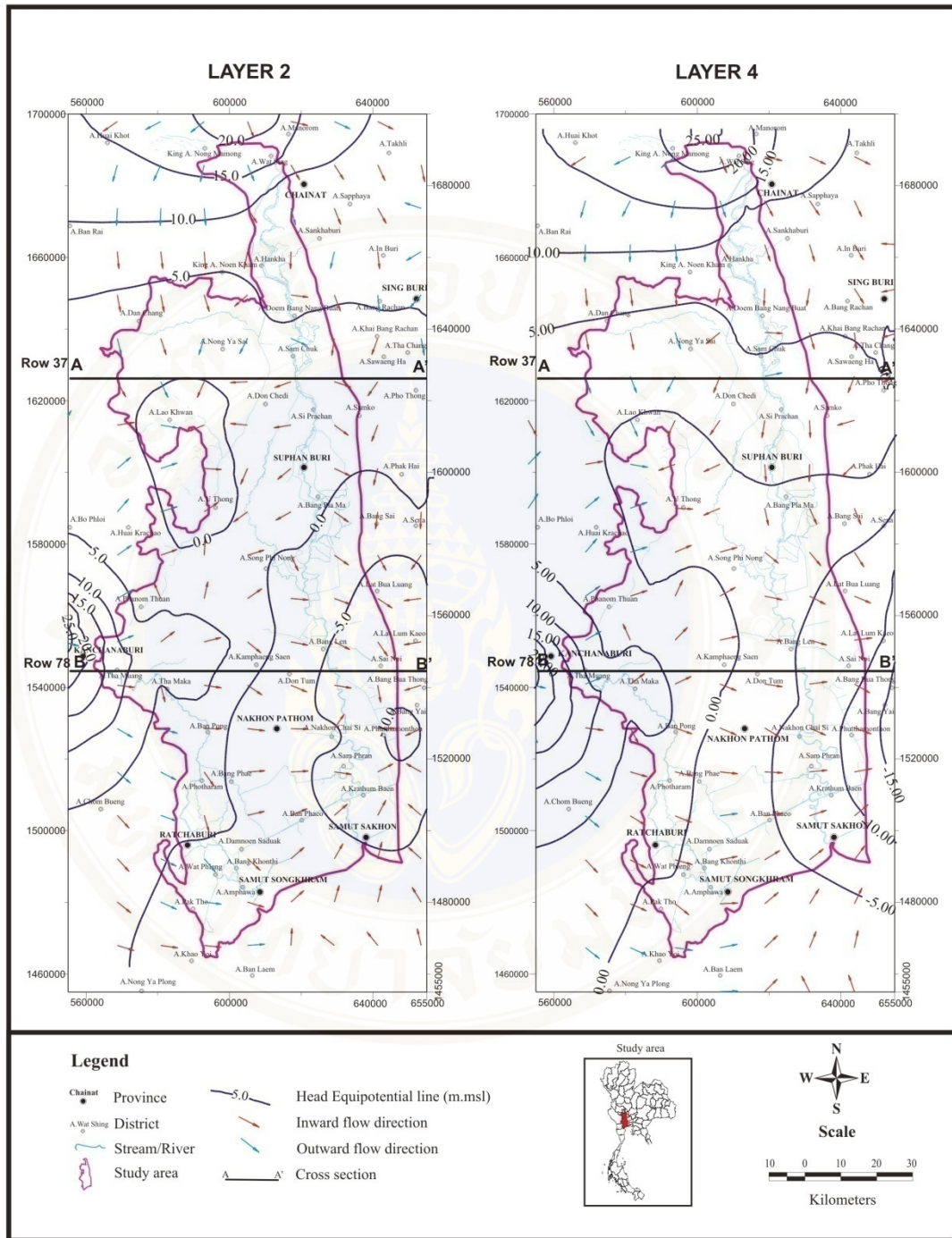


Figure 4-1(a) plan view

Figure 4-1: Steady state flow direction

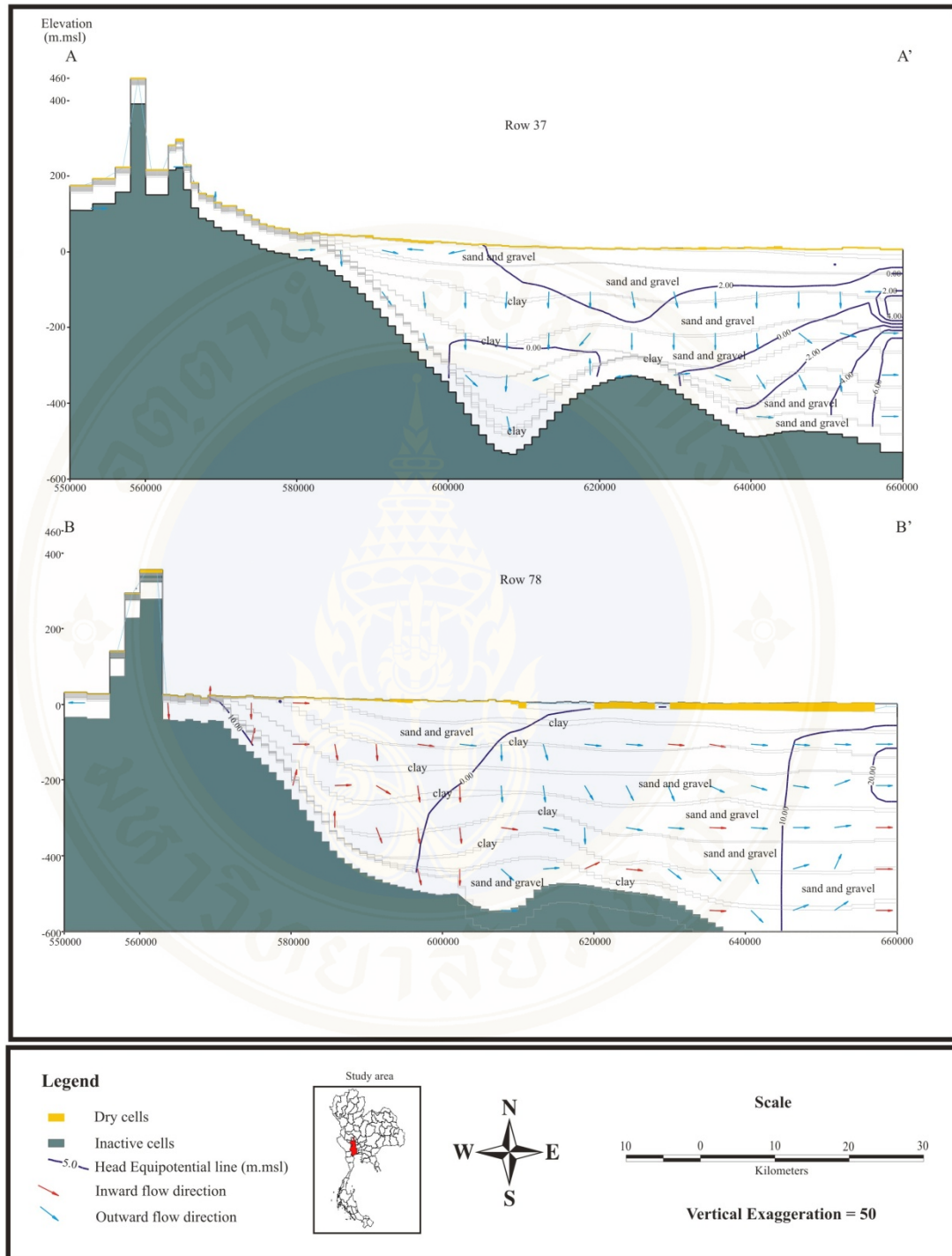


Figure 4-1(b) (cross sectional view)

Figure 4-1: Steady state flow direction (cont.)

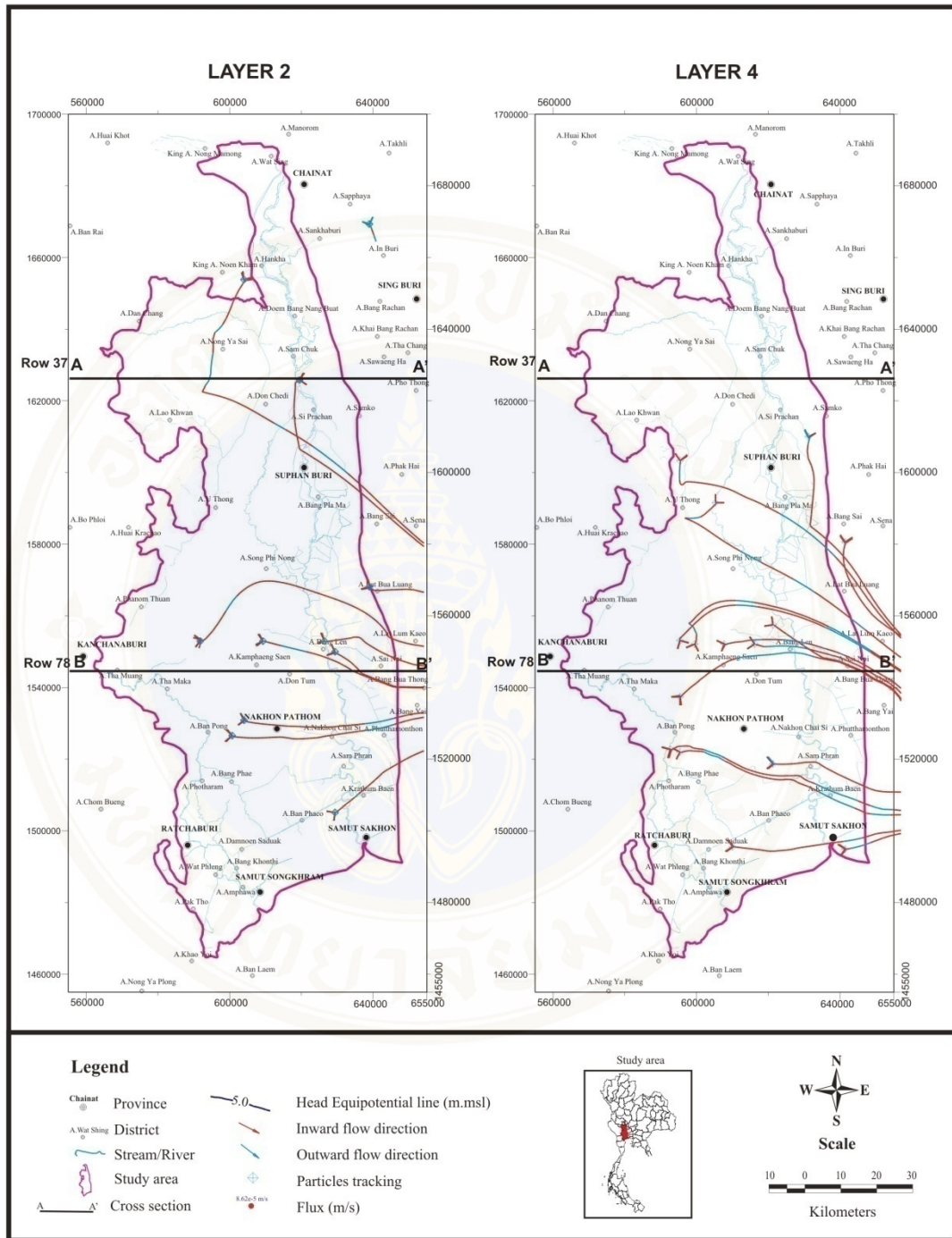


Figure 4-2(a)

Figure 4-2: Particle Tracking of steady state flow direction

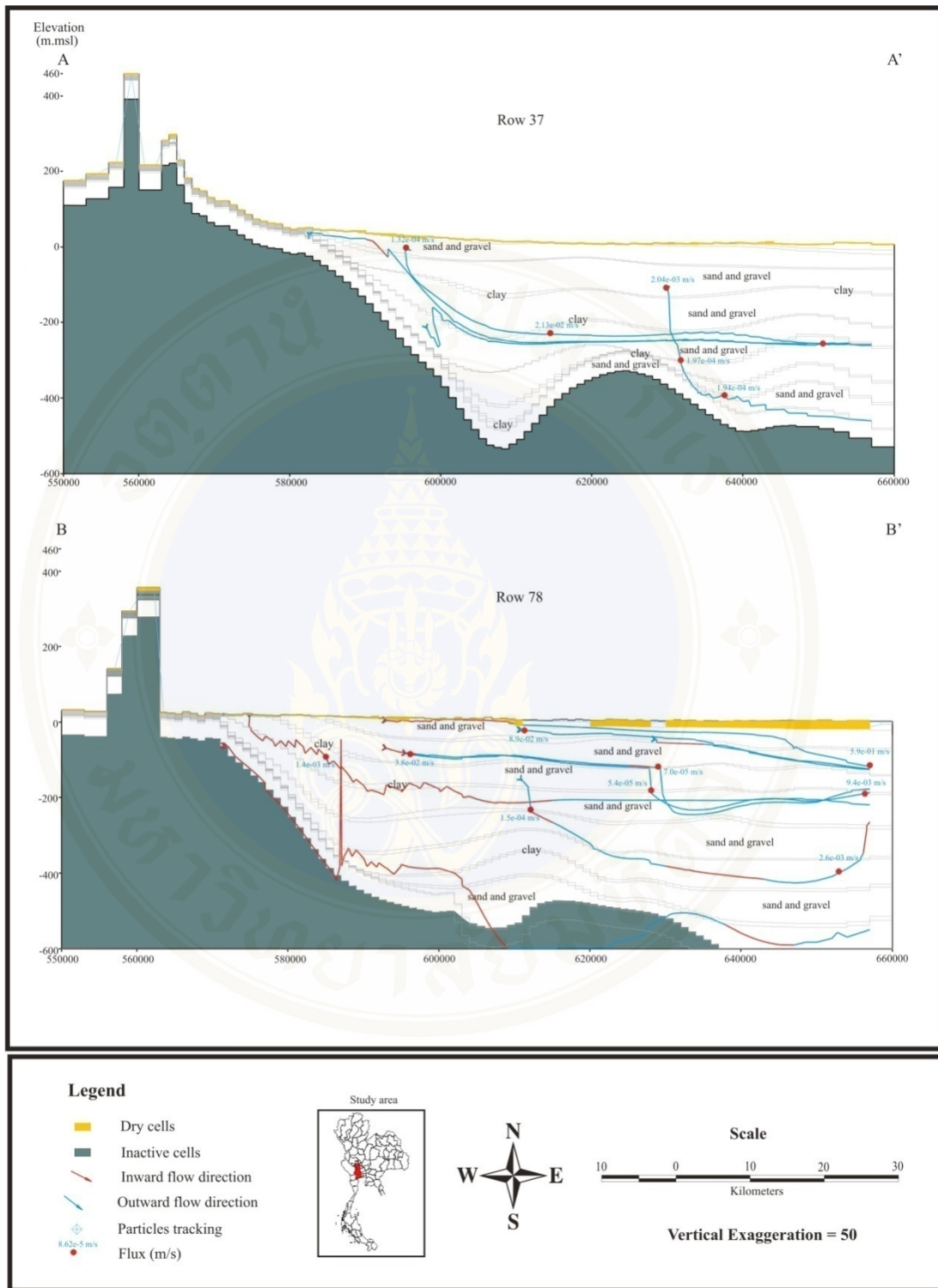


Figure 4-2(b)

Figure 4-2: Particle Tracking of steady state flow direction (cont.)

### 4.3 Groundwater Flow System (GFS)

According to Toth's (31), in clusters of flow path, groundwater directs to the same way, from a point to another when projected on any 2-D plane. The analysis of hydrochemical facies and flow systems leads to the acknowledgement of flow systems that are the main factors of changes in groundwater basins.

According to Freeze and Cherry's (12), TDS in groundwater are increased regarding the distance from surface to saturated zone along the flow path, as a result of mineral dissolution. There are less TDS found in shallow groundwater in recharge areas than in deeper groundwater, despite of that in the same system; and in shallow groundwater in discharge areas.

According to Chebotarev's (9) and Back's (10), longer flow, more TDS attached. Hydrochemical elements in groundwater are likely to change to saltwater.

Toth's Principle Ions in Flow System Evolution:

Age and Distance Augmentation: =====>

Flow paths Augmentation:  $\text{HCO}_3 \Rightarrow \text{HCO}_3 + \text{SO}_4 \Rightarrow \text{SO}_4 + \text{HCO}_3 \Rightarrow \text{SO}_4 + \text{Cl} \Rightarrow \text{Cl} + \text{SO}_4 \Rightarrow \text{Cl}$

Age Augmentation: =====>

Groundwater flow system in the Tha Chin-Mae Klong Basin is the outcome of an analysis of the following factors along cross section A-A', B-B':

- Static water level
- TDS
- Hydrochemical facies
- Groundwater flow path from steady state simulation

The flow path and GFS on cross section A-A' and B-B' are displayed as Figure 4-3 to Figure 4-4. According to the study, it can be summarized that there are two GFS in the study area including: Intermediate Flow System (IFS), and Regional Flow System (RFS).

In short, Groundwater Flow Systems in research areas can be summarized as Table 4-3.

### 4.3.1 Intermediate Flow System (IFS)

Flow systems in research areas on cross section A-A' and B-B', ranged 100 - 140 m deep, prolong approximately 20 - 60 km.

There are 3 Intermediate flow systems as follow:

#### 4.3.1.1 Si Prachan IFS

Flow Direction: high terrain in Si Prachan District ==> lowland  
in Pho Thong District

Flow Distance: ~ 20 - 40 km

Flow Depth: ~ 100 - 110 m

TDS in Brackish water: ~ 1000 - 2000 mg/L

Hydrochemical Facies: Ca- HCO<sub>3</sub> => Ca-Cl

Groundwater velocity in gravel, sand:  $1.93 \times 10^{-1}$ ,  $2.04 \times 10^{-3}$  m/s

Groundwater velocity in clay:  $2.12 \times 10^{-4}$  m/s

#### 4.3.1.2 Don Tum IFS

Flow Direction: high terrain in Don Tum District => lowland  
in Sai Noi District

Flow Distance: ~ 30 - 40 km

Flow Depth: ~ 80 - 100 m

TDS in Fresh water: < 1000 - 2000 mg/L

Hydrochemical Facies: Ca-HCO<sub>3</sub> => Ca-HCO<sub>3</sub>-Cl => Ca-Cl  
=> Na-Cl

Groundwater velocity in gravel, sand:  $5.93 \times 10^{-1}$ ,  $8.90 \times 10^{-2}$  m/s

Groundwater velocity in clay:  $7.03 \times 10^{-5}$  m/s

#### 4.3.1.3 Kamphaeng Saen IFS

Flow Direction: Kamphaeng Saen District => Discharge areas  
in Sai Noi District

Flow Distance ~ 50 - 60 km.

Flow Depth: ~ 130 - 140 m.

Hydrochemical Facies: Ca-HCO<sub>3</sub> => Na-HCO<sub>3</sub>-Cl =>  
Na-HCO<sub>3</sub> => Na-Cl => Na-HCO<sub>3</sub>

Groundwater velocity in gravel, sand, and clay:  $3.86 \times 10^{-2}$ ,  
 $9.44 \times 10^{-3}$  and  $5.48 \times 10^{-5}$  m/s

### 4.3.2 Regional Flow System (RFS)

RFS in research areas on cross section AA'-BB', ranged over 200 m deep, prolong over 50 km.

There are 3 Regional flow systems as follow:

#### 4.3.2.1 Lao khwan RFS

Flow Direction: groundwater inflow => system

Flow Distance: ~ 60 - 70 km

Flow Depth: ~ 270 - 290 m

Hydrochemical Facies: Ca-HCO<sub>3</sub> => Na-Cl

Groundwater velocity in gravel and sand clay:  $8.50 \times 10^{-3}$ ,  $8.50 \times 10^{-3}$  and  $1.94 \times 10^{-4}$  m/s

#### 4.3.2.2 Nong Ya Sai RFS

Flow Direction: Recharge areas in Nong Ya Sai District  
=> Discharge areas in Pho Thong District

Flow Distance: ~ 50 - 60 km

Flow Depth: ~ 230 - 260 m

Hydrochemical Facies: Na-Cl

Groundwater velocity in sand and silt:  $2.13 \times 10^{-2}$  m/s

Groundwater velocity in clay:  $2.13 \times 10^{-4}$  m/s

#### 4.3.2.3 Thamaka RFS

Flow Direction: Recharge areas in Thamaka District =>  
Discharge areas in Sai Noi District

Flow Distance: ~ 70 - 80 km

Flow Depth: ~ 200 - 230 m

Hydrochemical Facies: Ca-HCO<sub>3</sub> => Na-HCO<sub>3</sub>-Cl  
=> Na-HCO<sub>3</sub> => Na-Cl => Na-HCO<sub>3</sub>  
=> Na-Cl

Groundwater velocity in gravel, sand, and clay:  $2.63 \times 10^{-2}$ ,  $1.43 \times 10^{-3}$  and  $1.55 \times 10^{-4}$  m/s

Table 4-3: GFS in Tha Chin-Mae Klong Basin

Flow System	Name	Media	Hydrological Facies Change	Flow direction	Distance (m)	Depth (m)	Flux (m/s)
IFS	Si Prachan	gravel, sand, and clay	Ca-HCO <sub>3</sub> => Ca-Cl	W → E	20-40	100-110	1.93 x 10 <sup>-1</sup> , 2.04 x 10 <sup>-3</sup> , 2.13 x 10 <sup>-4</sup>
IFS	DonTu m	gravel, sand, and clay	Ca-HCO <sub>3</sub> => Na-Cl	W → E	30-40	80 -100	5.93 x 10 <sup>-1</sup> , 8.90 x 10 <sup>-2</sup> , 7.03 x 10 <sup>-5</sup>
IFS	Kham phaeng Saen	gravel, sand, and clay	Ca-HCO <sub>3</sub> => Na-HCO <sub>3</sub>	W → E	50-60	140-130	3.86 x 10 <sup>-2</sup> , 9.44 x 10 <sup>-3</sup> , 5.48 x 10 <sup>-5</sup>
RFS	Lao Khwan	gravel, sand, and clay	Ca-HCO <sub>3</sub> => Na-Cl	W → E	60-70	270-290	8.50 x 10 <sup>-3</sup> , 8.50 x 10 <sup>-3</sup> , 1.94 x 10 <sup>-4</sup>
RFS	Nong Ya Sai	gravel, sand, and clay	Ca-HCO <sub>3</sub> => Na-Cl	W → E	50-60	260-230	2.13 x 10 <sup>-3</sup> , 2.13 x 10 <sup>-3</sup> , 1.97 x 10 <sup>-4</sup>
RFS	Tha Maka	gravel, sand, and clay	Ca-HCO <sub>3</sub> => Na-Cl	W → E	70-80	200-230	2.36 x 10 <sup>-2</sup> , 1.43 x 10 <sup>-3</sup> , 1.55 x 10 <sup>-4</sup>

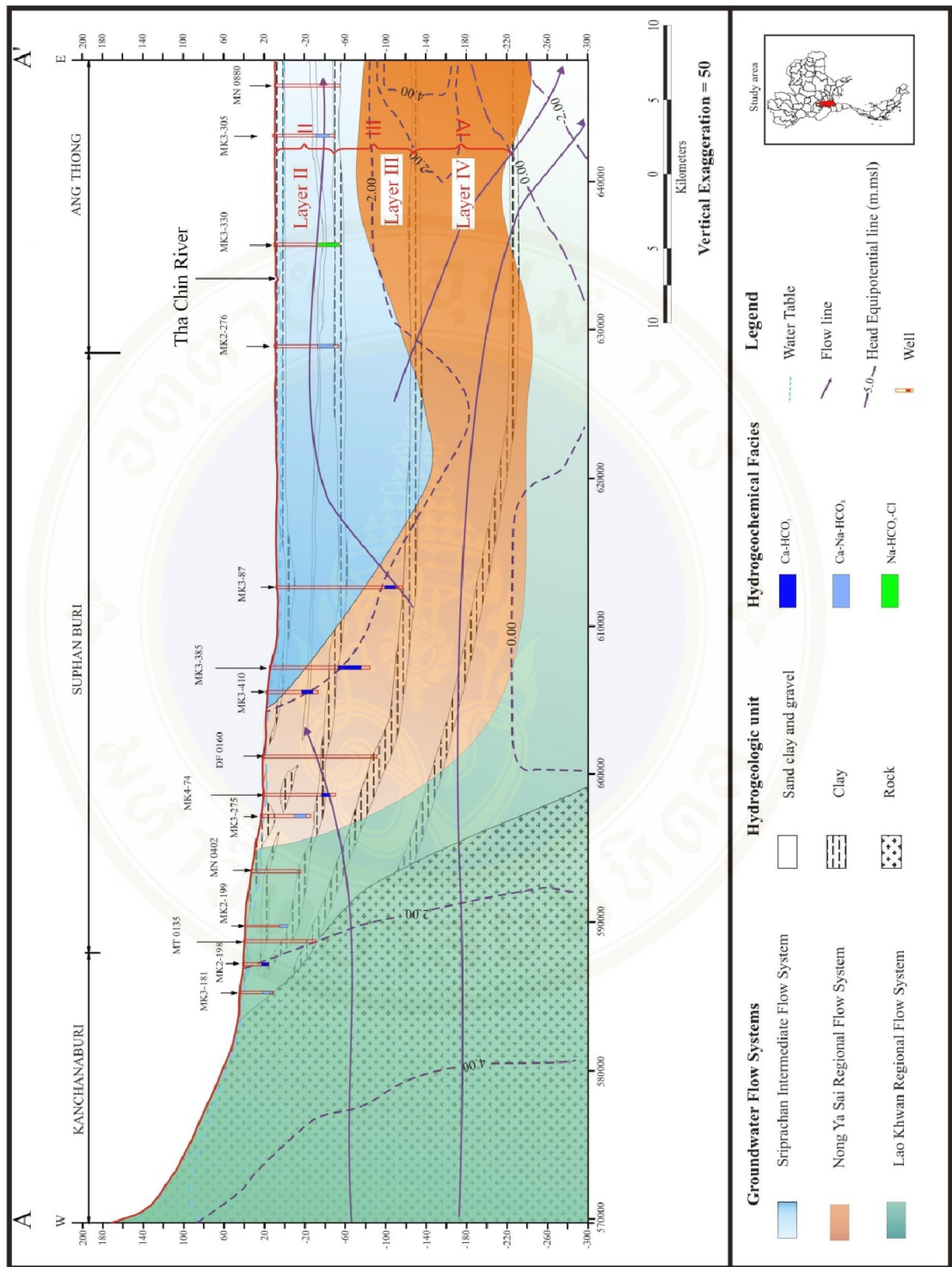


Figure 4-3: Flow Path and Groundwater Flow System on Cross Section A-A'

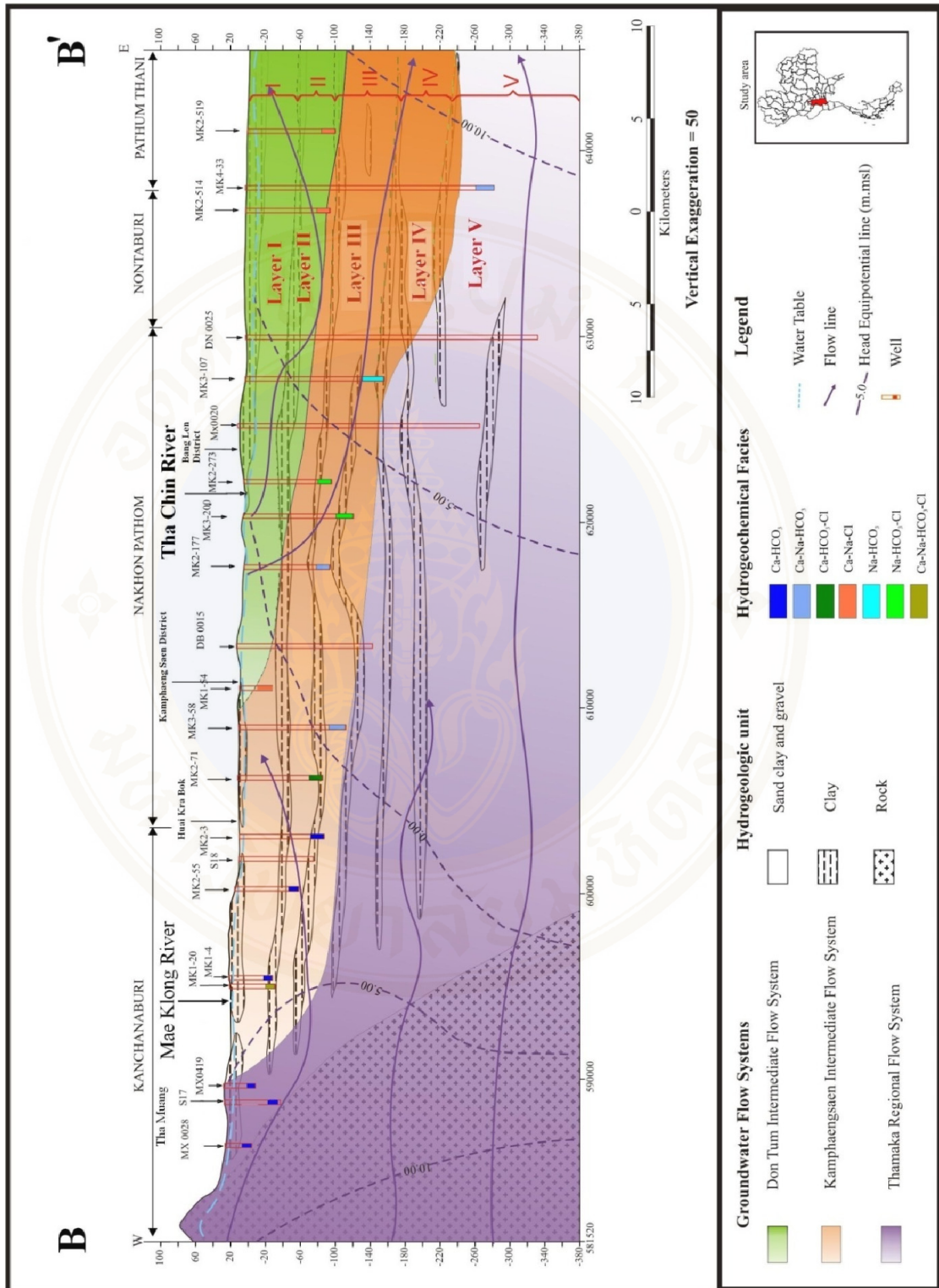


Figure 4-4: Flow Path and Groundwater Flow System on Cross Section B-B'

## 4.4 Hydrochemical Facies Analysis

There are 4 methods of analysis:

### 4.4.1 Ion ratio comparison

This method of analysis leads to the results of Hydrochemical Facies of groundwater in each well by calculating ion ratio of cluster of wells along flow paths selected. However, the results are the answers to basic expectations of hydrochemical facies in each well. The results of analysis on Ion ratio based on Principle Flow direction and hydrogeologic cross section A-A' and B-B' are shown on table 4-4 and table 4-5 respectively.

### 4.4.2 X-Y Plot

This method aims to experiment the relation between ions and hydrochemical process that tends to occur in groundwater flow paths.

X-Y plot of ion exchange is shown on Figure: 4-5 to 4-6.

### 4.4.3 Piper Diagram

- Plotting on diagram the ions of groundwater in flow path from recharge areas to discharge areas.
- Hydrogeochemical analysis on specific points or on any changes.
- Comparing the possibility of changes in diagram to the standard one of Hounslow, A.W. (10).

Plots and Piper diagram analysis based on hydrogeologic cross section A-A' and B-B' shown on Figure: 4-7(a-g) and Figure: 4-8(a-j), respectively.

### 4.4.4 Durov Diagram

- Plotting on diagram the ions of groundwater in flow path from recharge areas to discharge areas.
- Hydrogeochemical analysis on specific points or on any changes.
- Comparing the possibility of changes in diagram to the standard one of Hounslow, A.W (1995).

Diagram plotting and Durov diagram analysis based on hydrogeologic cross section A-A' and B-B' are shown as Figure: 4-9(a-g) and Figure: 4-10(a-j), respectively.

Table 4-4: Comparison of ions ratio along Kanchanburi – Ang Thong flow path (hydrogeologic cross section A-A')

Sample ID.	Water Type	pH	TDS mg/l	SO <sub>4</sub> meq/l	Na/Na+Cl	Ca/Ca+SO <sub>4</sub>	Ca+Mg/SO <sub>4</sub>	(Na+K-Cl)/(Na+K-Cl+Ca)	Cl/sum Anions	HCO <sub>3</sub> /sum Cations	Possible Meaning
MK3-181	Na-Ca-HCO <sub>3</sub>	8.00	532.00	0.23	0.87	0.93	19.89	0.61	0.07	0.96	1, 3, 5, 7, 8
MK2-198	Ca-Na-Mg-HCO <sub>3</sub> -Cl	6.00	220.00	0.10	0.51	0.93	17.99	0.08	0.21	0.77	1, 3, 4, 5, 7, 8, 10
MK2-199	Na-Ca-Mg-HCO <sub>3</sub>	8.00	344.00	0.23	0.88	0.91	17.49	0.51	0.05	0.89	1, 3, 4, 5, 7, 8, 13
MK3-275	Ca-Na-HCO <sub>3</sub>	8.00	220.00	0.06	0.87	0.97	41.95	0.40	0.06	0.90	1, 3, 5, 7, 8
MK4-74	Ca-Mg-HCO <sub>3</sub>	7.00	366.00	0.10	0.90	0.97	46.77	0.24	0.02	0.90	3, 4, 5, 7
MK3-410	Ca-HCO <sub>3</sub>	7.00	282.00	0.23	0.78	0.95	19.30	0.15	0.05	0.94	1, 3, 5, 7, 14
MK3-385	Ca-Na-HCO <sub>3</sub>	8.00	412.00	0.00	0.90	1.00	-	0.26	0.03	0.96	1, 3, 5, 7, 8, 13
MK3-87	Ca-Mg-HCO <sub>3</sub>	8.00	268.00	0.04	0.87	0.99	117.77	0.25	0.03	0.89	3, 4, 5, 7
MK2-276	Ca-Na-Mg-HCO <sub>3</sub>	6.00	156.00	0.23	0.92	0.82	8.16	0.46	0.03	0.85	1, 3, 4, 5, 7, 13, 14
MK3-330	Na-Ca-HCO <sub>3</sub> -SO <sub>4</sub>	7.00	448.00	2.29	0.77	0.41	1.16	0.68	0.18	0.56	1, 3, 5, 7, 8, 13
MK3-305	Na-Ca-HCO <sub>3</sub> -Cl	8.00	440.00	0.71	0.71	0.76	4.49	0.49	0.21	0.66	1, 3, 5, 7, 8, 10
MK3-468	Na-Ca-Mg-HCO <sub>3</sub> -Cl-SO <sub>4</sub>	8.00	615.00	2.33	0.63	0.44	1.50	0.51	0.33	0.38	1, 3, 5, 7, 8, 10, 13

Refer to table 2-3 (pages 24-25); Units are usually in meq/L except SiO<sub>2</sub> is in mmol/L (3)

Remarks: 1) Sodium source other than halite – albite 2) Reverse softening, seawater 3) Calcium source other than gypsum 4) Dolomite weathering 5) Plagioclase weathering possible 6) Plagioclase weathering unlikely 7) Rock weathering 8) Silicate or carbonate weathering 9) Gypsum dissolution 10) Seawater, or brine, or evaporates carbonates or silicates 11) Halite solution 12) Calcium removal-ion exchange or calcite precipitation 13) Analysis error 14) Rain water

Table 4-5: Comparison of ions ratio along Kanchanburi – Pathum thani flow path (hydrogeologic cross section B-B')

Sample ID.	Water Type	pH	TDS mg/l	SO <sub>4</sub> meq/l	Na/ Na+Cl	Ca/ Ca+SO <sub>4</sub>	Ca+Mg/ SO <sub>4</sub>	(Na+K-Cl)/ (Na+K-Cl+Ca)	Cl/ sum Anions	HCO <sub>3</sub> / sum Cations	Possible Meaning
MK3-189	Ca-Mg-HCO <sub>3</sub>	8.00	195.00	0.19	0.68	0.94	19.56	0.05	0.04	0.67	3, 4, 5, 7, 10
MK1-20	Na-Mg-Ca-HCO <sub>3</sub> -Cl	8.00	477.00	0.81	0.55	0.75	6.25	0.27	0.38	0.49	1, 3, 4, 5, 7, 8, 10, 13
MK1-4	Ca-Na-HCO <sub>3</sub>	8.00	304.00	0.10	0.77	0.97	43.66	0.20	0.06	0.98	1, 3, 5, 7, 8
MK2-55	Ca-Mg-Na-HCO <sub>3</sub> -Cl	8.00	383.00	0.29	0.50	0.93	20.01	0.01	0.21	0.77	1, 3, 4, 5, 7, 8, 10, 13
MK2-3	Ca-Mg-Na-HCO <sub>3</sub>	8.00	206.00	0.19	0.72	0.90	17.21	0.28	0.09	0.84	1, 3, 4, 5, 7, 8, 13
MK2-71	Ca-Mg-Na-Cl-HCO <sub>3</sub>	8.00	748.00	0.19	0.27	0.97	56.51	-120.54	0.66	0.33	1, 3, 4, 5, 7, 8, 10, 13
MK3-58	Na-Ca-Mg-HCO <sub>3</sub>	8.00	314.00	0.42	0.83	0.81	7.67	0.63	0.11	0.80	1, 3, 4, 5, 7, 8, 13
MK1-54	Na-Ca-Mg-Cl	7.00	2682.00	3.60	0.39	0.76	5.77	15.03	0.78	0.13	1, 3, 4, 5, 7, 8, 10
MK2-177	Na-Mg-Ca-HCO <sub>3</sub>	8.00	455.00	0.17	0.67	0.93	26.21	0.41	0.19	0.78	1, 3, 4, 5, 7, 8, 13
MK3-200	Na-HCO <sub>3</sub> -Cl	8.00	576.00	1.08	0.69	0.65	2.53	0.68	0.33	0.55	1, 6, 7, 10
MK2-273	Na-HCO <sub>3</sub> -Cl	8.00	500.00	1.52	0.74	0.50	1.80	0.73	0.25	0.56	1, 6, 7, 10
MK3-107	Na-HCO <sub>3</sub>	9.00	316.00	0.15	0.87	0.80	7.49	0.87	0.12	0.69	1, 3, 5, 7, 8
MK2-514	Na-Ca-Cl	7.00	6270.00	3.75	0.31	0.90	13.84	4.33	0.92	0.04	2, 3, 6, 10
MK2-519	Ca-Na-Mg-Cl	7.00	8900.00	4.79	0.30	0.93	20.92	5.36	0.94	0.03	1, 3, 4, 5, 7, 8, 10
MK4-33	Na-Ca-HCO <sub>3</sub>	8.00	528.00	0.10	0.81	0.97	49.98	0.47	0.10	0.91	1, 3, 5, 7, 8

Refer to table 2.3 (pages 24-25); Units are usually in meq/L except SiO<sub>2</sub> is in mmol/L (3)

Remarks: 1) Sodium source other than halite – albite 2) Reverse softening, seawater 3) Calcium source other than gypsum 4) Dolomite weathering 5) Plagioclase weathering possible 6) Plagioclase weathering unlikely 7) Rock weathering 8) Silicate or carbonate weathering 9) Gypsum dissolution 10) Seawater, or brine, or evaporates carbonates or silicates 11) Halite solution 12) Calcium removal-ion exchange or calcite precipitation 13) Analysis error 14) Rain water

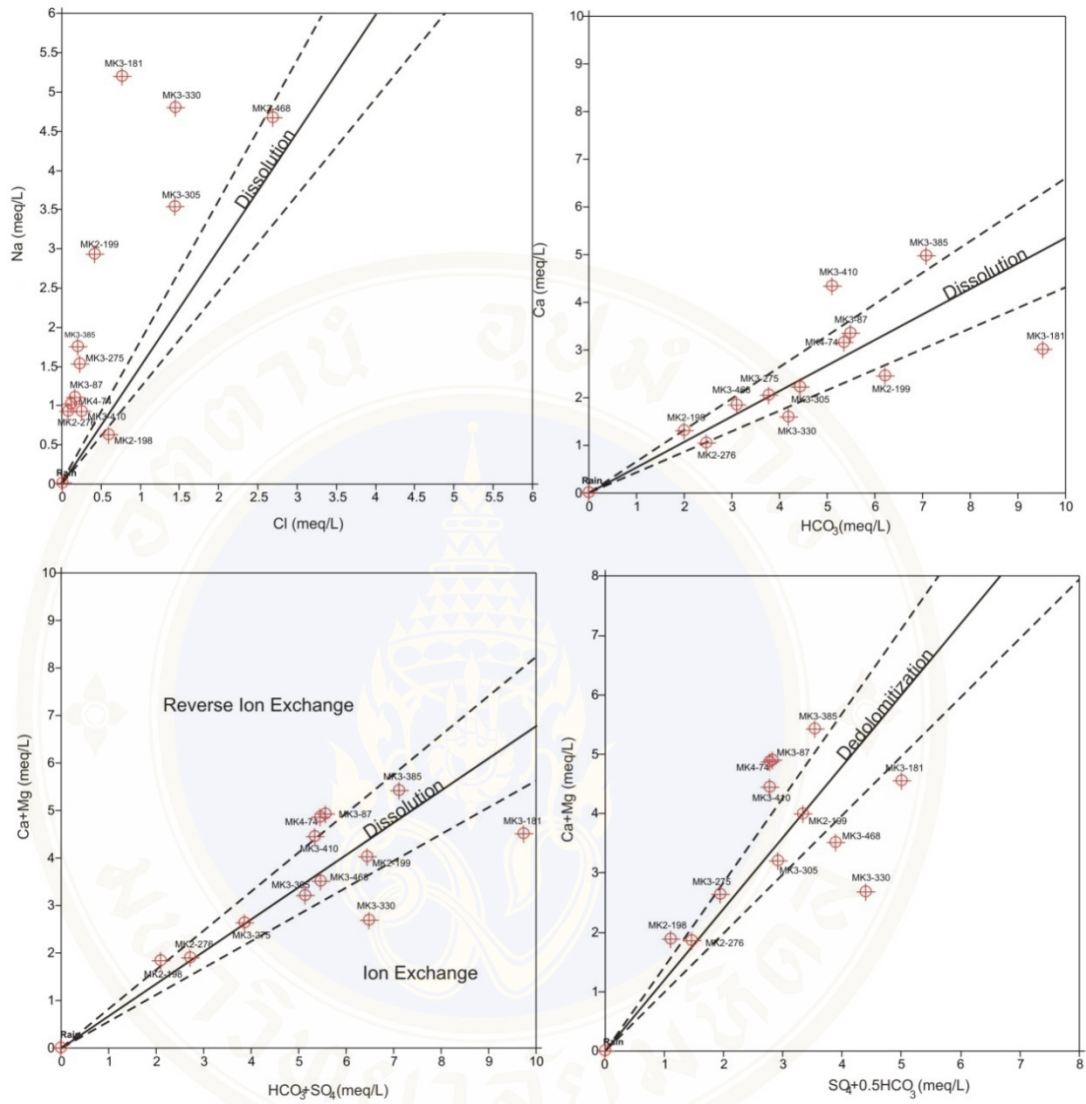


Figure 4-5: X-Y Plot of ions in Kanchanburi – Angthong flow path (hydrogeologic cross section A-A')

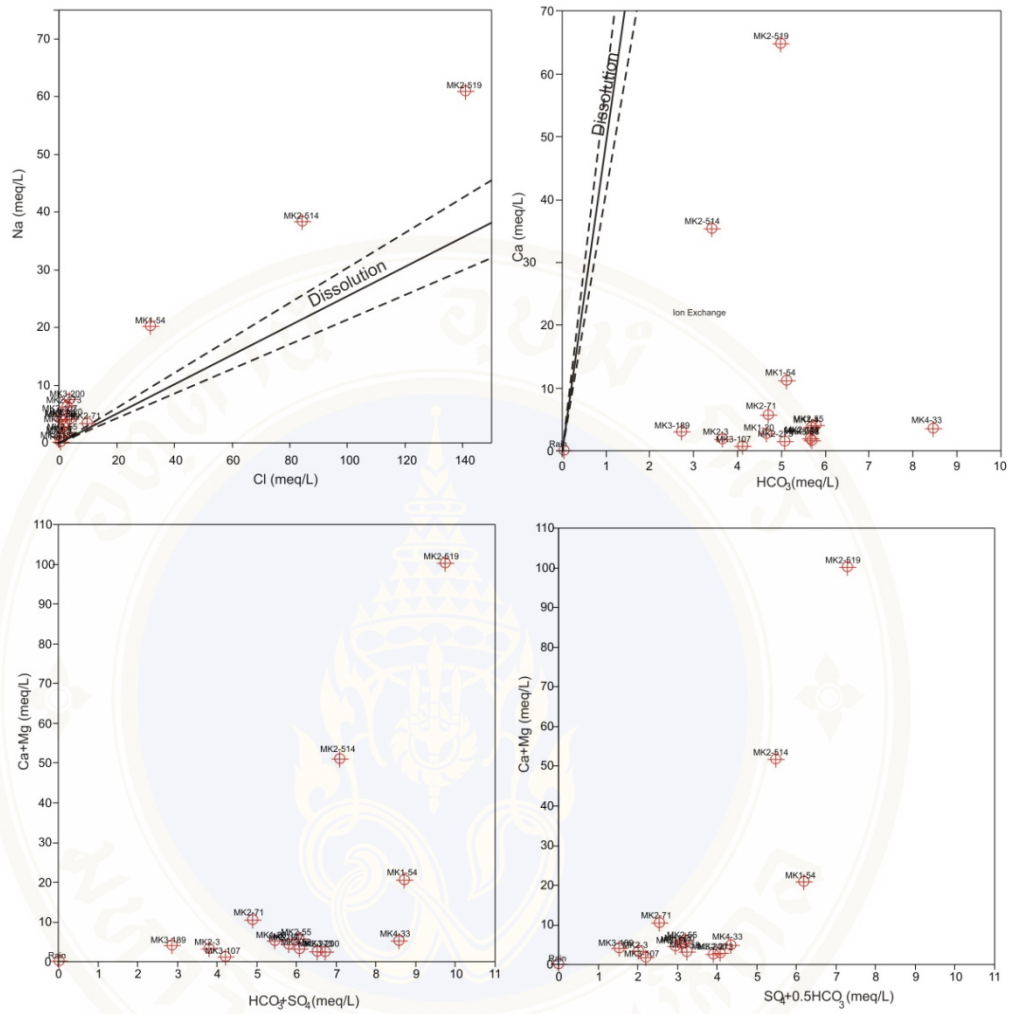


Figure 4-6: X-Y Plot of ions in Kanchanburi – Pathum thani flow path (hydrogeologic cross section B-B')

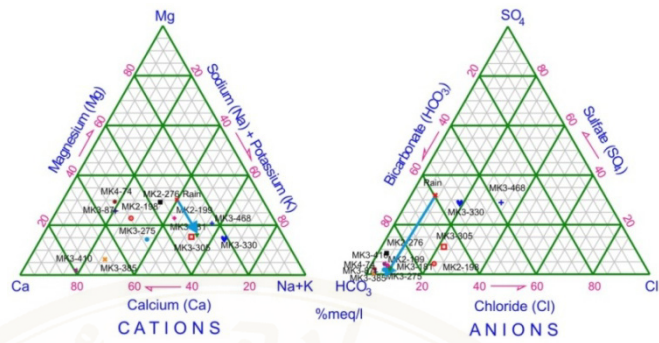


Figure 4-7a: Hydrochemical change in rain water → MK3-181

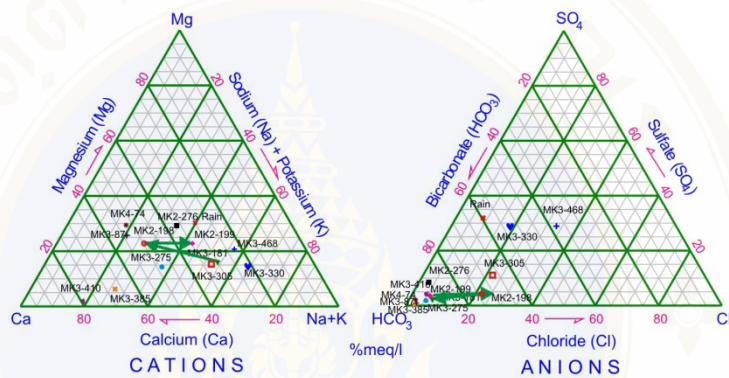


Figure 4-7b: Hydrochemical change in MK3-181 → MK2-198 → MK2-198

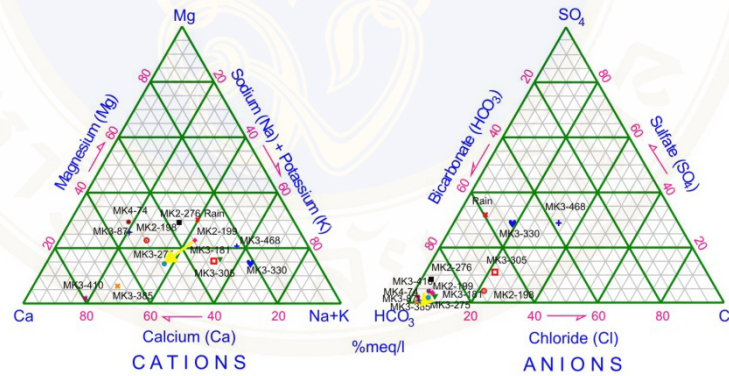


Figure 4-7c: Hydrochemical change in MK2-198 → MK3-275

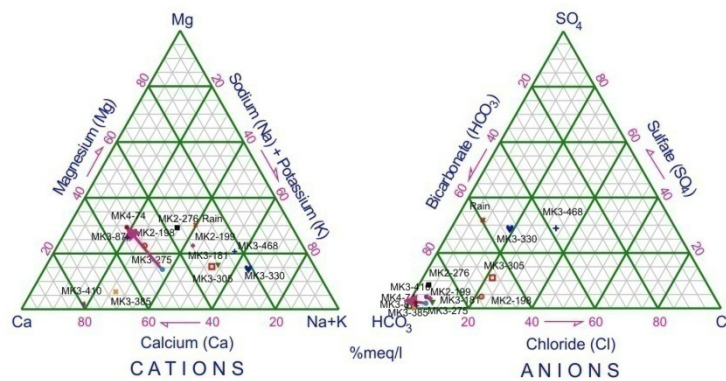


Figure 4-7d: Hydrochemical change in MK3-275 → MK4-74



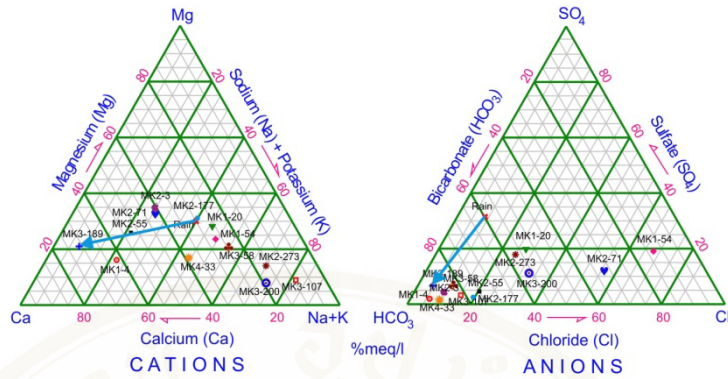


Figure 4-8a: Hydrochemical change in rain water → MK3-189

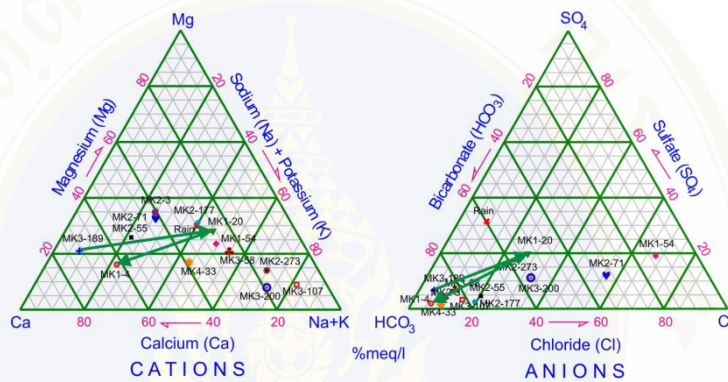


Figure 4-8b: Hydrochemical change in MK3-189 → MK1-20 → MK1-4

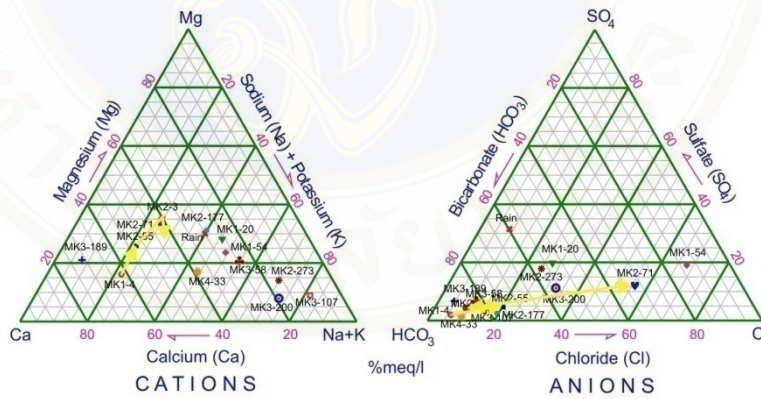


Figure 4-8c: Hydrochemical change in MK1-4 → MK2-55 → MK2-3 → MK2-71

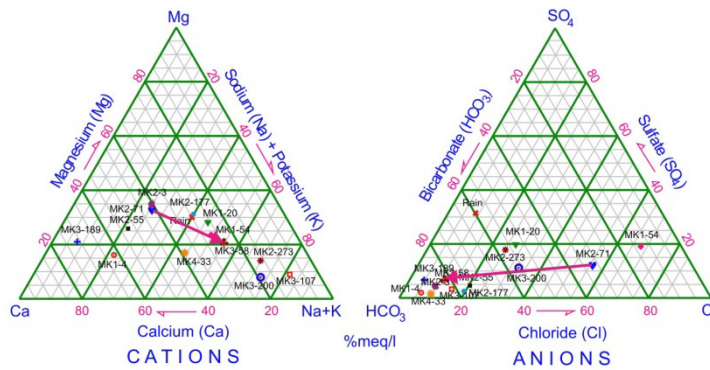


Figure 4-8d: Hydrochemical change in MK2-71 → MK3-58

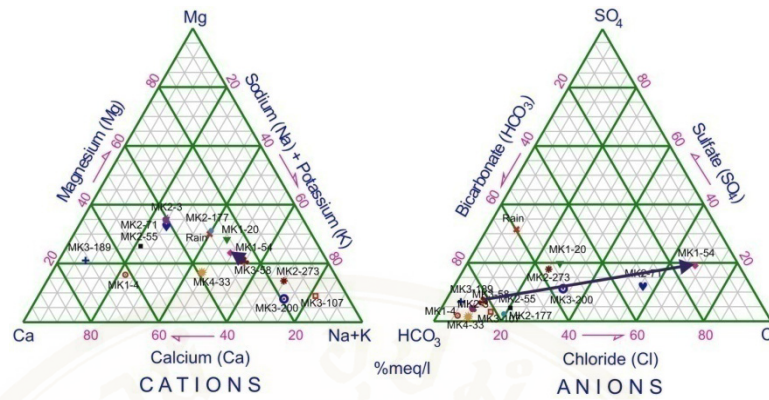


Figure 4-8e: Hydrochemical change in MK3-58 → MK1-54

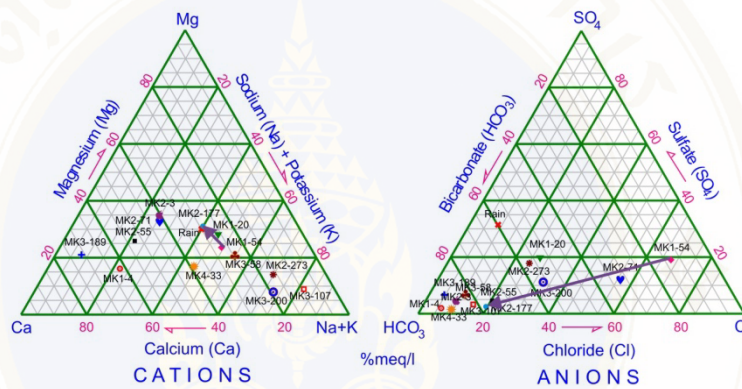


Figure 4-8f: Hydrochemical change in MK1-54 → MK2-177.

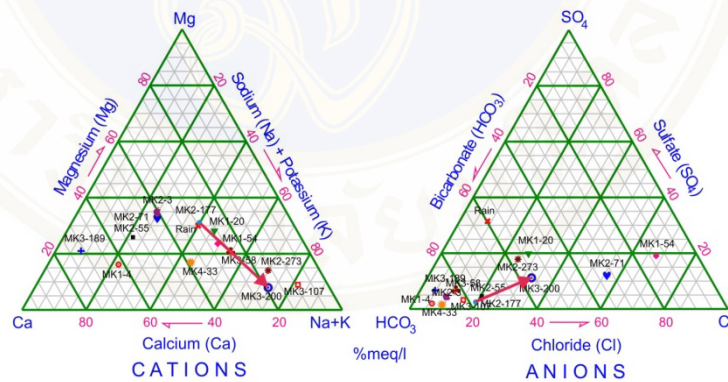


Figure 4-8g: Hydrochemical change in MK2-177 → MK3-200

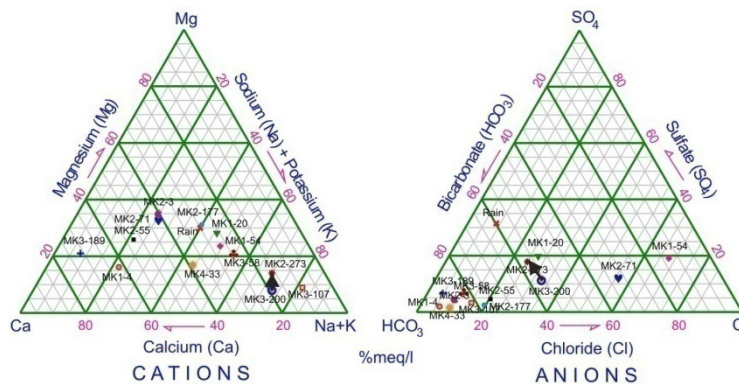


Figure 4-8h: Hydrochemical change in MK3-200 → MK2-273

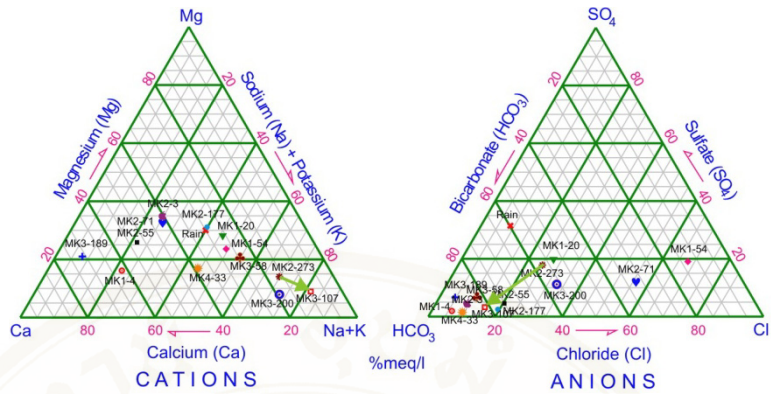


Figure 4-8i: Hydrochemical change in MK2-273 → MK3-107

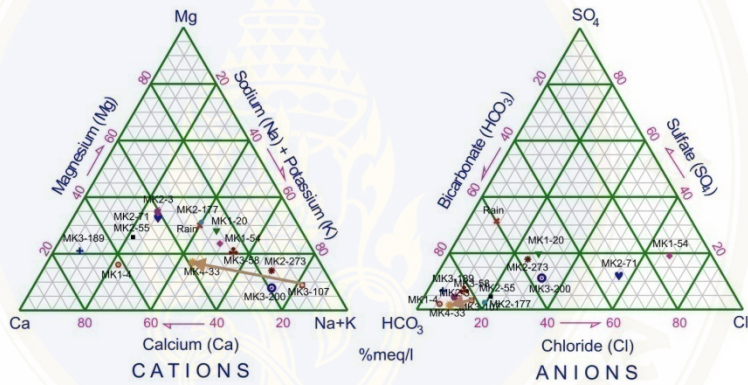
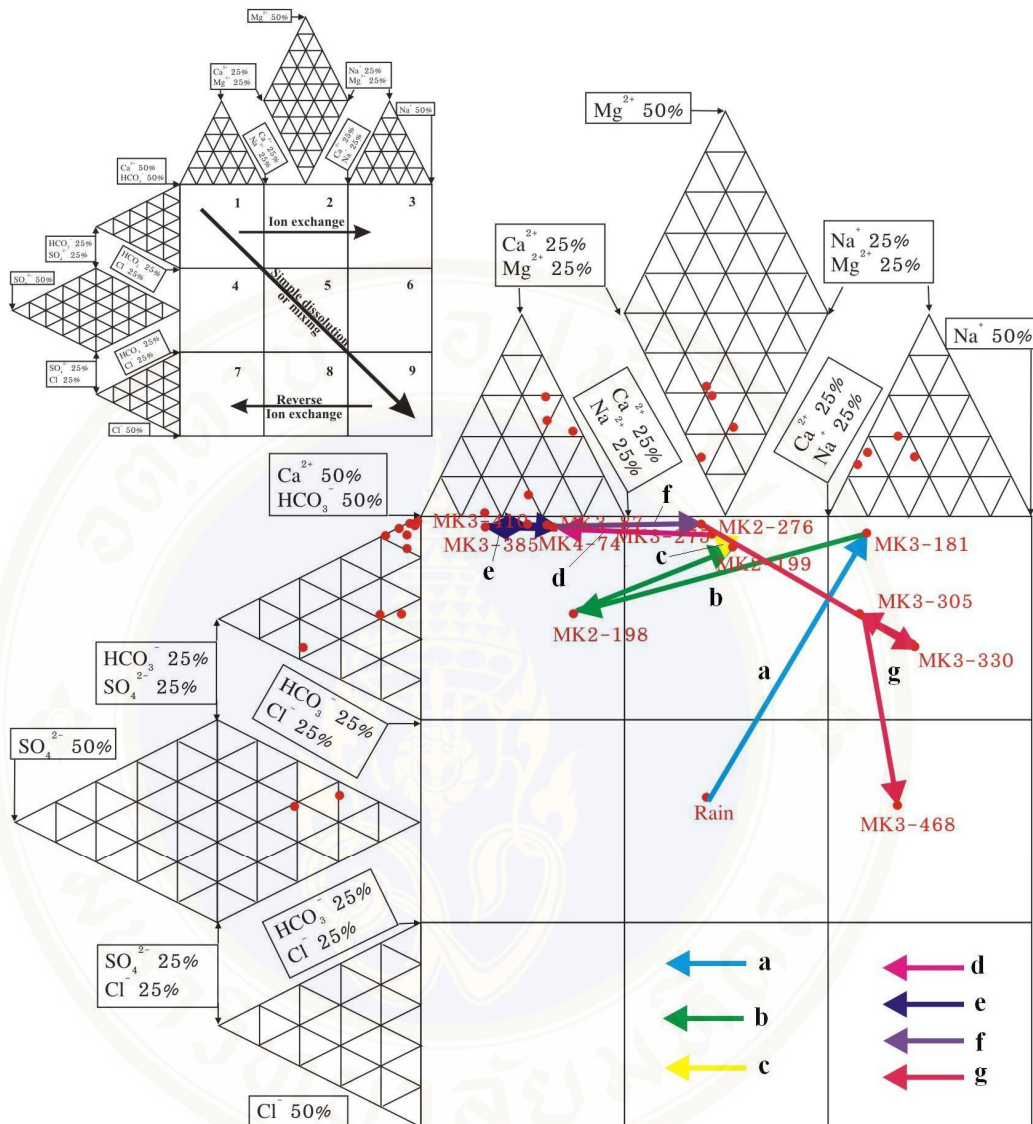


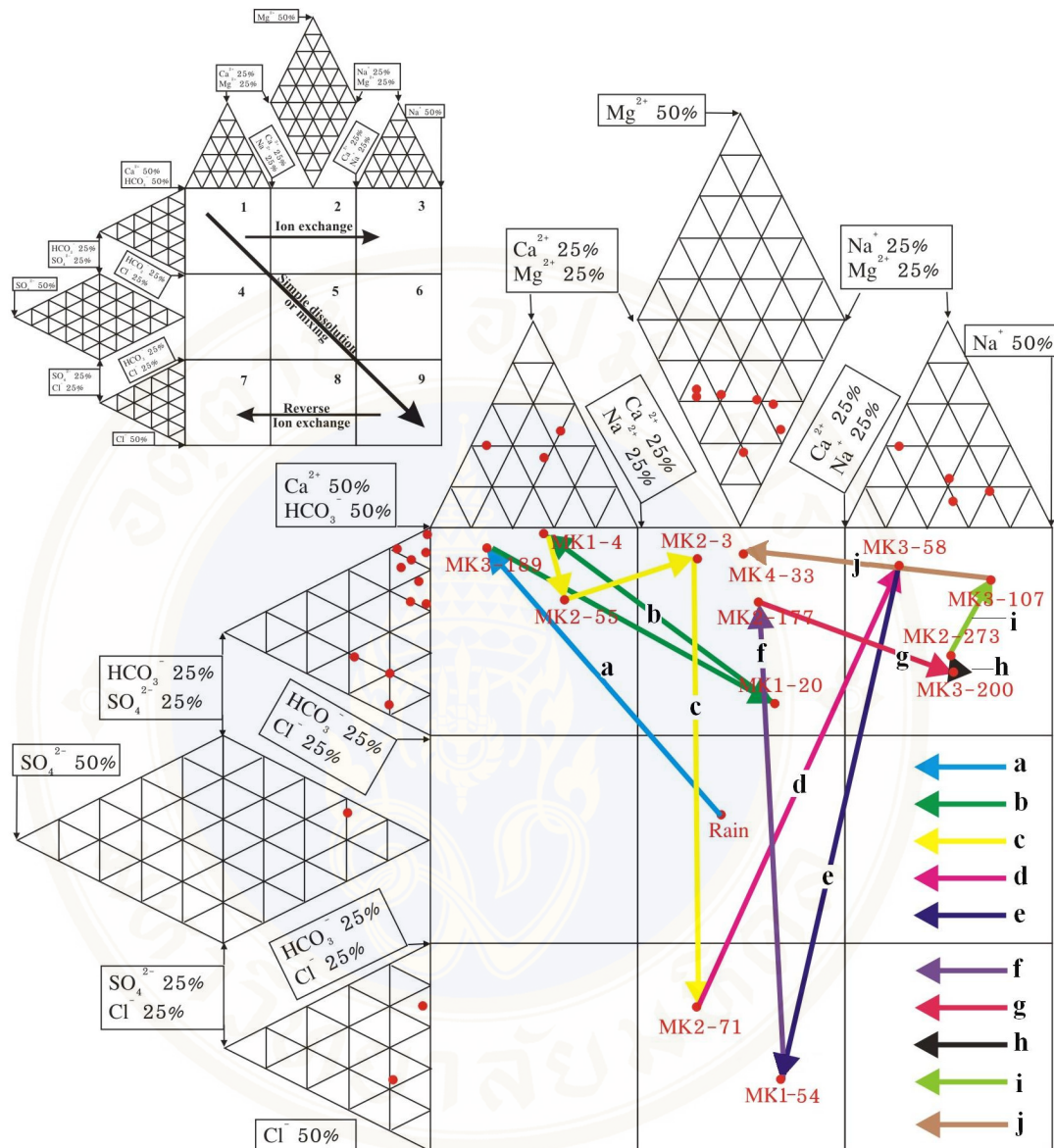
Figure 4-8j: Hydrochemical change in MK3-107 → MK4-33

Figure 4-8 : (a-j) Piper Diagram of hydrogeochemical Process along cross section B-B'



- a: rain water → MK3-181
- b: MK3-181 → MK2-198 → MK2-199
- c: MK2-199 → MK3-275
- d: MK3-275 → MK4-74
- e: MK4-74 → MK3-410 → MK3-385 → MK3-387
- f: MK3-387 → MK2-276
- g: MK2-276 → MK3-330 → MK3-305 → MK3-468

Figure 4-9: (a-g) Durov Diagram of hydrochemical changes on cross section A-A'



a: rain water → MK3-189, b: MK3-189 → MK1-20 → MK1-4,  
 c: MK1-4 → MK2-55 → MK2-3 → MK2-71, d: MK2-71 → MK3-58,  
 e: MK3-58 → MK1-54, f: MK1-54 → MK2-177,  
 g: MK2-177 → MK3-200, h: MK3-200 → MK2-273,  
 i: MK2-273 → MK3-107 and j: K3-107 → MK4-33

Figure 4-10: (a-j) Durov Diagram of Hydrochemical changes on cross section B-B'

#### 4.5 Hydrogeochemical Process along Kanchanaburi – Angthong Flow Path (A-A')

**Flow path:** Rainwater => recharge Area (West of Laokwan) => discharge area (West of Chao Phraya Basin)

**Distance:** 74.4 km

**TDS:** < 1000 mg/L

The flow path through aquifers is shown as the following diagram:

Metamorphic rock aquifer  $\implies$  colluvial aquifer  $\implies$  alluvial aquifer

Ion ratio and TDS are shown as table 4.4 and Figure 4-5. Hydrogeochemical facies in recharge areas of MK3-181 are totally different: quantity of most ions is increased as the flow distance.

TDS in starting groundwater const of ions mostly in  $\text{HCO}_3^-$ ,  $\text{Na}^+$  and  $\text{Ca}^{2+}$  and change into  $\text{Na}^+$ ,  $\text{Ca}^{2+}$ ,  $\text{Cl}^-$  and  $\text{SO}_4^{2-}$  in Discharge areas.

**Hydrogeochemical Facies:** Rain water  $\implies$  Recharge areas  $\implies$  Discharge areas:

$\text{Ca-HCO}_3 \implies \text{Na-Ca-HCO}_3 \implies \text{Ca-Na-HCO}_3 \implies \text{Ca-Na-Mg-HCO}_3 \implies \text{Ca-Na-Mg-HCO}_3\text{-Cl-SO}_4$

##### Hydrogeochemical Process for A-A' Flow Path

- 1) **Rain water** => Aquifer Layer III (NL):  
=> MK3-181 (TDS: ~532 mg/L)

Reaction and Dissolution: Calcite (Figure 4-5 the X-Y plots of Ca against  $\text{HCO}_3$ );

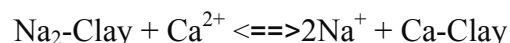
Carbonate dissolution: (Figure 4-7a Piper diagram)

- 2) **Aquifer Layer III (NL)** => Layer II (PD):  
(MK3-181) => (MK2-198) => (MK2-199)

Reaction and Dissolution: Calcite (Figure 4-7b Piper diagram);  
 $\text{Ca}^{2+}$  -  $\text{Mg}^{2+}$  (Figure 4-9b Durov diagram);

Ion Exchange: (Figure 4-5 the X-Y plot of ions  $\text{Ca}^{2+}$  +  $\text{Mg}^{2+}$  against  $\text{HCO}_3 + \text{SO}_4$ )

The reaction of ion exchange may be written as follow:



**3) Aquifer Layer II (PD) => Layer III (NL):**

(MK2-199) =&gt; (MK3-275)

Reaction and Dissolution: Calcite (Figure 4-7c Piper diagram)**4) Aquifer Layer III (NL) => Layer IV (NB):**

(MK3-275) =&gt; (MK4-74)

Reaction and Dissolution: Ca- HCO<sub>3</sub> (Figure 4-7d Piper diagram);Rainwater and Gypsum Dissolution: (Figure 4-5 X-Y plot of Ca<sup>2+</sup> against HCO<sub>3</sub>)**5) Aquifer Layer IV (NB) => Layer III (NL):**

(MK4-74) =&gt; (MK3-410) =&gt; (MK3-385) =&gt; (MK3-87)

Reaction and Dissolution: Calcite (Figure 4-7e Piper diagram);Reverse ion exchange : (Figure 4-5 the X-Y plot of Ca+ Mg against HCO<sub>3</sub>+SO<sub>4</sub>)**6) Aquifer Layer III (NL) => Layer II (PD):**

(MK3-87) =&gt; (MK2-276)

Carbonate Dissolution: (Figure 4-5 the X-Y plots of Ca against HCO<sub>3</sub>);Ion Exchange: (shown as Figure 4-7f Piper diagram and Figure 4-9f Durov diagram)**7) Aquifer Layer II (PD) => discharge area of Layer III (NL):**

(MK2-276) =&gt; (MK3-330) =&gt; (MK3-305) =&gt; (MK3-468)

Halite Dissolution: (Figure 4-5 the X-Y plots of ions Na against Cl);Ion Exchange: (shown as Figure 4-7g Piper diagram and Figure 4-9g Durov diagram)

**Conclusion:** Trend of hydrochemical process along the flow path in Kanchanaburi-Angthong basin in aquifer layer III (NL):

Recharge areas (Laokhwan) =&gt; discharge areas (Chaophraya Basin)

**Reactions:**

Cation and anion change => dissolution and crystallization of carbonate=>ion exchange. Summary of hydrochemical processes for A-A' flow path please see the table 4-6 as shown below:

Table 4-6: Analysis on Hydrogeochemical Process along Kanchanaburi (Lao Kwan) – Anghthong Flow Path (A-A')

Well-to-Well FLOW PATH	STUDY METHODS			DUROV DIAGRAM
	ION RATIO	X-Y PLOT	PIPER DIAGRAM	
Rain --> MK3-181	<ul style="list-style-type: none"> <li>- Na<sup>2+</sup> from Halite-Albite / Ion Exchange</li> <li>- Weathering of Plagioclase</li> </ul>	<ul style="list-style-type: none"> <li>- Ion Exchange (Ca+Mg-HCO<sub>3</sub> +SO<sub>4</sub> Graph)</li> </ul>	<ul style="list-style-type: none"> <li>- Dissolution of Albite-Calcite / Ion Exchange</li> </ul>	
MK3-181 --> MK2-198 --> MK2-199	<ul style="list-style-type: none"> <li>- Na<sup>2+</sup> from Halite-Albite / Ion Exchange</li> <li>- Weathering of Silicate/Carbonate Minerals</li> <li>- Sea/Saltwater Intrusion</li> </ul>	<ul style="list-style-type: none"> <li>- Dissolution / Ion Exchange (Ca+Mg-HCO<sub>3</sub> +SO<sub>4</sub> Graph)</li> </ul>	<ul style="list-style-type: none"> <li>- Dissolution of Albite-Calcite / Ion Exchange</li> </ul>	<ul style="list-style-type: none"> <li>- Ion Exchange</li> </ul>
MK2-199 --> MK3-275	<ul style="list-style-type: none"> <li>- Na<sup>2+</sup> from Halite-Albite / Ion Exchange</li> <li>- Weathering of Silicate/Carbonate Minerals</li> </ul>	<ul style="list-style-type: none"> <li>- Dissolution of Gypsum (Ca+Mg-HCO<sub>3</sub> +SO<sub>4</sub> Graph)</li> </ul>	<ul style="list-style-type: none"> <li>- Dissolution of Calcite</li> </ul>	
MK3-275 --> MK4-74	<ul style="list-style-type: none"> <li>- Weathering of Plagioclase</li> <li>- Ca<sup>2+</sup> from Gypsum/ Carbonate group/ Silicate group</li> <li>- Sea/Saltwater Intrusion</li> </ul>	<ul style="list-style-type: none"> <li>- Ion Exchange (Ca+Mg-HCO<sub>3</sub> +SO<sub>4</sub> Graph)</li> <li>- Dissolution of Calcium-Carbonate (Ca-HCO<sub>3</sub> Graph)</li> </ul>	<ul style="list-style-type: none"> <li>- Dissolution of Calcite/ Gypsum.</li> <li>- Dolomite Decomposition</li> </ul>	
MK4-74 --> MK3-410 --> MK3-385 --> MK3-87	<ul style="list-style-type: none"> <li>- Na<sup>2+</sup> from Halite-Albite / Ion Exchange</li> </ul>	<ul style="list-style-type: none"> <li>- Dissolution / Ion Exchange (Ca+Mg-HCO<sub>3</sub> +SO<sub>4</sub> Graph)</li> </ul>	<ul style="list-style-type: none"> <li>- Dissolution of Calcite</li> </ul>	
MK3-87 --> MK2-276	<ul style="list-style-type: none"> <li>- Ca<sup>2+</sup> from Gypsum / Carbonate Minerals / Silicate Minerals</li> </ul>	<ul style="list-style-type: none"> <li>- Ion Exchange (Ca+Mg-HCO<sub>3</sub> +SO<sub>4</sub> Graph)</li> <li>- Dissolution Calcium Carbonate (Ca-HCO<sub>3</sub> Graph)</li> </ul>	<ul style="list-style-type: none"> <li>- Ion Exchange</li> </ul>	<ul style="list-style-type: none"> <li>- Ion Exchange</li> </ul>
MK2-276 --> MK3-330 --> MK3-305 --> MK3-468	<ul style="list-style-type: none"> <li>- Ca<sup>2+</sup> from Gypsum / Carbonate Minerals / Silicate Minerals</li> </ul>	<ul style="list-style-type: none"> <li>- Dissolution of Halite (Na-Cl Graph)</li> <li>- Dissolution or Ion Exchange (Ca+Mg-HCO<sub>3</sub> +SO<sub>4</sub> Graph)</li> </ul>	<ul style="list-style-type: none"> <li>- Ion Exchange</li> </ul>	<ul style="list-style-type: none"> <li>- Ion Exchange</li> </ul>

#### 4.6 Hydrogeochemical Process along Kanchanaburi (Thamaka) – Pathum thani Flow path (B-B')

**Flow path:** Rainwater => Recharge Area (Thamaka) => Discharge area (Sai Noi, Pathum Thani)

**Distance:** 82.2 km

**TDS in MK2-519(deep groundwater):** ~ 8900 mg/L

**The flow path through aquifers is shown as the following diagram:**

Metamorphic rock aquifer => colluvial aquifer => alluvial aquifer

Ion ratio plots and TDS are shown as Figure 4-6 and table 4-5 respectively.

Hydrogeochemical facies in recharge areas of MK2-519 are totally different: quantity of ions is increased as the flow distance and aquifer layers.

**Hydrogeochemical Facies:** Rain water => Recharge areas => Discharge areas:

Ca- HCO<sub>3</sub> => Ca-Mg- HCO<sub>3</sub> => Ca-Mg-Na- HCO<sub>3</sub> => Na- HCO<sub>3</sub>-Cl => Ca-Na-Mg-Cl

##### Hydrogeochemical Process for B-B' Flow Path

##### 1) Rain water of Aquifer Layer III (NL): MK3-189

TDS: ~200 mg/L

Carbonate Dissolution: (Figure 4-6 the X-Y plot Ca against HCO<sub>3</sub>);

Mixing water: (Figure 4-10 Durov Diagram);

Calcite (Figure 4-8a Piper diagram)

Carbonate-saturated Zone

##### 2) Aquifer Layer III (NL) => Layer I (BK) :

(MK3-189) => (MK1-20) => (MK1-4)

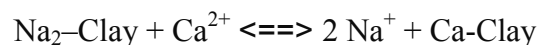
Reaction and Dissolution: Dissolution&Crystallization of Carbonate (Figure 4-8b Piper diagram);

Albite-Calcite (cement + main component of sand and gravel)

(Figure 4-10b Durov diagram);

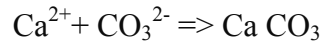
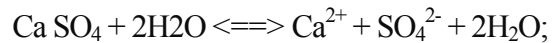
Ion Exchange: (Figure 4-6: the X-Y plot Ca<sup>2+</sup>+Mg<sup>2+</sup> vs. HCO<sub>3</sub> + SO<sub>4</sub>);

The reaction of ion exchange may be



**3) Aquifer Layer I (BK) => Layer II (PD):**

(MK1-4) =&gt; (MK2-55) =&gt; (MK2-3) =&gt; (MK2-71)

Reaction and Dissolution: Gypsum dissolution:Ion Exchange: (shown as Figure 4-8c Piper diagram);Ca+Mg-HCO<sub>3</sub>+ SO<sub>4</sub> (Figure 4-6 the X-Y plot)**4) Aquifer Layer II (PD) => Layer III (NL): (MK2-71) => (MK3-58)**Reaction and Dissolution: (Figure 4-8d Piper diagram and Figure 4-6 the X-Y plot Ca vs.HCO<sub>3</sub>)**5) Aquifer Layer III (NL) => Layer I (BK): (MK3-58) => (MK1-54)**Reaction and Dissolution: Saltwater intrusion (Figure 4-8e Piper diagram)Ion Exchange: (Figure 4-6 the X-Y plot [Ca<sup>2+</sup>+ Mg<sup>2+</sup>] vs. [HCO<sub>3</sub>+ SO<sub>4</sub>])**6) Aquifer Layer I (BK) => Layer II (PD): (MK1-54) => (MK2-177)**Reaction and Dissolution: Ca: HCO<sub>3</sub> (Figure 4-6 X-Y Graph)Ion Exchange: Ca+ Mg : HCO<sub>3</sub>+ SO<sub>4</sub>**7) Aquifer Layer II (PD) => Layer III (NL)**Ion exchange: : (Figure 4-6 the X-Y plot [Ca<sup>2+</sup>+ Mg<sup>2+</sup>] vs. [HCO<sub>3</sub>+ SO<sub>4</sub>])**8) Aquifer Layer III (NL) => Discharge area of Layer IV (NB):**

(MK3-107) =&gt; (MK4-33)

Reaction and Dissolution: Ca: HCO<sub>3</sub> (Figure 4-6);

Saltwater intrusion (Figure 4-8f Piper diagram)

**Conclusion:** (See Table 4-7)**Flow direction in Kanchanaburi-Pathum thani:**

Recharge areas (Thamaka) =&gt; Discharge areas (Sai Noi, Pathum thani)

**Reactions:**

Calcite Dolomite Gypsum or Silicate mineral Dissolution =&gt; Ion exchange =&gt;

Saltwater Intrusion

Table 4-7: Analysis on Hydrogeochemical Process along Kanchanaburi – Pathum Thani Flow path (B-B')

Well-to-Well FLOW PATH	STUDY METHODS			PIPER DIAGRAM	DUROV DIAGRAM
	ION RATIO	X-Y PLOT			
Rain --> MK3-189	- Ca <sup>2+</sup> from Gypsum / Carbonate Minerals / Silicate Minerals - Sea/Saltwater Intrusion	- Dissolution or Ion Exchange (Ca+Mg-HCO <sub>3</sub> +SO <sub>4</sub> Graph)	- Occurrence of Calcite/Dolomite	- Dissolution / Mixing Water	
MK3-189 --> MK1-20 --> MK1-4	- Na <sup>2+</sup> from Halite-Albite / Ion Exchange - Weathering of Plagioclase	- Ion Exchange (Ca+Mg-HCO <sub>3</sub> +SO <sub>4</sub> Graph)	- Dissolution of Albite-Calcite / Ion Exchange	- Ion Exchange	
MK1-4 --> MK2-55 --> MK2-3 --> MK2-71	- Na <sup>2+</sup> from Halite-Albite / Ion Exchange - Sea/Saltwater Intrusion	- Dissolution of Gypsum (Ca+Mg-HCO <sub>3</sub> +SO <sub>4</sub> Graph)	- Ion Exchange		
MK2-71 --> MK3-58	- Ca <sup>2+</sup> from Gypsum / Carbonate Minerals / Silicate Minerals	- Dissolution of Calcium Carbonate (Ca-HCO <sub>3</sub> Graph)	- Dissolution of Albite-Calcite / Ion Exchange		
MK3-58 --> MK1-54	- Na <sup>2+</sup> from Halite-Albite / Ion Exchange - Sea/Saltwater Intrusion	- Ion Exchange (Ca+Mg-HCO <sub>3</sub> +SO <sub>4</sub> Graph)	- Ion Exchange - Saltwater Contamination		
MK1-54 --> MK2-177	- Na <sup>2+</sup> from Halite-Albite / Ion Exchange - Ca <sup>2+</sup> from Gypsum / Carbonate Minerals / Silicate Minerals - Sea/Saltwater Intrusion	- Dissolution of Gypsum (Ca+Mg-HCO <sub>3</sub> +SO <sub>4</sub> Graph) - Dissolution of Calcium Carbonate (Ca-HCO <sub>3</sub> Graph) - Ion Exchange (Ca+Mg-HCO <sub>3</sub> +SO <sub>4</sub> Graph)	- Occurrence of Calcite/Dolomite		
MK2-177 --> MK3-200	- Na <sup>2+</sup> from Halite-Albite / Ion Exchange - Sea/Saltwater Intrusion	- Ion Exchange (Ca+Mg-HCO <sub>3</sub> +SO <sub>4</sub> Graph)	- Dissolution of Albite-Calcite / Ion Exchange	- Ion Exchange	

Table 4-7: Analysis on Hydrogeochemical Process along Kanchanaburi – Pathum Thani Flow path (B-B') (cont.)

Well-to-Well FLOW PATH	STUDY METHODS			DUROV DIAGRAM
	ION RATIO	X-Y PLOT	PIPER DIAGRAM	
MK3-200 --> MK2-273	<ul style="list-style-type: none"> <li>- Na<sup>2+</sup> from Halite-Albite / Ion Exchange</li> <li>- Sea/Saltwater Intrusion</li> </ul>	<ul style="list-style-type: none"> <li>- Ion Exchange (Ca+Mg-HCO<sub>3</sub>+SO<sub>4</sub> Graph)</li> </ul>	<ul style="list-style-type: none"> <li>- Ion Exchange</li> </ul>	
MK2-273 --> MK3-107	<ul style="list-style-type: none"> <li>- Na<sup>2+</sup> from Halite-Albite / Ion Exchange</li> <li>- Sea/Saltwater Intrusion</li> </ul>	<ul style="list-style-type: none"> <li>- Ion Exchange (Ca+Mg-HCO<sub>3</sub>+SO<sub>4</sub> Graph)</li> </ul>	<ul style="list-style-type: none"> <li>- Dissolution of Albite-Calcite / Ion Exchange</li> </ul>	
MK3-107 --> MK4-33	<ul style="list-style-type: none"> <li>- Ca<sup>2+</sup> from Gypsum / Carbonate Minerals / Silicate Minerals</li> <li>- Sea/Saltwater Intrusion</li> </ul>	<ul style="list-style-type: none"> <li>- Dissolution of Calcium-Carbonate (Ca-HCO<sub>3</sub> Graph)</li> </ul>	<ul style="list-style-type: none"> <li>- Ion Exchange</li> <li>- Saltwater Contamination</li> </ul>	

## **4.7 Groundwater Quality Management applied according to the Research and Analysis**

The analysis from the study and hydrogeochemical interpretations are decent to be applied efficiently as tools or backup for groundwater quality management as to keep nature balance, avoid any hazard outcomes and the aftermaths, for instance, Saltwater intrusion, contamination by other dissolved solids.

Groundwater quality trends and situations:

1. According to the hydrogeochemical research, hydrogeochemical facies, water types, and water quality evaluation of each aquifer layer on Appendix C indicate that Aquifer Layer I and II, near the southeastern most and that contacting Thai gulf, are contaminated by saltwater. There should be the control measure of the use of groundwater in these areas to keep its balance. However, in deeper layers, Layer III to Layer V, groundwater is still in good quality. Anyhow, the groundwater quality control measure must be applied to groundwater in these layers as well.

2. According to the results of this study, the following three areas of categorized groundwater types were delineated for groundwater quality management: (See Figure 4-11)

Area (i): High to very high quality freshwater

This water type is found in the westernmost and the north of research areas; and all over layers. From recharge areas and other water sources, most of water spread through the ground, whereas that of Layer I spread through since the surface of ground from the rain. Thus, Protection areas are necessary in such areas for the control of the agro and industrial chemicals released.

Area (ii): Moderate to high quality freshwater

Brackish water is found in the central part of most areas, as on Chapter 4.1 - 4.4(see Figure 4-11). In these areas should be strict control measure and the follow-up in case of deterioration and its improvement before the degradation of groundwater.

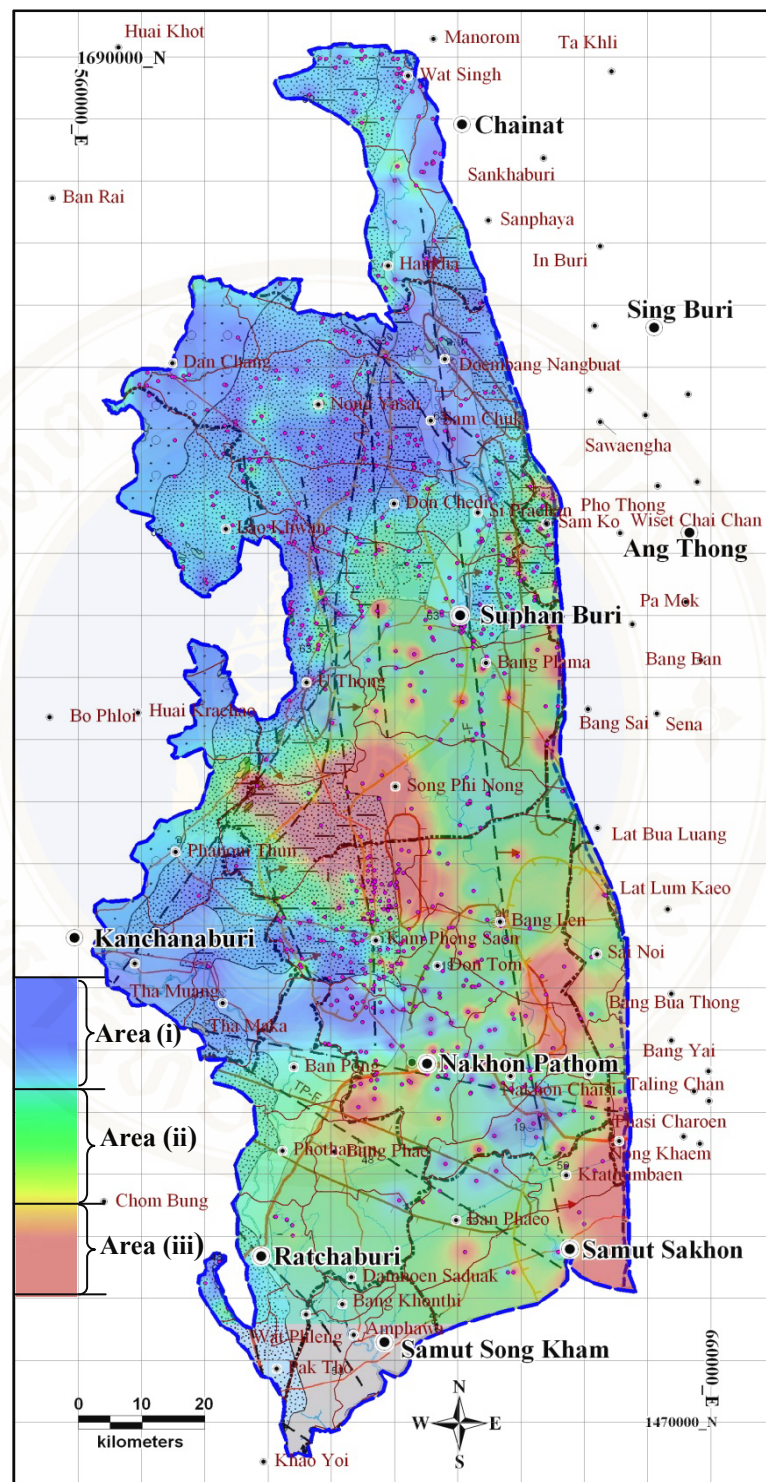
Area (iii): Low to moderate quality (salt-contaminated water)

This water type is found in the end of groundwater in the south easternmost and the south of research areas. Also, natural saltwater intrusion and human activities could change other water type. However, the hydrogeochemical interpretation; analysis on Piper diagram, Durov diagram, Ion Ratio, Stiff diagram, and XY plot allow us to learn about groundwater facts, hydrogeochemical process, water quality evaluation in the research areas, realization of water quality management, such as the reduction of groundwater use for nature balance, and the Aquifer Storage and Recovery (ASR)

3. According to Sodium Adsorption Ratio (SAR) analysis, the results revealed that the value is ranged from zero up to sixty six meq/l. After Mass, 1999 (20), they were divided into four classes of groundwater quality, the SAR value ranged by low (86.92%), moderate (10.63%) high (2.28%) and very high (0.17%) of sodium hazard. Map of SAR distribution of the study area is shown in Figure 4-12. Due to Wilcox diagram for irrigation, water types are classified according to Class Status for Irrigation by USDA (21), that lead to the water quality management for agriculture as suggested on chapter 2 and chapter 3. Analysis on diagrams for each layer are shown as Appendix D, bring to the summarization that over 90% of groundwater quality is applicable to agriculture. And the matching of water types to different agricultural activities is as the Standard Analysis on Table 2-1 and 2-2.

By all means, the suggestions from the research are released for the application in terms of the water quality and the agriculture only, not including other agricultural factors: weather, geography, lands, etc.

4. According to the research for contaminated groundwater quality management, the saline groundwater management mentioned on chapter 3.6.2 is raised for the improvement of groundwater quality in each Aquifer Layer.



Where: Area (i), groundwater quality is high to very high.

Area (ii), groundwater quality is moderate to high.

Area (iii), groundwater quality is low to moderate (contaminated).

Figure 4-11: Map of categorization groundwater types for groundwater quality management.

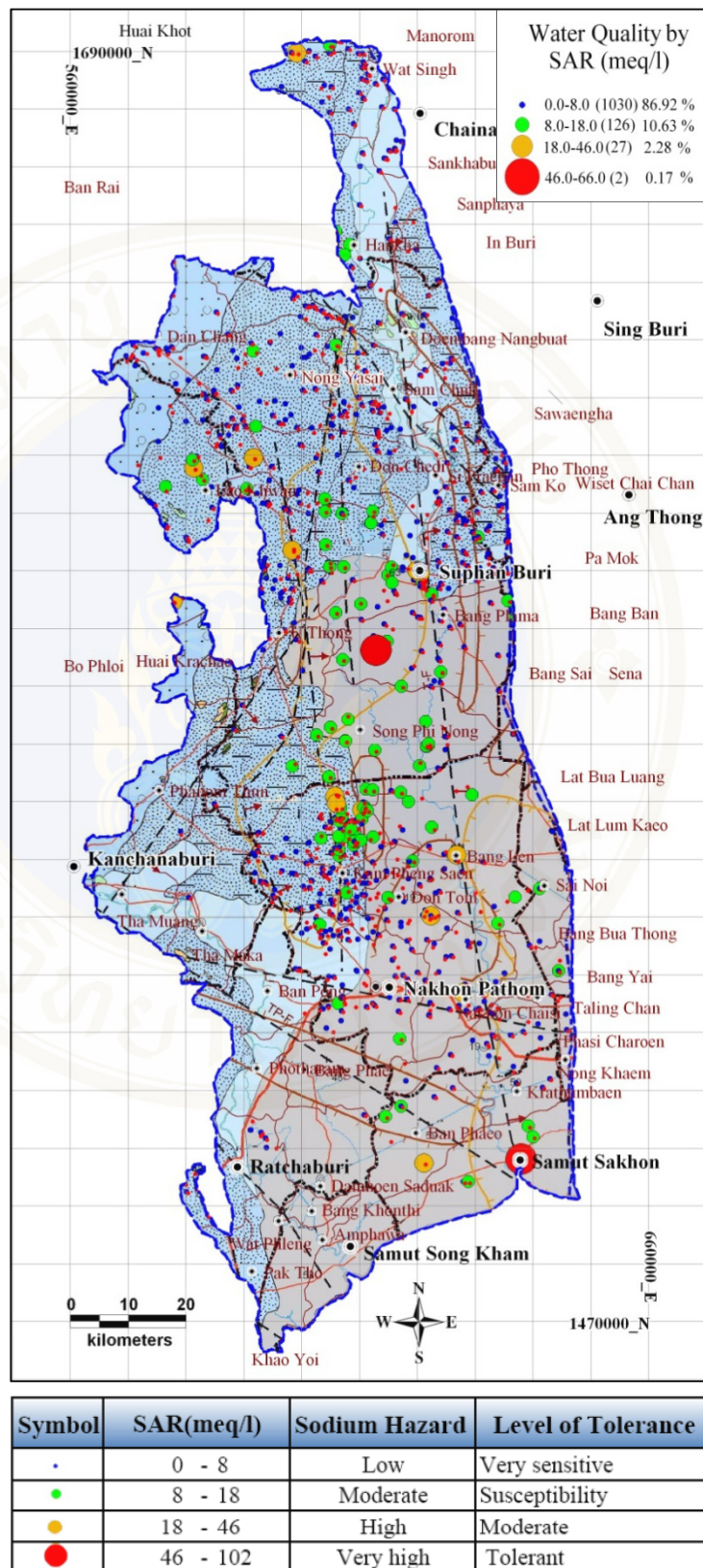


Figure 4-12: Map of SAR distribution of the study area.

## CHAPTER V

### CONCLUSION AND RECOMMENDATIONS

After the hydrochemical analysis of the Tha Chin-Mae Klong Basin with Aquachem version 5.0, the conclusion is as follows:

#### 5.1 Conclusion

##### 5.1.1 Hydrochemical analysis and interpretation

According to the hydrogeochemical analysis by Piper diagram, Durov diagram, Ion ratio, and XY graph, groundwater can be classified into 10 facies of 4 main groups:

Group 1: Calcium-Sodium-Bicarbonate {Ca- HCO<sub>3</sub>, Ca-Na-HCO<sub>3</sub> and Na-HCO<sub>3</sub>}

This water group, young aged and weakly acidic, is found in new groundwater in high plain and in the west of Recharge areas: Ratchburi, Kanchanaburi, Suphan Buri, upnorth to Chai Nat. This water quality is Freshwater. The groundwater quality management for this water group aims to keep its quality sustainability.

Group 2: Calcium-Bicarbonate-Chloride and Calcium-Sodium-Bicarbonate-Chloride {Ca-HCO<sub>3</sub> -Cl, Na-HCO<sub>3</sub> -Cl and Ca-Na-HCO<sub>3</sub> -Cl}

This water group is found in groundwater that is far from recharge areas. The water quality is Freshwater, despite of brackish water in some areas or mixing water contaminated by saltwater. The strict control measure is necessary to be applied to the water deterioration.

Group 3: Sodium-Chloride (Na-Cl), Calcium-Chloride (Ca-Cl) and Calcium-Sodium-Chloride (Ca-Na-Cl)

This water group, found in discharge areas in the south of research areas next to seashore: Samut Sakhon, Samut Songkhram, some part of Ratchburi, Nakhon Pathom; move gradually away from recharge areas with salinity advection. The

strict control measure must be applied efficiently, as well as the water revival, such as the reduction of water use for the nature balance and the Aquifer Storage and Recovery (ASR).

Group 4: Sulphate ( $\text{SO}_4$ )

This water type, found throughout Aquifer Layer II (PD) only: Sa Mae Dam, Tha Kham, Bang Khun Thian of Bangkok, mostly comes with Chloride, possibly contaminated by saltwater or dissolution of Sulphate. Nevertheless, it is also found in recharge areas: Sankhaburi of Chainat and Inburi of Singburi. Human activities may be the main causes of the contamination in water in shallow layers of some areas, for instance, chemical usage, agricultural activities and washing, etc.

### 5.1.2 Hydrogeochemical analysis on Stiff diagram

There are 3 hydrogeochemical facies as follow:

Group 1: Calcium-Carbonate ( $\text{Ca-CO}_3$  type)

This type, found throughout the Tha Chin River in Chainat, in upper aquifer layers in Suphan Buri and in deeper aquifer layers in Nakhon Pathom and Samut Sakhorn, usually appears in oxidation zone or results from dissolution of carbonate source rocks.

Group 2: Sodium-Carbonate ( $\text{Na-CO}_3$  type)

This type found throughout the west and in the central part of Tha Chin Basin in Suphan Buri; in both deeper and upper aquifer layers, appears in oxidation zone. The ion exchange from  $\text{Ca} \Rightarrow \text{Na}$  happens through deeper layers, after Aquifer Layer I.

Group 3: Chloride Group ( $\text{Ca-Cl}$  and  $\text{Na-Cl}$  type)

Calcium-Chloride ( $\text{Ca-Cl}$ ) type is found mostly in Nakhon Pathom and in some part of Samut Sakhorn. Transitional zone, between seawater and freshwater (mixing zone), is found in Aquifer Layer II (PD).

Sodium-Chloride ( $\text{Na-Cl}$ ) type is found in brackish and saltwater zone: Nakhon Pathom and in the south of Suphan Buri {(PD), (NL) and (NB)}

Hydrochemical setting is in reducing environment. Water quality of long evaluation, its TDS is very in high quantity. This water group is found in the areas contacting Thai Gulf and in central part of Tha Chin Basin in Samut Sakhon and Nakhon Pathom. These areas' state indicates the water quality of long evaluation or the saltwater intrusion.

### 5.1.3 Hydrogeochemical Analysis on principle Flow paths

The analysis on ion ratio comparison, XY graph, Piper diagram and Durov diagram by 2 flow paths is as follows:

#### 5.1.3.1 Kanchanaburi – Ang Thong Flow path (A-A')

**Flow path:** Rainwater => Recharge areas (West of Lao Khwan)  
=> Discharge areas (eastern Chao Phraya Basin)

**Distance:** 74.4 km

**Hydrochemical Facies:**

Ca-HCO<sub>3</sub> => Na-Ca-HCO<sub>3</sub> => Ca-Na-HCO<sub>3</sub> =>  
Ca-Na-Mg-HCO<sub>3</sub> => Ca-Na-Mg-HCO<sub>3</sub>-Cl-SO<sub>4</sub>

#### 5.1.3.2 Kanchanaburi – Pathum Thani Flowpath (B-B')

**Flow path:** Rainwater => Recharge areas (Tha Maka) =>  
Discharge areas (Sai Noi, Pathum Thani)

**Distance:** 82.2 km

**Hydrochemical Facies:**

Ca-HCO<sub>3</sub> => Ca-Na-HCO<sub>3</sub> => Ca-Mg-Na-HCO<sub>3</sub> =>  
Na-HCO<sub>3</sub>-Cl => Ca-Na-Mg-Cl

### 5.1.4 Groundwater Quality Management

#### 5.1.4.1 Groundwater zoning

The following three areas of categorized groundwater types were delineated for groundwater quality management: (i) where groundwater quality is high to very high (mostly groundwater types in Group 1). Preventive measures are required for these areas, (ii) where groundwater quality is moderate to high (mostly groundwater types in Group 2). There should be measures taken for groundwater quality monitoring and (iii) in contaminated areas (mostly groundwater types in groups 3 and 4). Remediation measures and groundwater utilization control are necessary.

#### 5.1.4.2 Analysis for Irrigation

According to Sodium Adsorption Ratio (SAR) analysis, and plotting Wilcox diagram for irrigation, bring to the summarization that over 90% of groundwater quality is applicable to agriculture. Groundwater quality for agriculture mostly is proper to average, except in the coastal and certain part of the central area.

## 5.2 Recommendations for further study

5.2.1 Research from different timings and sources give different results. Water quality analysis was undergone once after the sample experiment, as a result, the water quality comparison is not sufficiently accurate. Schedules on time and space of water collection should be well organized for the accurate interpretation.

5.2.2 The methods of sample collecting are unknown after well drillings. The improper cleansing could cause the mixing ions among water from different layers. The well selection and sample collecting correctly are necessary for the improvement.

5.2.3 Data from Thailand's Groundwater Database (Pasutara) may not completely accurate because of certain regular mistakes: typographical errors, or wrong labels on sample containers. Good preparation and organization of sample collecting need to be applied.

5.2.4 Selected secondary data in some aquifer layer, especially Layer I (BK), is insufficient. Saltwater intrusion is an obstacle for water sample collecting. Thus, water collecting in unused wells is optional for the additional experiments and analysis.

5.2.5 Other methods of hydrochemical analysis should be applied for more efficient interpretation: Isotope analysis, analysis on Bromine (Br) and Silica Oxide (SiO<sub>2</sub>), also the model of well selection.

5.2.6 Data collected is insufficient for local flow system analysis. More sample from upper layers throughout areas need to be collected for the better local flow system analysis, water quality evaluation, relation between water types and flow system in both Intermediate flow system and Regional flow system.

Despite of the difficulties mentioned above, the analysis and its results can be well applied to water quality management in the Tha Chin-Mae Klong Basin. Water quality in some areas is in very good quality: Recharge areas. There should be groundwater development and conservation plans along with other schemes of Department of Groundwater Resources: the study on water balance, water potential, water usage, etc.

## REFERENCES

- 1 กรมทรัพยากรน้ำบาดาล. (2551). โครงการประเมินศักยภาพแหล่งน้ำบาดาลโดยอาศัยแบบจำลองคณิตศาสตร์เพื่อหาปริมาณการสูบน้ำที่เหมาะสมของชั้นน้ำบาดาลตะกอนหินร่วน (Safe yield) เป็นรายจังหวัด พื้นที่ลุ่มน้ำท่าจีนและแม่กลอง. กรุงเทพฯ: สำนักอนุรักษ์และฟื้นฟูแหล่งน้ำบาดาล กรมทรัพยากรน้ำบาดาล กระทรวงทรัพยากรธรรมชาติและสิ่งแวดล้อม.
- 2 A Modular Three-Dimensional Finite Difference Groundwater Flow Model, Waterloo Hydrogeologic Inc., 1999.
- 3 Hounslow, A.W. (1995). Water Quality: Analysis and Interpretation. New York: Lewis.
- 4 Waterloo Hydrogeologic, Inc. (2006). AquaChem v. 5.0. Canada: Waterloo Hydrogeologic, Inc.
- 5 Hounslow, A.W., & Goff, K.D. (1994). WATEVAL V.8.10L 9/94. Oklahoma: Geology Department, Oklahoma State University.
- 6 Golden Software, Inc. (2002). Surfer 8. Colorado: Golden Software, Inc.
- 7 Environmental Systems Research Institute Inc. (1996). ArcView GIS Version 3.2.
- 8 Pitney Bowes Software Inc. mapinfo professional version 8.0, One Global View, Troy, NY 12180 USA.
- 9 Chebotarev, I.I. (1955). Metamorphism of natural waters in the crust of weathering. *Geochim et Cosmochim Acta*, 8. (p.22-212).
- 10 Back, W. (1960). Origin of Hydrochemical Facies of Ground Water in the Atlantic and Gulf Coastal Plains. In Back W, & Freeze. R.A. (Eds.). (1983) *Chemical Hydrogeology : Benchmark Papers in Geology*, 73. (p.79-87). PA: Hutchison Ross Publ.

- 11 Back, W., Baedeker, M.J., & Wood, W. W. (1993). Scale in Chemical Hydrogeology: A Historical Perspective. In: Alley W. M., editor. Regional Groundwater Quality. New York: Van Nostrand Reinhold. p.111-130.
- 12 Freeze, R.A., & Cherry, J.A. (1979). Groundwater. N.J.: Prentice Hall. Inc. Englewood Cliffs.
- 13 Tóth, J. (1999). Groundwater as a geologic agent: and overview of the causes, processes, and manifestations. Hydrogeology, 7. (p.1-14).
- 14 Fetter, C.W., (1988). Applied Hydrogeology. Ohio: Merrill Publishinh Company.
- 15 Domenico, P.A., & Schwartz F.W. (1998). Physical and Chemical Hydrogeology. 2nd ed. New York: John Wiley&Sons. Inc.
- 16 Lloyd, J.W., & Heathcote, J.A. (1985). Natural Inorganic Hydrochemistry in Relation to Groundwater. Oxford: Clarendon Press.
- 17 Piper, A. M. (1944). A graphical Procedure in the Geochemical interpretation of Water Analyses. In Back W, & Freeze. R.A. (Eds.). (1983) Chemical Hydrogeology: Benchmark Papers in Geology, 73. (p.50-59). PA: Hutchison Ross Publ.
- 18 Galloway, W.E., & Kaiser, W.R. (1980). Catahoula Formation of Texas Coastal Plain: Origin, Geochemical Evolution, and Characteristics of Uranium Deposits: The University of Texas at Austin, Bureau of Economic Geology Report of Investigations no. 100.
- 19 Emamgholizadeh, S. (2008). Water Quality Assessment of the Kopal River (IRAN). International Meeting on Soil Fertility Land Management and Agroclimatology. Turkey. p: 827-837.
- 20 Mass (1990) Crop salt tolerance. In: Agricultural Assessment and Management Manual. K.K. Tanji (ed.). ASCE, New York. pp. 262-304.
- 21 Us Salinity Laboratory, 1954. Diagnoses and Improvement of Saline and Alkali Soils. Agriculture Handbook No. 60, USDA.
- 22 กรมทรัพยากรธรณี, 2542, แผนที่ธรณีวิทยาประเทศไทย มาตรฐาน 1:1,000,000, กรุงเทพมหานคร.

- 23 กรมทรัพยากรธรณี, 2540, แผนที่น้ำบาดาลจังหวัดสุพรรณบุรี มาตรฐาน 1:100,000, กรุงเทพมหานคร.
- 24 กรมทรัพยากรธรณี, 2540, แผนที่น้ำบาดาลจังหวัดราชบุรี มาตรฐาน 1:100,000, กรุงเทพมหานคร.
- 25 Foster, S., and Kemper, K., eds. Sustainable groundwater management: concepts and tools (Briefing note series). Washington D.C.: World Bank, 2004.
- 26 เกียรติศักดิ์ ศรีสุข. (2543). น้ำใต้ดิน-แบบจำลอง-การปนเปื้อน. ขอนแก่น: ภาควิชาเทคโนโลยี ธรณี คณะเทคโนโลยี มหาวิทยาลัยขอนแก่น.
- 27 Srisuk, K. (1994). Genetic Characteristics of the Groundwater Regime in the Khon Kaen Drainage Basin, Northeast Thailand. Ph.D. in Geology, Department of Geology, University of Alberta, Canada.
- 28 อัญชลี นาคปล้อง, รุ่งเรือง เลิศศิริวรกุล และ อรุณี ชูนิยม (2005). ระบบการไหลของน้ำบาดาล ในเขตอำเภอมหาเมธาสถา จังหวัดนครราชสีมา ภาคตะวันออกเฉียงเหนือ ประเทศไทย. ขอนแก่น: มหาวิทยาลัยขอนแก่น.
- 29 Hem, J.D. (1992). Study and Interpretation of the Chemical Characteristics of Natural Water. 3rd ed. U.S. Geological Survey Water-Supply Paper 2254. VA: United States Government Printing Office.
- 30 Eaton, FM (1950). Significance of carbonates in irrigation waters. Soil Sci. 69, 123-133.
- 31 Tóth, J. (1963). A theoretical analysis of groundwater flow small drainage basin. In Freeze. R.A. & W, Back (Eds.). (1983) Physical Hydrogeology: Benchmark Papers in Geology, 72. (p.328-345). PA: Hutchison Ross Publ.
- 32 Mohammad R. al-Agha, and, Hamed A. El-Nakhal. (2004). Hydrochemical facies of groundwater in the Gaza. Department of Environment and Earth Science, The Islamic University of Gaza, PO Box 108, Gaza Strip, Palestine.
- 33 Paul L. Younger, (2007). Groundwater in the Environment: An Introduction, Blackwell Publishing, Oxford, UK & Malden, Massachusetts, 318 pp., ISBN 1-4051-2143-2
- 34 Frank van Weert et al., (2009). Global Overview of Saline Groundwater Occurrence and Genesis, IGRAC P.O. Box 85467 3508, TA, Utrecht, The Netherlands.



## APPENDIX A

### LIST OF CLASSIFICATION OF WATER TYPES FOR AQUIFER LAYER IV

order unit	Sample ID	Well ID	East (m)	North (m)	calc TDS	Calc Alk.	Total Hardness	Sum of Anions	Sum of Cations	E.N. %	SAR	Water Type
Layer I (BK)												
1	MK1-39	MN178	590340	1607440	634	326	318	7.85	4.53	1.77	0.73	Ca-HCO <sub>3</sub>
2	MK1-40	MN179	592290	1600190	693	404	390	8.80	4.26	4.20	0.15	Ca-HCO <sub>3</sub>
3	MK1-49	MN284	589900	1593050	653	381	397	8.12	4.20	0.34	0.10	Ca-HCO <sub>3</sub>
4	MK1-61	MN383	596900	1550500	438	232	236	5.35	3.40	-1.84	0.65	Ca-HCO <sub>3</sub>
5	MK1-81	MT2	692900	1605500	610	335	381	7.37	4.19	-3.15	0.15	Ca-HCO <sub>3</sub>
6	MK1-84	MT3	693590	1611400	748	447	463	9.31	5.22	-2.61	0.24	Ca-HCO <sub>3</sub>
7	MK1-87	MT32	692200	1598590	688	394	425	8.51	4.56	-1.17	0.10	Ca-HCO <sub>3</sub>
8	MK1-95	MT48	693400	1699690	509	254	309	6.23	3.49	-1.70	0.17	Ca-HCO <sub>3</sub>
9	MK1-100	MT72	693790	1601400	716	402	466	8.83	5.01	-4.29	0.14	Ca-HCO <sub>3</sub>
10	MK1-104	MT80	691700	1697500	509	269	287	6.21	3.53	-0.72	0.36	Ca-HCO <sub>3</sub>
11	MK1-110	DB153	594070	1545546	422	253	229	5.19	3.26	-2.90	0.60	Ca-Mg-HCO <sub>3</sub>
12	MK1-48	MN282	590500	1606190	454	244	274	5.68	3.33	-2.12	0.32	Ca-Mg-HCO <sub>3</sub>
13	MK1-50	MN292	594450	1611550	757	449	475	9.69	5.22	-1.10	0.18	Ca-Mg-HCO <sub>3</sub>
14	MK1-60	MN367	694790	1596400	550	318	356	6.91	4.07	-4.67	0.21	Ca-Mg-HCO <sub>3</sub>
15	MK1-72	MS120	583632	1491085	638	350	378	8.08	4.74	-1.58	0.47	Ca-Mg-HCO <sub>3</sub>
16	MK1-88	MT344	597150	1596700	491	260	307	6.29	3.63	-2.41	0.30	Ca-Mg-HCO <sub>3</sub>
17	MK1-101	MT73	696700	1695190	696	376	379	9.47	5.05	4.54	0.63	Ca-Mg-HCO <sub>3</sub>
18	MK1-102	M174	695400	1595190	696	376	379	9.47	5.05	4.54	0.63	Ca-Mg-HCO <sub>3</sub>
19	MK1-103	MT75	695400	1697500	779	440	481	9.84	6.09	-4.29	0.56	Ca-Mg-HCO <sub>3</sub>
20	MK1-68	MN9	594340	1611150	482	264	322	6.59	3.43	-0.29	0.12	Mg-Ca-HCO <sub>3</sub>
21	MK1-11	DB174	593333	1545903	273	167	133	3.60	2.42	4.41	0.94	Ca-Mg-Na-HCO <sub>3</sub> -CO <sub>3</sub>
22	MK1-4	DB122	596400	1544090	480	285	228	6.13	3.55	3.02	0.81	Ca-Na-HCO <sub>3</sub>
23	MK1-5	DB125	591790	1546190	432	174	163	4.35	2.73	3.13	0.78	Ca-Na-HCO <sub>3</sub>
24	MK1-9	DB135	599176	1547224	571	295	272	7.29	5.08	-2.44	1.40	Ca-Na-HCO <sub>3</sub>
25	MK1-17	DF28	626800	1622450	327	170	135	3.99	2.80	-0.02	1.16	Ca-Na-HCO <sub>3</sub>
26	MK1-36	MN111	589900	1592940	769	400	354	9.72	6.10	2.49	1.32	Ca-Na-HCO <sub>3</sub>
27	MK1-105	MT9	604790	1611190	336	179	156	4.09	2.80	-2.34	0.80	Ca-Na-HCO <sub>3</sub>
28	MK1-8	DB134	595515	1550150	616	320	260	7.68	5.57	-0.64	1.81	Ca-Na-Mg-HCO <sub>3</sub>
29	MK1-25	MD222	582300	1493150	621	374	284	8.07	5.33	-0.29	1.42	Mg-Na-Ca-HCO <sub>3</sub>
30	MK1-7	DB133	601090	1549090	432	223	166	5.36	4.12	-2.42	1.86	Na-Ca-HCO <sub>3</sub>
31	MK1-45	MN25	630590	1622300	215	118	45	2.67	2.25	-0.22	2.65	Na-Ca-HCO <sub>3</sub>
32	MK1-59	MN358	602750	1611650	1274	670	294	16.08	13.92	-2.21	6.29	Na-Ca-HCO <sub>3</sub>
33	MK1-75	MT12	607290	1609590	1253	682	332	15.64	13.55	-3.60	5.54	Na-Ca-HCO <sub>3</sub>
34	MK1-2	DB117	593407	1554491	707	390	244	8.85	6.80	-1.18	2.76	Na-Ca-Mg-HCO <sub>3</sub>
35	MK1-28	MD458	589700	1612400	689	388	203	8.55	5.88	4.57	2.66	Na-Ca-Mg-HCO <sub>3</sub>
36	MK1-74	MT10	601200	1611100	649	385	189	7.85	6.74	-4.53	3.48	Na-Mg-Ca-HCO <sub>3</sub>
37	MK1-43	MN214	596450	1598500	927	363	467	13.02	7.97	3.00	1.07	Ca-Mg-HCO <sub>3</sub> -Cl
38	MK1-37	MN148	606090	1558590	1872	277	752	30.24	23.26	0.28	5.70	Na-Ca-Mg-Cl
39	MK1-46	MN253	591700	1598590	1305	111	483	21.29	18.31	-3.31	6.06	Na-Ca-Mg-Cl
40	MK1-53	MN33	592500	1549750	4036	203	1872	62.76	48.80	0.09	6.96	Na-Ca-Mg-Cl
41	MK1-54	MN34	613290	1544090	2434	257	1041	39.09	30.51	-0.04	6.23	Na-Ca-Mg-Cl
42	MK1-82	MT283	598700	1603250	5079	203	1143	83.81	76.75	-1.07	19.31	Na-Mg-Cl
43	MK1-33	MN108	589650	1612750	583	327	117	7.22	6.47	0.25	4.82	Na-HCO <sub>3</sub>
44	MK1-64	MN68	627500	1623800	272	134	52	3.39	3.03	-0.73	3.39	Na-HCO <sub>3</sub>
45	MK1-57	MN354	606090	1561090	2451	492	275	35.17	34.29	0.50	19.00	Na-Cl-HCO <sub>3</sub>
46	MK1-42	MN212	591200	1613690	1053	551	98	13.28	13.87	-0.89	12.91	Na-HCO <sub>3</sub> -Cl
47	MK1-51	MN294	605129	1600400	1714	742	194	22.45	20.35	0.64	13.14	Na-HCO <sub>3</sub> -Cl
48	MK1-52	MN295	636000	1594550	1097	412	139	14.38	13.94	-1.57	10.63	Na-HCO <sub>3</sub> -Cl
49	MK1-97	MT56	610250	1594250	861	299	69	10.64	11.61	-2.90	13.06	Na-HCO <sub>3</sub> -Cl
50	MK1-3	DB121	594900	1542500	1011	302	502	14.86	10.73	-1.81	2.52	Ca-Na-Cl-HCO <sub>3</sub>
51	MK1-69	MN93	588650	1572250	568	176	315	8.04	5.19	-0.51	1.13	Ca-Na-Cl-HCO <sub>3</sub>
52	MK1-27	MD254	556850	1532250	1545	420	900	21.72	14.67	-3.00	1.89	Mg-Na-Cl-HCO <sub>3</sub>
53	MK1-13	DB64	599450	1602350	554	276	301	7.85	5.05	-1.07	1.10	Mg-Na-HCO <sub>3</sub> -Cl
54	MK1-24	MD163	578000	1497900	1248	606	701	17.91	11.43	-1.26	1.66	Mg-Na-HCO <sub>3</sub> -Cl
55	MK1-106	MU354	584075	1488160	590	239	286	8.02	6.41	-3.16	1.96	Mg-Na-HCO <sub>3</sub> -Cl
56	MK1-12	DB56	594600	1611500	474	269	227	6.36	4.97	0.25	1.73	Mg-Na-HCO <sub>3</sub> -CO <sub>3</sub> -Cl
57	MK1-18	DF34	619200	1611100	1064	235	349	14.36	13.54	-3.68	5.36	Na-Ca-Cl-HCO <sub>3</sub>
58	MK1-65	MN70	631790	1620440	576	148	131	7.69	7.07	0.44	4.95	Na-Ca-Cl-HCO <sub>3</sub>
59	MK1-66	MN71	625400	1618440	302	138	113	3.95	2.98	-0.60	1.68	Na-Ca-HCO <sub>3</sub> -Cl
60	MK1-1	BK0004	628166	1526588	727	289	243	10.21	7.76	0.87	3.35	Na-Ca-Mg-HCO <sub>3</sub> -Cl
61	MK1-6	DB132	698590	1546900	440	197	165	5.92	4.24	2.05	1.97	Na-Ca-Mg-HCO <sub>3</sub> -Cl
62	MK1-44	MN238	609150	1598150	661	253	260	8.70	6.26	0.15	2.16	Na-Ca-Mg-HCO <sub>3</sub> -Cl
63	MK1-20	DS24	595373	1543463	641	231	254	8.48	6.83	-2.65	2.65	Na-Mg-Ca-HCO <sub>3</sub> -Cl
64	MK1-34	MN109	590900	1614150	336	171	92	4.54	3.32	3.87	2.50	Na-Mg-HCO <sub>3</sub> -Cl
65	MK1-55	MN347	605009	1601226	1994	853	666	29.44	20.98	3.36	5.35	Na-Mg-HCO <sub>3</sub> -Cl
66	MK1-19	DMR20	594540	1588190	768	344	405	8.94	6.02	0.76	0.95	Ca-Mg-HCO <sub>3</sub> -SO <sub>4</sub>
67	MK1-21	DS37	590946	1549606	542	225	242	6.17	4.84	-0.90	1.48	Ca-Na-HCO <sub>3</sub> -SO <sub>4</sub>
68	MK1-15	DF255	645750	1612300	441	176	217	5.20	4.66	-4.22	1.57	Mg-Na-Ca-HCO <sub>3</sub> -SO <sub>4</sub>

order unit	Sample ID	Well ID	East (m)	North (m)	calc TDS	Calc Alk.	Total Hardness	Sum of Anions	Sum of Cations	E.N. %	SAR	Water Type
69	MK1-70	MN99	598900	1566500	1432	292	297	16.35	18.85	-1.88	9.12	Na-SO4-Cl-HCO3
70	MK1-63	MN425	596400	1547690	431	254	228	5.34	3.33	-2.20	0.66	Ca-HCO3
71	MK1-89	MT35	593100	1596900	445	244	270	5.48	3.29	-3.66	0.32	Ca-HCO3
72	MK1-98	MT68	693400	1599900	575	309	361	7.28	4.12	-2.68	0.21	Ca-HCO3
73	MK1-99	MT69	692700	1600190	684	350	411	8.60	5.22	-3.60	0.49	Ca-HCO3
74	MK1-19	DMR20	594540	1588190	763	389	409	9.13	5.84	-0.05	0.86	Ca-Mg-HCO3
75	MK1-36	MN111	589900	1592940	427	215	237	5.26	2.82	4.49	0.26	Ca-Mg-HCO3
76	MK1-41	MN180	592750	1598000	361	188	198	4.41	2.54	0.09	0.34	Ca-Mg-HCO3
77	MK1-49	MN284	589900	1593050	318	168	171	3.92	2.29	0.18	0.40	Ca-Mg-HCO3
78	MK1-68	MN9	594340	1611150	832	473	492	10.84	6.04	-0.34	0.51	Ca-Mg-HCO3
79	MK1-78	MT159	590450	1613850	713	403	473	8.88	4.94	-3.87	0.09	Ca-Mg-HCO3
80	MK1-77	MT134	598750	1603650	558	332	380	7.29	4.08	-3.72	0.14	Mg-Ca-HCO3
81	MK1-24	MD163	578000	1497900	756	447	470	10.06	5.35	0.12	0.30	Mg-HCO3
82	MK1-16	DF27	626400	1620950	153	92	56	1.87	1.39	0.64	1.04	Ca-Na-HCO3
83	MK1-83	MT29	696290	1612800	534	317	267	6.62	4.30	-2.30	0.98	Ca-Na-Mg-HCO3
84	MK1-94	MT42	600000	1611500	571	336	254	7.05	5.11	-3.88	1.58	Ca-Na-Mg-HCO3
85	MK1-25	MD222	582300	1493150	739	444	358	9.44	6.20	-1.53	1.33	Mg-Ca-Na-HCO3
86	MK1-93	MT4	597340	1610500	750	445	383	9.63	6.36	-2.61	1.29	Mg-Ca-Na-HCO3
87	MK1-34	MN109	590900	1614150	440	229	170	5.72	4.11	-0.43	1.84	Na-Ca-HCO3
88	MK1-64	MN68	627500	1623800	262	121	58	3.11	3.04	-4.81	3.13	Na-Ca-HCO3
89	MK1-33	MN108	589650	1612750	411	226	162	5.15	3.66	0.04	1.57	Na-Ca-Mg-HCO3
90	MK1-35	MN11	598150	1609940	583	314	172	7.62	5.85	0.33	3.15	Na-Ca-Mg-HCO3
91	MK1-92	MT38	601090	1613400	969	563	250	11.90	10.00	-2.15	4.68	Na-Mg-HCO3
92	MK1-90	MT36	692590	1698400	239	97	120	2.95	1.58	3.96	0.27	Ca-Mg-HCO3-Cl
93	MK1-67	MN8	598750	1606900	1086	376	887	16.91	8.86	-2.30	-	Mg-Ca-Cl-HCO3
94	MK1-32	MD78	605400	1550900	2135	325	871	33.56	24.35	3.76	5.26	Na-Ca-Mg-Cl
95	MK1-71	MQ1029	630855	1605614	5221	57	2237	84.01	66.98	0.51	9.20	Na-Ca-Mg-Cl
96	MK1-96	MT54	614900	1594700	2415	338	952	38.56	31.94	-2.68	7.19	Na-Ca-Mg-Cl
97	MK1-1	BK0004	628166	1526588	2384	271	1051	39.66	31.55	-2.46	6.44	Na-Mg-Ca-Cl
98	MK1-37	MN148	606090	1558590	1796	262	713	29.25	23.01	-0.53	5.92	Na-Mg-Ca-Cl
99	MK1-23	GWA71	620405	1591655	430	239	58	5.07	4.64	-0.60	5.24	Na-HCO3
100	MK1-45	MN25	630590	1622300	259	133	42	3.10	2.68	2.57	3.43	Na-HCO3
101	MK1-62	MN40	607250	1609590	1122	607	184	13.77	13.18	-3.99	8.29	Na-HCO3
102	MK1-38	MN157	604450	1604250	1214	652	155	15.13	16.01	-0.50	11.50	Na-HCO3-CO3-Cl
103	MK1-69	MN93	588650	1572250	396	75	202	5.90	4.13	-0.24	1.47	Ca-Na-Cl-HCO3
104	MK1-65	MN70	631790	1620440	554	139	126	7.45	6.78	0.81	4.80	Na-Ca-Cl-HCO3
105	MK1-66	MN71	625400	1618440	301	139	111	4.01	2.80	2.58	1.53	Na-Ca-HCO3-Cl
106	MK1-14	DB94	696790	1545090	470	219	181	6.16	4.79	-1.90	2.16	Na-Ca-Mg-HCO3-Cl
107	MK1-56	MN348	614200	1606100	523	189	248	7.59	5.50	-1.85	1.85	Na-Ca-Mg-HCO3-Cl
108	MK1-91	MT37	696500	1696800	1206	479	377	15.60	12.90	0.69	4.69	Na-Mg-Ca-HCO3-Cl
109	MK1-31	MD77	606750	1550340	3473	260	1118	47.50	41.39	4.04	8.86	Na-Ca-Cl-SO4
Layer 2 (PD)												
110	MK2-20	DB27	601590	1538150	345	189	200	4.29	2.69	-3.52	0.43	Ca-HCO3
111	MK2-57	DF319	600930	1539058	315	188	167	3.95	2.24	1.20	0.40	Ca-HCO3
112	MK2-99	MC224	630250	1668000	207	116	108	2.66	1.55	0.90	0.38	Ca-HCO3
113	MK2-149	MC42	617590	1674050	261	147	138	3.17	2.03	-2.57	0.52	Ca-HCO3
114	MK2-157	MC713	614590	1671190	302	174	163	3.62	2.06	-0.06	0.31	Ca-HCO3
115	MK2-161	MC719	615400	1657190	689	408	378	8.53	5.31	-3.01	0.78	Ca-HCO3
116	MK2-248	MN30	585250	1559340	605	364	352	7.66	3.88	1.96	0.16	Ca-HCO3
117	MK2-249	MN310	579090	1636800	602	354	343	7.61	4.18	0.48	0.38	Ca-HCO3
118	MK2-282	MN454	583700	1636800	276	139	145	3.41	2.23	-2.84	0.51	Ca-HCO3
119	MK2-335	MP188	618900	1676750	240	140	126	2.93	1.64	0.69	0.28	Ca-HCO3
120	MK2-453	MT6	695700	1698090	756	436	485	9.41	5.44	-4.32	0.24	Ca-HCO3
121	MK2-461	MT83	699000	1605300	780	477	440	9.87	5.17	1.92	0.29	Ca-HCO3
122	MK2-523	PD0111	602338	1538429	356	196	194	4.58	2.58	1.31	0.41	Ca-HCO3
123	MK2-534	Q214	579250	1554200	481	282	271	5.85	3.67	-3.49	0.56	Ca-HCO3
124	MK2-106	MC256	604750	1681940	202	123	133	2.61	1.34	-0.71	0.01	Ca-Mg-HCO3
125	MK2-127	MC352	603750	1651300	699	433	354	8.91	4.93	2.72	0.72	Ca-Mg-HCO3
126	MK2-160	MC717	613650	1648590	368	212	209	4.65	2.78	-1.88	0.42	Ca-Mg-HCO3
127	MK2-162	MC720	624650	1661340	294	136	154	3.70	2.45	-0.99	0.63	Ca-Mg-HCO3
128	MK2-168	MC792	624250	1661090	315	174	175	3.79	2.34	-2.35	0.39	Ca-Mg-HCO3
129	MK2-169	MC793	623790	1650000	285	135	151	3.40	2.30	-1.23	0.57	Ca-Mg-HCO3
130	MK2-209	MN163	599340	1647400	642	390	332	8.15	4.85	0.13	0.76	Ca-Mg-HCO3
131	MK2-244	MN283	592450	1604300	365	189	217	4.65	2.85	-3.12	0.41	Ca-Mg-HCO3
132	MK2-246	MN293	601750	1599840	761	454	398	9.60	5.98	-1.44	0.89	Ca-Mg-HCO3
133	MK2-332	MP185	615400	1672500	181	110	84	2.29	1.32	3.36	0.47	Ca-Mg-HCO3
134	MK2-334	MP187	616400	1672840	187	107	91	2.30	1.37	0.50	0.41	Ca-Mg-HCO3
135	MK2-411	MT132	594150	1600900	363	184	228	4.74	2.66	-1.60	0.20	Ca-Mg-HCO3
136	MK2-525	PD0121	623219	1508606	545	327	299	6.72	4.15	-2.76	0.55	Ca-Mg-HCO3
137	MK2-530	PD0131	617510	1506980	485	295	245	6.08	3.80	-1.18	0.67	Ca-Mg-HCO3
138	MK2-26	DB55	587850	1614100	568	357	321	7.44	4.07	1.38	0.44	Mg-Ca-HCO3

order unit	Sample ID	Well ID	East (m)	North (m)	calc TDS	Calc Alk.	Total Hardness	Sum of Anions	Sum of Cations	E.N. %	SAR	Water Type
139	MK2-132	MC37	601695	1653031	406	244	204	5.31	3.02	2.82	0.67	Mg-Ca-HCO3
140	MK2-159	MC716	602340	1664840	550	312	321	7.11	4.37	-2.90	0.61	Mg-Ca-HCO3
141	MK2-187	MD54	580100	1493600	612	354	315	7.73	4.94	-1.67	0.64	Mg-Ca-HCO3
142	MK2-193	MN110	597290	1610550	391	240	210	5.20	2.86	2.76	0.48	Mg-Ca-HCO3
143	MK2-460	MT82	593750	1600100	690	419	372	9.09	4.92	2.92	0.52	Mg-Ca-HCO3
144	MK2-27	DB61	601400	1599800	371	272	239	4.56	3.67	-2.77	0.65	Mg-HCO3-CO3
145	MK2-489	PD0006	656174	1516845	1454	19	493	25.34	21.09	-1.14	7.06	Na-Cl
146	MK2-492	PD0019	638300	1497800	29696	0	4017	507.83	461.92	0.57	65.92	Na-Cl
147	MK2-501	PD0062	649800	1504800	16587	197	3762	291.37	240.28	3.27	32.64	Na-Cl
148	MK2-518	PD0102	617284	1518666	4143	311	1158	67.35	59.86	-1.57	14.06	Na-Cl
149	MK2-529	PD0129	652547	1526141	7501	103	2037	127.23	108.38	0.86	19.28	Na-Cl
150	MK2-3	DB114	603540	1544800	326	181	162	4.15	2.69	-0.71	0.79	Ca-Mg-Na-HCO3
151	MK2-81	G124	621090	1679750	159	90	80	2.08	1.28	0.21	0.49	Ca-Mg-Na-HCO3
152	MK2-118	MC324	590900	1656550	369	195	186	4.54	3.03	-3.50	0.70	Ca-Mg-Na-HCO3
153	MK2-137	MC374	592400	1681840	416	221	217	5.56	3.45	-0.41	0.86	Ca-Mg-Na-HCO3
154	MK2-181	MD300	565500	1538650	617	294	302	7.33	5.12	-0.13	1.15	Ca-Mg-Na-HCO3
155	MK2-8	DB150	599899	1530711	467	264	189	5.61	4.23	-3.07	1.61	Ca-Na-HCO3
156	MK2-125	MC350	617200	1617590	119	67	49	1.43	0.99	-1.51	0.62	Ca-Na-HCO3
157	MK2-126	MC351	616500	1672650	133	74	51	1.64	1.04	3.80	0.67	Ca-Na-HCO3
158	MK2-208	MN162	601450	1645650	661	395	266	8.23	5.17	2.83	1.52	Ca-Na-HCO3
159	MK2-218	MN183	626090	1599150	343	189	128	4.42	3.04	1.66	1.50	Ca-Na-HCO3
160	MK2-239	MN27	590250	1637400	707	392	256	9.08	6.32	1.46	2.31	Ca-Na-HCO3
161	MK2-258	MN340	628294	1603134	292	164	123	3.60	2.62	-3.09	1.18	Ca-Na-HCO3
162	MK2-262	MN350	623290	1620090	529	240	227	6.62	4.93	-0.83	1.73	Ca-Na-HCO3
163	MK2-271	MN372	611250	1634400	450	267	199	5.62	3.60	0.60	1.05	Ca-Na-HCO3
164	MK2-322	MP126	616290	1685090	351	207	165	4.22	2.99	-4.39	1.02	Ca-Na-HCO3
165	MK2-329	MP164	611317	1687043	465	269	208	5.70	3.84	-1.76	1.15	Ca-Na-HCO3
166	MK2-351	MP85	624790	1661150	382	203	172	4.60	3.19	-0.95	1.06	Ca-Na-HCO3
167	MK2-480	MX4	617090	1523400	489	253	212	6.22	4.24	0.56	1.44	Ca-Na-HCO3
168	MK2-539	TA155	618457	1655272	283	149	121	3.49	2.51	-3.12	1.11	Ca-Na-HCO3
169	MK2-143	MC409	630040	1661400	349	175	162	4.33	2.95	0.25	0.96	Ca-Na-Mg-HCO3
170	MK2-198	MN129	587400	1624940	763	425	320	9.97	6.60	1.24	1.85	Ca-Na-Mg-HCO3
171	MK2-221	MN200	625000	1604190	286	162	121	3.57	2.59	-2.44	1.19	Ca-Na-Mg-HCO3
172	MK2-225	MN229	632400	1602090	269	152	107	3.25	2.54	-4.70	1.35	Ca-Na-Mg-HCO3
173	MK2-235	MN250	623750	1611440	390	206	163	5.03	3.57	-1.10	1.40	Ca-Na-Mg-HCO3
174	MK2-276	MN413	628800	1625200	227	123	92	2.68	1.91	-0.95	0.95	Ca-Na-Mg-HCO3
175	MK2-410	MT131	626900	1644350	338	159	164	4.00	3.09	-3.03	1.09	Ca-Na-Mg-HCO3
176	MK2-488	NL0088	632900	1524800	457	260	189	5.86	3.74	3.36	1.30	Ca-Na-Mg-HCO3
177	MK2-120	MC326	592790	1654590	825	505	420	10.46	6.88	-2.70	1.27	Mg-Ca-Na-HCO3
178	MK2-469	MU727	581600	1495500	620	372	328	8.04	5.21	-2.12	1.06	Mg-Na-Ca-HCO3
179	MK2-470	MX10	607450	1547440	573	335	220	7.25	4.73	3.16	1.70	Mg-Na-HCO3
180	MK2-9	DB156	607960	1557842	626	367	150	7.66	5.89	3.90	3.51	Na-Ca-HCO3
181	MK2-58	DF320	599301	1530773	524	287	125	6.25	5.29	2.17	3.59	Na-Ca-HCO3
182	MK2-102	MC245	610840	1689340	685	358	201	8.04	6.62	-0.36	3.25	Na-Ca-HCO3
183	MK2-103	MC249	598540	1689440	728	434	215	8.98	6.80	0.20	3.18	Na-Ca-HCO3
184	MK2-105	MC252	610090	1689300	179	102	47	2.25	1.73	1.06	1.84	Na-Ca-HCO3
185	MK2-116	MC309	605450	1683550	606	354	143	7.57	5.80	2.46	3.52	Na-Ca-HCO3
186	MK2-210	MN168	605400	1643750	899	507	167	11.11	9.39	0.81	5.90	Na-Ca-HCO3
187	MK2-217	MN177	588900	1624800	951	532	215	12.03	9.67	1.20	5.11	Na-Ca-HCO3
188	MK2-223	MN206	624900	1593000	362	216	88	4.54	3.33	4.20	2.55	Na-Ca-HCO3
189	MK2-236	MN254	620290	1600840	351	216	92	4.38	3.51	4.99	2.63	Na-Ca-HCO3
190	MK2-267	MN360	621450	1598250	350	202	68	4.17	3.66	-1.42	3.53	Na-Ca-HCO3
191	MK2-274	MN387	615496	1542896	547	267	145	6.87	5.74	0.05	3.51	Na-Ca-HCO3
192	MK2-323	MP127	627290	1683500	595	297	224	7.16	6.03	-4.76	2.53	Na-Ca-HCO3
193	MK2-333	MP186	616500	1672650	168	91	53	2.03	1.53	0.46	1.25	Na-Ca-HCO3
194	MK2-347	MP282	614152	1680050	182	89	49	2.33	1.77	2.13	1.74	Na-Ca-HCO3
195	MK2-371	MQ557	646150	1614690	671	362	148	7.84	7.07	-1.99	4.54	Na-Ca-HCO3
196	MK2-378	MQ571	672290	1588900	656	336	129	7.50	7.43	-4.49	5.35	Na-Ca-HCO3
197	MK2-403	MT113	613400	1623590	422	247	121	5.27	4.30	-0.38	2.73	Na-Ca-HCO3
198	MK2-408	MT128	620750	1599750	367	200	100	4.48	3.84	-3.04	2.78	Na-Ca-HCO3
199	MK2-433	MT226	627100	1549600	197	109	61	2.41	2.02	-1.75	1.78	Na-Ca-HCO3
200	MK2-448	MT47	617790	1699800	374	218	72	4.53	3.87	-0.06	3.64	Na-Ca-HCO3
201	MK2-454	MT65	694700	1635400	784	458	280	9.63	7.20	-1.69	2.50	Na-Ca-HCO3
202	MK2-459	MT81	601900	1699590	598	350	195	7.64	5.31	2.91	2.31	Na-Ca-HCO3
203	MK2-464	MT90	693790	1629400	970	568	302	11.84	9.42	-2.20	3.51	Na-Ca-HCO3
204	MK2-528	PD0128	600010	1530587	552	267	159	6.38	5.06	2.28	2.65	Na-Ca-HCO3
205	MK2-536	TA105	606380	1654163	457	240	110	5.59	4.85	-1.65	3.52	Na-Ca-HCO3
206	MK2-313	MN72	624040	1600440	241	158	76	2.87	2.46	-0.03	1.85	Na-Ca-HCO3-CO3
207	MK2-455	MT77	618400	1600190	321	210	65	3.82	3.62	3.29	3.61	Na-Ca-HCO3-CO3
208	MK2-15	DB208	611809	1545809	557	303	178	6.93	5.39	-0.06	2.71	Na-Ca-Mg-HCO3
209	MK2-39	DF1	620900	1597600	336	195	108	4.09	3.38	-3.89	2.13	Na-Ca-Mg-HCO3

order unit	Sample ID	Weil ID	East (m)	North (m)	calc TDS	Calc Alk.	Total Hardness	Sum of Anions	Sum of Cations	E.N. %	SAR	Water Type
210	MK2-110	MC298	639540	1682440	416	248	140	5.16	3.93	-1.52	2.13	Na-Ca-Mg-HCO3
211	MK2-199	MN130	590590	1624650	567	311	201	7.07	4.99	1.38	2.06	Na-Ca-Mg-HCO3
212	MK2-213	MN171	583400	1636840	1169	636	445	15.21	10.69	0.42	2.85	Na-Ca-Mg-HCO3
213	MK2-434	MT23	627000	1608500	273	158	96	3.30	2.65	-4.16	1.04	Na-Ca-Mg-HCO3
214	MK2-471	MX11	636200	1497190	667	353	218	8.71	6.06	4.34	2.57	Na-Ca-Mg-HCO3
215	MK2-522	PD0110	622640	1539919	653	293	251	8.13	6.34	-0.21	2.36	Na-Ca-Mg-HCO3
216	MK2-436	MT246	630550	1598050	234	138	85	2.86	2.68	-3.01	1.94	Na-Ca-Mg-HCO3-CO3
217	MK2-122	MC328	698150	1662050	812	425	261	10.62	8.05	-0.14	3.23	Na-Mg-Ca-HCO3
218	MK2-177	MD149	617540	1545000	543	283	219	7.19	5.10	-0.00	1.97	Na-Mg-Ca-HCO3
219	MK2-204	MN149	603540	1556940	875	405	193	10.59	9.80	-1.09	5.61	Na-Mg-HCO3
220	MK2-257	MN337	606200	1592500	1733	1001	291	21.06	18.42	0.60	8.90	Na-Mg-HCO3
221	MK2-395	MQ834	668700	1587700	428	214	108	5.09	4.94	-2.41	3.64	Na-Mg-HCO3
222	MK2-48	DF210	628350	1607900	326	106	198	4.98	2.93	0.80	0.65	Ca-Mg-Cl-HCO3
223	MK2-93	GWA0096	651984	1583486	305	82	193	4.86	2.55	4.59	0.38	Ca-Mg-Cl-HCO3
224	MK2-297	MN541	635296	1618582	634	149	419	9.87	6.31	-3.04	0.94	Ca-Mg-Cl-HCO3
225	MK2-462	MT84	629590	1608500	515	109	340	8.43	4.70	1.84	0.59	Ca-Mg-Cl-HCO3
226	MK2-481	MX5	611500	1524190	940	233	600	14.71	8.99	0.14	1.23	Ca-Mg-Cl-HCO3
227	MK2-482	MX6	612950	1524440	1044	217	729	17.13	10.02	0.07	1.02	Ca-Mg-Cl-HCO3
228	MK2-484	MX8	600540	1523300	1137	209	814	18.99	10.92	0.10	0.98	Ca-Mg-Cl-HCO3
229	MK2-123	MC329	592613	1667578	369	194	200	4.89	2.61	3.72	0.40	Ca-Mg-HCO3-Cl
230	MK2-479	MX3	617090	1525590	511	184	351	7.36	3.86	0.04	0.19	Ca-Mg-HCO3-Cl
231	MK2-90	GWA0071	628415	1586485	1997	153	1558	34.43	22.27	-4.30	1.65	Ca-Mg-Cl
232	MK2-298	MN542	630590	1609900	716	106	543	12.04	7.10	-2.11	0.60	Ca-Mg-Cl
233	MK2-451	MT55	629400	1608800	665	93	481	11.24	6.45	-0.23	0.63	Ca-Mg-Cl
234	MK2-510	PD0090	629200	1534700	2677	212	1997	47.19	27.99	-0.15	1.75	Ca-Mg-Cl
235	MK2-511	PD0091	618400	1528100	1419	212	986	24.12	14.19	0.93	1.33	Ca-Mg-Cl
236	MK2-526	PD0125	611469	1530372	1744	221	1224	30.48	17.22	1.85	1.37	Ca-Mg-Cl
237	MK2-231	MN241	632400	1601050	942	99	594	16.03	10.45	-1.06	1.68	Ca-Mg-Na-Cl
238	MK2-507	PD0087	632900	1524800	2202	206	1433	38.43	24.53	0.00	2.64	Ca-Mg-Na-Cl
239	MK2-51	DF258	642946	1617907	1124	105	649	18.15	12.73	-1.53	2.39	Ca-Na-Cl
240	MK2-201	MN137	629450	1608800	730	88	470	12.28	7.51	0.59	1.20	Ca-Na-Cl
241	MK2-289	MN486	641200	1615550	1152	129	585	18.41	13.85	-1.81	3.24	Ca-Na-Cl
242	MK2-290	MN502	645090	1612250	1204	168	747	20.22	12.50	1.04	1.75	Ca-Na-Cl
243	MK2-366	MQ497	648700	1613800	3832	192	2126	64.75	46.34	-0.91	5.38	Ca-Na-Cl
244	MK2-367	MQ498	643950	1618800	2129	203	1283	35.74	24.00	-0.83	3.05	Ca-Na-Cl
245	MK2-372	MQ558	645200	1613150	1083	148	718	17.88	11.32	-1.06	1.49	Ca-Na-Cl
246	MK2-428	MT214	622850	1595450	1326	201	747	21.85	13.67	2.99	2.23	Ca-Na-Cl
247	MK2-497	PD0056	654100	1531200	10264	47	5558	182.21	130.57	-0.97	9.92	Ca-Na-Cl
248	MK2-59	DF35	623850	1612100	902	113	560	15.05	10.13	-2.15	1.82	Ca-Na-Mg-Cl
249	MK2-83	GWA0022	666228	1588605	2862	217	1767	48.15	32.32	-0.45	3.42	Ca-Na-Mg-Cl
250	MK2-91	GWA0088	636670	1571749	7706	230	4979	136.66	85.39	1.31	4.93	Ca-Na-Mg-Cl
251	MK2-307	MN593	642250	1614840	1358	118	767	22.53	15.68	-0.38	2.83	Ca-Na-Mg-Cl
252	MK2-497	PD0056	654100	1531200	9090	70	5059	159.86	112.36	-0.05	8.57	Ca-Na-Mg-Cl
253	MK2-513	PD0093	627100	1550500	13791	216	8372	236.36	166.84	-1.04	9.04	Ca-Na-Mg-Cl
254	MK2-292	MN504	646200	1610300	974	157	657	15.63	10.92	-3.57	1.65	Mg-Ca-Na-Cl
255	MK2-517	PD0100	621463	1497147	6395	56	4204	113.66	79.04	-2.07	5.64	Mg-Ca-Na-Cl
256	MK2-92	GWA0092	648067	1572625	14630	277	6008	248.76	200.35	-1.11	17.97	Na-Ca-Cl
257	MK2-490	PD0009	653900	1507200	8454	32	3898	145.33	113.40	-1.05	11.85	Na-Ca-Cl
258	MK2-499	PD0059	653800	1552300	11226	70	5767	199.82	142.62	0.03	11.06	Na-Ca-Cl
259	MK2-502	PD0066	645100	1559400	10602	124	5267	181.68	137.00	-1.10	11.39	Na-Ca-Cl
260	MK2-505	PD0082	657600	1521400	8851	66	2891	154.55	129.81	-1.11	18.61	Na-Ca-Cl
261	MK2-514	PD0094	639148	1544581	5192	168	2597	89.90	64.54	0.67	7.51	Na-Ca-Cl
262	MK2-359	MQ469	658700	1591400	2910	299	1414	47.51	36.91	-2.72	5.96	Na-Ca-Mg-Cl
263	MK2-404	MT118	621000	1585800	1634	123	796	27.88	20.40	-0.33	4.32	Na-Ca-Mg-Cl
264	MK2-498	PD0057	652166	1511145	6650	128	3083	113.27	87.79	-0.85	10.19	Na-Ca-Mg-Cl
265	MK2-515	PD0098	628166	1526588	1672	235	745	27.85	20.22	0.80	4.62	Na-Ca-Mg-Cl
266	MK2-531	PD0133	656955	1505829	16733	120	6544	268.66	227.37	-0.60	19.90	Na-Ca-Mg-Cl
267	MK2-532	PD0134	656982	1509451	3176	254	1383	53.61	42.00	-1.55	7.37	Na-Ca-Mg-Cl
268	MK2-206	MN151	605000	1555440	1830	294	689	29.06	22.57	1.19	5.92	Na-Mg-Ca-Cl
269	MK2-524	PD0115	609408	1552874	1205	135	350	18.49	14.01	3.02	5.58	Na-Mg-Cl
270	MK2-18	DB227	604359	1555334	781	414	101	9.62	9.77	-2.69	8.67	Na-HCO3
271	MK2-80	G1202	671840	1586940	598	326	95	6.90	7.06	-1.14	6.24	Na-HCO3
272	MK2-88	GWA0065	619858	1600118	832	447	57	9.28	10.67	-0.89	13.22	Na-HCO3
273	MK2-89	GWA0070	613357	1586910	556	303	41	7.00	6.98	1.84	10.14	Na-HCO3
274	MK2-121	MC327	606200	1658500	865	472	62	10.41	10.21	-1.79	12.08	Na-HCO3
275	MK2-128	MC354	608400	1679690	574	324	75	6.93	6.10	0.93	5.97	Na-HCO3
276	MK2-130	MC36	592790	1654590	1140	635	185	14.16	12.35	0.02	7.51	Na-HCO3
277	MK2-153	MC475	608650	1656190	590	323	78	7.16	6.74	-2.18	6.70	Na-HCO3
278	MK2-155	MC620	598540	1689440	979	581	144	11.84	10.23	1.00	7.26	Na-HCO3
279	MK2-175	MD112	673950	1587690	669	351	118	7.86	7.37	-1.31	5.70	Na-HCO3
280	MK2-197	MN127	590090	1626800	1172	684	160	14.18	12.73	-0.28	8.71	Na-HCO3

order unit	Sample ID	Well ID	East (m)	North (m)	calc TDS	Calc Alk.	Total Hardness	Sum of Anions	Sum of Cations	E.N. %	SAR	Water Type
281	MK2-207	MN156	607150	1643090	359	204	84	4.37	3.81	-2.32	3.18	Na-HCO3
282	MK2-211	MN169	598750	1646900	403	230	88	4.93	4.24	-1.35	3.52	Na-HCO3
283	MK2-214	MN173	597340	1633750	713	367	141	9.16	7.75	0.36	5.24	Na-HCO3
284	MK2-216	MN175	592000	1619300	1128	659	46	13.58	13.00	0.74	18.29	Na-HCO3
285	MK2-219	MN184	620840	1597900	364	222	59	4.36	4.24	-0.39	4.70	Na-HCO3
286	MK2-226	MN232	614900	1599050	552	310	24	6.58	6.47	0.29	12.59	Na-HCO3
287	MK2-238	MN267	624090	1587050	366	211	83	4.40	3.88	-2.59	3.30	Na-HCO3
288	MK2-245	MN287	621700	1605590	443	253	88	5.30	4.73	-2.02	4.04	Na-HCO3
289	MK2-260	MN344	615090	1587500	491	284	41	5.80	6.05	-2.70	8.77	Na-HCO3
290	MK2-261	MN345	614700	1590400	610	329	72	7.40	7.07	-1.28	7.45	Na-HCO3
291	MK2-360	MQ475	670040	1586300	613	331	95	7.26	6.70	2.20	5.81	Na-HCO3
292	MK2-361	MQ476	673450	1587690	704	367	102	8.11	8.14	-3.12	7.02	Na-HCO3
293	MK2-379	MQ582	671590	1589900	676	366	128	8.01	6.97	1.56	5.01	Na-HCO3
294	MK2-382	MQ626	667700	1588590	507	281	93	5.67	6.37	-4.02	5.43	Na-HCO3
295	MK2-405	MT119	695750	1589750	376	225	55	4.61	4.27	1.40	4.98	Na-HCO3
296	MK2-406	MT126	620900	1597950	415	221	77	5.19	4.60	-1.16	4.32	Na-HCO3
297	MK2-416	MT146	617550	1579700	505	294	28	5.95	6.38	-2.15	11.45	Na-HCO3
298	MK2-418	MT15	621290	1600500	438	240	80	5.29	4.77	-1.17	4.38	Na-HCO3
299	MK2-432	MT225	624300	1580350	397	239	49	4.57	4.85	-1.63	6.05	Na-HCO3
300	MK2-443	MT33	619500	1592500	437	246	82	5.22	4.95	-4.28	4.52	Na-HCO3
301	MK2-450	MT53	621500	1598200	384	225	56	4.66	4.09	0.69	4.65	Na-HCO3
302	MK2-457	MT79	620500	1699190	381	232	64	4.63	4.30	2.03	4.52	Na-HCO3
303	MK2-404	PD0053	643300	1526500	640	347	48	7.82	7.57	-1.16	10.04	Na-HCO3
304	MK2-535	S20	624790	1662090	704	316	127	8.23	7.85	-0.02	5.83	Na-HCO3
305	MK2-542	TA270	598504	1681766	766	440	151	9.47	8.08	-0.43	5.32	Na-HCO3
306	MK2-545	TA308	597046	1661767	747	450	95	9.22	7.95	2.05	7.14	Na-HCO3
307	MK2-63	DF87	624400	1582200	454	276	40	5.22	6.06	-3.08	8.90	Na-HCO3-CO3
308	MK2-222	MN205	621200	1597250	339	207	72	3.94	4.01	-2.27	3.79	Na-HCO3-CO3
309	MK2-407	MT127	620900	1598800	349	218	62	4.12	4.39	-1.24	4.71	Na-HCO3-CO3
310	MK2-439	MT261	620850	1591650	363	228	68	4.25	4.24	-0.36	4.10	Na-HCO3-CO3
311	MK2-7	DB131	606822	1556387	1053	290	219	15.19	14.89	-3.02	8.52	Na-Cl-HCO3
312	MK2-75	DS106	611051	1558697	1625	284	170	22.85	22.71	1.66	16.02	Na-Cl-HCO3
313	MK2-205	MN150	606142	1557020	1057	328	241	14.71	13.05	0.16	6.79	Na-Cl-HCO3
314	MK2-4	DB126	607200	1552590	726	269	124	9.81	9.56	-1.98	7.43	Na-HCO3-Cl
315	MK2-5	DB127	608308	1554738	867	341	127	10.93	10.89	1.74	8.51	Na-HCO3-Cl
316	MK2-79	DS95	607099	1558650	1468	561	166	18.04	21.29	-4.03	15.21	Na-HCO3-Cl
317	MK2-104	MC250	599500	1689400	1821	733	98	23.37	23.99	-2.61	23.23	Na-HCO3-Cl
318	MK2-229	MN237	604340	1610000	1429	492	207	18.79	17.37	-0.84	10.49	Na-HCO3-Cl
319	MK2-265	MN357	615900	1600900	1000	395	94	12.92	12.99	-1.65	12.38	Na-HCO3-Cl
320	MK2-273	MN386	622509	1546425	652	252	137	8.07	7.66	-1.07	5.32	Na-HCO3-Cl
321	MK2-317	MN84	630090	1544150	542	236	107	6.87	6.59	-0.79	5.27	Na-HCO3-Cl
322	MK2-362	MQ479	670290	1584190	599	262	117	7.53	7.42	-1.31	5.64	Na-HCO3-Cl
323	MK2-413	MT139	614350	1608700	1929	709	332	25.24	24.41	-2.01	11.46	Na-HCO3-Cl
324	MK2-444	MT34	625400	1571190	534	254	108	6.90	6.03	-0.93	4.74	Na-HCO3-Cl
325	MK2-452	MT59	620790	1699690	465	232	100	6.15	5.27	1.40	4.22	Na-HCO3-Cl
326	MK2-520	PD0106	620865	1560536	662	286	70	8.18	8.57	-0.48	9.34	Na-HCO3-Cl
327	MK2-19	DB244	609085	1556356	1393	350	448	19.34	17.55	-0.34	6.17	Na-Mg-Cl-HCO3
328	MK2-66	DN288	606004	1556677	1503	303	428	22.42	19.10	0.85	7.16	Na-Mg-Cl-HCO3
329	MK2-476	MX2	624400	1527690	901	196	587	15.08	9.17	0.14	1.36	Ca-Mg-Na-Cl-HCO3
330	MK2-491	PD0018	637412	1510997	1121	267	655	17.77	11.49	-0.07	1.87	Ca-Mg-Na-Cl-HCO3
331	MK2-55	DF315	600640	1544768	563	289	292	7.51	4.55	1.23	0.94	Ca-Mg-Na-HCO3-Cl
332	MK2-486	N66	608340	1535840	261	98	150	3.79	2.56	-3.49	0.78	Ca-Mg-Na-HCO3-Cl
333	MK2-272	MN374	625900	1610250	484	141	297	7.29	4.65	-2.19	0.88	Ca-Na-Cl-HCO3
334	MK2-294	MN506	634650	1619900	538	94	325	8.73	5.67	-0.62	1.28	Ca-Na-Cl-HCO3
335	MK2-299	MN543	646040	1616800	709	209	394	10.76	7.00	-0.50	1.47	Ca-Na-Cl-HCO3
336	MK2-376	MQ566	646750	1614500	842	205	502	13.21	8.47	-0.87	1.48	Ca-Na-Cl-HCO3
337	MK2-512	PD0092	609400	1524350	1095	281	569	16.49	10.62	2.56	2.01	Ca-Na-Cl-HCO3
338	MK2-43	DF124	605700	1632200	244	115	94	3.17	2.40	1.42	1.44	Ca-Na-HCO3-Cl
339	MK2-60	DF57	588950	1631650	231	91	119	3.03	2.13	0.50	0.72	Ca-Na-HCO3-Cl
340	MK2-77	DS38	592597	1552212	996	414	411	14.11	9.49	2.44	2.58	Ca-Na-HCO3-Cl
341	MK2-86	GWA0046	621764	1644237	317	156	119	4.05	2.62	2.91	1.20	Ca-Na-HCO3-Cl
342	MK2-119	MC325	602590	1653550	825	382	381	11.30	7.39	0.40	1.78	Ca-Na-HCO3-Cl
343	MK2-365	MQ496	648090	1611750	578	225	281	8.10	5.71	-2.30	1.66	Ca-Na-HCO3-Cl
344	MK2-467	MT98	628200	1598800	321	131	133	4.53	3.08	1.66	1.44	Ca-Na-HCO3-Cl
345	MK2-537	TA149	630000	1660600	416	209	180	5.34	3.88	-3.03	1.49	Ca-Na-HCO3-Cl
346	MK2-50	DF256	646750	1615750	718	229	415	10.84	6.90	-0.73	1.28	Ca-Na-Mg-Cl-HCO3
347	MK2-293	MN505	646790	1612750	658	203	353	10.04	6.52	0.30	1.55	Ca-Na-Mg-Cl-HCO3
348	MK2-375	MQ563	650580	1607129	726	201	365	11.14	7.78	-1.20	2.10	Ca-Na-Mg-Cl-HCO3
349	MK2-483	MX7	612250	1524940	1147	226	669	17.97	11.86	0.14	2.00	Ca-Na-Mg-Cl-HCO3
350	MK2-56	DF316	601576	1546107	675	320	330	9.19	5.94	0.87	1.44	Ca-Na-Mg-HCO3-Cl
351	MK2-435	MT24	625500	1606500	296	146	142	3.83	2.72	-3.41	1.02	Ca-Na-Mg-HCO3-Cl

order unit	Sample ID	Well ID	East (m)	North (m)	calc TDS	Calc Alk.	Total Hardness	Sum of Anions	Sum of Cations	E.N. %	SAR	Water Type
352	MK2-233	MN247	626900	1524300	550	144	310	9.08	5.40	4.56	1.24	Mg-Ca-Na-Cl-HCO3
353	MK2-474	MX16	630950	1523900	414	149	230	6.35	4.08	-0.07	1.18	Mg-Ca-Na-Cl-HCO3
354	MK2-234	MN248	628958	1524710	642	254	341	9.20	6.37	-2.40	1.51	Mg-Ca-Na-HCO3-Cl
355	MK2-473	MX15	630500	1523690	557	221	321	8.33	5.17	-0.14	1.09	Mg-Ca-Na-HCO3-Cl
356	MK2-468	MU664	584850	1498239	802	324	420	10.83	7.91	-3.43	1.80	Mg-Na-Ca-HCO3-Cl
357	MK2-496	PD0055	654109	1538551	1893	702	869	25.02	18.59	-0.50	3.25	Mg-Na-Ca-HCO3-Cl
358	MK2-472	MX12	641950	1510250	966	180	587	16.75	10.95	-0.08	2.10	Mg-Na-Cl-HCO3
359	MK2-477	MX21	601000	1551400	753	252	360	11.37	8.12	-0.14	2.39	Mg-Na-Cl-HCO3
360	MK2-547	TL129	577255	1497787	2000	564	877	31.87	23.64	-0.54	5.00	Mg-Na-Cl-HCO3
361	MK2-61	DF81	632950	1594200	482	141	112	7.10	6.01	0.03	4.52	Na-Ca-Cl-HCO3
362	MK2-263	MN353	607500	1556000	1490	315	366	21.93	18.50	2.55	7.69	Na-Ca-Cl-HCO3
363	MK2-380	MQ595	655150	1591840	1076	238	263	16.49	14.13	-0.40	6.98	Na-Ca-Cl-HCO3
364	MK2-398	MS603	603275	1523811	737	169	244	10.36	8.66	-1.25	3.90	Na-Ca-Cl-HCO3
365	MK2-17	DB211	609911	1541572	627	239	170	7.91	7.20	-2.07	4.01	Na-Ca-HCO3-Cl
366	MK2-23	DB33	593340	1554340	833	317	325	11.63	9.02	-1.80	3.14	Na-Ca-HCO3-Cl
367	MK2-112	MC305	605150	1679090	687	239	259	9.23	7.11	-0.48	2.81	Na-Ca-HCO3-Cl
368	MK2-188	MD60	590040	1576440	868	363	273	11.25	8.81	1.67	3.63	Na-Ca-HCO3-Cl
369	MK2-224	MN211	585950	1622900	437	198	126	5.22	3.57	4.14	1.98	Na-Ca-HCO3-Cl
370	MK2-283	MN455	578750	1631300	390	180	144	4.98	3.91	-2.24	1.92	Na-Ca-HCO3-Cl
371	MK2-295	MN52	633450	1600190	429	188	92	5.72	4.95	-0.76	4.08	Na-Ca-HCO3-Cl
372	MK2-363	MQ480	668340	1585500	850	336	246	11.27	9.78	-2.70	4.61	Na-Ca-HCO3-Cl
373	MK2-383	MQ628	648200	1591090	438	210	147	5.79	4.31	0.83	2.30	Na-Ca-HCO3-Cl
374	MK2-397	MQ900	669929	1588157	420	166	123	5.61	4.66	-0.44	2.98	Na-Ca-HCO3-Cl
375	MK2-420	MT17	622700	1594590	571	193	202	7.92	6.42	-1.12	3.03	Na-Ca-HCO3-Cl
376	MK2-421	MT18	634200	1585090	567	205	184	7.99	6.46	-1.42	3.33	Na-Ca-HCO3-Cl
377	MK2-458	MT8	624790	1692000	535	201	195	7.42	5.97	-2.93	2.80	Na-Ca-HCO3-Cl
378	MK2-506	PD0083	657600	1521400	768	275	252	10.68	7.89	4.10	3.29	Na-Ca-HCO3-Cl
379	MK2-533	PD0141	644759	1526087	635	275	216	8.96	6.41	2.37	2.81	Na-Ca-HCO3-Cl
380	MK2-186	MD517	607200	1523500	915	271	396	12.85	10.49	-3.72	3.21	Na-Ca-Mg-Cl-HCO3
381	MK2-243	MN280	617650	1644190	827	341	378	11.38	8.07	-1.12	2.02	Na-Ca-Mg-HCO3-Cl
382	MK2-495	PD0054	638613	1519846	683	288	280	9.66	6.54	2.72	2.18	Na-Ca-Mg-HCO3-Cl
383	MK2-22	DB32	602700	1551800	845	296	370	12.07	9.46	-3.48	2.94	Na-Mg-Ca-Cl-HCO3
384	MK2-232	MN246	601590	1550690	1225	287	567	18.69	14.15	-1.15	3.49	Na-Mg-Ca-Cl-HCO3
385	MK2-350	MP81	633450	1686900	1528	449	649	19.75	16.06	-3.79	3.76	Na-Mg-Ca-HCO3-Cl
386	MK2-29	DB63	597800	1599100	396	149	91	5.21	4.98	-2.99	4.10	Na-Mg-HCO3-Cl
387	MK2-42	DF121	592500	1634800	284	133	115	3.72	3.00	-2.34	1.67	Na-Mg-HCO3-Cl
388	MK2-134	MC371	590200	1690250	1528	407	379	20.19	16.50	1.65	6.48	Na-Mg-HCO3-Cl
389	MK2-215	MN174	589400	1621750	551	192	141	7.37	6.58	-1.02	4.14	Na-Mg-HCO3-Cl
390	MK2-396	MQ898	668350	1589100	557	253	134	6.94	7.04	-3.46	4.89	Na-Mg-HCO3-Cl
391	MK2-527	PD0126	614819	1505176	601	258	145	7.53	7.19	2.00	4.69	Na-Mg-HCO3-Cl
392	MK2-179	MD238	582300	1492700	1719	391	569	23.26	20.61	-3.96	3.43	Na-Mg-K-Cl-HCO3
393	MK2-251	MN312	598790	1633840	141	52	59	1.64	1.15	4.69	0.48	Ca-Mg-Na-HCO3-SO4
394	MK2-327	MP141	625340	1663500	380	171	191	4.37	3.08	-0.40	0.79	Ca-Mg-Na-HCO3-SO4
395	MK2-67	DN30	607136	1554919	2540	368	1146	34.83	27.68	1.40	4.76	Ca-Na-Cl-SO4
396	MK2-124	MC330	613750	1668940	609	233	241	6.78	5.44	1.59	1.91	Ca-Na-HCO3-SO4
397	MK2-324	MP138	630150	1654190	462	196	203	5.41	4.04	1.46	1.41	Ca-Na-HCO3-SO4
398	MK2-325	MP139	630900	1661400	655	204	312	7.94	6.05	0.68	1.65	Ca-Na-HCO3-SO4-Cl
399	MK2-82	GWA0019	654235	1590047	328	114	167	4.04	3.17	-3.59	1.08	Ca-Na-Mg-HCO3-Cl-SO4
400	MK2-417	MT149	615800	1589800	1287	297	287	16.86	16.40	-0.85	7.96	Na-Ca-Cl-HCO3-SO4
401	MK2-508	PD0088	615200	1543100	3592	388	1293	53.23	43.52	2.36	8.47	Na-Ca-Cl-SO4
402	MK2-342	MP239	632540	1668840	828	333	326	9.30	8.08	-1.71	2.65	Na-Ca-HCO3-SO4
403	MK2-34	DB77	608250	1556400	2149	281	952	27.23	26.65	-4.95	5.50	Na-Ca-Mg-Cl-SO4
404	MK2-140	MC40	624790	1666400	820	290	290	9.28	8.03	2.05	2.96	Na-Ca-Mg-HCO3-SO4
405	MK2-320	MN887	652550	1619750	650	235	260	7.87	6.40	0.03	2.35	Na-Ca-Mg-HCO3-SO4-Cl
406	MK2-306	MN58	605040	1564050	2181	523	353	26.08	29.03	-2.43	13.53	Na-Cl-HCO3-SO4
407	MK2-442	MT28	607400	1584300	1201	299	145	15.78	16.17	-0.23	12.22	Na-Cl-HCO3-SO4
408	MK2-456	MT78	615500	1501000	1123	285	123	13.99	16.09	-2.21	13.33	Na-Cl-HCO3-SO4
409	MK2-24	DB37	606790	1551400	1082	343	178	11.87	13.15	-0.83	8.49	Na-HCO3-SO4
410	MK2-78	DS62	607256	1557090	1411	452	265	16.49	17.47	-2.07	9.09	Na-HCO3-SO4-Cl
411	MK2-40	DF107	628600	1645500	324	139	126	3.73	3.27	-1.10	1.71	Na-Mg-Ca-HCO3-SO4
412	MK2-69	DN33	606989	1556940	1337	358	403	16.74	16.34	-2.82	6.07	Na-Mg-HCO3-Cl-SO4
413	MK2-192	MN102	607840	1570250	2485	466	411	29.15	32.58	-0.79	13.98	Na-SO4-Cl-HCO3
414	MK2-32	DB73	608725	1556900	1037	295	212	11.24	13.52	-4.19	7.76	Na-SO4-HCO3
415	MK2-96	MC220	621950	1679900	252	139	130	3.00	1.75	-0.41	0.35	Ca-HCO3
416	MK2-144	MC41	614900	1671090	243	131	110	2.76	1.67	0.49	0.46	Ca-HCO3
417	MK2-170	MC794	624650	1661340	304	150	169	3.56	2.31	-1.35	0.40	Ca-HCO3
418	MK2-241	MN273	591590	1639150	286	153	138	3.69	2.20	2.54	0.59	Ca-HCO3
419	MK2-353	MP87	616290	1672500	212	121	106	2.57	1.54	-0.51	0.40	Ca-HCO3
420	MK2-422	MT181	597250	1589450	581	294	383	6.99	4.03	-3.96	0.10	Ca-HCO3
421	MK2-541	TA245	587681	1681939	376	229	206	4.67	2.69	-0.67	0.42	Ca-HCO3
422	MK2-57	DF319	600930	1539058	178	108	107	2.19	1.45	-4.26	0.29	Ca-Mg-HCO3

order unit	Sample ID	Well ID	East (m)	North (m)	calc TDS	Calc Alk.	Total Hardness	Sum of Anions	Sum of Cations	E.N. %	SAR	Water Type
423	MK2-140	MC40	624790	1666400	191	91	84	2.19	1.38	-1.10	0.47	Ca-Mg-HCO3
424	MK2-193	MN110	597290	1610550	605	376	328	7.93	4.12	3.74	0.43	Ca-Mg-HCO3
425	MK2-244	MN283	592450	1604300	359	194	202	4.67	2.69	0.19	0.43	Ca-Mg-HCO3
426	MK2-277	MN419	612050	1649450	267	154	132	3.23	2.00	-1.08	0.53	Ca-Mg-HCO3
427	MK2-280	MN430	603275	1536271	356	207	208	4.53	2.57	-0.87	0.30	Ca-Mg-HCO3
428	MK2-326	MP140	623790	1667300	217	123	120	2.72	1.50	0.04	0.18	Ca-Mg-HCO3
429	MK2-341	MP237	622090	1677500	158	89	83	2.03	1.15	1.61	0.31	Ca-Mg-HCO3
430	MK2-73	DN50	600060	1541310	387	230	226	5.04	2.98	-1.06	0.40	Mg-Ca-HCO3
431	MK2-183	MD331	577650	1493350	722	413	384	9.67	5.29	3.65	0.67	Mg-Ca-HCO3
432	MK2-122	MC328	698150	1662050	911	574	486	12.20	7.12	1.26	1.03	Mg-HCO3
433	MK2-187	MD54	580100	1493600	547	322	352	7.30	4.36	-2.94	0.39	Mg-HCO3
434	MK2-501	PD0062	649800	1504800	14412	175	3039	251.39	215.60	1.67	33.15	Na-Cl
435	MK2-30	DB7	601650	1544840	483	268	257	6.14	4.05	-3.05	0.87	Ca-Mg-Na-HCO3
436	MK2-97	MC222	610650	1617550	248	137	120	3.07	1.85	0.53	0.60	Ca-Mg-Na-HCO3
437	MK2-115	MC308	602700	1653690	949	549	448	12.02	8.14	-2.20	1.67	Ca-Mg-Na-HCO3
438	MK2-179	MD238	582300	1492700	310	150	154	3.93	2.58	0.28	0.74	Ca-Mg-Na-HCO3
439	MK2-349	MP79	594250	1689250	693	422	330	8.71	5.84	-2.22	1.39	Ca-Mg-Na-HCO3
440	MK2-41	DF12	582350	1632350	260	132	113	3.18	2.42	-3.53	1.14	Ca-Na-HCO3
441	MK2-107	MC272	610700	1687090	244	135	110	3.16	2.01	0.71	0.87	Ca-Na-HCO3
442	MK2-125	MC350	617200	1617590	238	109	93	2.81	2.17	-2.49	1.26	Ca-Na-HCO3
443	MK2-152	MC472	596400	1679690	176	95	60	1.95	1.33	1.76	0.90	Ca-Na-HCO3
444	MK2-173	MC980	613116	1684090	277	149	110	3.12	2.07	-0.75	0.87	Ca-Na-HCO3
445	MK2-329	MP164	611317	1687043	228	119	94	2.80	2.01	-2.26	0.95	Ca-Na-HCO3
446	MK2-402	MT11	608900	1641500	595	321	300	7.38	4.97	-3.10	1.10	Ca-Na-HCO3
447	MK2-464	MT90	693790	1629400	490	286	204	6.12	4.25	-1.40	1.49	Ca-Na-HCO3
448	MK2-466	MT93	588790	1624400	901	467	444	11.84	7.80	-1.46	1.55	Ca-Na-HCO3
449	MK2-540	TA159	623353	1666879	155	85	65	1.88	1.32	-1.70	0.75	Ca-Na-HCO3
450	MK2-35	DB8	592450	1551250	652	337	320	8.11	5.72	0.16	1.36	Ca-Na-Mg-HCO3
451	MK2-100	MC225	610000	1654190	185	105	82	2.22	1.39	0.63	0.62	Ca-Na-Mg-HCO3
452	MK2-149	MC42	617590	1674050	151	84	65	1.82	1.18	0.25	0.59	Ca-Na-Mg-HCO3
453	MK2-196	MN12	605340	1623050	540	316	230	6.72	4.72	-1.74	1.52	Ca-Na-Mg-HCO3
454	MK2-240	MN272	570840	1637250	623	329	271	7.76	5.24	-0.44	1.45	Ca-Na-Mg-HCO3
455	MK2-336	MP198	626011	1677111	217	112	109	2.65	1.93	-4.62	0.75	Ca-Na-Mg-HCO3
456	MK2-441	MT267	628850	1609900	229	122	96	2.85	2.27	-3.08	1.24	Ca-Na-Mg-HCO3
457	MK2-465	MT92	687700	1624690	445	229	187	5.43	3.97	-3.10	1.47	Ca-Na-Mg-HCO3
458	MK2-488	NL0088	632900	1524800	507	290	210	6.55	4.32	1.29	1.47	Ca-Na-Mg-HCO3
459	MK2-189	MD61	576600	1491000	588	332	280	7.79	4.72	1.78	1.09	Mg-Ca-Na-HCO3
460	MK2-266	MN359	601540	1600050	874	515	392	11.20	7.50	-0.79	1.71	Mg-Ca-Na-HCO3
461	MK2-346	MP277	696040	1677500	581	347	297	7.36	5.00	-3.87	1.11	Mg-Ca-Na-HCO3
462	MK2-127	MC352	603750	1651300	372	230	152	4.87	2.95	4.65	1.13	Mg-Na-Ca-HCO3
463	MK2-548	X65	536950	1499850	671	418	296	8.73	5.91	-0.07	1.72	Mg-Na-HCO3
464	MK2-47	DF190	627700	1590400	335	197	78	4.05	3.58	-1.88	3.06	Na-Ca-HCO3
465	MK2-52	DF26	620800	1633600	269	147	86	3.29	2.59	-1.39	1.83	Na-Ca-HCO3
466	MK2-105	MC252	610090	1689300	237	135	55	2.80	2.31	-0.75	2.28	Na-Ca-HCO3
467	MK2-151	MC471	611840	1685650	444	258	110	5.51	3.98	4.52	2.65	Na-Ca-HCO3
468	MK2-200	MN135	633450	1599440	277	158	53	3.48	2.70	4.35	2.87	Na-Ca-HCO3
469	MK2-218	MN183	626090	1599150	291	158	102	3.73	2.71	0.63	1.59	Na-Ca-HCO3
470	MK2-237	MN266	624040	1596750	313	188	79	3.90	2.85	3.97	2.25	Na-Ca-HCO3
471	MK2-239	MN27	590250	1637400	655	363	215	8.41	5.59	4.36	2.31	Na-Ca-HCO3
472	MK2-270	MN365	620700	1600190	408	210	100	5.22	4.30	-0.30	3.22	Na-Ca-HCO3
473	MK2-314	MN80	628540	1528090	640	294	157	7.84	6.59	1.83	3.93	Na-Ca-HCO3
474	MK2-316	MN829	647463	1628695	401	175	161	4.75	3.98	-3.17	1.82	Na-Ca-HCO3
475	MK2-363	MQ480	668340	1585500	674	369	145	7.92	7.11	-1.60	4.66	Na-Ca-HCO3
476	MK2-364	MQ481	669650	1587150	401	205	106	4.66	4.20	-2.90	3.00	Na-Ca-HCO3
477	MK2-382	MQ626	667700	1588590	627	331	150	7.33	6.78	-3.64	4.26	Na-Ca-HCO3
478	MK2-393	MQ832	668450	1587500	452	214	118	5.61	4.63	1.11	3.12	Na-Ca-HCO3
479	MK2-425	MT189	623850	1601500	355	194	102	4.31	3.74	-4.47	2.58	Na-Ca-HCO3
480	MK2-528	PD0128	600010	1530587	541	265	173	6.60	5.45	-1.87	2.72	Na-Ca-HCO3
481	MK2-535	S20	624790	1662090	318	170	73	3.80	3.26	-1.76	2.96	Na-Ca-HCO3
482	MK2-95	MC148	602700	1688800	961	512	371	12.55	9.23	-1.40	2.87	Na-Ca-Mg-HCO3
483	MK2-225	MN229	632400	1602090	233	132	69	2.96	2.07	4.52	1.57	Na-Ca-Mg-HCO3
484	MK2-230	MN239	621290	1600690	342	198	95	4.10	3.51	-3.40	2.45	Na-Ca-Mg-HCO3
485	MK2-235	MN250	623750	1611440	294	146	106	3.63	3.06	-4.11	1.86	Na-Ca-Mg-HCO3
486	MK2-313	MN72	624040	1600440	302	140	117	3.61	2.83	-0.33	1.45	Na-Ca-Mg-HCO3
487	MK2-522	PD0110	622640	1539919	622	285	242	7.72	6.16	-1.42	2.35	Na-Ca-Mg-HCO3
488	MK2-46	DF189	623350	1611850	310	177	120	3.91	3.11	-2.28	1.75	Na-Mg-Ca-HCO3
489	MK2-312	MN706	640475	1609790	302	177	98	3.74	2.72	2.12	1.71	Na-Mg-Ca-HCO3
490	MK2-321	MN89	633900	1524250	433	212	157	5.29	4.38	-4.70	1.53	Na-Mg-Ca-HCO3
491	MK2-94	MC131	610250	1682500	434	249	99	5.18	4.71	-4.51	3.54	Na-Mg-HCO3
492	MK2-146	MC412	621200	1680250	894	479	191	11.28	9.59	0.04	5.50	Na-Mg-HCO3
493	MK2-159	MC716	602340	1664840	875	517	267	10.82	8.88	-2.92	3.73	Na-Mg-HCO3

order unit	Sample ID	Well ID	East (m)	North (m)	calc TDS	Calc Alk.	Total Hardness	Sum of Anions	Sum of Cations	E.N. %	SAR	Water Type
494	MK2-178	MD150	617650	1543500	583	290	140	7.42	6.48	1.15	4.23	Na-Mg-HCO3
495	MK2-190	MD88	628290	1493900	650	385	199	8.31	6.38	-0.14	3.12	Na-Mg-HCO3
496	MK2-264	MN355	615750	1547690	625	330	212	7.70	6.63	-4.76	3.02	Na-Mg-HCO3
497	MK2-401	MT109	611250	1634400	234	130	71	2.80	2.44	-2.79	1.91	Na-Mg-HCO3
498	MK2-523	PD0111	602338	1538429	422	201	212	5.65	3.21	4.22	0.66	Ca-HCO3-Cl
499	MK2-202	MN140	627150	1605590	456	122	279	7.16	4.20	1.42	0.76	Ca-Mg-Cl-HCO3
500	MK2-297	MN541	635296	1618582	625	144	390	10.05	5.90	1.53	0.95	Ca-Mg-Cl-HCO3
501	MK2-281	MN431	608070	1537364	415	174	240	5.84	3.70	-1.40	0.73	Ca-Mg-HCO3-Cl
502	MK2-486	N66	608340	1535840	513	230	294	7.30	4.41	-0.11	0.84	Ca-Mg-HCO3-Cl
503	MK2-201	MN137	629450	1608800	748	116	512	12.60	7.64	-0.41	1.02	Ca-Mg-Cl
504	MK2-301	MN547	636650	1604690	1132	75	842	19.92	11.78	-0.77	1.03	Ca-Mg-Cl
505	MK2-302	MN548	635616	1604854	1295	91	958	22.85	13.45	-0.36	1.14	Ca-Mg-Cl
506	MK2-354	MQ1027	630855	1605614	901	76	660	15.52	9.46	-1.33	1.02	Ca-Mg-Cl
507	MK2-415	MT144	629850	1606450	1042	98	731	17.88	10.83	-0.68	1.19	Ca-Mg-Cl
508	MK2-510	PD0090	629200	1534700	2635	194	1924	46.93	26.39	2.18	1.59	Ca-Mg-Cl
509	MK2-511	PD0091	618400	1528100	1439	214	1052	24.37	14.58	-0.83	1.19	Ca-Mg-Cl
510	MK2-65	DF91	628350	1612150	528	55	367	8.87	5.69	-1.91	1.00	Ca-Mg-Na-Cl
511	MK2-231	MN241	632400	1601050	908	77	605	15.84	10.16	-1.09	1.54	Ca-Mg-Na-Cl
512	MK2-507	PD0087	632900	1524800	1569	239	952	26.52	17.09	0.34	2.40	Ca-Mg-Na-Cl
513	MK2-526	PD0125	611469	1530372	2687	171	1808	46.60	29.70	-0.40	2.66	Ca-Mg-Na-Cl
514	MK2-64	DF88	624300	1591150	881	42	494	15.41	10.36	0.69	2.35	Ca-Na-Cl
515	MK2-111	MC302	696150	1680800	3508	174	1657	59.03	43.35	0.06	6.59	Ca-Na-Cl
516	MK2-147	MC413	634750	1610840	1880	83	1051	31.89	21.93	0.08	3.40	Ca-Na-Cl
517	MK2-291	MN503	645290	1612090	1014	66	648	17.06	11.00	-0.11	1.71	Ca-Na-Cl
518	MK2-369	MQ555	645540	1616150	1442	171	984	24.14	15.28	-1.85	1.66	Ca-Na-Cl
519	MK2-370	MQ556	644590	1616650	766	89	461	12.50	8.54	-1.64	1.76	Ca-Na-Cl
520	MK2-446	MT43	634400	1579000	9547	145	5893	165.44	111.77	-0.23	6.80	Ca-Na-Cl
521	MK2-463	MT85	607900	1626590	1388	118	794	23.30	15.58	0.19	2.63	Ca-Na-Cl
522	MK2-493	PD0052	639500	1503539	2532	20	1377	45.64	31.60	0.35	4.69	Ca-Na-Cl
523	MK2-285	MN480	646040	1606690	975	162	614	16.24	10.09	-0.05	1.51	Ca-Na-Mg-Cl
524	MK2-373	MQ559	646590	1613800	901	65	573	15.52	10.27	-1.42	1.82	Ca-Na-Mg-Cl
525	MK2-377	MQ567	644540	1617800	623	94	370	10.16	7.21	-3.31	1.77	Ca-Na-Mg-Cl
526	MK2-499	PD0059	653800	1552300	5271	56	3085	93.32	63.11	0.60	5.72	Ca-Na-Mg-Cl
527	MK2-500	PD0061	640500	1534700	6405	85	3919	113.13	79.74	-1.95	6.40	Ca-Na-Mg-Cl
528	MK2-503	PD0068	665126	1569478	2805	157	1675	48.84	32.83	-0.35	3.83	Ca-Na-Mg-Cl
529	MK2-513	PD0093	627100	1550500	12934	206	8328	227.61	167.08	-4.62	9.06	Ca-Na-Mg-Cl
530	MK2-519	PD0105	641430	1544695	8700	247	5017	148.43	111.72	-3.62	8.60	Ca-Na-Mg-Cl
531	MK2-317	MN84	630090	1544150	2351	11	977	36.69	29.95	0.10	6.20	Na-Ca-Cl
532	MK2-355	MQ1028	630855	1605614	843	110	362	13.19	10.39	-1.19	3.43	Na-Ca-Cl
533	MK2-487	NL0012	665126	1569478	3569	193	1702	58.74	46.84	-3.13	7.17	Na-Ca-Cl
534	MK2-489	PD0006	656174	1516845	1172	28	365	20.94	15.86	3.59	6.15	Na-Ca-Cl
535	MK2-132	MC37	601695	1653031	939	120	437	13.88	11.06	-1.31	3.12	Na-Ca-Mg-Cl
536	MK2-388	MQ747	651385	1591717	867	170	423	13.64	10.53	-1.81	2.96	Na-Ca-Mg-Cl
537	MK2-502	PD0066	645100	1559400	4084	60	2039	67.91	48.71	2.36	6.07	Na-Ca-Mg-Cl
538	MK2-508	PD0088	615200	1543100	3540	379	1417	52.26	44.85	-1.42	8.09	Na-Ca-Mg-Cl
539	MK2-514	PD0094	639148	1544581	6357	147	2641	107.65	87.91	-1.57	11.85	Na-Ca-Mg-Cl
540	MK2-517	PD0100	621463	1497147	6586	213	3867	116.19	81.36	-0.82	6.79	Na-Ca-Mg-Cl
541	MK2-521	PD0109	640287	1501648	2604	112	1515	45.28	32.79	-2.11	4.47	Na-Ca-Mg-Cl
542	MK2-530	PD0131	617510	1506980	7502	253	3836	134.84	95.38	0.42	9.13	Na-Ca-Mg-Cl
543	MK2-206	MN151	605000	1555440	1830	284	700	29.02	23.01	0.06	6.02	Na-Mg-Ca-Cl
544	MK2-389	MQ749	657079	1583113	8085	139	3318	143.60	107.72	1.82	12.84	Na-Mg-Cl
545	MK2-529	PD0129	652547	1526141	7443	114	2581	124.47	109.59	-2.79	16.27	Na-Mg-Cl
546	MK2-101	MC226	602250	1653590	1656	189	512	23.28	19.86	-2.80	6.52	Na-Mg-Cl-NO3
547	MK2-45	DF164	624050	1584250	356	212	45	4.16	4.27	-2.01	5.63	Na-HCO3
548	MK2-62	DF85	623750	1587250	355	200	66	4.45	3.74	3.39	3.69	Na-HCO3
549	MK2-103	MC249	598540	1689440	1001	586	148	12.03	11.03	-1.67	7.81	Na-HCO3
550	MK2-153	MC475	608650	1656190	546	308	43	6.68	6.10	1.57	8.55	Na-HCO3
551	MK2-156	MC700	672040	1588050	585	315	71	6.96	6.23	3.31	6.50	Na-HCO3
552	MK2-182	MD330	580432	1492181	909	522	128	11.06	9.87	0.23	7.53	Na-HCO3
553	MK2-204	MN149	603540	1556940	873	384	171	10.77	10.19	-1.67	6.42	Na-HCO3
554	MK2-219	MN184	620840	1597900	404	235	72	4.96	4.25	0.51	4.10	Na-HCO3
555	MK2-252	MN314	619500	1583400	445	251	40	5.40	5.14	-0.86	7.41	Na-HCO3
556	MK2-339	MP221	608340	1651400	1107	578	97	13.47	13.62	-3.25	12.79	Na-HCO3
557	MK2-361	MQ476	673450	1587690	688	372	112	7.94	7.95	-0.51	6.42	Na-HCO3
558	MK2-414	MT141	606200	1638850	1495	853	138	17.74	18.01	-4.25	14.07	Na-HCO3
559	MK2-447	MT46	616300	1596200	443	246	68	5.30	4.97	-2.06	5.10	Na-HCO3
560	MK2-207	MN156	607150	1643090	343	212	76	4.02	4.04	-1.61	3.69	Na-HCO3-CO3
561	MK2-386	MQ742	669197	1584764	506	260	75	5.99	6.84	-2.84	7.04	Na-HCO3-CO3
562	MK2-400	MT108	621650	1596550	459	286	29	5.19	5.99	-0.09	10.46	Na-HCO3-CO3
563	MK2-437	MT247	625950	1589900	221	142	22	2.47	3.04	-2.48	5.56	Na-HCO3-CO3
564	MK2-2	DB1	606700	1556500	1129	308	262	15.82	14.50	-1.26	7.25	Na-Cl-HCO3

order unit	Sample ID	Well ID	East (m)	North (m)	calc TDS	Calc Alk.	Total Hardness	Sum of Anions	Sum of Cations	E.N. %	SAR	Water Type
565	MK2-6	DB13	603200	1557500	1060	322	171	14.08	13.98	-2.05	9.33	Na-Cl-HCO3
566	MK2-38	DB95	611090	1561800	1277	304	156	17.15	18.20	-1.47	13.22	Na-Cl-HCO3
567	MK2-205	MN150	606142	1557020	978	291	177	13.69	12.26	1.53	7.82	Na-Cl-HCO3
568	MK2-220	MN194	611150	1558840	2054	334	252	28.85	29.32	-0.38	16.82	Na-Cl-HCO3
569	MK2-315	MN802	638350	1621300	702	196	138	8.84	9.32	-4.43	6.66	Na-Cl-HCO3
570	MK2-18	DR227	604359	1555334	715	341	128	9.50	8.27	4.40	6.16	Na-HCO3-Cl
571	MK2-25	DB4	603450	1557800	941	384	104	11.55	11.99	-2.33	10.66	Na-HCO3-Cl
572	MK2-54	DF295	633461	1600132	467	143	97	6.13	5.55	0.98	4.41	Na-HCO3-Cl
573	MK2-117	MC310	609290	1677090	1072	454	261	14.31	11.89	-0.39	5.66	Na-HCO3-Cl
574	MK2-195	MN113	599650	1587690	588	283	128	7.78	6.36	1.69	4.34	Na-HCO3-Cl
575	MK2-229	MN237	604340	1610000	1320	446	175	17.40	16.28	-0.96	10.82	Na-HCO3-Cl
576	MK2-520	PD0106	620865	1560536	701	286	77	8.68	9.07	-3.34	9.40	Na-HCO3-Cl
577	MK2-1	C488	571211	1504722	739	208	452	11.04	7.68	-4.00	1.45	Ca-Mg-Na-Cl-HCO3
578	MK2-71	DN44	606566	1544127	899	235	530	14.42	8.94	0.98	1.53	Ca-Mg-Na-Cl-HCO3
579	MK2-319	MN88	628700	1526900	772	141	467	12.83	8.24	0.26	1.59	Ca-Mg-Na-Cl-HCO3
580	MK2-491	PD0018	637412	1510997	1175	249	696	19.26	12.34	0.29	1.98	Ca-Mg-Na-Cl-HCO3
581	MK2-148	MC414	643250	1617500	779	152	415	12.37	8.60	-1.45	2.11	Ca-Na-Cl-HCO3
582	MK2-247	MN299	624400	1597500	485	141	217	7.46	5.18	0.76	1.98	Ca-Na-Cl-HCO3
583	MK2-286	MN481	647700	1615400	700	193	407	10.72	7.00	-1.22	1.40	Ca-Na-Cl-HCO3
584	MK2-288	MN484	643400	1618190	659	162	353	9.76	6.96	-2.06	1.74	Ca-Na-Cl-HCO3
585	MK2-374	MQ560	646750	1615840	753	180	428	11.86	7.65	-0.07	1.56	Ca-Na-Cl-HCO3
586	MK2-512	PD0092	609400	1524350	950	198	519	14.61	10.15	-0.84	2.10	Ca-Na-Cl-HCO3
587	MK2-49	DF23	621600	1634500	289	139	128	3.71	2.58	-0.84	1.08	Ca-Na-HCO3-Cl
588	MK2-84	GWA0042	619326	1660284	477	175	234	6.22	4.39	-0.52	1.17	Ca-Na-HCO3-Cl
589	MK2-85	GWA0043	619326	1660284	514	199	262	6.66	4.67	-1.40	1.10	Ca-Na-HCO3-Cl
590	MK2-131	MC364	587650	1657150	614	202	316	8.46	5.71	-1.08	1.32	Ca-Na-HCO3-Cl
591	MK2-158	MC714	636540	1686590	702	235	292	9.29	6.37	2.84	1.99	Ca-Na-HCO3-Cl
592	MK2-275	MN396	587550	1640700	755	316	333	9.96	6.98	-0.57	1.98	Ca-Na-HCO3-Cl
593	MK2-233	MN247	626900	1524300	697	239	390	10.25	6.92	-2.24	1.48	Ca-Na-Mg-Cl-HCO3
594	MK2-284	MN477	646200	1616400	525	98	300	8.52	5.61	-0.21	1.43	Ca-Na-Mg-Cl-HCO3
595	MK2-287	MN482	646400	1615590	747	217	448	11.39	7.63	-3.11	1.42	Ca-Na-Mg-Cl-HCO3
596	MK2-300	MN544	635840	1604800	436	109	261	6.85	4.49	-0.37	1.05	Ca-Na-Mg-Cl-HCO3
597	MK2-310	MN67	628150	1601090	313	98	144	4.30	3.25	-1.49	1.41	Ca-Na-Mg-Cl-HCO3
598	MK2-368	MQ553	646070	1615745	758	197	448	11.72	7.37	-0.09	1.32	Ca-Na-Mg-Cl-HCO3
599	MK2-375	MQ563	650580	1607129	763	213	423	11.55	7.86	-1.57	1.71	Ca-Na-Mg-Cl-HCO3
600	MK2-387	MQ746	651335	1591365	779	155	414	12.08	9.11	-3.80	2.35	Ca-Na-Mg-Cl-HCO3
601	MK2-475	MX19	605500	1520000	649	128	340	10.15	7.13	0.22	2.03	Ca-Na-Mg-Cl-HCO3
602	MK2-485	MX9	607450	1525940	837	179	484	12.91	8.57	0.19	1.70	Ca-Na-Mg-Cl-HCO3
603	MK2-198	MN129	587400	1624940	206	100	94	2.74	1.64	3.71	0.63	Ca-Na-Mg-HCO3-Cl
604	MK2-434	MT23	627000	1608500	325	130	147	4.50	3.05	0.75	1.22	Ca-Na-Mg-HCO3-Cl
605	MK2-509	PD0089	626100	1515900	519	223	259	7.11	4.86	-1.57	1.30	Ca-Na-Mg-HCO3-Cl
606	MK2-470	MX10	607450	1547440	491	135	247	7.87	5.38	0.34	1.85	Mg-Na-Ca-Cl-HCO3
607	MK2-318	MN86	623250	1530150	385	190	165	5.20	3.66	0.79	1.49	Mg-Na-Ca-HCO3-Cl
608	MK2-243	MN280	617650	1644190	555	115	279	8.56	6.00	1.92	1.80	Mg-Na-Cl-HCO3
609	MK2-113	MC306	608900	1652400	73	25	31	0.94	0.65	1.07	0.36	Mg-Na-HCO3-Cl
610	MK2-340	MP222	587049	1654801	531	199	256	7.53	5.54	-2.99	1.58	Mg-Na-HCO3-Cl
611	MK2-445	MT342	591230	1617750	276	144	143	3.77	2.66	2.20	0.91	Mg-Na-HCO3-Cl
612	MK2-174	MD108	607540	1448590	982	325	369	13.98	10.12	3.06	3.28	Na-Ca-Cl-HCO3
613	MK2-399	MT1	624400	1582300	1172	216	410	17.88	15.59	-3.66	5.59	Na-Ca-Cl-HCO3
614	MK2-515	PD0098	628166	1526588	1458	300	457	22.66	19.06	-1.53	6.72	Na-Ca-Cl-HCO3
615	MK2-36	DB9	610950	1559650	950	324	322	12.97	11.13	-3.05	4.36	Na-Ca-HCO3-Cl
616	MK2-102	MC245	610840	1689340	906	345	230	11.33	9.42	-1.41	4.59	Na-Ca-HCO3-Cl
617	MK2-108	MC273	605090	1689300	1261	468	491	17.60	12.91	-0.30	3.61	Na-Ca-HCO3-Cl
618	MK2-194	MN112	599290	1599300	809	372	270	11.08	7.82	3.32	3.05	Na-Ca-HCO3-Cl
619	MK2-295	MN52	633450	1600190	428	200	84	5.67	4.77	0.73	4.17	Na-Ca-HCO3-Cl
620	MK2-394	MQ833	665850	1592350	771	359	246	9.89	7.75	0.60	3.33	Na-Ca-HCO3-Cl
621	MK2-72	DN46	592416	1554230	1090	365	477	16.04	11.43	0.20	2.99	Na-Ca-Mg-Cl-HCO3
622	MK2-180	MD29	606150	2051050	1038	254	398	15.56	12.99	-3.44	4.47	Na-Ca-Mg-Cl-HCO3
623	MK2-232	MN246	601590	1550690	1291	265	622	20.07	14.58	-0.17	3.32	Na-Ca-Mg-Cl-HCO3
624	MK2-268	MN361	622700	1579690	975	234	374	15.05	12.11	-2.30	4.30	Na-Ca-Mg-Cl-HCO3
625	MK2-311	MN69	625250	1614250	285	123	118	3.71	2.97	-4.27	1.56	Na-Ca-Mg-HCO3-Cl
626	MK2-390	MQ750	659059	1592333	712	259	265	10.19	7.67	0.16	2.94	Na-Ca-Mg-HCO3-Cl
627	MK2-412	MT136	590100	1625850	633	308	286	8.47	6.25	-3.53	1.91	Na-Ca-Mg-HCO3-Cl
628	MK2-495	PD0054	638613	1519846	696	284	279	9.65	6.93	0.81	2.40	Na-Ca-Mg-HCO3-Cl
629	MK2-477	MX21	601000	1551400	963	312	439	14.52	10.04	1.17	2.64	Na-Mg-Ca-Cl-HCO3
630	MK2-494	PD0053	643300	1526500	776	157	395	12.65	8.46	1.59	2.19	Na-Mg-Ca-Cl-HCO3
631	MK2-474	MX16	630950	1523900	467	239	201	6.39	4.36	0.37	1.66	Na-Mg-Ca-HCO3-Cl
632	MK2-525	PD0121	623219	1508606	511	176	207	6.50	6.08	-4.63	2.72	Na-Mg-Ca-HCO3-Cl
633	MK2-17	DB211	609911	1541572	521	173	167	7.57	6.11	2.08	3.37	Na-Mg-Cl-HCO3
634	MK2-56	DF316	601576	1516107	390	141	160	5.64	4.23	1.33	1.99	Na-Mg-Cl-HCO3
635	MK2-184	MD335	593300	1502400	1275	360	355	19.15	15.84	0.46	6.47	Na-Mg-Cl-HCO3

order unit	Sample ID	Well ID	East (m)	North (m)	calc TDS	Calc Alk.	Total Hardness	Sum of Anions	Sum of Cations	E.N. %	SAR	Water Type
636	MK2-381	MQ596	665040	1592550	631	194	194	8.83	8.18	-3.98	4.37	Na-Mg-Cl-HCO3
637	MK2-423	MT182	598300	1594950	548	174	175	7.91	7.09	-0.70	3.95	Na-Mg-Cl-HCO3
638	MK2-424	MT183	598200	1594250	514	164	176	7.57	6.66	-1.14	3.61	Na-Mg-Cl-HCO3
639	MK2-478	MX27	606090	1551690	860	221	303	13.50	10.51	0.19	4.30	Na-Mg-Cl-HCO3
640	MK2-176	MD147	631160	1778070	542	271	160	7.31	5.73	-0.07	3.27	Na-Mg-HCO3-Cl
641	MK2-278	MN427	608623	1550148	509	240	120	6.60	6.18	-0.10	4.49	Na-Mg-HCO3-Cl
642	MK2-384	MQ641	664290	1591590	589	221	158	8.11	6.88	-0.42	4.16	Na-Mg-HCO3-Cl
643	MK2-430	MT219	598650	1596550	821	290	278	10.64	9.02	-0.06	3.66	Na-Mg-HCO3-Cl
644	MK2-527	PD0126	614819	1505176	877	304	270	11.29	10.63	-4.48	4.76	Na-Mg-HCO3-Cl
645	MK2-55	DF315	600640	1544768	323	176	130	4.30	3.38	2.77	1.76	Na-Mg-HCO3-Cl-CO3
646	MK2-163	MC787	629790	1669190	772	316	328	9.46	6.90	1.57	1.39	Ca-Mg-Na-HCO3-Cl-SO4
647	MK2-164	MC788	634290	1666590	731	344	312	8.26	6.77	-2.88	2.04	Ca-Na-HCO3-SO4
648	MK2-166	MC790	633400	1668590	766	330	329	8.87	7.10	-1.04	2.09	Ca-Na-HCO3-SO4
649	MK2-167	MC791	624290	1661000	597	114	286	6.45	6.03	-4.17	1.72	Ca-Na-Mg-SO4-Cl-HCO3
650	MK2-109	MC296	625500	1664940	426	119	210	4.66	3.81	0.16	1.17	Ca-Na-SO4-HCO3
651	MK2-504	PD0074	663979	1562311	1859	0	1416	16.86	15.42	-2.40	0.23	Ca-SO4
652	MK2-255	MN322	607569	1600395	2667	391	402	35.84	35.53	2.18	15.68	Na-Cl-SO4
653	MK2-13	DB2	609900	1555190	1046	340	155	11.95	12.94	-0.86	9.09	Na-HCO3-SO4
654	MK2-21	DB3	609707	1556537	1200	372	253	13.22	14.78	-3.52	7.65	Na-HCO3-SO4
655	MK2-308	MN621	647090	1610500	367	153	154	4.50	3.80	-3.08	1.83	Na-Mg-HCO3-SO4
656	MK2-516	PD0099	606391	1560903	8734	230	3092	95.37	105.53	0.59	13.30	Na-Mg-SO4-Cl
657	MK2-192	MN102	607840	1570250	2265	282	249	26.04	30.61	1.32	17.76	Na-SO4-Cl
658	MK2-254	MN319	607900	1570190	2367	410	376	28.05	31.43	-0.52	14.22	Na-SO4-Cl-HCO3
659	MK2-306	MN58	605040	1564050	2041	416	335	24.07	27.76	-1.81	13.29	Na-SO4-Cl-HCO3
660	MK2-31	DB72	610724	1556710	1063	327	171	11.71	13.94	-0.96	9.31	Na-SO4-HCO3-Cl
Layer3 (NL)												
661	MK3-192	MD478	580540	1604940	508	299	318	6.13	3.48	-3.28	0.06	Ca-HCO3
662	MK3-222	MN159	606590	1643690	727	366	385	9.27	5.31	1.55	0.67	Ca-HCO3
663	MK3-226	MN166	604150	1644340	526	314	268	6.70	3.47	4.73	0.43	Ca-HCO3
664	MK3-410	MT89	603290	1625090	445	256	219	5.50	3.20	1.91	0.62	Ca-HCO3
665	MK3-422	NL0005	654109	1538551	409	171	193	5.01	3.20	2.91	0.72	Ca-HCO3
666	MK3-454	NL0114	602338	1538429	360	209	189	4.62	2.39	4.79	0.32	Ca-HCO3
667	MK3-521	TA62	624750	1667190	188	105	90	2.35	1.39	1.37	0.42	Ca-HCO3
668	MK3-525	TP489	587450	1595887	688	282	370	8.47	5.51	-2.66	0.93	Ca-HCO3
669	MK3-33	DB216	603409	1537748	465	239	275	6.05	3.63	-1.82	0.47	Ca-Mg-HCO3
670	MK3-69	DB81	598090	1511090	389	209	232	4.92	3.12	-4.49	0.46	Ca-Mg-HCO3
671	MK3-120	DS36	604233	1535386	245	137	128	3.05	1.90	-0.45	0.46	Ca-Mg-HCO3
672	MK3-170	MD187	585300	1621500	643	380	364	8.25	4.50	0.70	0.41	Ca-Mg-HCO3
673	MK3-189	MD365	580850	1543150	279	165	183	3.27	2.14	-3.68	0.22	Ca-Mg-HCO3
674	MK3-258	MN291	582840	1630500	131	67	68	1.63	1.07	-1.83	0.37	Ca-Mg-HCO3
675	MK3-269	MN371	612790	1629300	560	337	279	6.97	4.36	-1.09	0.83	Ca-Mg-HCO3
676	MK3-440	NL0089	626100	1515900	439	257	236	5.80	3.13	2.79	0.42	Ca-Mg-HCO3
677	MK3-526	TP490	585135	1598433	394	243	250	4.83	3.36	-2.14	0.49	Ca-Mg-HCO3-CO3
678	MK3-184	MD319	580350	1605500	521	283	329	6.95	3.55	1.23	0.11	Mg-Ca-HCO3
679	MK3-262	MN35	619340	1534090	244	135	143	3.33	1.91	0.00	0.40	Mg-Ca-HCO3
680	MK3-421	NB0135	656982	1509451	10583	142	3137	179.93	154.08	-0.15	21.76	Na-Cl
681	MK3-423	NL0018	649800	1504800	21100	166	5808	357.45	299.69	2.09	31.41	Na-Cl
682	MK3-452	NL0110	621463	1497147	732	21	109	11.89	11.19	0.17	9.60	Na-Cl
683	MK3-459	NL0128	614819	1505176	1077	164	134	16.45	15.42	0.41	12.02	Na-Cl
684	MK3-460	NL0129	625247	1526141	765	89	109	12.32	11.72	-1.58	10.02	Na-Cl
685	MK3-156	GWA0112	637942	1580159	538	202	14	7.43	8.86	-0.39	23.05	Na-Cl-CO3
686	MK3-173	MD213	577850	1594450	887	533	426	11.55	6.82	2.51	1.20	Ca-Mg-Na-HCO3
687	MK3-213	MN138	633290	1519190	471	276	225	6.08	4.03	2.98	1.13	Ca-Mg-Na-HCO3
688	MK3-228	MN172	585150	1630500	202	112	96	2.58	1.64	0.77	0.62	Ca-Mg-Na-HCO3
689	MK3-264	MN363	618290	1629400	580	352	286	7.22	4.56	-1.14	0.90	Ca-Mg-Na-HCO3
690	MK3-286	MN441	610100	1629750	335	198	168	4.16	2.71	-2.42	0.70	Ca-Mg-Na-HCO3
691	MK3-287	MN444	613300	1624050	457	270	232	5.61	3.89	-4.86	0.91	Ca-Mg-Na-HCO3
692	MK3-289	MN446	613300	1623050	353	212	170	4.35	2.93	-2.81	0.83	Ca-Mg-Na-HCO3
693	MK3-301	MN50	626400	1510190	495	298	210	6.32	4.00	2.39	1.23	Ca-Mg-Na-HCO3
694	MK3-53	DB28	611200	1528090	439	230	222	5.58	3.68	-1.83	0.91	Ca-Na-HCO3
695	MK3-85	DF20	613430	1628800	667	371	305	8.21	6.07	-4.71	1.70	Ca-Na-HCO3
696	MK3-167	MD177	586100	1605300	353	163	134	3.97	2.99	-0.14	1.43	Ca-Na-HCO3
697	MK3-187	MD323	577300	1628500	881	522	320	11.19	7.39	3.22	2.29	Ca-Na-HCO3
698	MK3-196	MD515	604150	1533590	459	242	217	5.74	3.94	-2.10	1.03	Ca-Na-HCO3
699	MK3-197	MD516	610840	1528440	480	248	243	6.14	3.90	-0.14	0.84	Ca-Na-HCO3
700	MK3-223	MN160	602700	1645190	669	399	302	8.29	5.09	1.48	1.15	Ca-Na-HCO3
701	MK3-237	MN208	612500	1627500	377	226	163	4.86	2.84	4.40	0.85	Ca-Na-HCO3
702	MK3-254	MN271	624790	1634900	244	135	87	3.02	2.33	-2.82	1.49	Ca-Na-HCO3
703	MK3-265	MN364	619090	1627500	548	326	243	6.66	4.35	-0.69	1.09	Ca-Na-HCO3
704	MK3-276	MN415	610700	1637550	548	322	254	6.66	4.71	-4.02	1.26	Ca-Na-HCO3
705	MK3-277	MN416	606400	1638800	598	347	287	7.30	5.12	-4.28	1.23	Ca-Na-HCO3

order unit	Sample ID	Well ID	East (m)	North (m)	calc TDS	Calc Alk.	Total Hardness	Sum of Anions	Sum of Cations	E.N. %	SAR	Water Type
706	MK3-278	MN42	622040	1647590	188	107	74	2.38	1.59	1.55	0.91	Ca-Na-HCO3
707	MK3-294	MN451	608250	1628450	605	361	267	7.46	4.86	-0.35	1.22	Ca-Na-HCO3
708	MK3-295	MN452	610650	1628450	517	303	246	6.31	4.29	-3.21	1.08	Ca-Na-HCO3
709	MK3-296	MN459	612350	1628750	516	303	237	6.33	4.05	-0.31	0.99	Ca-Na-HCO3
710	MK3-297	MN461	618300	1629450	554	328	238	6.88	4.49	0.29	1.24	Ca-Na-HCO3
711	MK3-323	MN774	634350	1610200	348	201	136	4.42	3.00	0.98	1.38	Ca-Na-HCO3
712	MK3-392	MT120	606800	1636250	656	386	320	8.22	5.19	-0.87	1.00	Ca-Na-HCO3
713	MK3-393	MT121	606850	1636600	694	406	328	8.67	5.53	-0.58	1.15	Ca-Na-HCO3
714	MK3-404	MT39	697290	1616300	542	322	229	6.74	4.33	1.23	1.27	Ca-Na-HCO3
715	MK3-408	MT67	602200	1623800	367	213	170	4.53	3.09	-2.55	1.00	Ca-Na-HCO3
716	MK3-467	S10	616340	1679690	135	75	54	1.67	1.17	-1.02	0.83	Ca-Na-HCO3
717	MK3-471	S9	624450	1676690	139	74	57	1.65	1.09	0.55	0.63	Ca-Na-HCO3
718	MK3-483	1A152	630500	1680200	250	124	86	3.09	2.51	-3.15	1.74	Ca-Na-HCO3
719	MK3-508	TA299	624074	1676065	320	176	129	3.94	2.84	-1.28	1.30	Ca-Na-HCO3
720	MK3-518	TA59	627090	1662500	219	121	90	2.75	1.85	0.82	0.96	Ca-Na-HCO3
721	MK3-520	TA61	632500	1657550	428	194	188	5.12	3.87	-1.02	1.40	Ca-Na-HCO3
722	MK3-257	MN290	613590	1642690	175	59	82	2.09	1.36	-0.38	0.58	Ca-Na-HCO3-NO3
723	MK3-13	DB138	604415	1546861	594	317	255	7.51	5.57	-3.04	1.83	Ca-Na-Mg-HCO3
724	MK3-97	DF36	609790	1635250	564	339	273	7.02	4.50	-1.33	0.95	Ca-Na-Mg-HCO3
725	MK3-188	MD324	577750	1627300	724	423	279	9.06	5.82	3.09	1.62	Ca-Na-Mg-HCO3
726	MK3-220	MN154	633290	1519340	526	293	206	6.69	4.56	1.89	1.67	Ca-Na-Mg-HCO3
727	MK3-238	MN215	607790	1627300	199	115	89	2.48	1.92	-2.63	0.97	Ca-Na-Mg-HCO3
728	MK3-243	MN240	615250	1627150	379	229	155	4.76	3.04	2.46	1.05	Ca-Na-Mg-HCO3
729	MK3-268	MN370	622290	1569690	385	227	164	4.72	3.24	-1.33	1.09	Ca-Na-Mg-HCO3
730	MK3-288	MN445	613350	1623100	448	264	221	5.50	3.77	-3.87	0.94	Ca-Na-Mg-HCO3
731	MK3-322	MN768	641876	1614304	382	222	165	4.69	3.35	-2.26	1.25	Ca-Na-Mg-HCO3
732	MK3-391	MT114	626400	1615300	519	313	231	6.46	4.24	-0.62	1.14	Ca-Na-Mg-HCO3
733	MK3-453	NL0113	622640	1539919	511	259	228	6.75	4.48	1.31	1.38	Ca-Na-Mg-HCO3
734	MK3-171	MD211	576800	1607200	96	50	40	1.17	0.89	-4.01	0.51	Mg-Ca-Na-HCO3
735	MK3-411	MX13	634250	1522250	356	188	189	4.63	2.94	0.10	0.76	Mg-Ca-Na-HCO3
736	MK3-4	DB108	617840	1514550	487	287	194	6.15	4.00	2.73	1.38	Mg-Na-Ca-HCO3
737	MK3-328	MN83	624840	1532650	444	223	185	5.83	4.01	1.81	1.50	Mg-Na-Ca-HCO3
738	MK3-332	MN85	628950	1523340	355	203	138	4.56	3.02	3.15	1.30	Mg-Na-Ca-HCO3
739	MK3-439	NL0088	632900	1524800	510	295	218	6.48	4.48	-0.70	1.50	Mg-Na-Ca-HCO3
740	MK3-383	MS357	574818	1611203	607	339	249	7.78	5.88	-3.02	2.10	Mg-Na-HCO3
741	MK3-93	DF321	604553	1529091	504	254	158	6.30	5.03	-0.15	2.70	Na-Ca-HCO3
742	MK3-128	E1588	649280	1586190	405	226	117	4.96	3.84	0.77	2.33	Na-Ca-HCO3
743	MK3-140	G1327	668050	1592300	731	371	212	9.02	7.40	-0.46	3.58	Na-Ca-HCO3
744	MK3-153	GWA0087	636670	1571749	367	214	92	4.52	3.27	4.57	2.31	Na-Ca-HCO3
745	MK3-212	MN136	627750	1598440	250	148	60	3.07	2.67	0.89	2.58	Na-Ca-HCO3
746	MK3-224	MN161	601000	1645550	715	425	213	8.83	6.51	1.52	2.89	Na-Ca-HCO3
747	MK3-247	MN249	528400	2020500	308	176	89	3.76	2.95	-0.27	2.03	Na-Ca-HCO3
748	MK3-251	MN265	619250	1600340	369	214	85	4.46	3.84	-1.78	3.16	Na-Ca-HCO3
749	MK3-272	MN392	627274	1540494	616	301	181	7.68	6.51	-1.80	3.43	Na-Ca-HCO3
750	MK3-291	MN448	626150	1636500	229	112	85	2.52	2.60	-4.61	1.84	Na-Ca-HCO3
751	MK3-292	MN449	625200	1635950	198	108	57	2.38	2.08	-4.66	1.96	Na-Ca-HCO3
752	MK3-325	MN776	630200	1605300	332	192	115	4.32	2.82	4.46	1.50	Na-Ca-HCO3
753	MK3-349	MP311	616250	1662800	383	205	124	4.54	3.58	-0.60	2.00	Na-Ca-HCO3
754	MK3-357	MQ494	641840	1632550	530	248	175	6.03	5.35	-2.86	2.66	Na-Ca-HCO3
755	MK3-362	MQ526	661340	1581940	644	358	144	7.72	6.91	-2.83	4.49	Na-Ca-HCO3
756	MK3-368	MQ818	666300	1588700	577	300	164	7.16	5.80	0.18	3.19	Na-Ca-HCO3
757	MK3-369	MQ877	657200	1584800	729	340	227	8.92	7.56	-1.65	3.47	Na-Ca-HCO3
758	MK3-370	MQ878	657250	1585350	622	283	171	7.73	6.60	-0.41	3.66	Na-Ca-HCO3
759	MK3-451	NL0106	617510	1506980	317	149	105	3.94	3.02	1.35	1.82	Na-Ca-HCO3
760	MK3-485	TA162	611000	1687800	392	234	68	4.78	3.86	2.67	3.74	Na-Ca-HCO3
761	MK3-486	TA163	611500	1686800	199	119	57	2.46	1.70	4.36	1.44	Na-Ca-HCO3
762	MK3-495	TA211	600364	1679082	738	426	264	9.03	7.01	-3.11	2.68	Na-Ca-HCO3
763	MK3-58	DB35	609290	1545090	537	283	160	6.67	5.47	-1.40	2.99	Na-Ca-Mg-HCO3
764	MK3-166	MD153	621650	1540940	590	269	229	7.43	6.07	-2.97	2.45	Na-Ca-Mg-HCO3
765	MK3-185	MD320	571800	1618200	948	582	292	12.09	8.23	4.26	3.05	Na-Ca-Mg-HCO3
766	MK3-348	MP310	610340	1663090	255	126	97	3.02	2.39	-3.11	1.32	Na-Ca-Mg-HCO3
767	MK3-352	MQ450	639400	1611840	296	171	98	3.57	2.84	-2.38	1.80	Na-Ca-Mg-HCO3
768	MK3-441	NL0090	629200	1534700	526	286	195	6.89	4.56	3.88	1.81	Na-Ca-Mg-HCO3
769	MK3-461	NL0130	623219	1508606	597	326	196	7.37	5.87	-1.99	2.71	Na-Ca-Mg-HCO3
770	MK3-488	TA165	606500	1691500	360	213	125	4.53	3.02	3.38	1.52	Na-Ca-Mg-HCO3
771	MK3-24	DB17	616650	1547190	578	279	133	7.28	6.65	-2.15	4.52	Na-Mg-HCO3
772	MK3-84	DF194	603800	1644700	577	365	163	6.98	6.16	-1.36	3.41	Na-Mg-HCO3
773	MK3-240	MN22	605210	1599550	1239	766	360	15.62	12.03	0.07	4.45	Na-Mg-HCO3
774	MK3-249	MN257	606200	1592500	1684	1001	393	20.77	16.71	1.00	6.26	Na-Mg-HCO3
775	MK3-513	TA335	600931	1687979	710	423	184	8.97	6.75	2.64	3.52	Na-Mg-HCO3
776	MK3-103	DF506	588143	1630952	477	277	93	5.69	6.28	-4.40	5.40	Na-Mg-HCO3-CO3

order unit	Sample ID	Well ID	East (m)	North (m)	calc TDS	Calc Alk.	Total Hardness	Sum of Anions	Sum of Cations	E.N. %	SAR	Water Type
777	MK3-527	TP492	585135	1598433	836	499	229	10.53	9.82	-0.02	4.89	Na-Mg-HCO3-CO3
778	MK3-444	NL0093	609400	1524350	948	297	585	14.20	8.30	1.27	0.94	Ca-Cl-HCO3
779	MK3-227	MN167	604900	1644150	571	270	300	7.49	4.19	2.57	0.63	Ca-HCO3-Cl
780	MK3-72	DB84	621950	1535840	888	160	621	14.64	9.29	-2.40	1.17	Ca-Mg-Cl-HCO3
781	MK3-194	MD492	594047	1501412	1071	305	680	16.50	10.16	-0.81	1.23	Ca-Mg-Cl-HCO3
782	MK3-263	MN36	618500	1526750	400	129	311	6.32	3.19	0.33	0.05	Ca-Mg-Cl-HCO3
783	MK3-3	DB106	610500	1537900	495	242	292	6.64	4.02	-1.94	0.59	Ca-Mg-HCO3-Cl
784	MK3-10	DB123	612500	1535190	532	236	331	7.54	4.21	0.40	0.43	Ca-Mg-HCO3-Cl
785	MK3-32	DB215	604512	1536695	492	248	305	6.42	3.96	-4.04	0.35	Ca-Mg-HCO3-Cl
786	MK3-50	DB252	603241	1536572	469	239	243	6.22	3.66	1.99	0.64	Ca-Mg-HCO3-Cl
787	MK3-54	DB29	616700	1531250	386	202	206	5.32	2.98	2.98	0.55	Ca-Mg-HCO3-Cl
788	MK3-55	DB30	616090	1534690	504	235	323	6.93	4.02	-2.01	0.36	Ca-Mg-HCO3-Cl
789	MK3-209	MN122	628650	1602690	370	143	216	5.32	3.30	-0.87	0.68	Ca-Mg-HCO3-Cl
790	MK3-218	MN152	618950	1527250	559	251	343	8.00	4.35	1.88	0.42	Ca-Mg-HCO3-Cl
791	MK3-219	MN153	621700	1528840	525	254	309	7.30	4.01	1.83	0.45	Ca-Mg-HCO3-Cl
792	MK3-221	MN158	606290	1643550	1291	452	719	16.57	10.38	-1.42	1.04	Ca-Mg-HCO3-Cl
793	MK3-413	MX17	617090	1525590	535	219	359	7.96	4.37	0.00	0.41	Ca-Mg-HCO3-Cl
794	MK3-419	NB0123	611469	1530372	467	213	281	6.59	3.47	2.80	0.29	Ca-Mg-HCO3-Cl
795	MK3-443	NL0092	618400	1528100	592	239	378	8.78	4.61	2.39	0.36	Ca-Mg-HCO3-Cl
796	MK3-458	NL0126	611469	1530372	523	274	283	7.16	3.88	3.27	0.54	Ca-Mg-HCO3-Cl
797	MK3-358	MQ495	638900	1609090	1098	115	806	18.63	11.25	-1.63	1.03	Ca-Cl
798	MK3-174	MD26	618590	1528940	1593	135	1229	28.33	15.33	1.87	0.81	Ca-Mg-Cl
799	MK3-320	MN755	642600	1615500	1667	114	1195	29.25	16.89	1.46	1.38	Ca-Mg-Cl
800	MK3-324	MN775	633400	1613650	951	71	655	16.96	9.99	1.06	1.21	Ca-Mg-Cl
801	MK3-430	NL0068	643300	1526500	1078	54	917	20.01	12.10	-3.02	0.92	Mg-Ca-Cl
802	MK3-63	DB71	618750	1536150	2075	155	1467	35.69	23.14	-1.91	2.16	Ca-Mg-Na-Cl
803	MK3-424	NL0019	636700	1513100	1664	85	1110	29.96	19.54	-1.08	2.48	Ca-Mg-Na-Cl
804	MK3-356	MQ483	670040	1620550	3851	280	2164	64.19	43.37	1.03	4.62	Ca-Na-Cl
805	MK3-456	NL0117	640287	1501648	2090	142	1196	34.35	21.18	2.46	2.64	Ca-Na-Cl
806	MK3-245	MN244	639200	1521800	1821	167	1086	30.76	21.78	-2.51	3.25	Ca-Na-Mg-Cl
807	MK3-319	MN754	637155	1606744	1934	91	1320	33.31	21.43	-1.42	2.16	Ca-Na-Mg-Cl
808	MK3-394	MT13	629450	1535550	1668	174	1035	28.35	19.08	-1.34	2.65	Ca-Na-Mg-Cl
809	MK3-434	NL0073	640500	1534700	2300	256	1323	37.00	27.81	-4.15	3.95	Ca-Na-Mg-Cl
810	MK3-450	NL0105	639148	1544581	6194	112	4232	112.90	67.64	1.49	3.81	Ca-Na-Mg-Cl
811	MK3-465	NL0143	644759	1526087	2198	198	1454	38.45	26.23	-2.25	2.97	Mg-Na-Ca-Cl
812	MK3-139	G1304	654350	1590100	788	107	262	12.88	10.18	1.58	4.57	Na-Ca-Cl
813	MK3-206	MN116	663900	1565300	9722	323	2602	155.81	138.20	0.06	21.86	Na-Ca-Cl
814	MK3-138	G1303	651700	1583800	1245	145	592	20.28	16.14	-3.05	4.11	Na-Ca-Mg-Cl
815	MK3-341	MN90	639150	1526340	796	68	402	13.56	10.02	-1.51	2.93	Na-Ca-Mg-Cl
816	MK3-378	MQ926	664850	1589500	5339	96	2853	93.99	65.90	0.64	6.93	Na-Ca-Mg-Cl
817	MK3-432	NL0070	652166	1511415	8058	157	3854	139.38	104.33	0.03	10.52	Na-Ca-Mg-Cl
818	MK3-457	NL0125	644684	1530410	4348	78	1706	76.07	59.20	0.61	10.11	Na-Ca-Mg-Cl
819	MK3-464	NL0136	656982	1509451	12372	140	6008	208.09	165.31	-2.20	13.47	Na-Ca-Mg-Cl
820	MK3-466	PD0123	644684	1530410	11239	84	5056	197.15	155.94	-2.17	14.69	Na-Ca-Mg-Cl
821	MK3-374	MQ884	667600	1590400	801	92	290	13.17	10.32	1.04	4.35	Na-Mg-Ca-Cl
822	MK3-427	NL0033	638300	1497800	11028	231	4592	198.18	147.20	1.67	14.77	Na-Mg-Ca-Cl
823	MK3-127	E1587	652826	1581506	1081	149	370	17.92	15.22	-1.86	5.88	Na-Mg-Cl
824	MK3-412	MX14	623650	1513650	19881	960	4876	332.93	294.91	-0.24	35.27	Na-Mg-Cl
825	MK3-98	DF377	625261	1569803	576	337	22	7.12	6.75	3.73	13.81	Na-HCO3
826	MK3-100	DF495	622212	1569164	401	193	28	4.51	5.13	0.16	9.05	Na-HCO3
827	MK3-101	DF496	653865	1585322	435	242	62	5.19	4.90	0.73	5.35	Na-HCO3
828	MK3-107	DN22	628032	1547616	444	255	56	5.48	5.40	0.86	6.38	Na-HCO3
829	MK3-115	DS103	623057	1555062	517	292	33	6.21	6.02	4.47	9.82	Na-HCO3
830	MK3-172	MD212	581850	1603850	534	292	72	6.36	6.15	-3.29	6.30	Na-HCO3
831	MK3-191	MD468	576650	1613700	1190	641	59	14.17	14.42	-2.45	17.67	Na-HCO3
832	MK3-195	MD494	583200	1615500	892	481	103	10.94	10.09	0.50	8.88	Na-HCO3
833	MK3-210	MN125	612450	1609300	592	338	46	7.08	6.76	-0.40	9.17	Na-HCO3
834	MK3-229	MN181	612590	1610050	898	416	36	9.57	9.22	1.16	14.62	Na-HCO3
835	MK3-241	MN231	616540	1595750	444	254	68	5.31	4.88	-1.47	5.00	Na-HCO3
836	MK3-309	MN55	612750	1639000	432	226	62	5.39	5.40	-2.91	5.81	Na-HCO3
837	MK3-399	MT155	621450	1596650	366	225	74	4.48	3.81	2.53	3.49	Na-HCO3
838	MK3-402	MT228	622300	1569400	494	291	25	5.94	6.01	1.23	11.31	Na-HCO3
839	MK3-403	MT287	624550	1572650	388	230	38	4.75	4.20	2.76	6.11	Na-HCO3
840	MK3-420	NB0131	655639	1583870	664	373	87	7.87	7.51	-2.23	6.98	Na-HCO3
841	MK3-435	NL0075	645100	1559400	378	179	50	4.50	4.96	-3.15	6.16	Na-HCO3
842	MK3-445	NL0094	627100	1550500	462	258	46	5.54	5.34	-1.47	7.03	Na-HCO3
843	MK3-449	NL0104	620865	1560536	495	285	37	5.99	6.06	0.97	9.28	Na-HCO3
844	MK3-500	TA279	597919	1677448	1192	616	208	15.12	13.44	-0.46	7.85	Na-HCO3
845	MK3-505	TA293	595840	1688698	1128	571	64	13.72	13.06	0.67	15.29	Na-HCO3
846	MK3-46	DB243	610701	1557853	1516	387	222	21.34	20.57	-0.44	12.28	Na-Cl-HCO3
847	MK3-57	DB34	607900	1561500	2467	499	187	33.30	35.45	-0.78	24.47	Na-Cl-HCO3

order unit	Sample ID	Well ID	East (m)	North (m)	calc TDS	Calc Alk.	Total Hardness	Sum of Anions	Sum of Cations	E.N. %	SAR	Water Type
848	MK3-109	DR48	652300	1589100	751	213	198	11.22	9.89	-2.29	5.57	Na-Cl-HCO3
849	MK3-116	DS107	626832	1561786	502	169	114	7.02	6.42	-1.91	4.88	Na-Cl-HCO3
850	MK3-121	DS43	616983	1555688	1039	301	229	13.74	13.25	-2.15	7.19	Na-Cl-HCO3
851	MK3-123	DS56	609741	1552769	792	273	81	10.83	10.86	0.01	11.11	Na-Cl-HCO3
852	MK3-124	DS57	609459	1552770	814	262	107	11.11	11.57	-2.92	10.08	Na-Cl-HCO3
853	MK3-143	GWA0020	666228	1588605	681	252	114	9.33	9.47	-4.03	7.74	Na-Cl-HCO3
854	MK3-233	MN193	611700	1558190	1733	356	262	24.78	23.16	4.04	12.64	Na-Cl-HCO3
855	MK3-261	MN324	605290	1572590	2525	434	445	35.87	35.75	-1.98	14.80	Na-Cl-HCO3
856	MK3-281	MN434	622167	1551809	656	172	115	9.54	9.04	-2.58	7.30	Na-Cl-HCO3
857	MK3-442	NL0091	615200	1543100	634	219	52	9.39	8.81	3.29	11.44	Na-Cl-HCO3
858	MK3-17	DB15	610750	1543590	665	287	86	8.90	8.33	-0.45	7.97	Na-HCO3-Cl
859	MK3-51	DB26	619500	1549440	843	299	88	11.82	10.95	1.01	10.68	Na-HCO3-Cl
860	MK3-92	DF302	612986	1568627	944	428	80	12.67	13.01	-0.00	13.60	Na-HCO3-Cl
861	MK3-144	GWA0021	666228	1588605	599	235	51	8.10	8.40	-1.75	11.02	Na-HCO3-Cl
862	MK3-200	MD523	620650	1545300	735	281	138	9.51	8.85	-0.91	6.29	Na-HCO3-Cl
863	MK3-216	MN147	617400	1561340	724	316	67	9.59	8.78	2.33	9.86	Na-HCO3-Cl
864	MK3-373	MQ883	668400	1588200	628	276	136	8.31	7.10	2.19	4.86	Na-HCO3-Cl
865	MK3-375	MQ885	669950	1588400	531	249	93	6.58	6.66	-1.93	5.85	Na-HCO3-Cl
866	MK3-379	MQ927	667350	1584600	602	261	91	7.85	7.48	0.31	6.84	Na-HCO3-Cl
867	MK3-409	MT70	620590	1566690	586	284	53	7.40	7.55	0.24	9.59	Na-HCO3-Cl
868	MK3-414	MX20	627090	1549650	620	217	119	8.76	7.80	-0.72	5.98	Na-HCO3-Cl
869	MK3-425	NL0024	639500	1503539	746	327	137	9.62	8.83	-1.46	6.32	Na-HCO3-Cl
870	MK3-428	NL0053	657655	1516264	995	363	74	13.88	13.05	0.67	14.15	Na-HCO3-Cl
871	MK3-448	NL0101	641430	1544695	492	210	100	6.62	5.85	-1.36	4.78	Na-HCO3-Cl
872	MK3-506	TA295	605123	1690692	1027	468	69	13.03	12.26	0.97	13.58	Na-HCO3-Cl
873	MK3-66	DB78	644290	1525440	1179	266	721	17.62	13.02	-4.86	2.11	Ca-Mg-Na-Cl-HCO3
874	MK3-165	MD152	621250	1540050	508	182	281	7.38	5.14	-3.35	1.32	Ca-Mg-Na-Cl-HCO3
875	MK3-321	MN767	649568	1618689	783	256	489	11.68	7.77	-3.73	1.26	Ca-Mg-Na-Cl-HCO3
876	MK3-426	NL0032	637412	1510997	1098	258	642	17.53	11.37	-0.17	1.89	Ca-Mg-Na-Cl-HCO3
877	MK3-28	DB207	608066	1539405	294	109	176	4.13	2.79	-3.70	0.69	Ca-Mg-Na-HCO3-Cl
878	MK3-246	MN245	605500	1540150	445	227	227	5.88	3.92	-2.10	1.01	Ca-Mg-Na-HCO3-Cl
879	MK3-381	MS270	593000	1502000	806	349	440	11.15	7.20	-1.04	1.29	Ca-Mg-Na-HCO3-Cl
880	MK3-433	NL0071	653800	1552300	1103	221	502	17.58	12.56	0.33	3.30	Ca-Na-Cl-HCO3
881	MK3-230	MN182	628950	1600550	321	163	142	4.25	2.61	3.06	0.91	Ca-Na-HCO3-Cl
882	MK3-299	MN494	645400	1597090	410	166	170	5.79	4.00	1.61	1.70	Ca-Na-HCO3-Cl
883	MK3-312	MN590	644700	1635690	574	228	299	8.15	4.99	2.27	1.11	Ca-Na-HCO3-Cl
884	MK3-90	DF275	638350	1611350	466	154	216	6.76	4.98	-1.70	1.84	Ca-Na-Mg-Cl-HCO3
885	MK3-157	GWA0115	642660	1598422	718	172	402	11.46	7.07	1.86	1.45	Ca-Na-Mg-Cl-HCO3
886	MK3-298	MN489	635590	1599400	854	173	477	13.96	8.93	1.04	1.81	Ca-Na-Mg-Cl-HCO3
887	MK3-447	NL0100	617284	1518666	1017	188	522	16.95	10.61	3.96	2.28	Ca-Na-Mg-Cl-HCO3
888	MK3-11	DB124	608700	1538690	711	268	381	10.09	6.92	-2.23	1.54	Ca-Na-Mg-HCO3-Cl
889	MK3-16	DB149	615033	1539247	444	220	230	5.86	4.10	-4.16	1.12	Ca-Na-Mg-HCO3-Cl
890	MK3-18	DB151	608339	1541219	496	244	241	6.58	4.52	-2.23	1.29	Ca-Na-Mg-HCO3-Cl
891	MK3-38	DB23	632400	1517500	616	276	267	8.13	5.63	0.04	1.76	Ca-Na-Mg-HCO3-Cl
892	MK3-142	GWA0017	654235	1590047	506	185	265	6.62	4.85	-3.34	1.23	Ca-Na-Mg-HCO3-Cl
893	MK3-168	MD180	622250	1539550	677	236	323	9.27	6.72	-0.18	1.89	Ca-Na-Mg-HCO3-Cl
894	MK3-382	MS277	591550	1504550	659	196	382	9.81	7.11	-4.38	1.65	Mg-Ca-Na-Cl-HCO3
895	MK3-111	DR54	651050	1584750	549	187	206	8.18	6.01	2.54	2.70	Na-Ca-Cl-HCO3
896	MK3-129	E1589	652814	1587879	721	222	260	10.76	8.02	1.13	3.24	Na-Ca-Cl-HCO3
897	MK3-300	MN495	644290	1597090	371	126	145	5.40	4.33	-0.03	2.31	Na-Ca-Cl-HCO3
898	MK3-327	MN828	640150	1621300	780	219	200	11.02	9.05	2.88	4.92	Na-Ca-Cl-HCO3
899	MK3-353	MQ458	648340	1582400	606	197	214	8.56	7.00	-2.61	3.27	Na-Ca-Cl-HCO3
900	MK3-359	MQ500	667340	1621440	926	203	265	14.39	11.73	0.17	5.53	Na-Ca-Cl-HCO3
901	MK3-364	MQ594	656500	1595500	742	285	254	10.36	8.76	-1.20	3.82	Na-Ca-Cl-HCO3
902	MK3-407	MT64	696400	1632590	1467	420	551	22.08	16.47	0.40	4.26	Na-Ca-Cl-HCO3
903	MK3-429	NL0057	657600	1521400	610	209	152	8.81	7.29	0.51	4.59	Na-Ca-Cl-HCO3
904	MK3-47	DB245	603872	1547284	710	356	245	9.35	6.64	2.62	2.61	Na-Ca-HCO3-Cl
905	MK3-94	DF322	605835	1529364	518	250	201	6.57	5.16	-3.40	2.12	Na-Ca-HCO3-Cl
906	MK3-214	MN14	610590	1591250	320	154	113	4.25	2.98	2.98	1.68	Na-Ca-HCO3-Cl
907	MK3-225	MN165	663900	1565300	896	334	225	11.73	10.24	-0.12	5.28	Na-Ca-HCO3-Cl
908	MK3-366	MQ612	668840	1618750	743	247	213	10.10	9.15	-3.81	4.77	Na-Ca-HCO3-Cl
909	MK3-489	TA166	603500	1683500	1162	539	440	15.94	11.08	1.58	3.11	Na-Ca-HCO3-Cl
910	MK3-201	MD524	615641	1552773	1264	225	480	19.42	15.82	-0.97	4.96	Na-Ca-Mg-Cl-HCO3
911	MK3-202	MD525	616500	1529500	424	80	183	6.68	4.90	-0.12	1.70	Na-Ca-Mg-Cl-HCO3
912	MK3-344	MN922	652550	1623900	534	162	249	7.88	5.96	-2.97	2.15	Na-Ca-Mg-Cl-HCO3
913	MK3-7	DB119	612272	1539811	554	253	190	7.46	5.71	-0.08	2.68	Na-Ca-Mg-HCO3-Cl
914	MK3-49	DB25	618750	1539400	442	194	208	5.94	4.59	-4.93	1.66	Na-Ca-Mg-HCO3-Cl
915	MK3-52	DB262	606320	1548001	584	278	170	7.87	6.09	1.27	3.34	Na-Ca-Mg-HCO3-Cl
916	MK3-56	DB31	602540	1550190	835	329	328	11.60	9.05	-2.17	3.12	Na-Ca-Mg-HCO3-Cl
917	MK3-397	MT14	626200	1533000	552	250	231	7.33	5.42	-1.18	1.97	Na-Ca-Mg-HCO3-Cl
918	MK3-431	NL0069	638613	1519846	538	273	179	7.24	5.09	3.29	2.41	Na-Ca-Mg-HCO3-Cl

order unit	Sample ID	Well ID	East (m)	North (m)	calc TDS	Calc Alk.	Total Hardness	Sum of Anions	Sum of Cations	E.N. %	SAR	Water Type
919	MK3-504	TA291	601185	1689768	838	339	327	10.94	8.83	-4.50	2.89	Na-Ca-Mg-HCO3-Cl
920	MK3-9	DB120	612790	1538400	447	182	175	6.20	4.92	-2.28	2.34	Na-Mg-Ca-HCO3-Cl
921	MK3-80	DF123	583900	1629450	266	137	101	3.49	2.53	3.07	1.39	Na-Mg-Ca-HCO3-Cl
922	MK3-117	DS11	611282	1547610	668	321	185	8.60	7.20	-1.11	3.84	Na-Mg-Ca-HCO3-Cl
923	MK3-510	TA319	608090	1651106	1581	317	430	20.16	18.03	-1.85	6.30	Na-Mg-Cl-HCO3
924	MK3-118	DS19	604277	1546887	409	216	149	5.36	4.37	0.21	2.28	Na-Mg-HCO3-Cl
925	MK3-169	MD186	582700	1616400	1237	545	326	16.57	13.25	0.70	5.50	Na-Mg-HCO3-Cl
926	MK3-250	MN261	609340	1616090	870	328	316	11.63	9.24	-0.19	2.94	Na-Mg-HCO3-Cl
927	MK3-345	MN95	596750	1571050	839	347	273	11.96	8.51	4.47	3.35	Na-Mg-HCO3-Cl
928	MK3-137	G1295	651639	1585156	367	197	81	4.77	4.19	4.10	3.67	Na-Mg-HCO3-Cl-CO3
929	MK3-190	MD462	585850	1605250	589	212	382	7.05	4.84	-3.37	0.51	Ca-Mg-HCO3-SO4
930	MK3-462	NL0131	600010	1530587	812	258	325	9.01	7.65	1.81	2.34	Ca-Na-HCO3-SO4
931	MK3-522	TA68	636290	1653150	388	148	183	4.36	3.77	-1.58	1.42	Ca-Na-HCO3-SO4
932	MK3-519	TA60	630150	1654190	465	198	208	5.57	4.14	0.33	1.39	Ca-Na-Mg-HCO3-SO4
933	MK3-204	MN1026	643379	1623610	503	166	143	5.81	5.21	2.94	3.09	Na-Ca-HCO3-SO4
934	MK3-267	MN37	622290	1522690	437	183	71	4.75	4.92	2.31	4.85	Na-Ca-HCO3-SO4
935	MK3-330	MN840	640060	1626529	575	210	133	6.83	6.15	3.14	4.14	Na-Ca-HCO3-SO4
936	MK3-270	MN382	613619	1536698	783	217	305	10.15	8.92	-2.72	3.26	Na-Ca-Mg-Cl-HCO3-SO4
937	MK3-335	MN876	652190	1629690	550	171	196	6.78	6.15	-2.29	2.92	Na-Ca-Mg-HCO3-Cl-SO4
938	MK3-468	S15	652090	1626900	561	155	175	6.97	6.40	-0.05	3.52	Na-Ca-Mg-HCO3-Cl-SO4
939	MK3-15	DB14	613540	1554500	1124	315	171	12.91	13.09	4.02	8.66	Na-HCO3-SO4-Cl
940	MK3-203	MN1022	652293	1629046	588	107	175	7.22	7.02	0.69	3.94	Na-Mg-Cl-SO4-HCO3
941	MK3-151	GWA0069	613357	1586910	1698	226	22	14.05	25.56	-1.65	53.52	Na-SO4
942	MK3-154	GWA0091	648067	1572625	1018	195	162	11.65	13.97	-4.57	9.51	Na-SO4-Cl-HCO3
943	MK3-83	DF14	595300	1626650	257	148	143	3.17	2.03	-4.12	0.44	Ca-HCO3
944	MK3-255	MN274	575500	1638150	503	303	266	6.45	3.36	3.88	0.37	Ca-HCO3
945	MK3-256	MN276	606340	1636150	505	306	250	6.40	3.63	2.52	0.63	Ca-HCO3
946	MK3-273	MN397	589100	1635100	471	268	221	5.68	3.71	-1.87	0.47	Ca-HCO3
947	MK3-318	MN753	636101	1609764	379	211	184	4.43	3.09	-4.79	0.58	Ca-HCO3
948	MK3-405	MT51	595700	1634900	458	263	247	5.69	3.56	-2.55	0.64	Ca-HCO3
949	MK3-14	DB139	625871	1523803	481	268	263	6.21	3.78	-0.81	0.67	Ca-Mg-HCO3
950	MK3-39	DB230	606913	1539478	395	208	227	5.19	2.91	1.32	0.40	Ca-Mg-HCO3
951	MK3-45	DB240	602988	1537419	469	228	254	6.05	3.72	0.77	0.63	Ca-Mg-HCO3
952	MK3-61	DB67	602790	1542000	346	202	201	4.32	2.58	-2.43	0.37	Ca-Mg-HCO3
953	MK3-76	DB89	622700	1524800	326	211	172	4.17	2.62	2.99	0.60	Ca-Mg-HCO3
954	MK3-87	DF21	614850	1626300	462	275	246	5.71	3.73	-3.80	0.69	Ca-Mg-HCO3
955	MK3-182	MD295	569850	1636150	377	208	197	4.74	2.88	-0.40	0.43	Ca-Mg-HCO3
956	MK3-193	MD478	580540	1604940	558	307	351	6.95	4.03	-1.98	0.21	Ca-Mg-HCO3
957	MK3-262	MN35	619340	1534090	426	247	221	5.49	3.24	0.72	0.62	Ca-Mg-HCO3
958	MK3-279	MN429	604809	1540481	227	137	136	2.85	1.89	-0.29	0.45	Ca-Mg-HCO3
959	MK3-440	NL0089	626100	1515900	406	230	218	5.30	3.12	0.37	0.56	Ca-Mg-HCO3
960	MK3-454	NL0114	602338	1538429	420	223	227	5.51	3.25	0.46	0.58	Ca-Mg-HCO3
961	MK3-498	TA266	622776	1681104	153	80	76	1.95	1.12	3.95	0.34	Ca-Mg-HCO3
962	MK3-509	TA304	605448	1690707	194	96	102	2.53	1.64	-0.57	0.52	Ca-Mg-HCO3
963	MK3-529	TP494	557899	1603368	473	235	289	5.99	3.32	-0.88	0.24	Ca-Mg-HCO3
964	MK3-31	DB214	606386	1537591	214	121	126	2.79	1.60	2.16	0.27	Mg-Ca-HCO3
965	MK3-517	TA358	601695	1652674	475	260	272	6.46	3.54	2.28	0.47	Mg-Ca-HCO3
966	MK3-530	TP495	583921	1608649	556	260	345	7.40	4.26	0.07	0.42	Mg-Ca-HCO3
967	MK3-179	MD292	579600	1595200	575	323	329	7.70	4.91	1.53	0.67	Mg-HCO3
968	MK3-34	DB225	604849	1541102	458	267	216	6.06	3.55	3.17	0.95	Ca-Mg-Na-HCO3
969	MK3-79	DB92	631700	1526300	450	256	215	5.56	3.97	-3.97	1.16	Ca-Mg-Na-HCO3
970	MK3-173	MD213	577850	1594450	530	274	287	6.87	4.61	-2.85	1.00	Ca-Mg-Na-HCO3
971	MK3-217	MN15	602250	1645690	462	282	210	5.83	3.71	0.16	1.11	Ca-Mg-Na-HCO3
972	MK3-243	MN240	615250	1627150	458	274	215	5.71	3.74	-1.05	0.95	Ca-Mg-Na-HCO3
973	MK3-339	MN883	652042	1626324	200	84	101	2.37	1.76	-3.44	0.69	Ca-Mg-Na-HCO3
974	MK3-88	DF22	613350	1628750	408	261	213	4.93	3.50	-1.81	0.83	Ca-Na-HCO3
975	MK3-145	GWA0041	619326	1660284	352	184	105	4.20	3.03	4.25	1.74	Ca-Na-HCO3
976	MK3-149	GWA0055	612503	1631495	636	376	286	7.83	5.10	-0.24	1.24	Ca-Na-HCO3
977	MK3-238	MN215	607790	1627300	336	203	146	4.28	2.49	4.70	0.76	Ca-Na-HCO3
978	MK3-252	MN268	607000	1626650	356	216	161	4.49	2.63	3.37	0.72	Ca-Na-HCO3
979	MK3-274	MN398	585300	1630600	178	98	88	2.25	1.46	-1.65	0.56	Ca-Na-HCO3
980	MK3-275	MN406	596900	1625300	328	189	130	4.05	2.88	-1.12	1.34	Ca-Na-HCO3
981	MK3-302	MN507	633790	1617300	360	194	129	4.47	3.38	-1.18	1.76	Ca-Na-HCO3
982	MK3-385	MT101	607400	1623800	597	354	269	7.32	4.67	-0.14	1.06	Ca-Na-HCO3
983	MK3-386	MT102	602790	1620090	586	352	256	7.25	4.75	-0.37	1.20	Ca-Na-HCO3
984	MK3-387	MT103	613700	1627400	469	280	212	5.83	3.72	0.12	0.99	Ca-Na-HCO3
985	MK3-388	MT104	613090	1628400	468	280	225	5.78	3.81	-2.23	0.96	Ca-Na-HCO3
986	MK3-406	MT62	596400	1625300	539	319	210	6.65	4.52	0.50	1.59	Ca-Na-HCO3
987	MK3-467	S10	616340	1679690	140	66	54	1.56	1.17	-3.11	0.83	Ca-Na-HCO3
988	MK3-476	TA120	614367	1684854	165	81	69	1.80	1.25	-3.54	0.48	Ca-Na-HCO3
989	MK3-479	TA133	611432	1684642	279	155	118	3.44	2.28	0.35	1.00	Ca-Na-HCO3

order unit	Sample ID	Well ID	East (m)	North (m)	calc TDS	Calc Alk.	Total Hardness	Sum of Anions	Sum of Cations	E.N. %	SAR	Water Type
990	MK3-85	DF20	613430	1628800	264	170	149	3.17	2.37	-3.11	0.64	Ca-Na-HCO3-CO3
991	MK3-20	DB165	605731	1542912	516	269	250	6.81	4.55	-1.47	1.21	Ca-Na-Mg-HCO3
992	MK3-60	DB6	603900	1548190	584	308	282	7.57	5.16	-1.96	1.32	Ca-Na-Mg-HCO3
993	MK3-82	DF13	593950	1628900	536	311	257	6.61	4.74	-4.79	1.30	Ca-Na-Mg-HCO3
994	MK3-102	DF5	594600	1639700	431	228	197	5.42	3.99	-4.39	1.36	Ca-Na-Mg-HCO3
995	MK3-147	GWA0045	621764	1644237	248	142	108	3.02	2.02	-0.14	0.75	Ca-Na-Mg-HCO3
996	MK3-211	MN13	600250	1621500	611	369	291	7.74	4.77	0.49	1.10	Ca-Na-Mg-HCO3
997	MK3-316	MN645	641200	1615690	391	232	155	4.89	3.40	-0.26	1.43	Ca-Na-Mg-HCO3
998	MK3-328	MN83	624840	1532650	513	258	206	6.51	4.33	2.29	1.52	Ca-Na-Mg-HCO3
999	MK3-384	MT100	613400	1620500	548	328	246	6.82	4.46	-0.48	1.11	Ca-Na-Mg-HCO3
1000	MK3-390	MT111	624800	1633300	502	299	208	6.30	4.25	0.19	1.42	Ca-Na-Mg-HCO3
1001	MK3-401	MT169	600050	1621550	517	310	235	6.47	4.29	-1.13	1.22	Ca-Na-Mg-HCO3
1002	MK3-453	NL0113	622640	1539919	496	255	222	6.45	4.38	0.39	1.37	Ca-Na-Mg-HCO3
1003	MK3-471	S9	624450	1676690	207	114	93	2.51	1.65	-1.17	0.72	Ca-Na-Mg-HCO3
1004	MK3-528	TP493	588654	1601812	243	152	137	2.99	2.19	-1.90	0.67	Ca-Na-Mg-HCO3-CO3
1005	MK3-36	DB228	602634	1540244	206	123	106	2.55	1.75	1.20	0.59	Mg-Ca-Na-HCO3
1006	MK3-176	MD272	611100	1505500	308	195	126	3.90	2.83	2.38	1.24	Mg-Na-HCO3
1007	MK3-5	DB11	611840	1543090	537	275	159	6.65	5.34	0.21	2.90	Na-Ca-HCO3
1008	MK3-164	MC54	605090	1689300	767	449	236	9.61	7.09	0.85	2.86	Na-Ca-HCO3
1009	MK3-177	MD289	574650	1610900	1050	622	325	13.11	9.13	3.16	3.21	Na-Ca-HCO3
1010	MK3-180	MD293	585400	1621900	795	439	180	9.53	7.43	2.11	4.02	Na-Ca-HCO3
1011	MK3-181	MD294	583800	1623900	835	477	228	10.42	7.65	2.96	3.46	Na-Ca-HCO3
1012	MK3-249	MN257	606200	1592500	1911	1164	491	23.58	17.90	1.96	5.65	Na-Ca-HCO3
1013	MK3-254	MN271	624790	1634900	249	139	84	2.93	2.36	-1.31	1.62	Na-Ca-HCO3
1014	MK3-271	MN385	606790	1551400	498	254	188	6.48	4.88	-1.72	2.12	Na-Ca-HCO3
1015	MK3-304	MN529	636950	1609690	270	154	72	3.22	2.76	0.41	2.26	Na-Ca-HCO3
1016	MK3-306	MN534	643900	1626090	474	214	132	5.82	5.29	-1.33	3.41	Na-Ca-HCO3
1017	MK3-380	MQ930	665900	1591050	728	350	159	9.05	7.73	0.75	4.83	Na-Ca-HCO3
1018	MK3-469	S21	633650	1635050	353	190	112	4.33	3.32	-0.16	2.05	Na-Ca-HCO3
1019	MK3-478	TA132	611728	1685800	371	209	94	4.47	3.88	-3.48	3.01	Na-Ca-HCO3
1020	MK3-480	TA134	610692	1684924	318	181	112	3.88	3.06	-3.42	1.81	Na-Ca-HCO3
1021	MK3-481	TA139	611000	1681500	279	156	86	3.40	2.88	-4.33	2.15	Na-Ca-HCO3
1022	MK3-487	TA164	608357	1690092	706	396	181	8.65	6.77	0.84	3.56	Na-Ca-HCO3
1023	MK3-19	DB16	614250	1541650	500	262	176	6.28	4.84	-0.61	2.27	Na-Ca-Mg-HCO3
1024	MK3-35	DB226	604742	1546469	588	312	221	7.69	5.21	2.98	2.02	Na-Ca-Mg-HCO3
1025	MK3-166	MD153	621650	1540940	573	287	215	7.21	5.41	0.37	2.22	Na-Ca-Mg-HCO3
1026	MK3-185	MD320	571800	1618200	876	528	315	10.66	8.50	-3.16	2.94	Na-Ca-Mg-HCO3
1027	MK3-220	MN154	633290	1519340	446	264	185	5.54	4.42	0.33	1.82	Na-Ca-Mg-HCO3
1028	MK3-314	MN63	634200	1515500	464	262	188	5.67	4.20	-1.65	1.62	Na-Ca-Mg-HCO3
1029	MK3-363	MQ562	631350	1613400	357	195	120	4.41	3.87	-3.01	2.30	Na-Ca-Mg-HCO3
1030	MK3-441	NL0090	629200	1534700	493	268	190	6.39	4.39	1.82	1.74	Na-Ca-Mg-HCO3
1031	MK3-26	DB191	608056	1545793	409	231	175	5.11	4.52	-3.67	2.04	Na-Ca-Mg-HCO3-CO3
1032	MK3-343	MN912	635700	1605100	286	176	94	3.41	3.06	0.21	2.07	Na-Ca-Mg-HCO3-CO3
1033	MK3-91	DF276	634989	1614593	292	143	113	3.51	2.97	-4.18	1.68	Na-Mg-Ca-HCO3
1034	MK3-130	G1210	649090	1586090	339	197	137	4.22	3.18	-3.06	1.53	Na-Mg-Ca-HCO3
1035	MK3-231	MN191	603830	1597900	835	488	285	10.17	8.43	-4.88	3.09	Na-Mg-HCO3
1036	MK3-395	MT135	588250	1626150	540	331	161	6.52	5.93	-3.02	3.23	Na-Mg-HCO3
1037	MK3-427	NL0033	638300	1497800	483	253	151	6.20	5.39	-3.94	3.01	Na-Mg-HCO3
1038	MK3-507	TA297	606952	1691438	449	244	108	5.37	4.82	-3.84	3.43	Na-Mg-HCO3
1039	MK3-531	TP496	584794	1610661	842	480	247	10.84	9.90	-2.36	4.71	Na-Mg-HCO3
1040	MK3-77	DB90	620900	1526500	1254	261	867	19.95	12.38	-1.84	1.20	Ca-Mg-Cl-HCO3
1041	MK3-326	MN82	617840	1529650	742	225	496	11.68	6.11	3.15	0.45	Ca-Mg-Cl-HCO3
1042	MK3-444	NL0093	609400	1524350	737	203	460	11.39	6.80	1.10	0.93	Ca-Mg-Cl-HCO3
1043	MK3-6	DB111	622290	1523800	360	184	187	4.99	2.90	2.48	0.67	Ca-Mg-HCO3-Cl
1044	MK3-165	MD152	621250	1540050	528	216	312	7.81	4.64	0.35	0.86	Ca-Mg-HCO3-Cl
1045	MK3-280	MN433	618497	1525483	520	246	328	7.04	4.05	-1.39	0.34	Ca-Mg-HCO3-Cl
1046	MK3-419	NB0123	611469	1530372	560	273	361	7.61	4.19	-1.07	0.23	Ca-Mg-HCO3-Cl
1047	MK3-443	NL0092	618400	1528100	655	244	444	9.71	5.44	-0.84	0.39	Ca-Mg-HCO3-Cl
1048	MK3-458	NL0126	611469	1530372	552	271	327	7.55	4.10	1.91	0.38	Ca-Mg-HCO3-Cl
1049	MK3-218	MN152	618950	1527250	315	94	209	4.82	3.15	-3.31	0.63	Mg-Ca-Cl-HCO3
1050	MK3-333	MN87	622790	1534690	805	149	551	13.31	8.40	-1.48	1.17	Mg-Ca-Cl-HCO3
1051	MK3-174	MD26	618590	1528940	1686	183	1297	29.39	16.13	1.10	0.81	Ca-Mg-Cl
1052	MK3-340	MN884	653069	1621821	646	53	368	10.81	7.59	-1.74	1.97	Ca-Na-Mg-Cl
1053	MK3-437	NL0083	657900	1523400	1218	57	692	20.87	14.47	-0.06	2.81	Ca-Na-Mg-Cl
1054	MK3-424	NL0019	636700	1513100	1607	45	1051	29.27	19.41	-0.88	2.68	Mg-Ca-Na-Cl
1055	MK3-8	DB12	612950	1543340	1383	189	778	22.83	15.77	-0.07	2.81	Mg-Na-Ca-Cl
1056	MK3-426	NL0032	637412	1510997	897	137	486	15.64	9.80	3.77	2.17	Mg-Na-Ca-Cl
1057	MK3-234	MN197	655450	1545840	3452	20	1611	59.86	47.35	-2.77	7.70	Na-Ca-Cl
1058	MK3-351	MQ1030	637350	1591700	8192	54	2676	126.77	119.04	-3.29	17.66	Na-Ca-Cl
1059	MK3-433	NL0071	653800	1552800	429	25	150	7.10	5.77	-0.55	3.34	Na-Ca-Cl
1060	MK3-436	NL0078	663979	1562311	11638	135	5802	202.59	154.60	-1.82	12.57	Na-Ca-Mg-Cl

order unit	Sample ID	Well ID	East (m)	North (m)	calc TDS	Calc Alk.	Total Hardness	Sum of Anions	Sum of Cations	E.N. %	SAR	Water Type
1061	MK3-457	NL0125	644684	1530410	4215	242	1905	71.51	54.66	-0.32	8.08	Na-Ca-Mg-Cl
1062	MK3-460	NL0129	652547	1526141	4376	171	2078	75.74	56.16	0.37	7.64	Na-Ca-Mg-Cl
1063	MK3-2	DB10	614090	1552940	1437	196	716	23.20	17.75	-2.16	3.90	Na-Mg-Ca-Cl
1064	MK3-434	NL0073	640500	1534700	1018	32	472	17.25	13.56	-1.48	4.01	Na-Mg-Ca-Cl
1065	MK3-466	PD0123	644684	1530410	11172	127	5506	191.06	151.77	-2.69	12.90	Na-Mg-Ca-Cl
1066	MK3-418	NB0112	640287	1501648	2379	112	803	39.72	34.76	-2.78	9.37	Na-Mg-Cl
1067	MK3-425	NL0024	639500	1493500	2566	87	1116	47.02	33.36	2.81	6.51	Na-Mg-Cl
1068	MK3-430	NL0068	643300	1526500	755	25	292	13.83	10.00	3.63	4.07	Na-Mg-Cl
1069	MK3-446	NL0098	628166	1526588	16332	568	4556	279.93	242.31	-0.83	29.01	Na-Mg-Cl
1070	MK3-66	DB78	644290	1525440	502	278	109	6.38	5.40	2.87	4.04	Na-HCO3
1071	MK3-105	DF8	598650	1634350	878	520	146	10.88	8.99	2.27	6.13	Na-HCO3
1072	MK3-110	DR50	652750	1588750	555	302	99	6.52	6.25	-0.59	5.24	Na-HCO3
1073	MK3-126	E1586	646454	1582421	428	230	77	5.24	4.80	-0.56	4.45	Na-HCO3
1074	MK3-131	G1238	651815	1586360	537	304	108	6.56	5.33	2.69	3.93	Na-HCO3
1075	MK3-152	GWA0083	621790	1569431	519	290	34	6.33	6.05	0.94	9.76	Na-HCO3
1076	MK3-160	MC357	605673	1689714	645	368	85	7.99	6.94	1.50	6.31	Na-HCO3
1077	MK3-206	MN116	663900	1565300	774	365	138	9.48	8.36	2.17	5.90	Na-HCO3
1078	MK3-208	MN120	624950	1551250	550	294	72	6.64	6.47	-3.23	6.72	Na-HCO3
1079	MK3-215	MN143	620900	1596900	417	240	51	5.08	4.56	0.70	5.61	Na-HCO3
1080	MK3-229	MN181	612590	1610050	895	442	50	10.18	10.97	-1.03	14.67	Na-HCO3
1081	MK3-259	MN315	621400	1597900	431	241	72	5.20	4.77	-1.61	4.72	Na-HCO3
1082	MK3-266	MN369	622250	1569750	461	258	44	5.55	5.56	-3.47	7.67	Na-HCO3
1083	MK3-293	MN45	600750	1643500	329	107	35	2.75	2.86	-4.98	4.20	Na-HCO3
1084	MK3-303	MN51	622840	1595650	465	246	40	5.47	5.93	-1.90	8.68	Na-HCO3
1085	MK3-313	MN6	604323	1612203	547	332	45	6.46	6.59	-0.32	9.07	Na-HCO3
1086	MK3-376	MQ899	665900	1591050	509	277	82	5.98	6.59	-4.07	6.25	Na-HCO3
1087	MK3-435	NL0075	645100	1559400	374	201	20	4.68	4.64	1.70	9.61	Na-HCO3
1088	MK3-445	NL0094	627100	1550500	507	227	45	6.21	6.58	-4.15	9.07	Na-HCO3
1089	MK3-114	DR73	653758	1576215	436	246	63	5.20	5.49	-1.71	6.03	Na-HCO3-CO3
1090	MK3-178	MD291	578100	1594400	948	608	37	11.20	11.55	3.11	18.20	Na-HCO3-CO3
1091	MK3-205	MN114	621150	1599250	324	207	72	3.80	3.70	0.03	3.43	Na-HCO3-CO3
1092	MK3-396	MT137	620850	1599650	305	190	64	3.51	3.78	-4.27	3.87	Na-HCO3-CO3
1093	MK3-532	TY143	581679	1617460	1526	890	90	18.47	19.63	1.16	19.73	Na-HCO3-CO3
1094	MK3-65	DB76	609290	1552190	740	294	110	10.20	9.86	0.75	8.29	Na-Cl-HCO3
1095	MK3-70	DB82	611950	1553340	837	239	91	11.79	11.82	-0.06	11.40	Na-Cl-HCO3
1096	MK3-95	DF325	616600	1549956	664	237	104	8.82	8.95	-1.32	7.68	Na-Cl-HCO3
1097	MK3-158	MC304	610790	1672050	600	135	109	8.28	7.48	-1.22	6.14	Na-Cl-HCO3
1098	MK3-163	MC485	602900	1571250	2471	606	380	35.70	32.76	1.38	14.77	Na-Cl-HCO3
1099	MK3-207	MN119	635590	1542650	985	181	269	15.70	12.98	0.57	6.21	Na-Cl-HCO3
1100	MK3-233	MN193	611700	1558190	1856	372	166	25.89	26.07	0.70	18.86	Na-Cl-HCO3
1101	MK3-428	NL0053	657655	1516264	1091	210	120	17.36	15.68	1.98	13.13	Na-Cl-HCO3
1102	MK3-438	NL0087	646100	1520200	412	87	59	6.29	5.97	-1.69	6.78	Na-Cl-HCO3
1103	MK3-442	NL0091	615200	1543100	628	214	48	9.07	8.79	0.23	11.90	Na-Cl-HCO3
1104	MK3-450	NL0105	639148	1544581	1062	292	253	14.28	12.90	0.31	6.29	Na-Cl-HCO3
1105	MK3-455	NL0115	609408	1552874	1208	289	242	17.41	15.13	3.02	8.11	Na-Cl-HCO3
1106	MK3-43	DB238	624073	1544219	691	322	155	8.99	7.23	3.77	4.55	Na-HCO3-Cl
1107	MK3-64	DB75	608200	1553500	699	289	141	9.05	9.26	-3.31	6.61	Na-HCO3-Cl
1108	MK3-112	DR55	651600	1586300	542	227	139	6.71	6.73	-2.49	4.43	Na-HCO3-Cl
1109	MK3-216	MN147	617400	1561340	749	330	82	9.74	9.08	1.75	9.08	Na-HCO3-Cl
1110	MK3-309	MN55	612750	1639000	452	211	84	5.62	5.58	-4.69	4.74	Na-HCO3-Cl
1111	MK3-414	MX20	627090	1549650	557	212	100	7.91	6.87	0.26	5.87	Na-HCO3-Cl
1112	MK3-415	MX23	609590	1550900	642	267	174	8.60	7.30	-0.92	4.16	Na-HCO3-Cl
1113	MK3-62	DB70	626750	1537340	791	194	489	12.27	8.42	-3.24	1.54	Ca-Mg-Na-Cl-HCO3
1114	MK3-63	DB71	618750	1536150	736	189	438	11.35	7.74	-2.43	1.54	Ca-Mg-Na-Cl-HCO3
1115	MK3-221	MN158	606290	1643550	972	259	537	12.55	8.51	-2.99	1.20	Ca-Mg-Na-HCO3-Cl
1116	MK3-133	G1267	647918	1602443	645	144	316	10.10	6.87	1.20	1.96	Ca-Na-Cl-HCO3
1117	MK3-308	MN540	636150	1619650	516	178	267	7.56	5.09	-1.11	1.41	Ca-Na-Cl-HCO3
1118	MK3-146	GWA0042	619326	1660284	477	175	234	6.20	4.40	-0.68	1.17	Ca-Na-HCO3-Cl
1119	MK3-230	MN182	628950	1600550	274	122	130	3.77	2.48	0.50	0.95	Ca-Na-HCO3-Cl
1120	MK3-310	MN550	653063	1625685	660	245	300	9.57	6.42	1.25	1.91	Ca-Na-HCO3-Cl
1121	MK3-81	DF126	590300	1635850	257	120	122	3.10	2.62	-2.26	1.18	Ca-Na-HCO3-Cl-CO3
1122	MK3-235	MN199	614250	1596500	674	131	403	10.77	6.85	0.29	1.30	Ca-Na-Mg-Cl-HCO3
1123	MK3-342	MN911	642309	1607985	456	160	226	6.72	4.44	0.85	1.39	Ca-Na-Mg-Cl-HCO3
1124	MK3-360	MQ501	671750	1620690	1204	268	613	18.11	12.88	-0.37	2.71	Ca-Na-Mg-Cl-HCO3
1125	MK3-412	MX14	623650	1513650	737	149	431	11.48	7.66	-0.11	1.61	Ca-Na-Mg-Cl-HCO3
1126	MK3-21	DB166	605665	1541996	495	254	223	6.43	4.84	-3.27	1.60	Ca-Na-Mg-HCO3-Cl
1127	MK3-30	DB213	606920	1536518	237	127	107	3.14	2.17	0.39	0.97	Ca-Na-Mg-HCO3-Cl
1128	MK3-232	MN192	636500	1519300	551	279	243	7.34	4.93	0.68	1.54	Ca-Na-Mg-HCO3-Cl
1129	MK3-246	MN245	605500	1540150	555	231	276	7.79	5.50	-2.63	1.57	Ca-Na-Mg-HCO3-Cl
1130	MK3-168	MD180	622250	1539550	663	216	312	9.10	6.83	-0.06	2.05	Mg-Na-HCO3-Cl
1131	MK3-113	DR71	655650	1595636	745	185	245	10.68	9.14	-2.03	4.17	Na-Ca-Cl-HCO3

order unit	Sample ID	Well ID	East (m)	North (m)	calc TDS	Calc Alk.	Total Hardness	Sum of Anions	Sum of Cations	E.N. %	SAR	Water Type
1132	MK3-136	G1286	652935	1587450	611	225	149	8.70	7.22	1.35	4.63	Na-Ca-Cl-HCO3
1133	MK3-307	MN535	644202	1620753	693	180	226	9.64	7.97	0.19	3.77	Na-Ca-Cl-HCO3
1134	MK3-315	MN64	639700	1534800	1041	177	457	17.00	12.09	1.65	3.44	Na-Ca-Cl-HCO3
1135	MK3-40	DB231	607547	1550588	690	344	177	8.95	7.07	1.78	3.93	Na-Ca-HCO3-Cl
1136	MK3-132	G1262	665100	1569567	388	169	131	5.20	4.38	-4.23	2.62	Na-Ca-HCO3-Cl
1137	MK3-134	G1283	658994	1584891	683	315	204	9.12	7.77	-0.40	3.96	Na-Ca-HCO3-Cl
1138	MK3-135	G1284	658968	1585225	694	293	205	9.45	8.23	-1.27	4.26	Na-Ca-HCO3-Cl
1139	MK3-155	GWA0095	651984	1583486	502	244	126	6.41	5.34	-0.48	3.49	Na-Ca-HCO3-Cl
1140	MK3-195	MD494	583200	1615500	1253	552	305	15.86	13.01	0.15	5.56	Na-Ca-HCO3-Cl
1141	MK3-305	MN533	644090	1626400	499	231	159	6.33	5.13	0.38	2.79	Na-Ca-HCO3-Cl
1142	MK3-336	MN878	646100	1622600	510	177	152	6.69	5.94	-0.70	3.52	Na-Ca-HCO3-Cl
1143	MK3-367	MQ627	648171	1599337	365	171	113	4.72	3.62	0.78	2.25	Na-Ca-HCO3-Cl
1144	MK3-448	NL0101	641430	1544695	498	249	109	6.53	5.37	2.68	4.05	Na-Ca-HCO3-Cl
1145	MK3-23	DB169	607444	1525149	757	148	327	12.11	8.27	3.98	2.65	Na-Ca-Mg-Cl-HCO3
1146	MK3-199	MD520	618450	1538900	684	230	319	9.85	7.30	-2.20	2.19	Na-Ca-Mg-Cl-HCO3
1147	MK3-341	MN90	639150	1526340	664	216	296	9.91	6.98	0.44	2.28	Na-Ca-Mg-Cl-HCO3
1148	MK3-22	DB168	608740	1542880	555	275	217	7.65	5.04	3.21	1.89	Na-Ca-Mg-HCO3-Cl
1149	MK3-25	DB19	613250	1541090	500	205	179	6.62	5.35	-1.59	2.60	Na-Ca-Mg-HCO3-Cl
1150	MK3-59	DB52	614500	1546900	663	257	269	9.31	7.13	-1.73	2.65	Na-Ca-Mg-HCO3-Cl
1151	MK3-78	DB91	705000	1527800	561	198	239	7.77	5.63	1.13	2.00	Na-Ca-Mg-HCO3-Cl
1152	MK3-361	MQ524	648290	1598250	391	198	154	5.09	3.84	-2.39	1.79	Na-Ca-Mg-HCO3-Cl
1153	MK3-431	NL0069	638613	1519846	541	251	185	7.28	5.47	0.38	2.56	Na-Ca-Mg-HCO3-Cl
1154	MK3-331	MN849	636800	1628300	490	189	140	6.16	5.79	-4.39	3.64	Na-Mg-Ca-HCO3-Cl
1155	MK3-12	DB136	608128	1544334	3046	521	1009	50.05	40.11	-0.03	9.46	Na-Mg-Cl-HCO3
1156	MK3-122	DS55	612590	1549200	687	236	192	9.76	8.03	1.00	4.39	Na-Mg-HCO3-Cl
1157	MK3-198	MD519	620340	1530150	311	105	82	4.26	3.79	-2.36	2.88	Na-Mg-HCO3-Cl
1158	MK3-240	MN22	605210	1599550	394	165	160	5.55	4.38	-0.03	2.14	Na-Mg-HCO3-Cl
1159	MK3-354	MQ470	658840	1593250	632	240	183	8.81	7.43	-1.83	4.05	Na-Mg-HCO3-Cl
1160	MK3-96	DF328	618468	1548760	539	257	124	6.99	7.39	-3.66	5.47	Na-Mg-HCO3-Cl-CO3
1161	MK3-462	NL0131	600010	1530587	814	259	342	9.88	7.58	3.35	2.14	Ca-Na-Mg-HCO3-SO4-Cl
1162	MK3-41	DB236	610015	1546225	866	285	268	10.78	8.89	3.64	3.72	Na-Ca-HCO3-Cl-SO4
1163	MK3-334	MN872	651500	1629400	709	217	250	8.71	7.83	-1.88	3.30	Na-Ca-HCO3-Cl-SO4
1164	MK3-502	TA285	604157	1677058	1378	369	456	16.52	15.45	-3.64	3.67	Na-Ca-HCO3-Cl-SO4
1165	MK3-311	MN555	632290	1606800	403	178	131	4.61	3.90	0.23	2.09	Na-Ca-Mg-HCO3-SO4
1166	MK3-125	DS7	612580	1561745	1076	246	107	13.50	15.49	-3.14	13.85	Na-Cl-HCO3-SO4
1167	MK3-260	MN323	608090	1574690	1996	294	300	27.05	27.73	-0.15	14.22	Na-Cl-SO4
1168	MK3-141	G1328	668500	1592150	642	289	71	7.11	7.73	1.17	8.27	Na-HCO3-SO4
1169	MK3-214	MN14	610590	1591250	1769	607	89	18.04	22.30	-0.43	22.65	Na-HCO3-SO4
1170	MK3-338	MN880	652200	1626700	501	114	154	6.16	5.98	0.23	3.51	Na-Mg-Cl-SO4-HCO3
1171	MK3-108	DN49	615796	1561627	1180	303	227	13.95	14.04	2.59	7.80	Na-SO4-HCO3-Cl
Layer 4 (NB)												
1172	MK4-79	MN263	575150	1638190	711	395	413	9.29	4.49	4.42	0.15	Ca-HCO3
1173	MK4-83	MN300	575400	1637300	419	239	261	5.47	2.85	0.13	0.12	Ca-HCO3
1174	MK4-156	NB0128	600010	1530587	343	203	170	4.30	2.26	4.51	0.33	Ca-HCO3
1175	MK4-2	DB189	618873	1528330	364	206	176	4.30	3.23	-2.17	0.59	Ca-Mg-HCO3
1176	MK4-74	MN216	599450	1624500	448	268	244	5.55	3.55	-3.39	0.64	Ca-Mg-HCO3
1177	MK4-141	NB0090	618400	1528100	437	265	250	5.57	3.02	0.61	0.25	Ca-Mg-HCO3
1178	MK4-142	NB0091	609400	1524350	653	353	386	8.68	4.57	1.81	0.27	Ca-Mg-HCO3
1179	MK4-161	PT0004	617284	1518666	577	358	331	7.31	3.79	1.84	0.14	Ca-Mg-HCO3
1180	MK4-176	SK0025	623219	1508606	584	361	293	7.40	3.96	3.93	0.48	Ca-Mg-HCO3
1181	MK4-125	NB0026	638300	1497800	25564	11	6403	153.03	389.53	0.10	40.24	Na-Cl
1182	MK4-144	NB0095	628166	1526588	15011	389	3152	255.48	232.61	-1.26	35.66	Na-Cl
1183	MK4-146	NB0098	620865	1560536	1580	41	363	28.28	22.89	3.35	10.05	Na-Cl
1184	MK4-158	NB0134	656955	1505829	23623	116	7205	384.67	359.97	-3.83	33.84	Na-Cl
1185	MK4-146	NB0103	620865	1560536	567	130	131	8.87	7.06	3.08	4.94	Na-Cl-HCO3
1186	MK4-137	NB0086	632900	1524800	412	235	196	5.28	3.26	1.79	0.87	Ca-Mg-Na-HCO3
1187	MK4-140	NB0089	629200	1534700	473	271	210	6.22	3.82	2.95	1.11	Ca-Mg-Na-HCO3
1188	MK4-153	NB0124	623219	1508606	539	324	260	6.76	4.22	0.05	0.92	Ca-Mg-Na-HCO3
1189	MK4-157	NB0133	617510	1506980	508	300	242	6.24	4.22	-2.33	1.01	Ca-Mg-Na-HCO3
1190	MK4-168	SK0009	617510	1506980	758	406	363	9.78	6.15	1.28	1.19	Ca-Mg-Na-HCO3
1191	MK4-175	SK0024	614819	1505176	678	411	299	8.64	5.10	3.96	1.11	Ca-Mg-Na-HCO3
1192	MK4-42	GWA0086	636670	1571749	207	98	92	2.65	1.68	4.00	0.64	Ca-Na-HCO3
1193	MK4-43	GWA0089	648067	1572625	369	191	143	4.60	3.18	2.82	1.46	Ca-Na-HCO3
1194	MK4-72	MN155	602150	1645650	560	336	229	7.03	4.50	2.09	1.32	Ca-Na-HCO3
1195	MK4-81	MN275	605700	1628690	707	392	256	9.08	6.32	1.46	2.31	Ca-Na-HCO3
1196	MK4-93	MN380	612950	1621500	457	271	206	5.61	3.65	-0.61	0.97	Ca-Na-HCO3
1197	MK4-180	TY128	582165	1619552	746	411	258	8.93	6.63	0.82	2.49	Ca-Na-HCO3
1198	MK4-85	MN308	602340	1638050	689	401	289	8.58	5.72	0.25	1.54	Ca-Na-Mg-HCO3
1199	MK4-163	SK0003	628166	1526588	396	230	168	4.83	3.37	-1.33	1.18	Ca-Na-Mg-HCO3
1200	MK4-138	NB0087	626100	1515900	413	245	182	5.46	3.28	3.47	1.00	Mg-Ca-Na-HCO3
1201	MK4-4	DB219	626981	1524262	285	161	134	3.70	2.49	-0.85	0.94	Mg-Na-Ca-HCO3

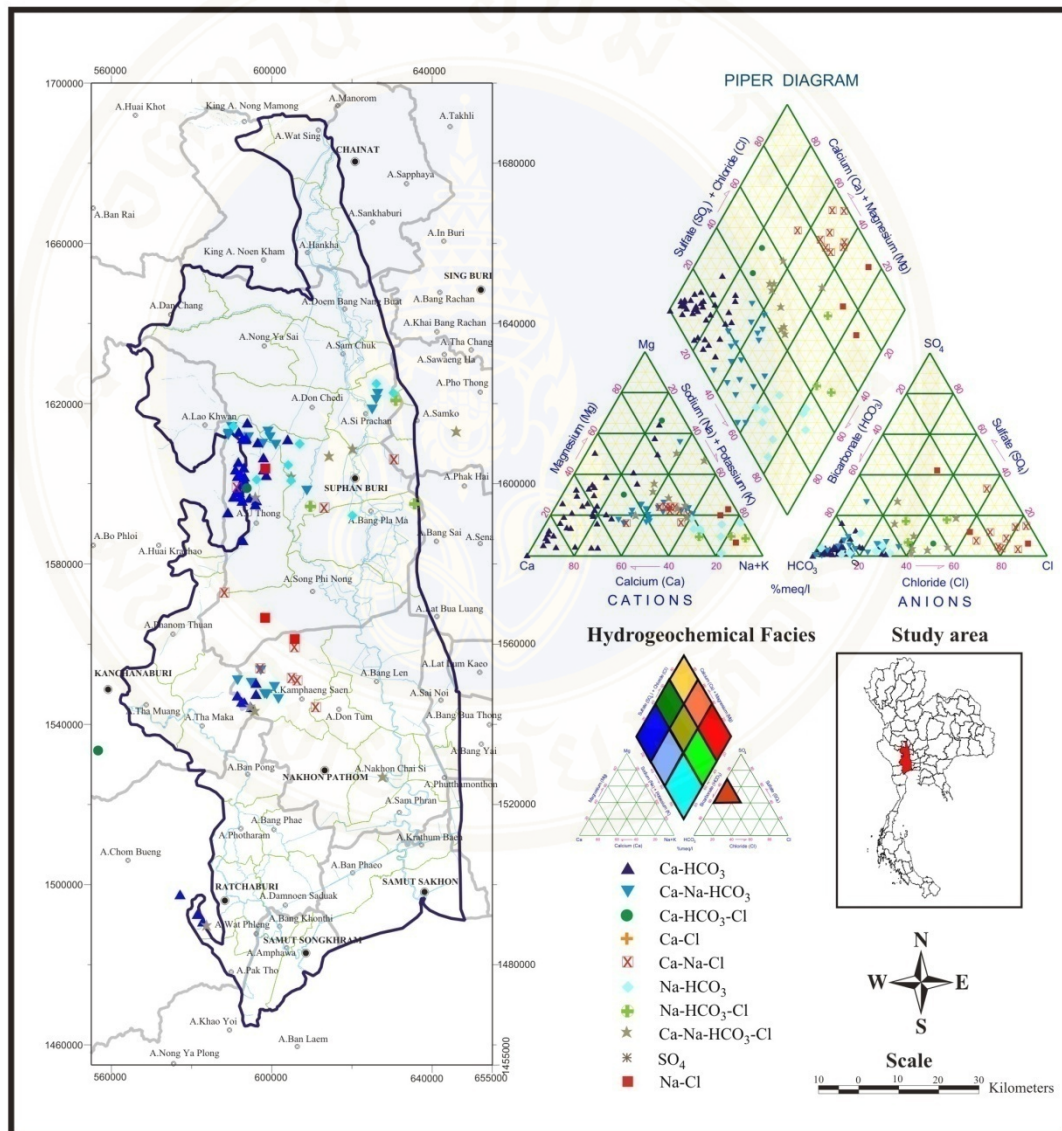
order unit	Sample ID	Well ID	East (m)	North (m)	calc TDS	Calc Alk.	Total Hardness	Sum of Anions	Sum of Cations	E.N. %	SAR	Water Type
1202	MK4-181	X69	632290	1517840	442	272	211	5.76	3.58	1.03	0.96	Mg-Na-Ca-HCO3
1203	MK4-82	MN28	570500	1636800	508	283	221	6.55	4.60	-1.01	1.49	Mg-Na-HCO3
1204	MK4-26	G1187	653840	1552250	689	376	140	8.24	6.91	0.73	4.41	Na-Ca-HCO3
1205	MK4-32	G1235	653284	1602185	450	244	153	5.54	4.92	-4.51	2.68	Na-Ca-HCO3
1206	MK4-33	G1251	648717	1548173	743	423	261	9.43	6.71	0.93	2.43	Na-Ca-HCO3
1207	MK4-38	GWA0068	619858	1600118	429	224	123	5.12	4.48	-3.04	2.86	Na-Ca-HCO3
1208	MK4-84	MN307	603700	1637400	611	377	141	7.14	6.48	0.76	4.14	Na-Ca-HCO3
1209	MK4-130	NB0063	654100	1531200	528	290	117	6.52	5.16	2.75	3.62	Na-Ca-HCO3
1210	MK4-159	NB0142	644759	1526087	528	292	116	6.49	5.58	-1.03	4.05	Na-Ca-HCO3
1211	MK4-68	MN126	595150	1617750	733	433	244	9.08	6.90	-1.03	2.70	Na-Ca-Mg-HCO3
1212	MK4-128	NB0061	638613	1519846	427	224	145	5.64	3.97	2.98	2.03	Na-Mg-Ca-HCO3
1213	MK4-67	MN1	663450	1535400	691	374	107	8.36	7.86	-1.80	6.55	Na-Mg-HCO3
1214	MK4-177	TP335	576874	1607576	1174	706	244	14.32	13.90	-1.62	6.97	Na-Mg-HCO3
1215	MK4-178	TP365	580165	1598565	1145	671	360	14.89	10.29	4.07	3.44	Na-Mg-HCO3
1216	MK4-3	DB217	607558	1524884	708	351	419	9.27	5.55	-1.28	0.49	Ca-Mg-HCO3-Cl
1217	MK4-24	DS63	616106	1532936	321	161	185	4.22	2.72	-3.22	0.58	Ca-Mg-HCO3-Cl
1218	MK4-113	MT122	585550	1644500	1008	511	567	13.67	8.08	-0.10	0.97	Mg-Ca-HCO3-Cl
1219	MK4-148	NB0108	609408	1552874	1493	268	335	18.95	19.24	-1.39	8.56	Na-Cl-SO4-HCO3
1220	MK4-108	MN73	573340	1637500	1172	112	794	19.58	12.50	-1.44	1.59	Ca-Na-Cl
1221	MK4-121	NB0001	656174	1516845	1933	168	1045	34.58	21.16	4.68	3.23	Ca-Na-Mg-Cl
1222	MK4-19	DS100	634247	1538661	2048	305	655	30.77	27.75	-0.91	8.16	Na-Ca-Cl
1223	MK4-122	NB0004	654109	1538551	2260	24	1141	40.04	29.12	-0.57	5.15	Na-Ca-Cl
1224	MK4-123	NB0015	653800	1552300	2311	221	1013	38.76	28.62	0.54	5.74	Na-Ca-Cl
1225	MK4-134	NB0079	657054	1511793	4799	101	1802	82.15	66.23	-0.56	11.28	Na-Ca-Cl
1226	MK4-20	DS108	685960	1524199	3517	144	1474	59.02	45.81	0.79	8.05	Na-Ca-Mg-Cl
1227	MK4-126	NB0050	657600	1521400	1495	220	683	25.59	16.71	4.62	3.66	Na-Ca-Mg-Cl
1228	MK4-127	NB0060	639500	1503539	7139	131	3763	127.60	90.57	-0.00	8.51	Na-Ca-Mg-Cl
1229	MK4-129	NB0062	652166	1511415	13052	123	6384	225.83	168.86	-0.18	13.07	Na-Ca-Mg-Cl
1230	MK4-94	MN381	604678	1524233	1324	180	538	20.41	16.46	-0.40	4.69	Na-Mg-Ca-Cl
1231	MK4-132	NB0066	649800	1504800	24903	185	6703	415.30	374.09	-1.05	37.21	Na-Mg-Cl
1232	MK4-162	PT0007	622640	1539919	556	101	131	8.84	7.97	0.38	5.70	Na-Mg-Cl
1233	MK4-167	SK0008	622640	1539919	732	38	220	12.80	10.64	-0.04	5.58	Na-Mg-Cl
1234	MK4-8	DF152	621900	1569350	316	223	55	3.58	4.57	-0.76	5.39	Na-CO3-HCO3
1235	MK4-37	GWA0053	621757	1609610	398	242	92	4.75	4.62	-3.85	3.77	Na-HCO3
1236	MK4-48	GWA0111	637942	1580159	708	345	94	8.50	7.94	1.19	7.20	Na-HCO3
1237	MK4-69	MN133	620790	1599300	886	468	20	10.48	10.57	1.23	22.93	Na-HCO3
1238	MK4-70	MN134	621090	1599940	398	235	67	4.94	3.94	4.03	3.94	Na-HCO3
1239	MK4-73	MN201	619900	1599940	884	455	42	10.42	10.59	0.26	15.60	Na-HCO3
1240	MK4-77	MN242	643500	1526300	503	258	95	5.98	5.74	-3.63	4.81	Na-HCO3
1241	MK4-107	MN7	620590	1599440	722	342	36	8.75	8.75	0.86	13.85	Na-HCO3
1242	MK4-150	NB0115	602338	1538429	628	381	40	7.63	7.47	2.51	11.08	Na-HCO3
1243	MK4-169	SK0011	641430	1544695	413	215	86	4.82	4.86	-1.30	4.22	Na-HCO3
1244	MK4-75	MN218	592290	1637650	1013	609	60	11.99	14.11	-2.04	17.30	Na-HCO3-CO3
1245	MK4-133	NB0068	645100	1559400	251	127	38	2.83	3.23	1.66	4.22	Na-HCO3-CO3
1246	MK4-25	DS92	628732	1562482	1140	303	175	17.15	15.86	0.08	10.52	Na-Cl-HCO3
1247	MK4-47	GWA0110	637942	1580159	618	172	21	8.81	9.39	-2.70	20.06	Na-Cl-HCO3
1248	MK4-115	MT171	616090	1620800	721	208	152	10.82	9.43	-0.47	6.36	Na-Cl-HCO3
1249	MK4-143	NB0092	627100	1550500	2021	354	479	33.60	25.86	4.74	9.54	Na-Cl-HCO3
1250	MK4-164	SK0004	620865	1560536	1390	336	242	22.05	18.21	4.10	10.08	Na-Cl-HCO3
1251	MK4-95	MN394	630950	1540900	593	273	133	7.60	6.64	-0.38	4.54	Na-HCO3-Cl
1252	MK4-139	NB0088	615200	1543100	673	366	10	8.72	8.85	4.42	27.06	Na-HCO3-Cl-CO3
1253	MK4-145	NB0097	617284	1518666	828	259	448	12.68	7.77	2.29	1.46	Ca-Mg-Na-Cl-HCO3
1254	MK4-30	G1200	650000	1594400	957	211	461	14.70	10.83	-1.41	2.84	Ca-Na-Cl-HCO3
1255	MK4-41	GWA0085	636670	1571749	211	97	96	2.76	1.72	3.79	0.62	Ca-Na-HCO3-Cl
1256	MK4-44	GWA0090	648067	1572625	259	101	110	3.27	2.44	0.44	1.24	Ca-Na-HCO3-Cl
1257	MK4-149	NB0109	622640	1539919	530	267	230	7.09	4.59	2.80	1.43	Ca-Na-Mg-HCO3-Cl
1258	MK4-152	NB0122	611469	1530372	910	317	406	11.93	9.09	-0.68	2.37	Ca-Na-Mg-HCO3-Cl
1259	MK4-21	DS110	641146	1517123	647	243	365	9.42	6.90	-1.82	1.62	Mg-Na-Ca-Cl-HCO3
1260	MK4-17	DR46	647950	1602500	521	153	139	7.31	6.21	0.02	4.06	Na-Ca-Cl-HCO3
1261	MK4-104	MN491	637710	1596731	488	119	193	7.51	5.65	-0.37	2.53	Na-Ca-Cl-HCO3
1262	MK4-136	NB0081	657600	1521400	892	250	333	13.38	10.43	-0.90	3.81	Na-Ca-Cl-HCO3
1263	MK4-103	MN490	637900	1597050	393	192	106	5.03	4.21	-1.80	2.95	Na-Ca-HCO3-Cl
1264	MK4-151	NB0121	644684	1530410	675	244	170	9.39	7.88	0.25	4.67	Na-Ca-HCO3-Cl
1265	MK4-124	NB0025	637412	1510997	717	183	330	11.36	8.24	-0.69	2.63	Na-Mg-Ca-Cl-HCO3
1266	MK4-22	DS22	623130	1539861	418	197	163	5.39	4.40	-4.22	2.01	Na-Mg-Ca-HCO3-Cl
1267	MK4-179	TP491	575629	1619500	650	345	254	8.21	7.50	-4.03	3.00	Na-Mg-Ca-HCO3-Cl
1268	MK4-50	GWA0114	642660	1598422	364	156	82	5.27	3.95	4.97	3.36	Na-Mg-HCO3-Cl
1269	MK4-154	NB0125	614819	1505176	610	233	154	7.68	7.28	1.34	4.56	Na-Mg-HCO3-Cl
1270	MK4-49	GWA0113	637942	1580159	983	377	21	9.59	14.85	-2.99	31.53	Na-SO4-CO3-HCO3
1271	MK4-9	DF16	600550	1630950	308	178	159	3.77	2.48	-3.21	0.62	Ca-HCO3
1272	MK4-10	DF25	575100	1654800	741	392	436	9.32	5.90	-3.64	0.73	Ca-HCO3

order unit	Sample ID	Well ID	East (m)	North (m)	calc TDS	Calc Alk.	Total Hardness	Sum of Anions	Sum of Cations	E.N. %	SAR	Water Type
1273	MK4-57	MD448	573750	1648750	699	393	401	8.51	4.83	-0.01	0.35	Ca-HCO3
1274	MK4-58	MD449	568540	1653300	664	377	398	8.32	4.37	0.15	0.15	Ca-HCO3
1275	MK4-59	MD450	568400	1656690	709	418	436	8.96	4.68	-0.11	0.14	Ca-HCO3
1276	MK4-60	MD451	575150	1654840	895	451	491	11.42	6.59	1.39	0.69	Ca-HCO3
1277	MK4-61	MD452	557290	1653840	626	369	378	7.83	4.17	0.17	0.15	Ca-HCO3
1278	MK4-63	MD455	556590	1653900	579	346	342	7.18	3.70	1.25	0.11	Ca-HCO3
1279	MK4-64	MD456	551750	1653750	518	265	264	6.26	4.05	0.44	0.80	Ca-HCO3
1280	MK4-99	MN420	554850	1653700	547	295	327	6.58	4.00	-4.04	0.38	Ca-HCO3
1281	MK4-14	DF53	592950	1634100	278	162	145	3.48	2.18	-1.82	0.51	Ca-Mg-HCO3
1282	MK4-51	MC478	571540	1636440	1191	522	599	15.11	8.94	1.03	1.14	Ca-Mg-HCO3
1283	MK4-52	MC480	569290	1653190	672	352	377	7.79	4.06	1.26	0.10	Ca-Mg-HCO3
1284	MK4-141	NB0090	618400	1528100	456	272	252	5.83	3.17	1.45	0.33	Ca-Mg-HCO3
1285	MK4-176	SK0025	623219	1508606	438	271	211	5.55	3.25	1.83	0.63	Ca-Mg-HCO3
1286	MK4-132	NB0066	649800	1504800	22640	14	4874	379.47	351.93	-1.10	43.01	Na-Cl
1287	MK4-143	NB0092	627100	1550500	9052	609	2107	159.36	126.61	3.80	22.75	Na-Cl
1288	MK4-144	NB0095	628166	1526588	15314	656	3343	263.65	225.87	1.23	33.12	Na-Cl
1289	MK4-167	SK0008	622640	1539919	473	58	72	7.88	6.51	4.54	6.67	Na-Cl
1290	MK4-174	SK0021	652547	1526141	790	40	130	13.43	12.38	-0.37	9.54	Na-Cl
1291	MK4-138	NB0087	626100	1515900	407	239	179	5.11	3.34	1.08	1.07	Ca-Mg-Na-HCO3
1292	MK4-140	NB0089	629200	1534700	448	255	199	5.88	3.81	0.92	1.20	Ca-Mg-Na-HCO3
1293	MK4-37	GWA0053	612503	1631495	579	336	248	7.01	4.87	-1.79	1.41	Ca-Na-HCO3
1294	MK4-87	MN313	605540	1626500	396	235	193	4.88	3.14	-1.37	0.78	Ca-Na-HCO3
1295	MK4-96	MN401	603600	1632900	408	236	204	4.95	3.47	-4.88	0.91	Ca-Na-HCO3
1296	MK4-98	MN409	602800	1640600	621	353	293	7.64	5.33	-3.53	1.30	Ca-Na-HCO3
1297	MK4-117	MT94	503700	1624800	498	296	246	6.09	3.96	-2.58	0.83	Ca-Na-HCO3
1298	MK4-155	NB0127	600010	1530587	612	266	266	7.64	5.71	-0.58	1.81	Ca-Na-HCO3
1299	MK4-71	MN144	610750	1617590	496	306	186	6.30	3.95	4.45	1.41	Ca-Na-Mg-HCO3
1300	MK4-92	MN376	602650	1631250	300	176	150	3.71	2.50	-3.85	0.75	Ca-Na-Mg-HCO3
1301	MK4-157	NB0133	617510	1506980	676	384	318	8.63	5.48	0.32	1.17	Ca-Na-Mg-HCO3
1302	MK4-175	SK0024	614819	1505176	729	395	331	9.44	6.35	-0.46	1.56	Ca-Na-Mg-HCO3
1303	MK4-56	MD446	578000	1650400	557	332	230	6.96	5.02	-1.79	1.72	Mg-Na-Ca-HCO3
1304	MK4-100	MN422	571200	1638800	320	186	150	4.03	2.93	-4.35	1.14	Mg-Na-Ca-HCO3
1305	MK4-27	G1197	648400	1599500	358	201	105	4.38	3.58	-2.02	2.42	Na-Ca-HCO3
1306	MK4-28	G1198	647790	1602300	400	235	89	4.63	4.57	-3.30	3.83	Na-Ca-HCO3
1307	MK4-29	G1199	647090	1601190	350	197	129	4.35	3.36	-3.19	1.77	Na-Ca-HCO3
1308	MK4-35	G1280	647660	1599762	369	212	106	4.55	3.64	0.52	2.45	Na-Ca-HCO3
1309	MK4-45	GWA0093	651984	1583486	495	258	109	5.82	5.15	-0.45	3.76	Na-Ca-HCO3
1310	MK4-46	GWA0094	651984	1583486	499	261	109	5.88	5.16	-0.23	3.74	Na-Ca-HCO3
1311	MK4-65	MD457	562250	1651650	373	188	72	4.45	4.10	-1.98	3.79	Na-Ca-HCO3
1312	MK4-31	G1201	649290	1595900	371	193	112	4.64	3.88	-2.65	2.55	Na-Ca-Mg-HCO3
1313	MK4-5	DB50	623700	1540150	422	219	180	5.46	4.15	0.85	1.72	Na-Mg-Ca-HCO3
1314	MK4-72	MN155	602150	1645650	387	225	122	4.79	3.72	-0.86	2.08	Na-Mg-Ca-HCO3
1315	MK4-76	MN236	608400	1615440	356	211	103	4.49	3.28	2.40	2.05	Na-Mg-Ca-HCO3
1316	MK4-81	MN275	605700	1628690	195	113	77	2.39	2.00	-1.51	1.24	Na-Mg-Ca-HCO3
1317	MK4-128	NB0061	638613	1519846	425	225	151	5.62	4.14	-0.19	2.05	Na-Mg-Ca-HCO3
1318	MK4-153	NB0124	623219	1508606	558	312	171	7.09	5.39	0.54	2.73	Na-Mg-Ca-HCO3
1319	MK4-36	G1281	647266	1601858	269	128	82	3.40	2.94	-3.77	2.31	Na-Mg-HCO3
1320	MK4-62	MD454	562700	1652500	699	400	136	8.76	7.52	-0.26	5.16	Na-Mg-HCO3
1321	MK4-86	MN309	600700	1633590	395	228	106	4.93	4.03	-1.67	2.71	Na-Mg-HCO3
1322	MK4-80	MN264	575250	1637690	468	234	285	6.25	3.41	0.79	0.31	Ca-HCO3-Cl
1323	MK4-142	NB0091	609400	1524350	516	262	304	6.93	3.93	0.45	0.40	Ca-Mg-HCO3-Cl
1324	MK4-152	NB0122	611469	1530372	633	256	382	9.00	5.25	0.65	0.65	Ca-Mg-HCO3-Cl
1325	MK4-109	MQ711	650608	1594015	2169	182	1509	37.69	23.98	-1.53	2.24	Ca-Mg-Na-Cl
1326	MK4-122	NB0004	654109	1538551	380	31	172	6.37	4.63	0.55	2.12	Ca-Na-Cl
1327	MK4-121	NB0001	656174	1516845	1215	38	510	21.65	15.92	1.52	4.63	Na-Ca-Cl
1328	MK4-123	NB0015	653800	1552800	4090	18	1399	71.74	56.18	1.65	11.17	Na-Ca-Cl
1329	MK4-134	NB0079	657054	1511793	4584	21	1750	80.88	60.99	2.40	10.30	Na-Ca-Cl
1330	MK4-135	NB0080	653500	1508800	10021	16	3086	178.93	140.44	2.43	19.58	Na-Ca-Cl
1331	MK4-129	NB0062	652166	1511415	11352	13	5344	201.99	154.03	-0.99	13.69	Na-Ca-Mg-Cl
1332	MK4-136	NB0081	657900	1523400	972	95	330	16.35	12.66	1.81	5.03	Na-Ca-Mg-Cl
1333	MK4-127	NB0060	639500	1503539	14470	148	5221	254.10	214.39	-2.39	22.28	Na-Mg-Cl
1334	MK4-137	NB0086	632900	1524800	1763	228	606	29.31	23.63	-0.36	7.07	Na-Mg-Cl
1335	MK4-149	NB0109	622640	1539919	11347	632	3292	193.38	160.96	0.65	22.00	Na-Mg-Cl
1336	MK4-171	SK0017	621463	1497147	5433	694	1181	86.41	78.64	-1.15	19.00	Na-Mg-Cl
1337	MK4-1	DB182	603477	1554011	957	530	38	12.17	10.91	3.85	16.97	Na-HCO3
1338	MK4-18	DR74	646030	1576318	619	304	99	6.95	8.01	-3.81	6.99	Na-HCO3
1339	MK4-39	GWA0081	621790	1569431	528	291	55	6.38	6.28	-1.64	7.63	Na-HCO3
1340	MK4-40	GWA0082	621790	1569431	467	255	21	5.64	5.50	0.21	11.46	Na-HCO3
1341	MK4-55	MD443	581500	1618900	980	526	128	11.76	11.23	-2.13	8.49	Na-HCO3
1342	MK4-70	MN134	621090	1599940	402	237	63	4.97	4.08	3.17	4.28	Na-HCO3
1343	MK4-73	MN201	619900	1599940	844	429	37	9.79	10.22	-0.38	16.13	Na-HCO3

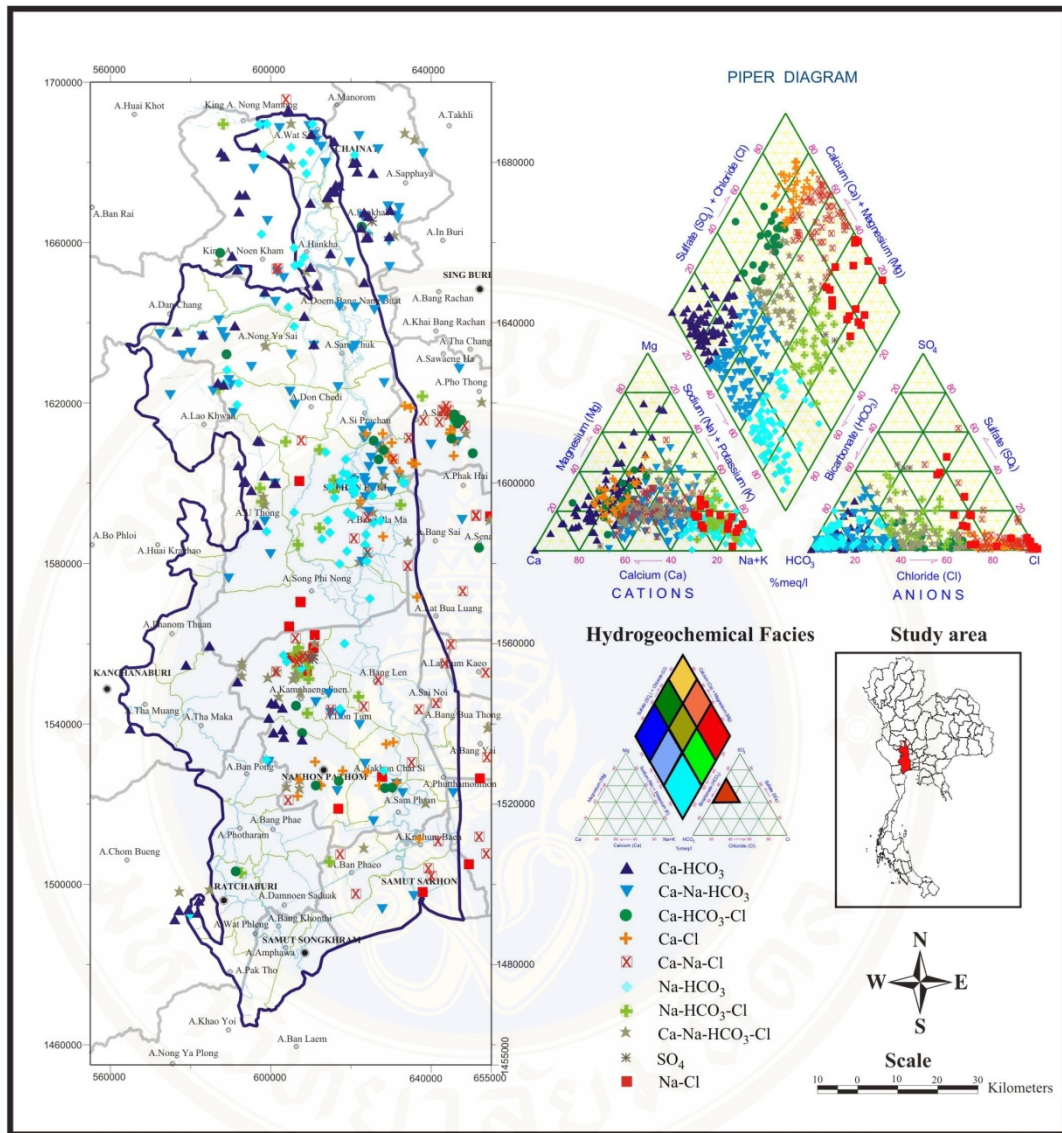
order unit	Sample ID	Well ID	East (m)	North (m)	calc TDS	Calc Alk.	Total Hardness	Sum of Anions	Sum of Cations	E.N. %	SAR	Water Type
1344	MK4-77	MN242	643500	1526300	519	287	91	6.41	5.30	3.39	4.51	Na-HCO3
1345	MK4-88	MN318	623900	1565500	429	239	40	5.20	4.92	-0.30	7.09	Na-HCO3
1346	MK4-89	MN32	620250	1599750	812	424	28	9.04	10.52	-2.36	19.09	Na-HCO3
1347	MK4-104	MN491	637710	1596731	300	169	44	3.56	3.28	-0.49	4.20	Na-HCO3
1348	MK4-106	MN65	631700	1549300	543	243	88	6.65	6.65	-3.55	6.09	Na-HCO3
1349	MK4-107	MN7	620590	1599440	791	431	32	9.11	9.80	0.04	16.81	Na-HCO3
1350	MK4-131	NB0065	640500	1534700	372	225	30	4.44	4.68	-1.06	7.81	Na-HCO3
1351	MK4-133	NB0068	645100	1559400	321	165	7	3.74	4.23	-2.11	14.77	Na-HCO3
1352	MK4-150	NB0115	602338	1538429	683	376	46	8.69	7.59	3.93	10.21	Na-HCO3
1353	MK4-90	MN321	622250	1569750	472	292	23	5.64	5.87	2.84	11.67	Na-HCO3-CO3
1354	MK4-148	NB0108	609408	1552874	1456	332	282	20.53	18.21	3.17	9.07	Na-HCO3
1355	MK4-164	SK0004	620865	1560536	1652	373	253	25.12	23.58	-1.71	13.14	Na-Cl-HCO3
1356	MK4-170	SK0015	629123	1493891	544	155	30	8.11	7.41	4.55	12.70	Na-Cl-HCO3
1357	MK4-120	MX22	610900	1558090	1399	428	22	17.91	19.10	0.04	40.28	Na-HCO3-Cl
1358	MK4-139	NB0088	615200	1543100	709	349	24	9.24	9.01	2.58	17.91	Na-HCO3-Cl
1359	MK4-112	MT106	577850	1647550	285	121	145	3.86	2.65	-1.48	0.90	Ca-Mg-Na-HCO3-Cl
1360	MK4-124	NB0025	637412	1510997	486	214	252	6.82	4.31	0.99	1.04	Ca-Mg-Na-HCO3-Cl
1361	MK4-7	DF11	577850	1638450	593	238	320	7.69	5.14	-3.00	1.07	Ca-Na-Mg-HCO3-Cl
1362	MK4-146	NB0101	620865	1560536	308	125	132	3.74	2.65	1.57	0.95	Ca-Na-Mg-HCO3-Cl
1363	MK4-173	SK0020	640287	1501648	488	199	276	6.80	4.49	-1.56	0.94	Mg-Ca-Na-HCO3-Cl
1364	MK4-54	MC484	577950	1653440	2529	668	1334	36.08	25.61	1.23	3.27	Mg-Na-Ca-Cl-HCO3
1365	MK4-110	MQ712	647601	1601977	353	181	144	4.66	3.63	1.10	1.81	Na-Ca-HCO3-Cl
1366	MK4-151	NB0121	644684	1530410	723	293	196	9.71	8.57	-3.27	4.67	Na-Ca-HCO3-Cl
1367	MK4-156	NB0128	652547	1526141	564	276	165	7.49	5.88	-0.07	3.22	Na-Ca-HCO3-Cl
1368	MK4-146	NB0103	620865	1560536	752	243	296	10.78	8.70	-2.78	3.29	Na-Ca-Mg-Cl-HCO3
1369	MK4-168	SK0009	617510	1506980	1374	414	605	20.17	15.49	-2.60	3.72	Na-Ca-Mg-Cl-HCO3
1370	MK4-66	MD493	595640	1499929	924	342	416	13.83	9.04	3.03	2.35	Na-Ca-Mg-HCO3-Cl
1371	MK4-163	SK0003	628166	1526588	441	226	183	5.79	3.94	0.51	1.45	Na-Ca-Mg-HCO3-Cl
1372	MK4-146	NB0098	620865	1560536	1369	18	204	23.36	21.72	-0.77	13.73	Na-Cl
1373	MK4-147	NB0106	621463	1497147	803	341	303	10.89	8.38	-0.74	3.00	Na-Mg-Ca-HCO3-Cl
1374	MK4-162	PT0007	622640	1539919	506	163	116	7.52	6.08	2.66	4.44	Na-Mg-Cl-HCO3
1375	MK4-125	NB0026	638300	1497800	452	207	101	6.41	5.15	4.46	3.89	Na-Mg-HCO3-Cl
1376	MK4-154	NB0125	614819	1505176	766	303	228	9.70	8.04	1.87	3.74	Na-Mg-HCO3-Cl
1377	MK4-166	SK0006	639148	1544581	403	120	175	4.55	4.04	-1.94	1.55	Ca-Na-Mg-HCO3-SO4
1378	MK4-111	MQ713	652003	1602301	1228	408	311	14.00	14.03	-1.27	6.17	Na-Ca-HCO3-SO4
1379	MK4-13	DF44	576950	1637450	2248	546	1085	26.86	23.90	-2.74	3.96	Na-Ca-Mg-SO4-HCO3-Cl
Layer 5 (all more deeper than NB)												
1380	MK5-13	PT0017	623219	1508606	545	335	257	7.00	4.03	3.09	0.76	Ca-Mg-HCO3
1381	MK5-14	PT0020	614819	1505176	686	425	331	8.75	5.11	2.02	0.86	Ca-Mg-HCO3
1382	MK5-6	PT0003	639148	1544581	616	69	79	10.31	9.20	2.61	9.32	Na-Cl
1383	MK5-4	GWA0045	621764	1644237	186	107	85	2.31	1.41	1.39	0.52	Ca-Mg-Na-HCO3
1384	MK5-8	PT0008	621463	1497147	611	366	251	7.89	4.92	3.58	1.37	Mg-Ca-Na-HCO3
1385	MK5-1	DF280	603258	1616881	574	335	189	7.14	5.35	-0.54	2.40	Na-Ca-HCO3
1386	MK5-7	PT0006	641430	1544695	436	234	82	5.10	5.24	-2.12	4.81	Na-Ca-HCO3
1387	MK5-5	MS656	587157	1485778	670	434	173	8.35	7.00	2.87	3.97	Na-Mg-HCO3
1388	MK5-11	PT0012	602338	1538429	652	388	43	7.94	7.52	3.01	10.59	Na-HCO3
1389	MK5-12	PT0016	644684	1532410	442	244	59	4.90	5.46	-3.22	6.22	Na-HCO3
1390	MK5-17	SK0018	602338	1538429	635	382	47	7.66	7.56	1.31	10.11	Na-HCO3
1391	MK5-16	PT0026	617510	1506980	1099	412	563	15.80	11.11	-2.23	2.20	Ca-Mg-Na-HCO3-Cl
1392	MK5-16	PT0026	617510	1506980	660	401	352	8.17	5.06	-2.28	0.67	Ca-Mg-HCO3
1393	MK5-15	PT0022	652547	1526141	686	126	109	10.77	10.40	-2.02	8.77	Na-Cl
1394	MK5-14	PT0020	614819	1505176	658	395	317	8.34	5.29	-0.55	1.05	Ca-Mg-Na-HCO3
1395	MK5-13	PT0017	623219	1508606	432	262	188	5.49	3.57	0.48	1.05	Mg-Ca-Na-HCO3
1396	MK5-8	PT0008	621463	1497147	628	358	244	8.10	5.46	1.32	1.75	Na-Mg-Ca-HCO3
1397	MK5-10	PT0011	640287	1501648	463	209	264	6.41	3.95	0.09	0.70	Mg-Ca-HCO3-Cl
1398	MK5-11	PT0012	602338	1538429	668	365	41	8.37	7.52	3.04	10.91	Na-HCO3
1399	MK5-17	SK0018	602338	1538429	661	363	56	8.40	7.22	4.14	8.75	Na-HCO3
1400	MK5-9	PT0010	629123	1493891	748	158	255	12.32	9.26	2.47	4.09	Na-Mg-Cl-HCO3
1401	MK5-3	DS1	643200	1511750	2814	98	1168	37.19	31.27	3.59	5.73	Ca-Na-Cl-SO4

## APPENDIX B

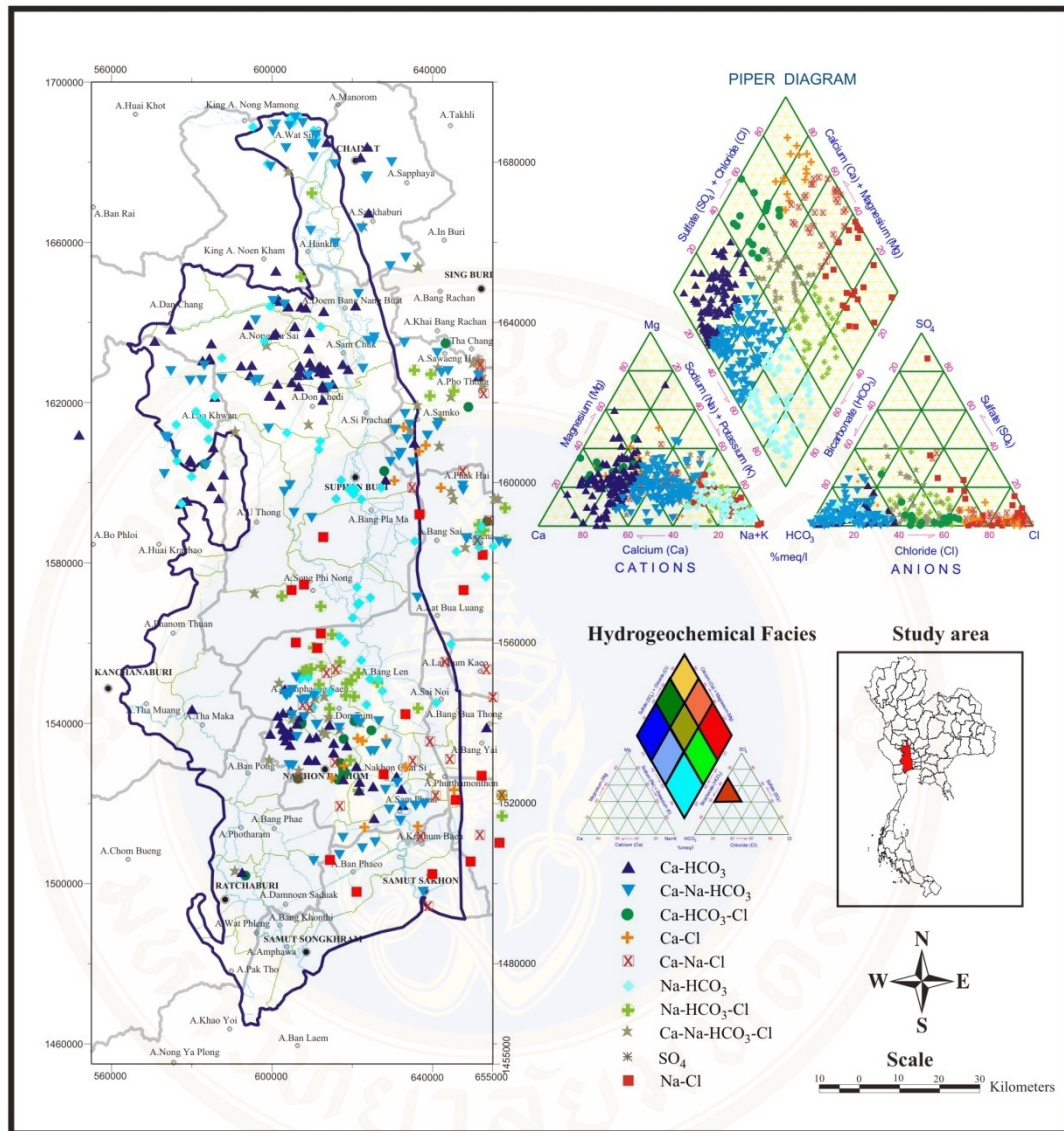
### PIPER DIAGRAM OF AQUIFER LAYER I-V



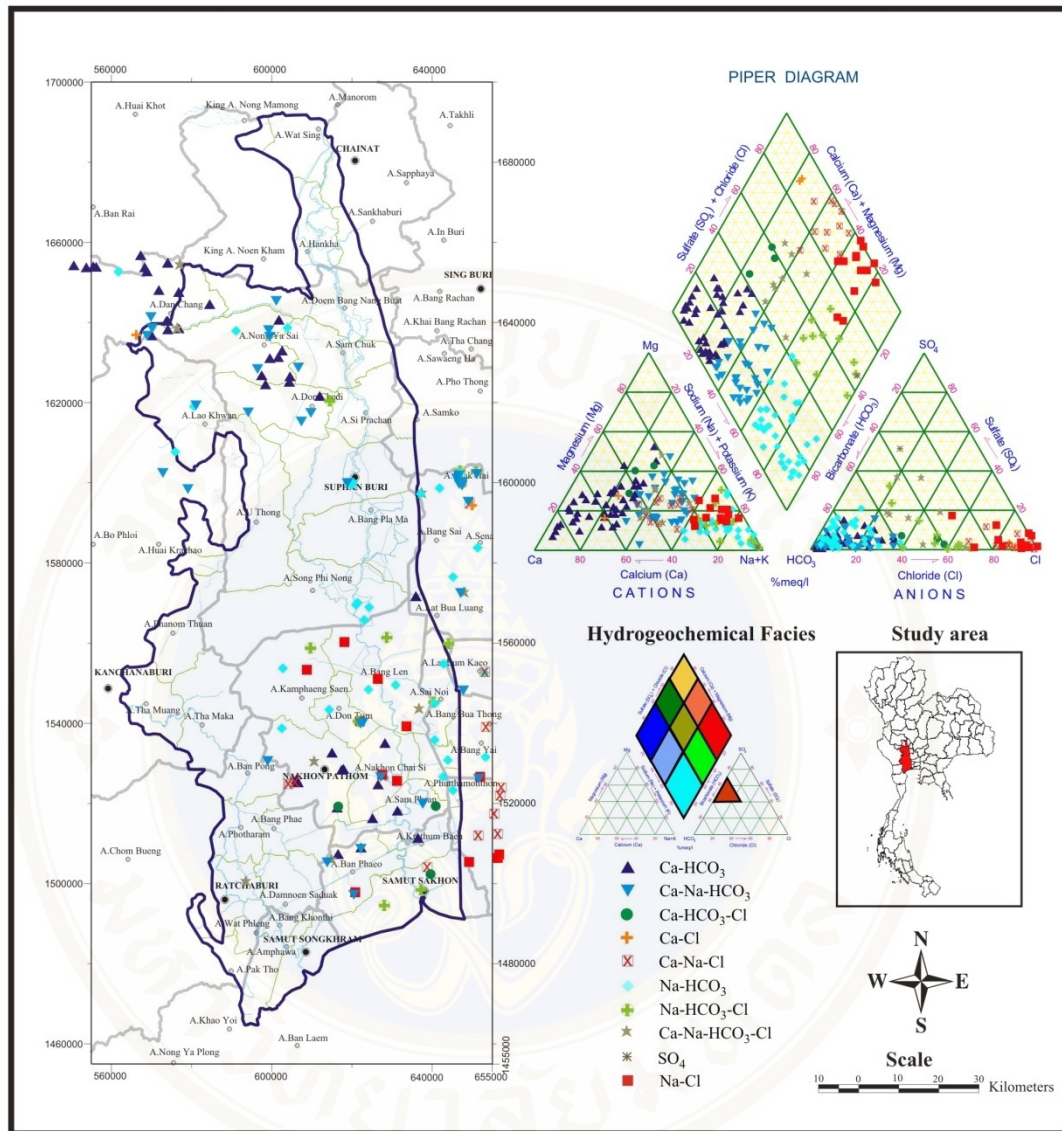
Appendix B1: Piper Diagram of Aquifer Layer I (BK)



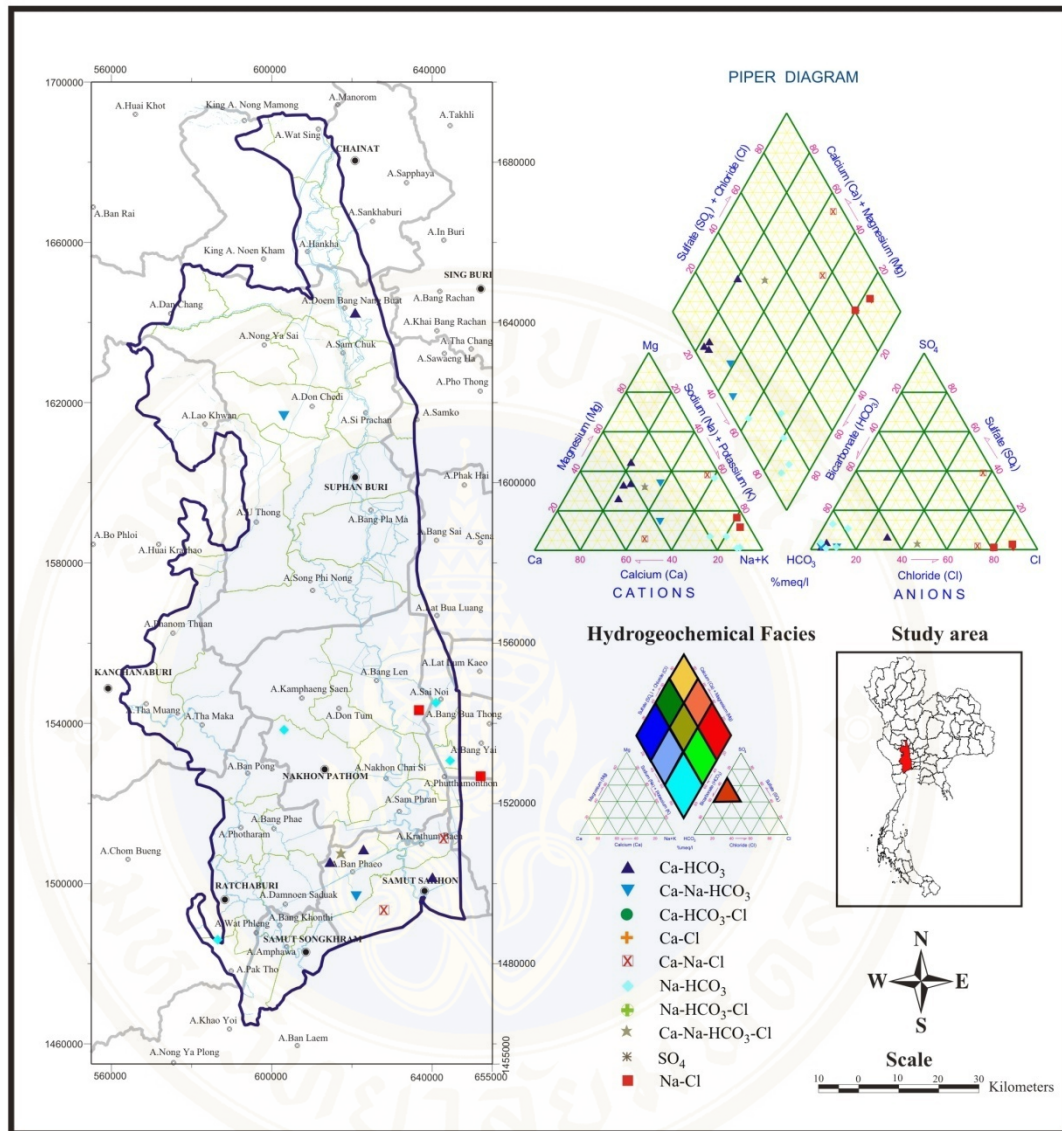
Appendix B2: Piper Diagram of Aquifer Layer II (PD)



Appendix B3: Piper Diagram of Aquifer Layer III (NL)



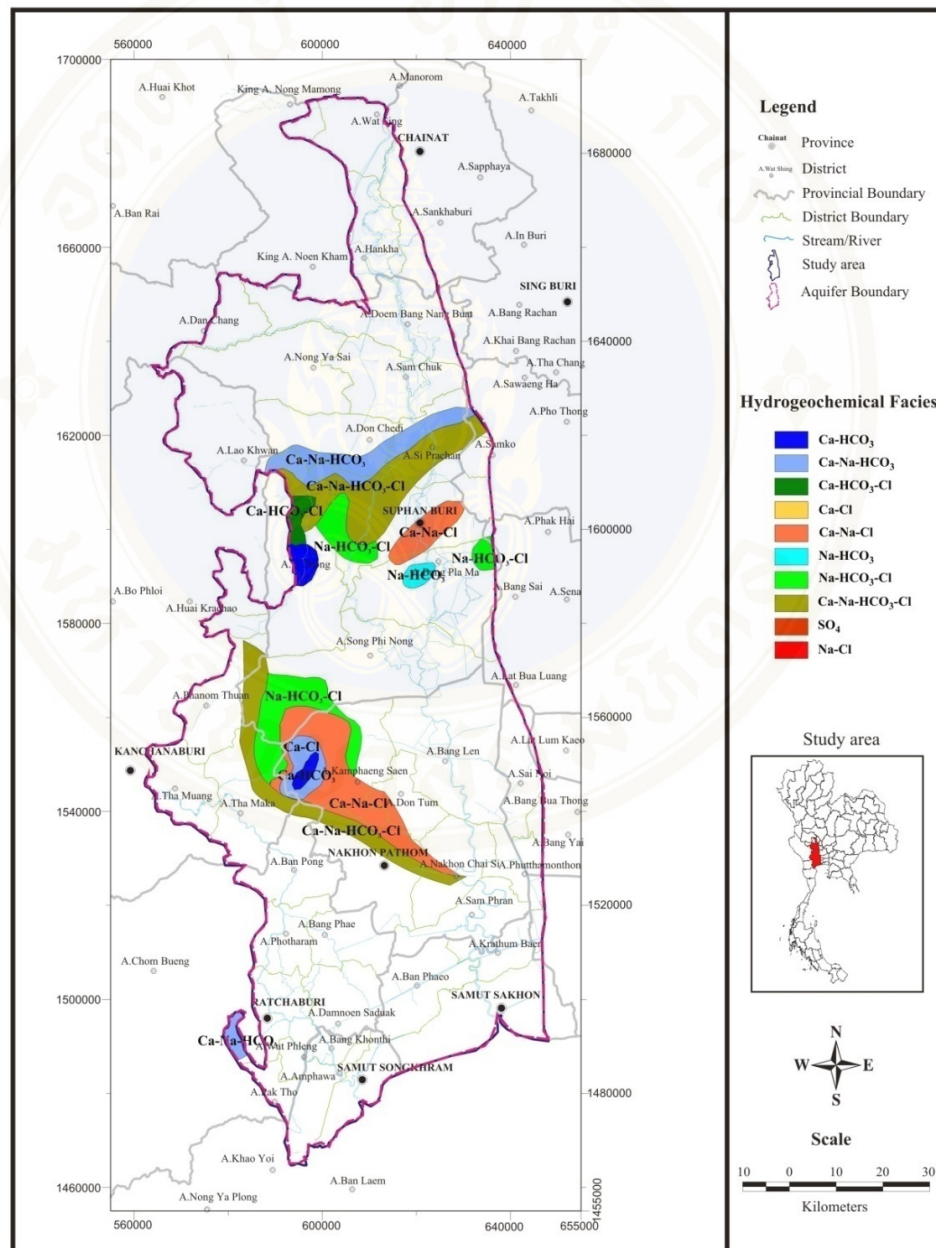
Appendix B4: Piper Diagram of Aquifer Layer IV (NB)



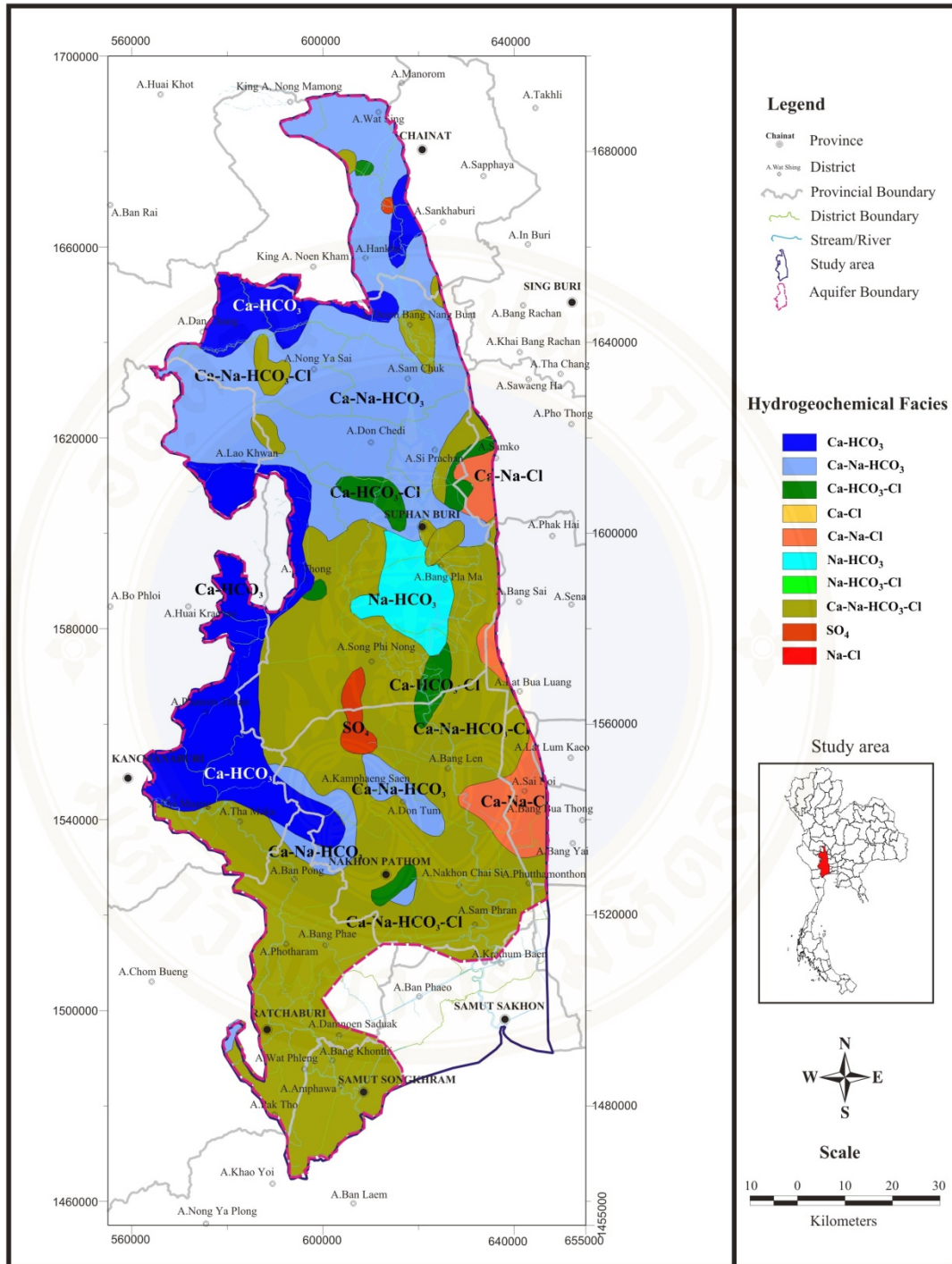
Appendix B5: Piper Diagram of Aquifer Layer V (Deeper layer than NB)

## APPENDIX C

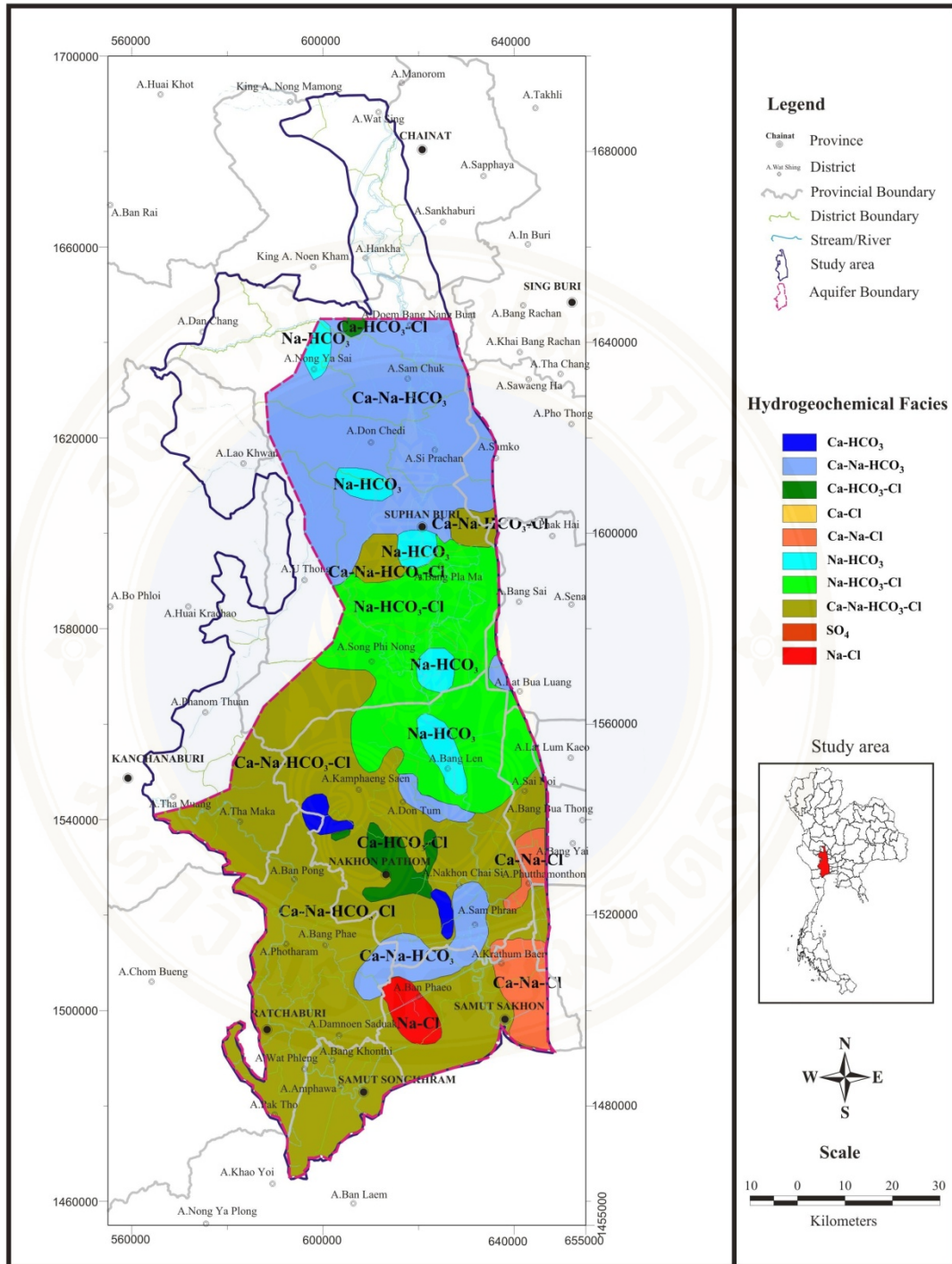
### MAP OF HYDROGEOCHEMICAL FACIES DISTRIBUTION OF AQUIFER I-V



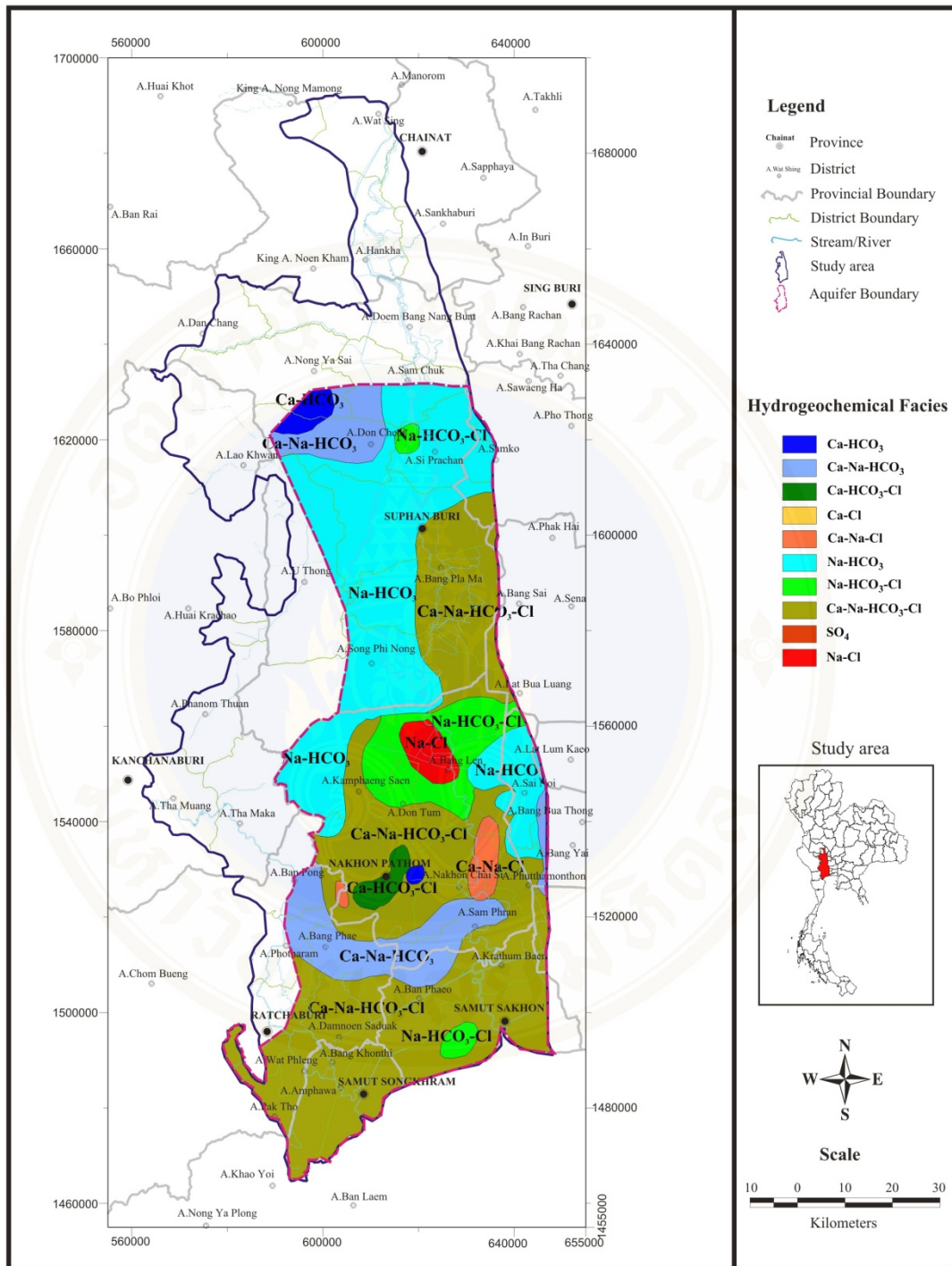
Appendix C1: Map of Hydrogeochemical Facies Distribution of Aquifer Layer I (BK)



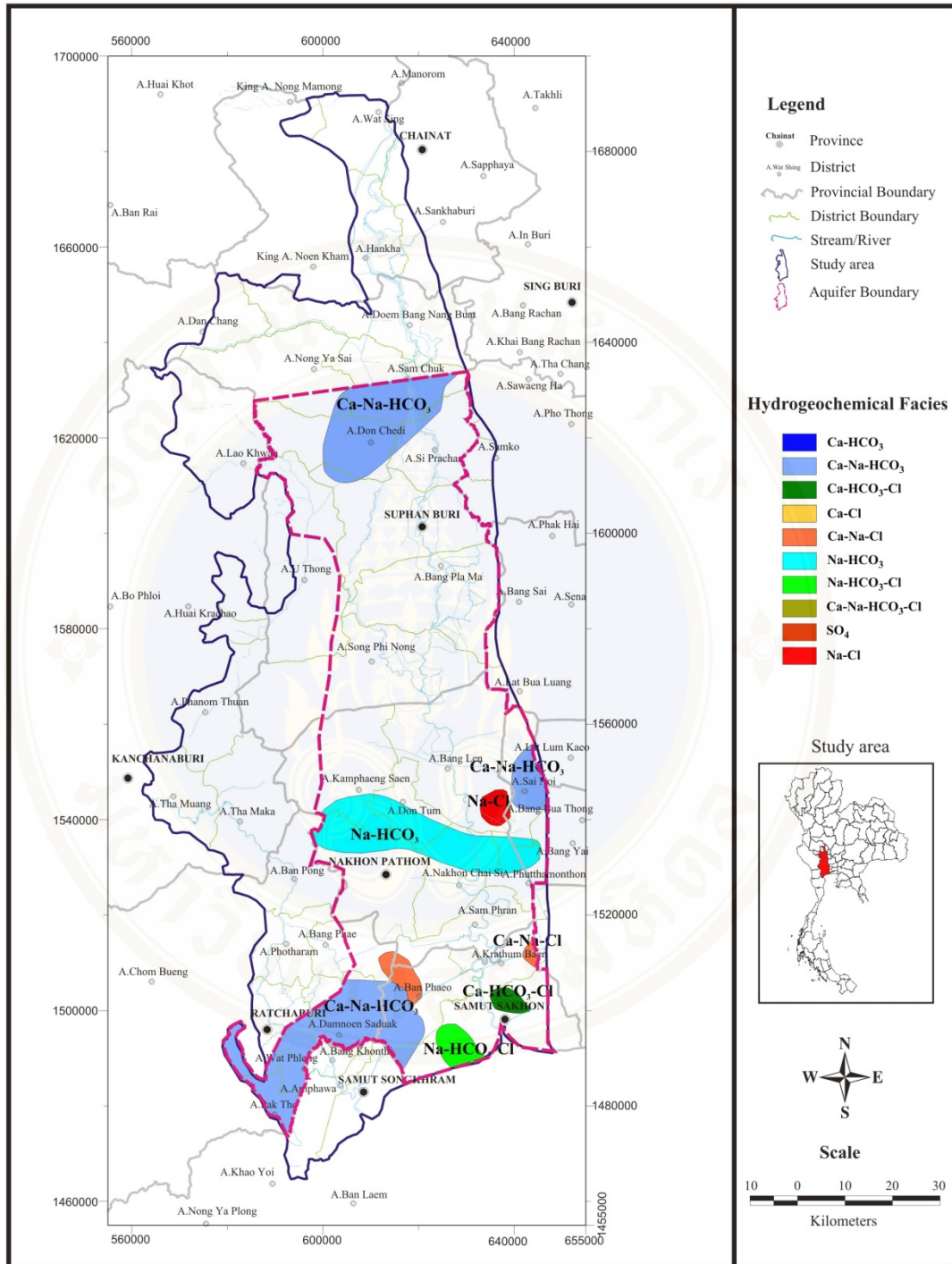
Appendix C2: Map of Hydrogeochemical Facies Distribution of Aquifer Layer II (PD)



Appendix C3: Map of Hydrogeochemical Facies Distribution of Aquifer Layer III (NL)



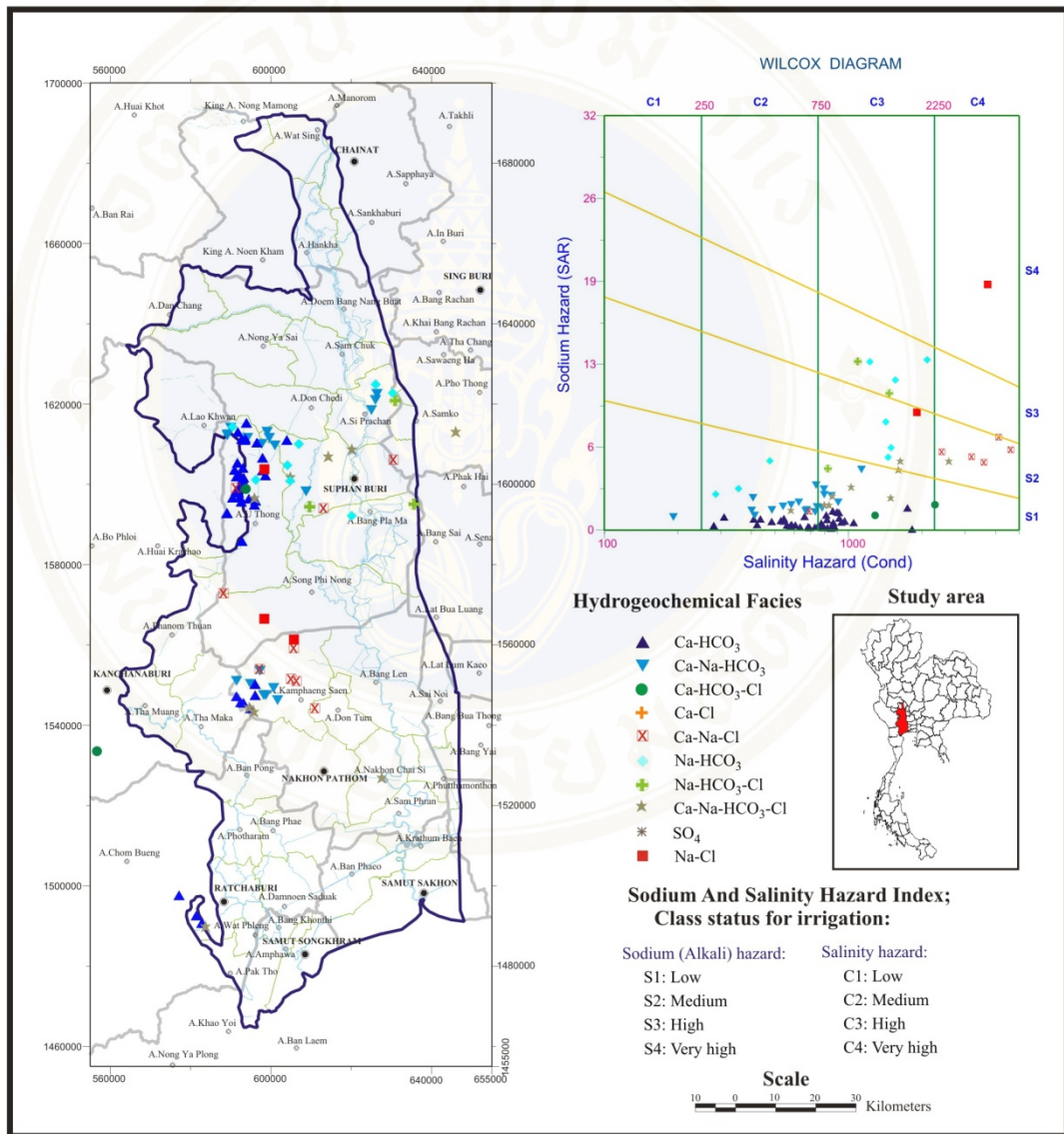
Appendix C4: Map of Hydrogeochemical Facies Distribution of Aquifer Layer IV (NB)



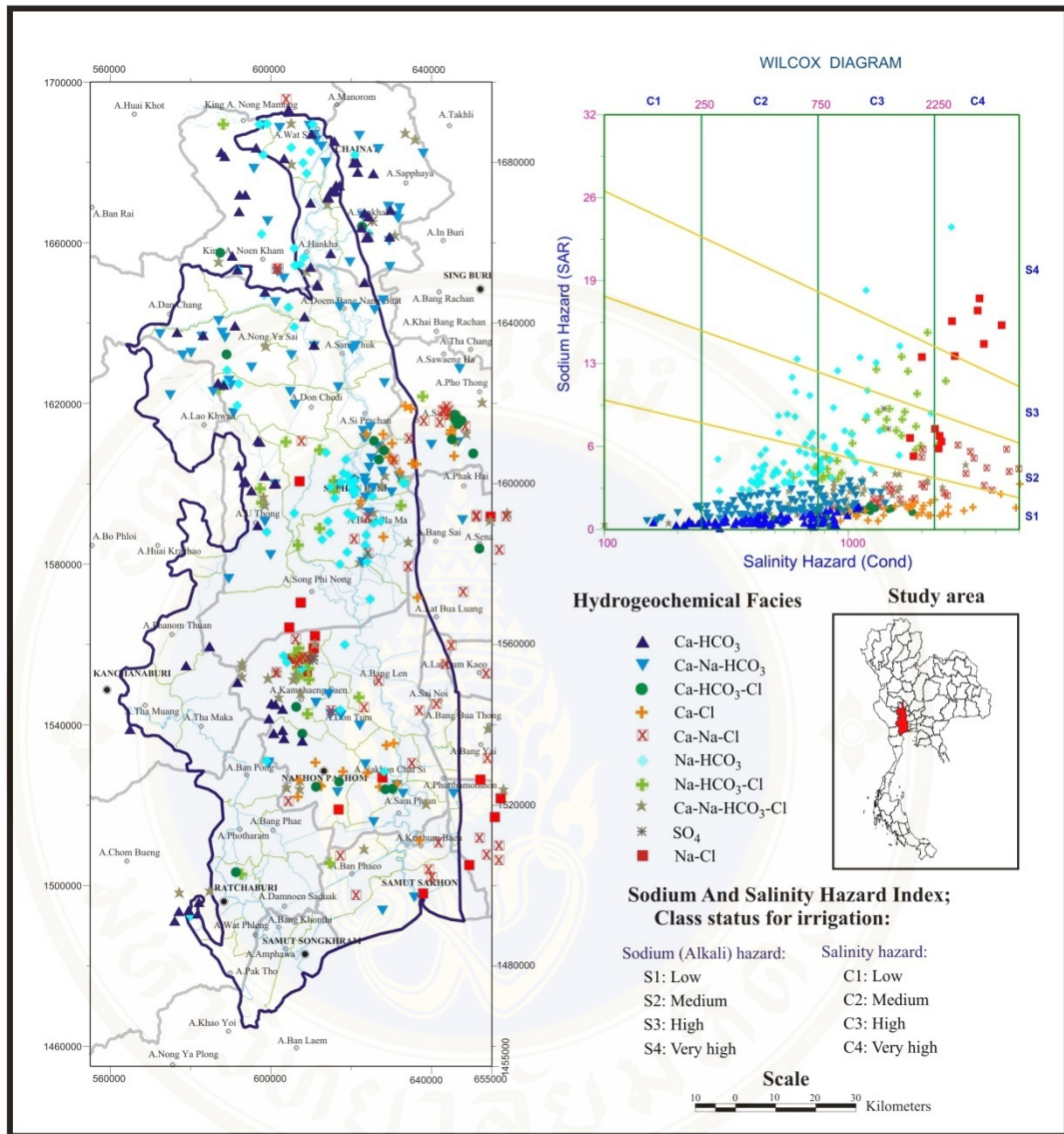
Appendix C5: Map of Hydrogeochemical Facies Distribution of Aquifer Layer V (Deeper layer than NB)

## APPENDIX D

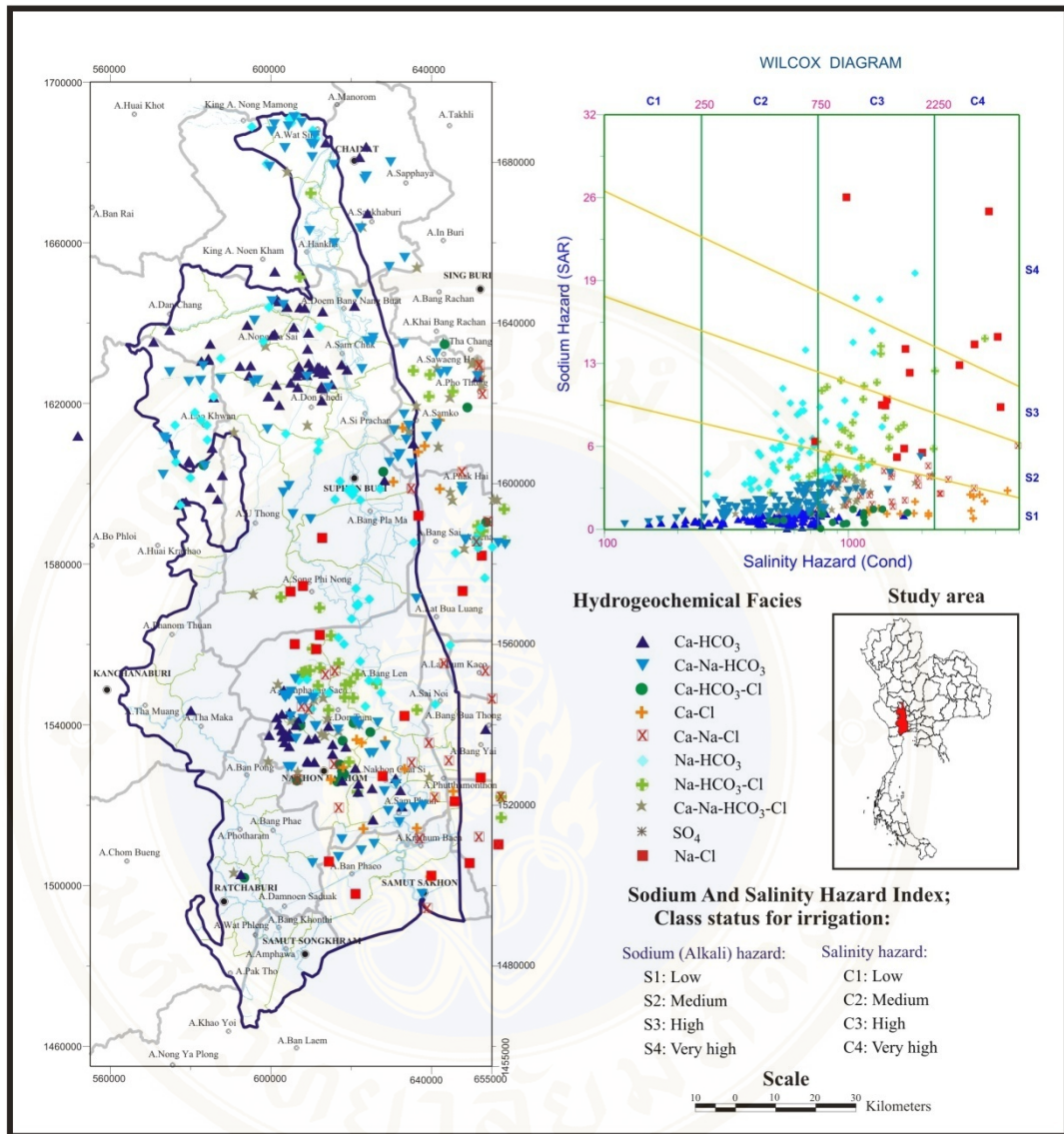
### WILCOX DIAGRAM OF AQUIFER LAYER I-V



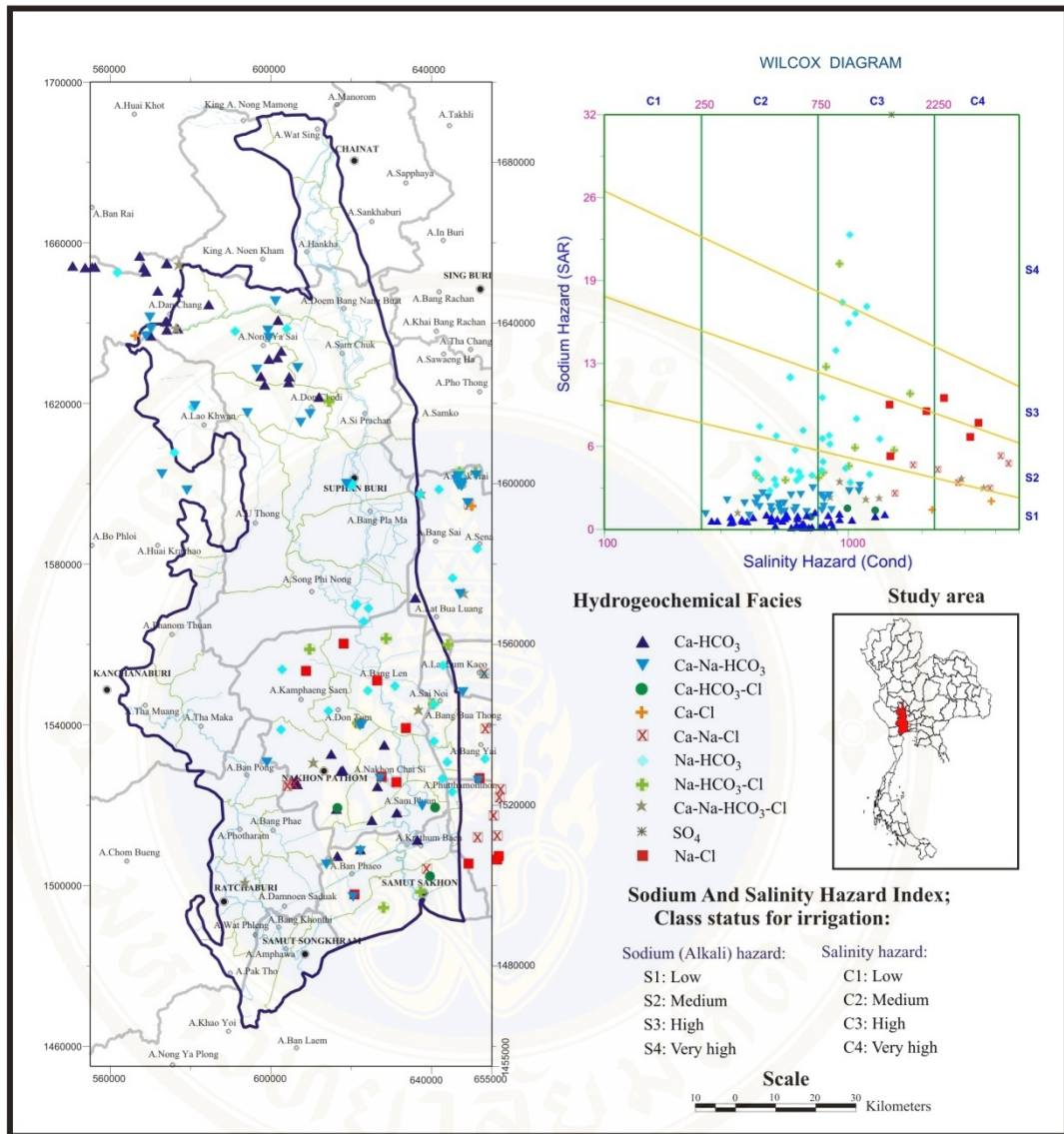
Appendix D1: Wilcox Diagram of Aquifer Layer I (BK)



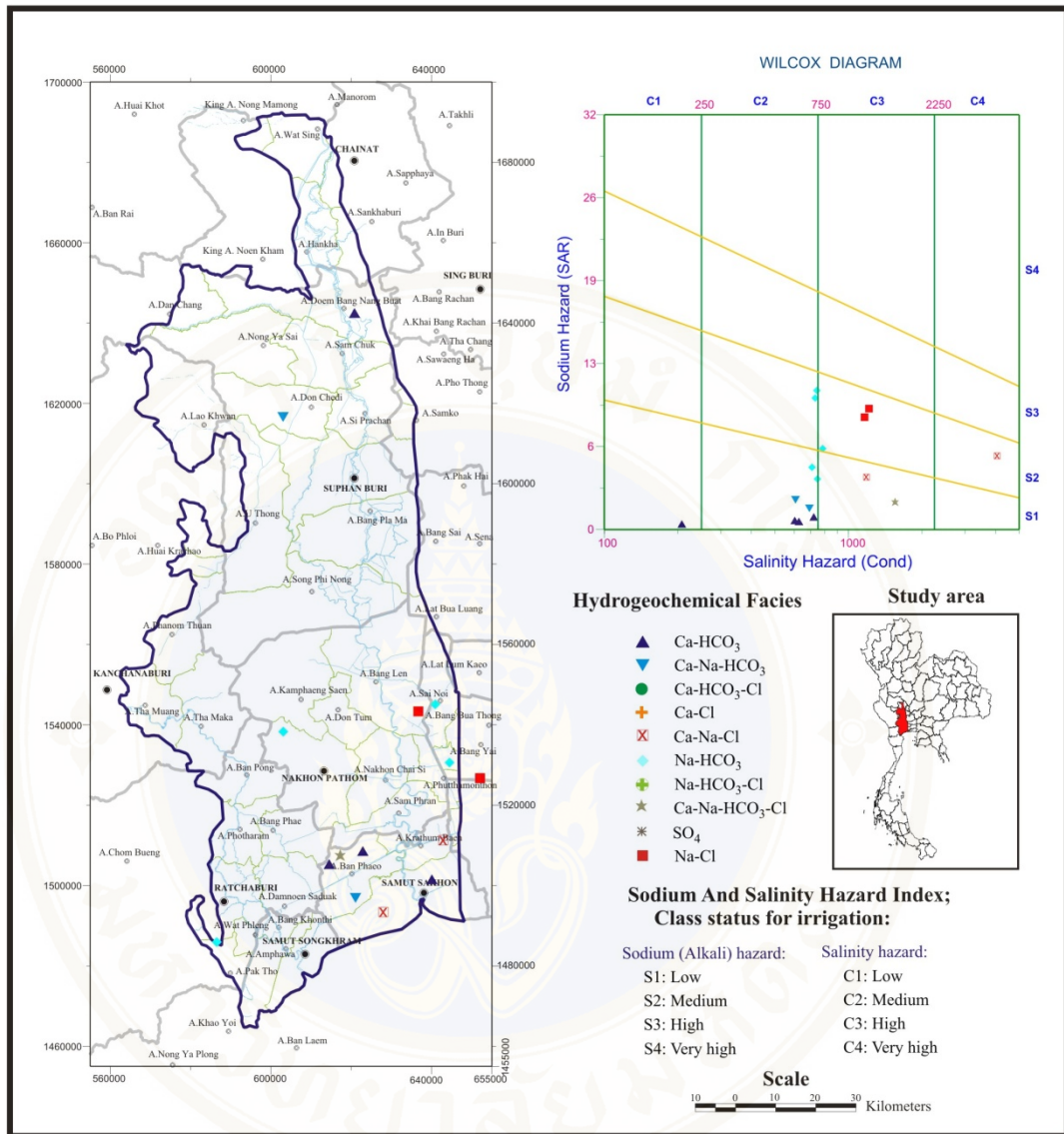
Appendix D2: Wilcox Diagram of Aquifer Layer II (PD)



Appendix D3: Wilcox Diagram of Aquifer Layer III (NL)



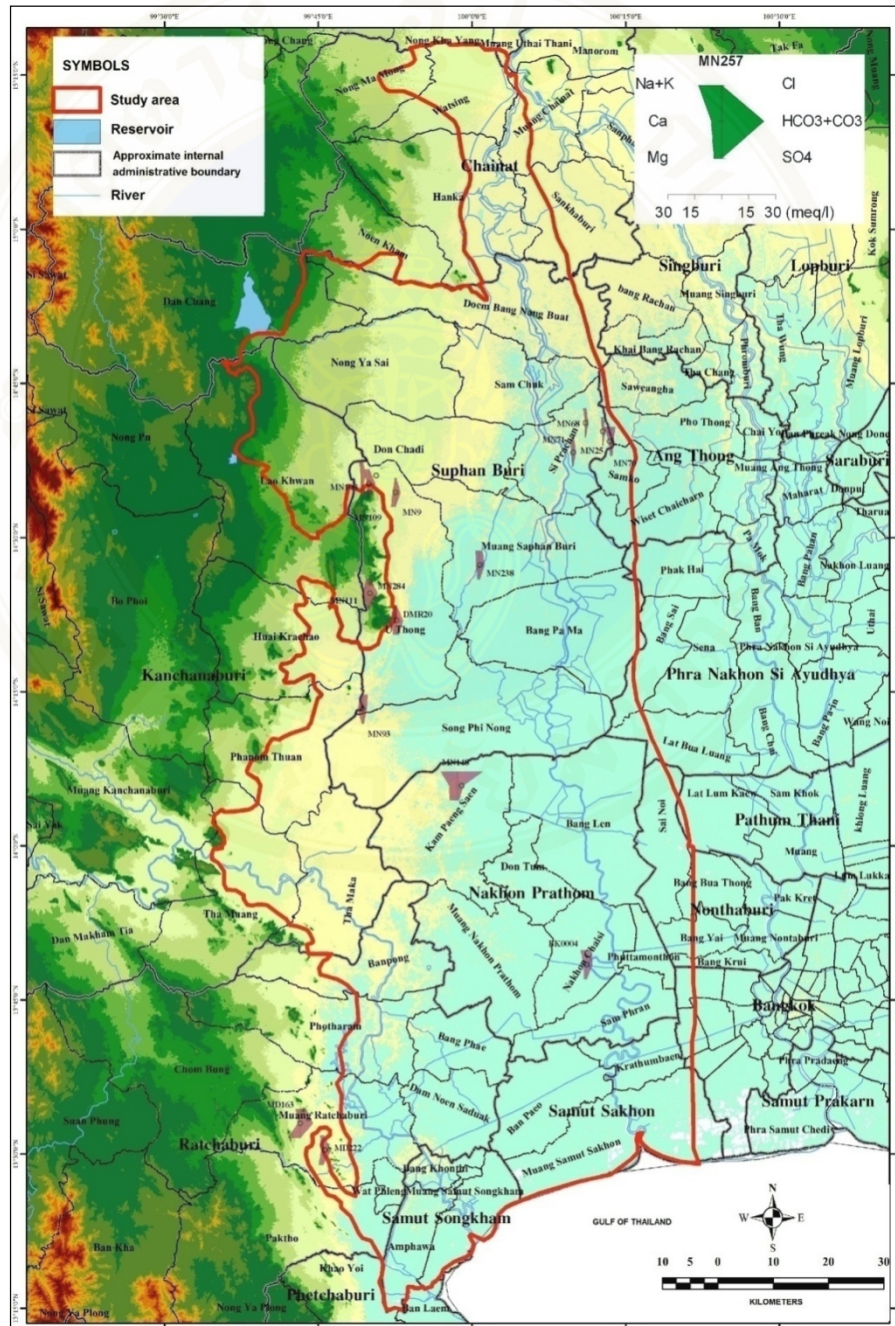
Appendix D4: Wilcox Diagram of Aquifer Layer IV (NB)



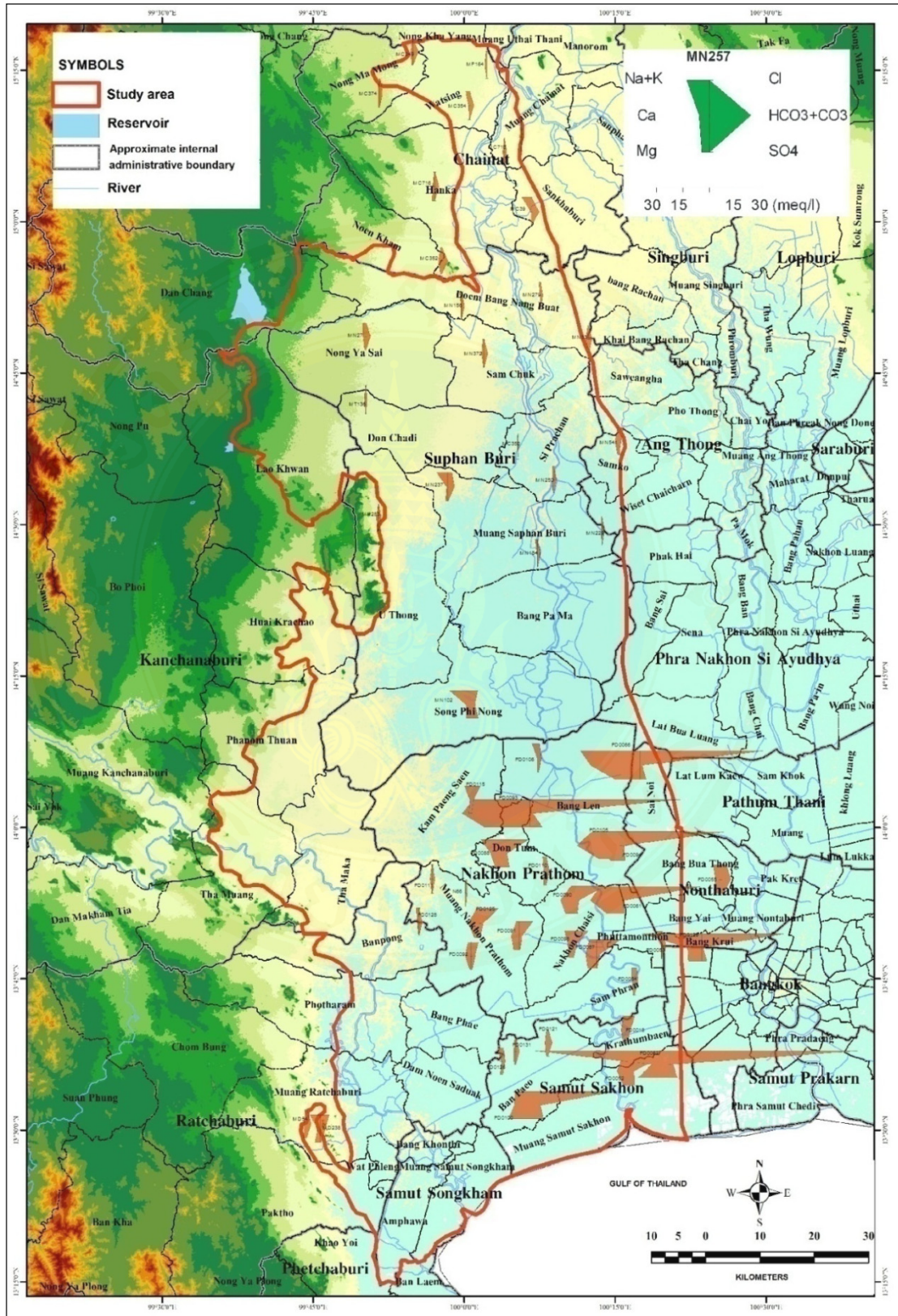
Appendix D5: Wilcox Diagram of Aquifer Layer V (Deeper layer than NB)

## APPENDIX E

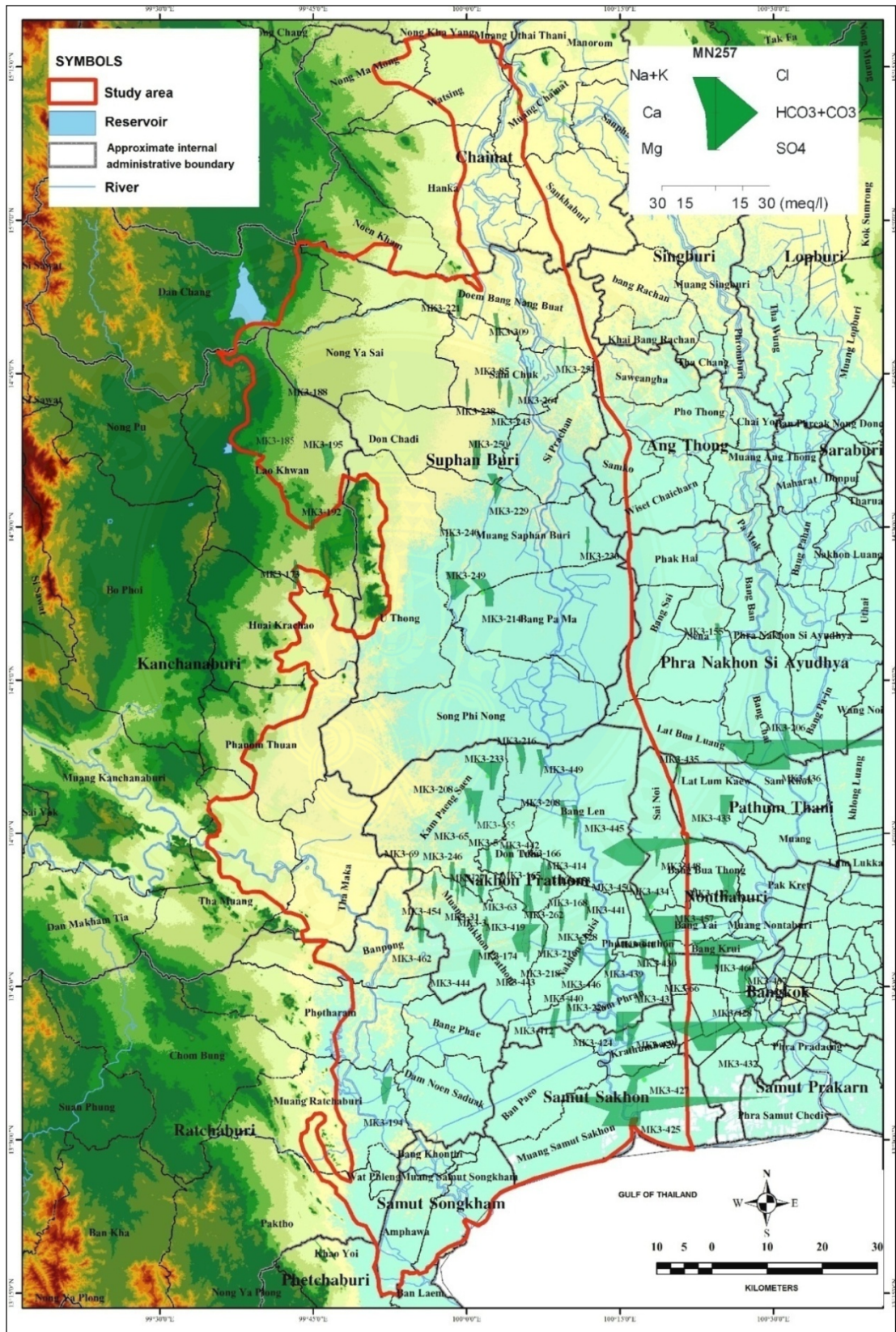
### MAP OF STIFF DIAGRAM DISTRIBUTION OF AQUIFER LAYER I-V



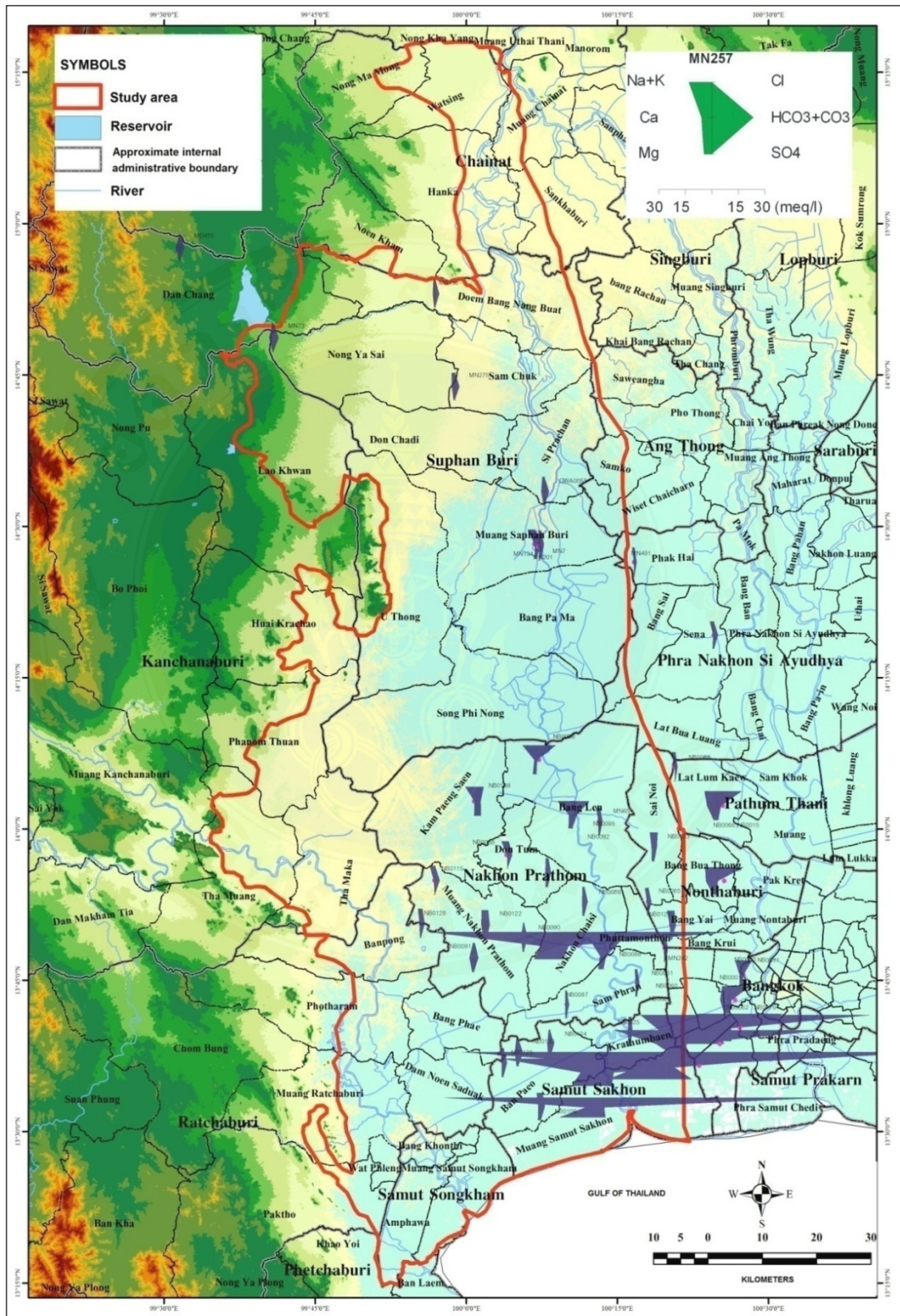
Appendix E1: Stiff Diagram of Aquifer Layer I (BK)



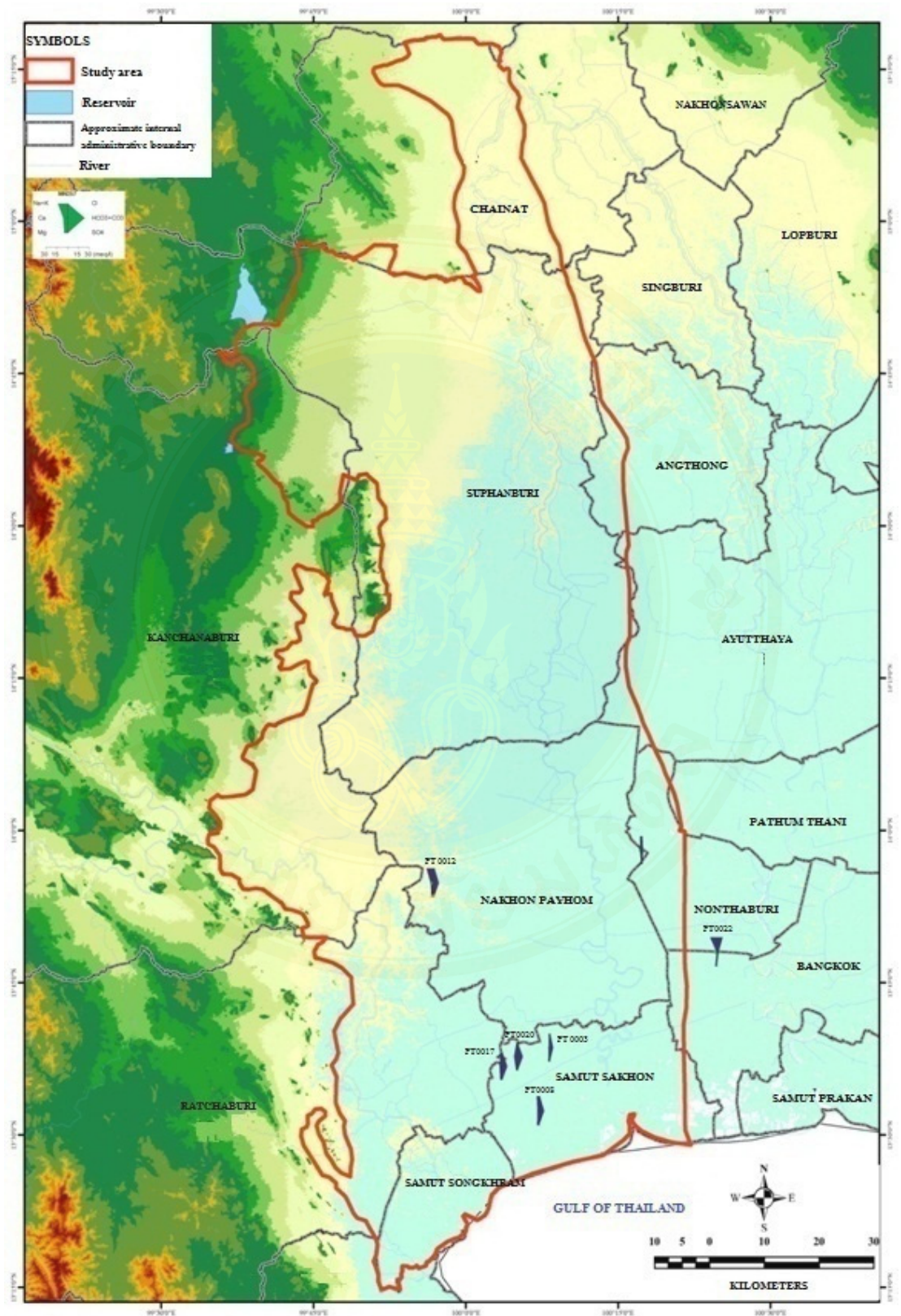
Appendix E2: Stiff Diagram of Aquifer Layer II (PD)



Appendix E3: Stiff Diagram of Aquifer Layer III (NL)



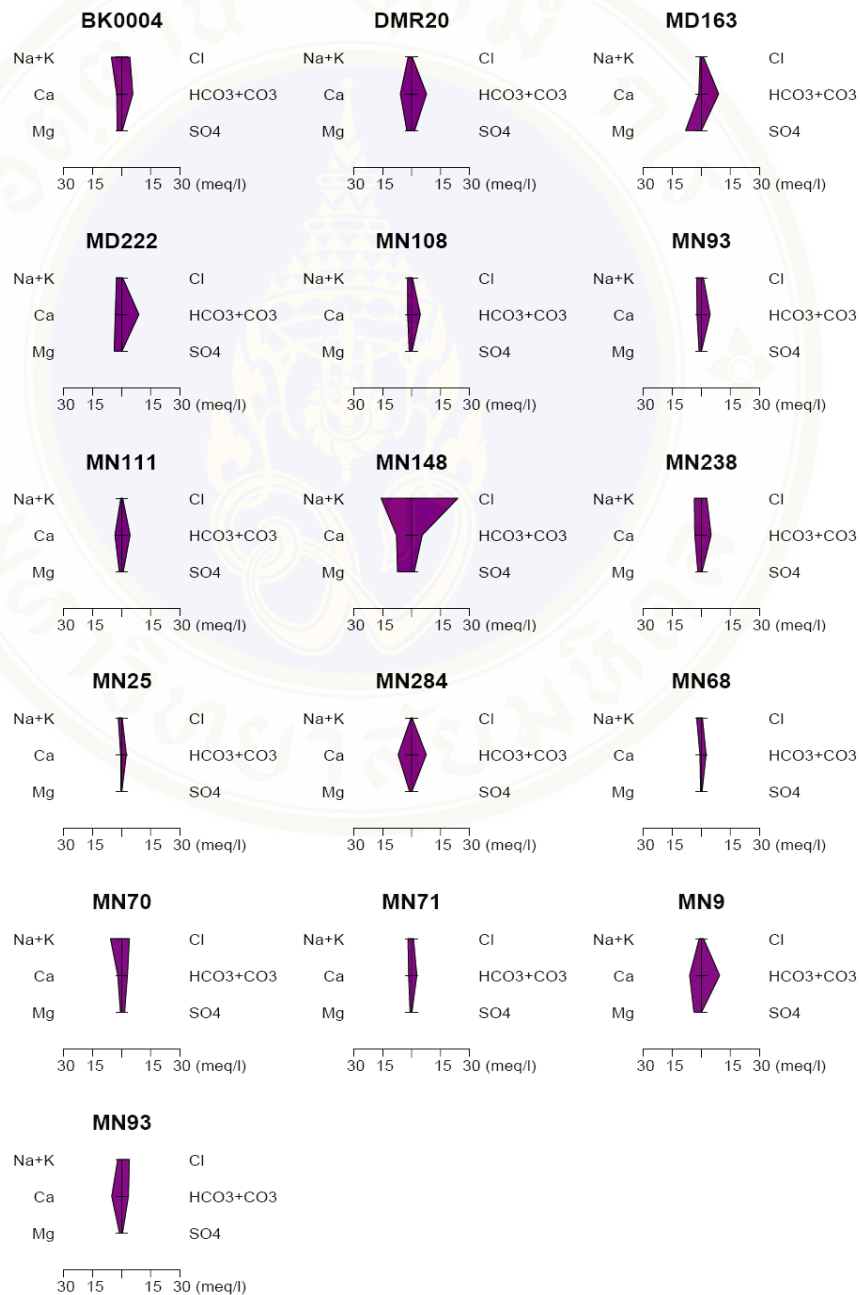
Appendix E4: Stiff Diagram of Aquifer Layer IV (NB)



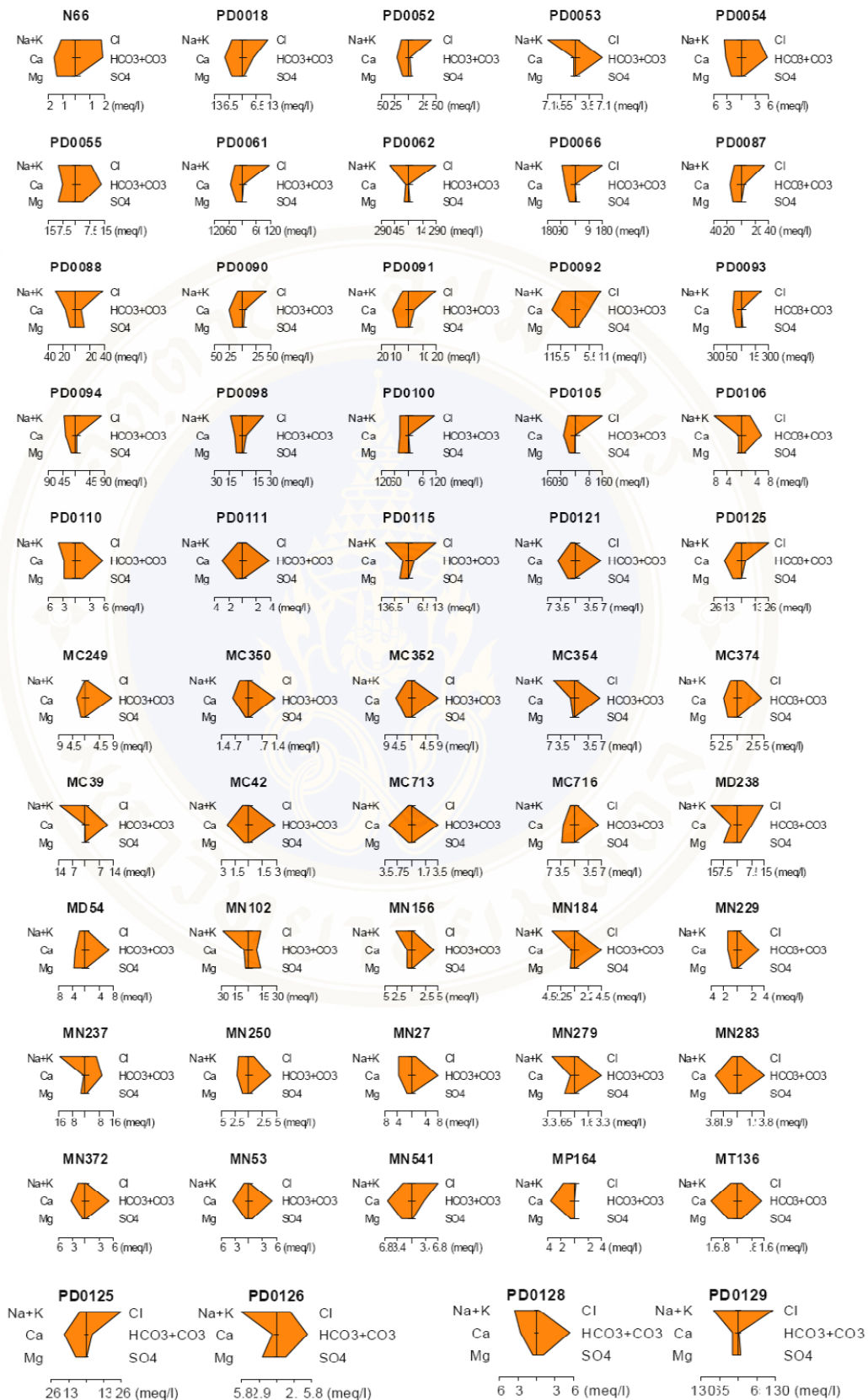
Appendix E5: Stiff Diagram of Aquifer Layer V (Deeper layer than NB)

## APPENDIX F

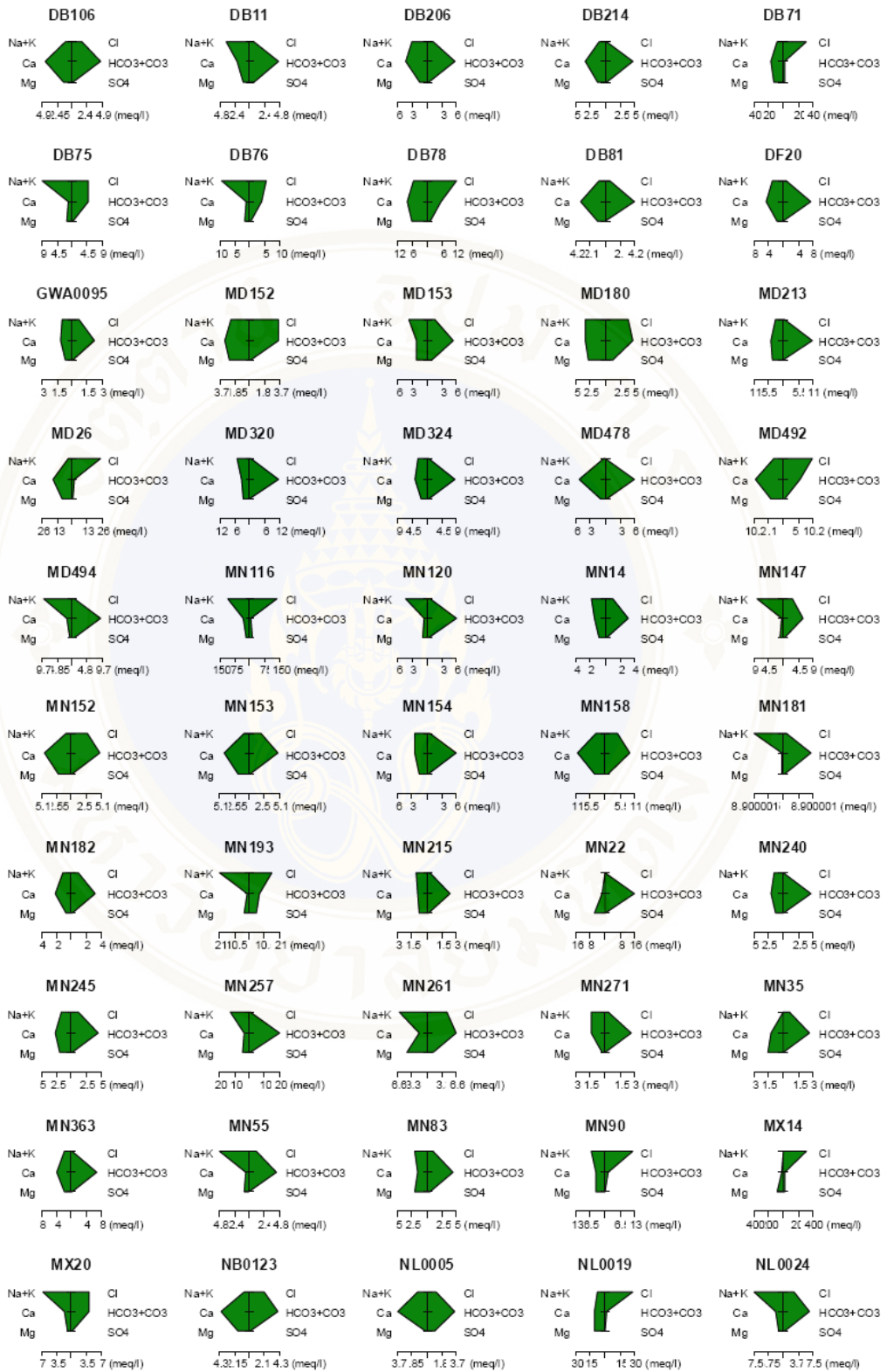
### STIFF DIAGRAMS OF EACH WELL FOR AQUIFER LAYER I-V



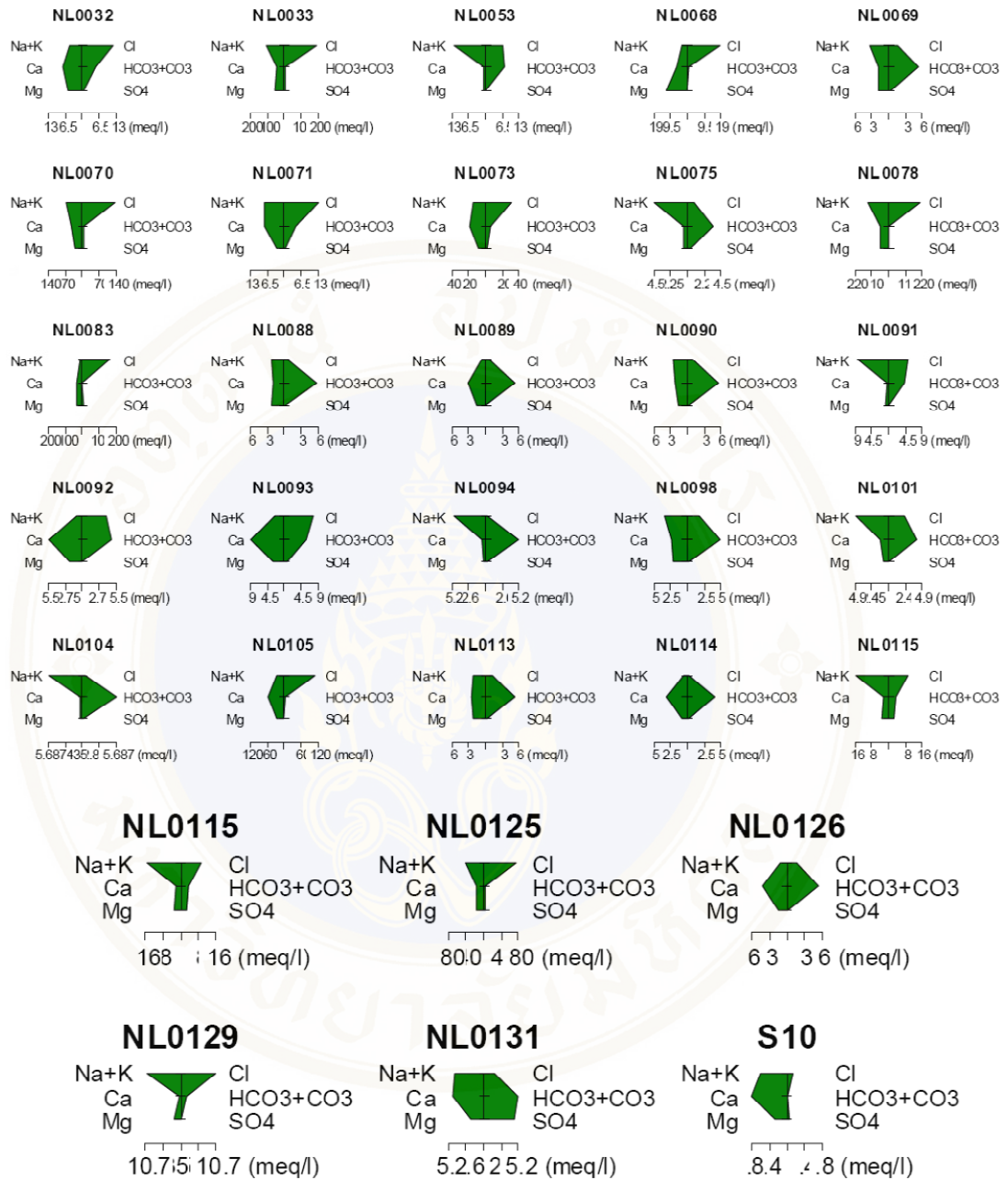
Layer I (BK)



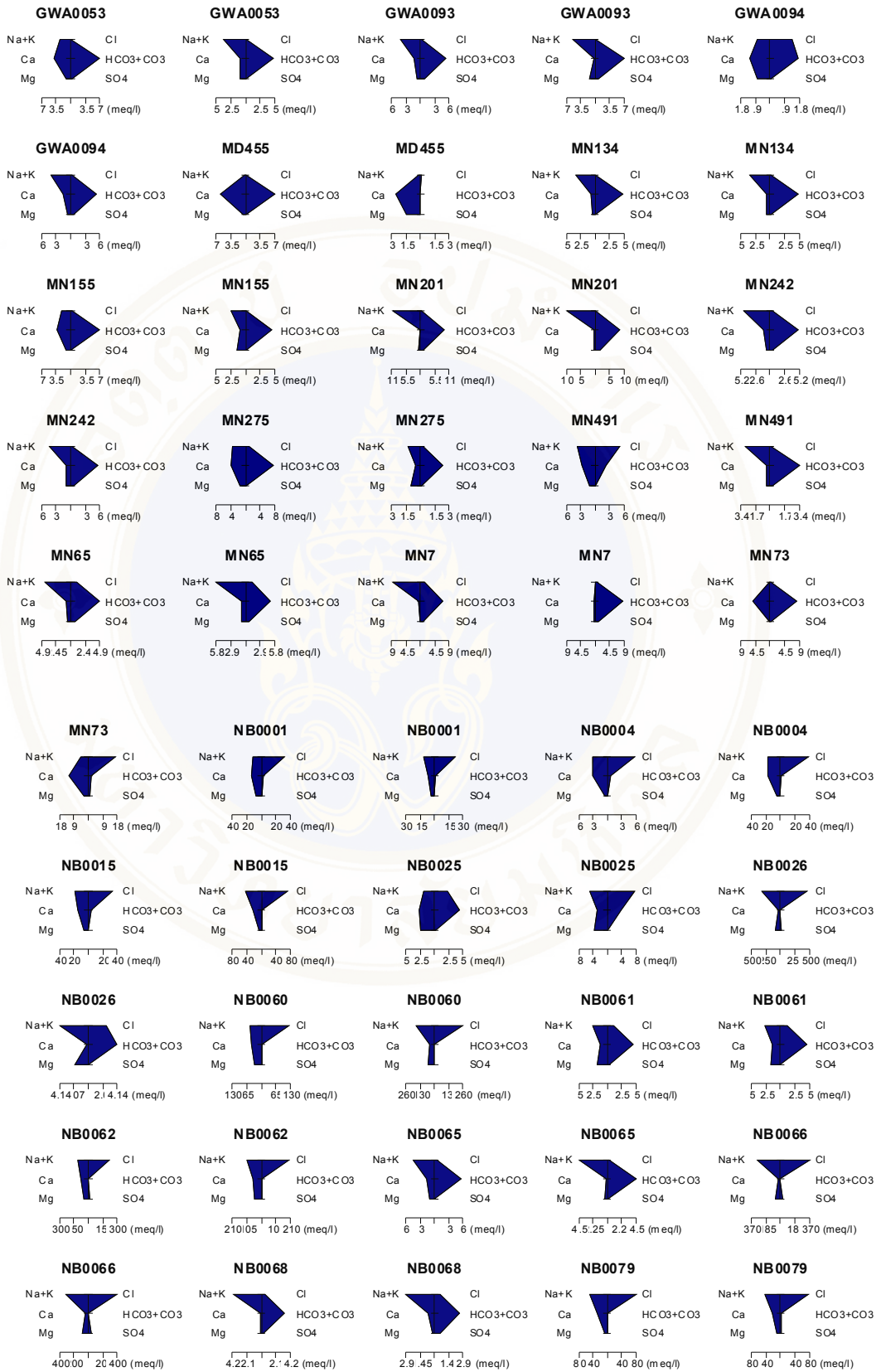
Layer II (PD)



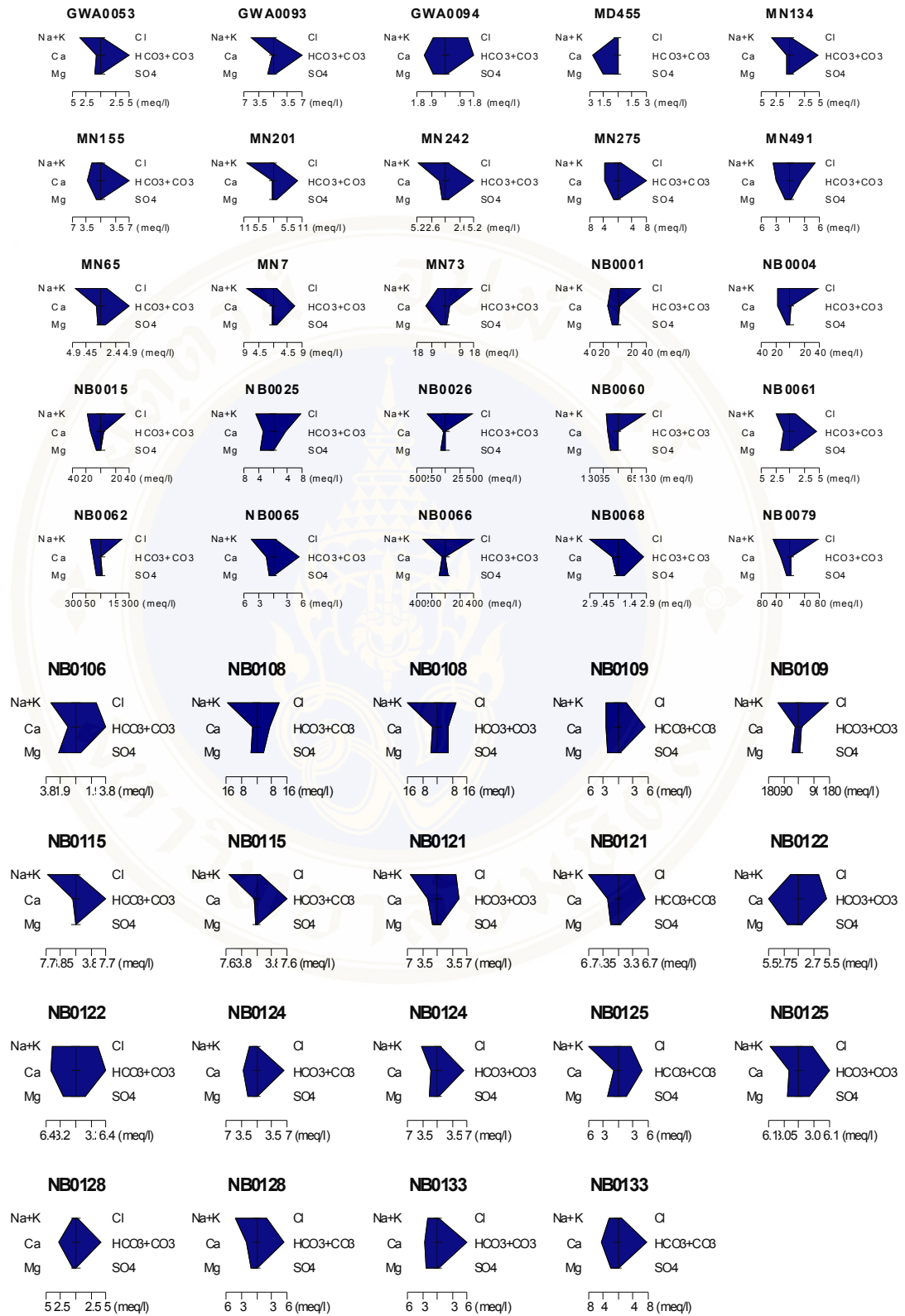
Layer III (NL)



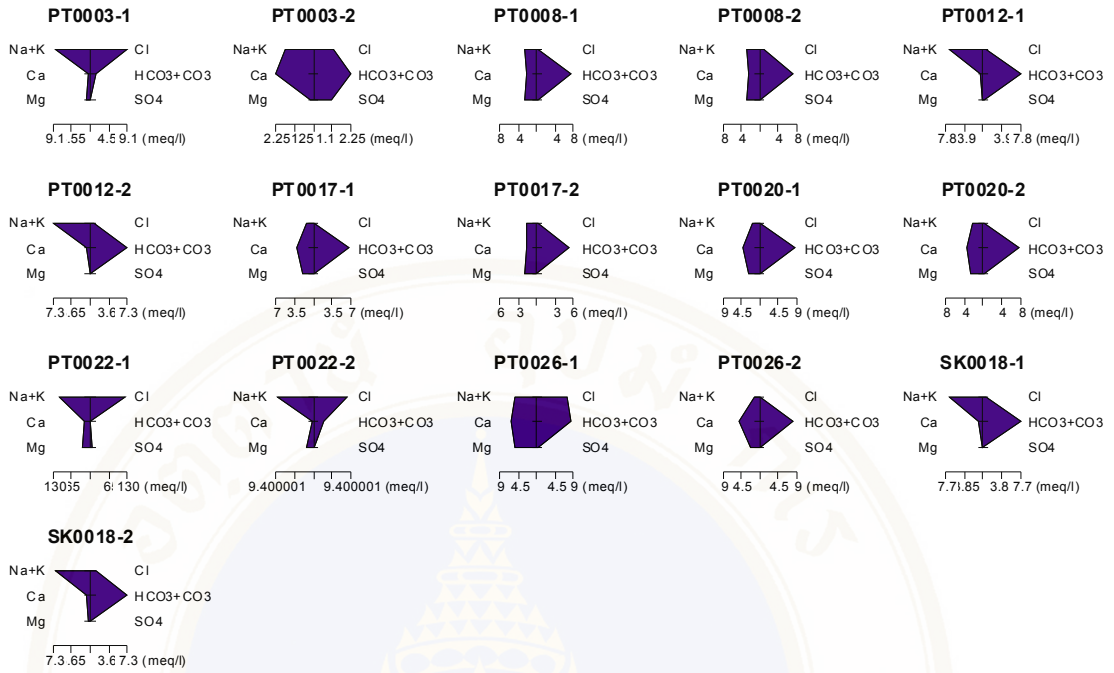
Layer III (NL) (cont.)



Layer IV (NB)



Layer IV (NB) (cont.)



Layer V (Deeper than NB)

APPENDIX G

DETAILS OF WELLS SELECTED ALONG PRINCIPLE FLOW PATHS

**The cluster of wells along Kanchanaburi - Angthong Flow Path (A - A')**

Order	Sample no.	Well ID.	Easting	Northing	Location	SubDistrict	District	Province	Depth(m)	Diameter(mm)	Slotted/screen	SWL(mbgs)	Collection date	pH	EC	Ca	Mg	Na	K	Fe	Mn	SO <sub>4</sub>	Cl	CO <sub>3</sub>	HCO <sub>3</sub>	F	NO <sub>2</sub>	NO <sub>3</sub>	TH	non-H	TDS
1	MK3-181	MD294	383800	1623900	วัดบ้านใหม่	บ้านใหม่	บ้านใหม่	กาญจนบุรี	30	100	24-30	12	305112	8	888	60	19	120	5.9	11	0	11	27	-	581	0.4	0	0	229	0	532
2	MK2-198	MN129	387400	1623940	บ้านใหม่	บ้านใหม่	บ้านใหม่	กาญจนบุรี	24	125	15-21	10.14	30811	6	248	26	7.1	14	3.5	0.57	0.08	4.5	21	-	122	0.2	0	6.7	94	0	220
3	MK2-198	MN130	390950	1624650	บ้านใหม่	บ้านใหม่	บ้านใหม่	กาญจนบุรี	42	125	30-42	17.1	30695	7.8	649	49	19	67	2.7	0.88	0	11	14	-	379	1.1	0.49	23	202	167	344
4	MK3-275	MN406	396900	1623300	บ้านใหม่	บ้านใหม่	บ้านใหม่	กาญจนบุรี	51	125	24-30/42-48	9.6	33169	7.6	379	41	6.6	35	2.3	1.9	0.02	3	8	-	230	0.4	0	0	130	0	220
5	MK3-74	DB86	617900	1513500	บ้านใหม่	บ้านใหม่	บ้านใหม่	กาญจนบุรี	159	125	188-144/150/156/26-97	34040	7.5	681	78	27	30	6.6	0	0.01	5	12	-	376	0.3	0.01	0.2	310	0	424	
6	MK3-416	MT39	603290	1623090	บ้านใหม่	บ้านใหม่	บ้านใหม่	กาญจนบุรี	51	125	42-48	7.5	33326	6.9	498	87	0.5	21	3.5	0.37	0.42	11	8.8	-	312	0.4	0.03	0	220	0	282
7	MK3-385	MQ495	638900	1600900	บ้านใหม่	บ้านใหม่	บ้านใหม่	กาญจนบุรี	166.5	100	138-162	9.86	32501	7.3	2100	247	46	67	9.4	0.52	2.4	10	575	-	140	0.1	0.04	0.4	806	691	1020
8	MK3-87	DF11	644850	1626000	บ้านใหม่	บ้านใหม่	บ้านใหม่	กาญจนบุรี	120	125	108-120	0	33751	7.7	532	67	19	25	7	0.22	0.35	2	6	-	335	0.6	0.04	0	240	0	268
9	MK2-276	MN413	628800	1623200	บ้านใหม่	บ้านใหม่	บ้านใหม่	กาญจนบุรี	63	125	54-60	6.6	33224	6.4	268	21	9.6	21	2.7	7.2	0.64	11	3	-	150	0.2	0.02	0.6	92	0	156
10	MK2-336	MP165	603700	1615860	บ้านใหม่	บ้านใหม่	บ้านใหม่	กาญจนบุรี	31.5	125	25.5-31.5	5.51	34016	7.3	928	120	44	23	5.1	0.13	0.1	3	12	-	540	0.5	0	0.2	490	50	552
11	MK2-346	MP81	633450	1686900	บ้านใหม่	บ้านใหม่	บ้านใหม่	กาญจนบุรี	36	100	30-36	6	33276	7.3	2110	100	97	220	0	1.8	0.05	110	250	-	548	0.2	0.53	200	650	201	1410
12	MK3-468	S15	653990	1626600	บ้านใหม่	บ้านใหม่	บ้านใหม่	กาญจนบุรี	66	200	57-63	5.19	25317	8	904	37	20	107	0	0.46	0	112	96	-	189	0	0	174	19	615	

Order	Sample no.	Well ID.	Easting	Northing	Location	SubDistrict	District	Province	Depth(m)	Diameter(mm)	Slotted/screen	SWL(mbgs)	Collection date	pH	EC	Ca	Mg	Na	K	Fe	Mn	SO <sub>4</sub>	Cl	CO3	HCO <sub>3</sub>	F	NO <sub>2</sub>	NO <sub>3</sub>	TH	non-H	TDS	
1	MK1-198	MD519	620340	1531050	บ้านโพธิ์ทอง	สามชัยวนาลัย	เมืองนครปฐม	นครปฐม	132	100	102-108,114-126	15.9	32682	8.1	480	8.2	15	60	14	0.7	0	13	71	-	128	0.3	0	0.9	84	0	299	
2	MK1-20	DS24	595773	1543463	บ้านศาลาหลัก	โพธิ์ทอง	บ้านโพธิ์	นครปฐม	48	150	36-44	12	36503	8.2	854	49	32	97	2.9	15	0.04	39	120	-	282	0.5	0.12	3.5	260	24	477	
3	MK1-4	DB112	596400	1544090	บ้านท่าทราย	โพธิ์ทอง	บ้านโพธิ์	นครปฐม	45	150	36-42	7.2	34345	7.5	534	73	11	28	2	0.12	0.12	5	13	-	347	0.5	0.07	0	230	0	304	
4	MK1-55	DF15	606640	1547768	บ้านบึงเขาส	บ้านบึงเขาส	บ้านโพธิ์	นครปฐม	75	150	69-75	14	35421	8.2	644	79	23	37	0.8	0.24	0.18	14	56	-	352	0.3	0.01	0.1	290	4	383	
5	MK1-3	DB114	603540	1544800	บ้านลำไย	โพธิ์ทอง	บ้านโพธิ์	นครปฐม	96	125	90-96	13.5	36621	8	376	35	18	23	3.1	0.5	0	9	14	-	221	0.3	0.01	2.1	160	0	206	
6	MK1-71	DN44	606566	1544127	บ้านหนองจอก	โพธิ์ทอง	บ้านโพธิ์	นครปฐม	96	150	78-90	18	36319	7.7	1480	120	56	81	4.6	0.06	0	9	340	-	286	0.5	0	2.1	530	300	748	
7	MK1-58	DB35	609390	1545090	บ้านหนองเขม	โพธิ์ทอง	บ้านโพธิ์	นครปฐม	123	125	117-123	16.2	33672	7.8	638	36	17	87	3.5	0.04	0.02	20	27	-	345	0.8	0.15	0	160	0	314	
8	MK1-87	DF21	614850	1636300	บ้านเกาะ	บ้านเกาะ	สามชัยวนาลัย	นครปฐม	120	125	108-120	0	33751	7.7	532	67	19	25	7	0.22	0.35	2	6	-	335	0.6	0.04	0	240	0	268	
9	MK1-54	MN34	613390	1544090	โรงเรียนบ้านโพธิ์	สามชัยวนาลัย	เมืองนครปฐม	นครปฐม	36	125	30-36	7.81	29334	7.3	4600	224	117	462				0.8	173	1137	-	313	0.3	0.01	5.8	1040	784	2682
10	MK1-177	MD149	617540	1545090	ศาลเจ้าบ้านท่าทราย	บ้านท่าทราย	บ้านโพธิ์	นครปฐม	97.5	150	87-90,93-96	9.86	28880	7.7	805	43	27	67				1.4	8.4	50	-	345	0.8	0	0	218	0	455
11	MK1-200	MD533	620650	1545300	โรงเรียนหนองเขม	สามชัยวนาลัย	เมืองนครปฐม	นครปฐม	126	150	99-105,117-123	12	32883	7.8	998	40	9.3	170	3.1	0.28	0.01	52	116	-	343	1.4	0	0	138	0	576	
12	MK1-273	MD336	622509	1546425	บ้านท่าทราย	บ้านท่าทราย	บ้านโพธิ์	นครปฐม	99	100	90-96	9.58	32959	7.8	909	30	15	143	2.7	2.5	0.01	73	77	-	307	2	0	0	136	0	500	
13	MK1-107	DN22	628032	1547616	โรงเรียนบ้านท่าทราย	บ้านท่าทราย	บ้านโพธิ์	นครปฐม	162	150	146-158	18	35751	8.9	518	12	6.4	110	2	0.22	0.03	7	26	31	248	1.7	0.02	0	55	0	316	
14	MK1-33	GI231	648717	1548173	โรงเรียนบ้านท่าทราย	บ้านท่าทราย	เมืองนครปฐม	นครปฐม	198	125	186-198	22.93	35131	7.5	786	73	19	90	7.4	0.1	0	5	32	-	516	0.3	0.06	0.5	260	0	528	

**BIOGRAPHY**

<b>NAME</b>	Mr. Banjong Promchan
<b>DATE OF BIRTH</b>	14 <sup>th</sup> January, 1962
<b>PLACE OF BIRTH</b>	Nan, Thailand
<b>INSTITUTIONS ATTENDED</b>	Chiangmai University, 1981 – 1987 Bachelor of Science (geology) Sukhothai Thammathirat University, 1993 – 1996 Bachelor of Public Administration (Personnel Administration) Mahidol University, 2007 – 2011 Master of Science (Technology of Environmental Management)
<b>ADDRESS</b>	13/4, Soi Chuchart Anusorn, Tiwanon Road, Tambon Bangtalat, Amphoe Pakkret, Nonthaburi, 11100, Thailand E-mail: bj_phromjan@yahoo.com
<b>OFFICE</b>	Department of Groundwater Resources 26/83 Soi Ngamwongwan 54, Ngamwongwan Road, Ladyao, Chatuchak, Bangkok Thailand 10900 Tel: (66)22993900 Fax: (66)22993926