International Journal of Environmental Engineering– IJEE
Volume 1 : Issue 4 [ISSN 2374-1724]
Publication Date : 27 December,2014

Assessing Groundwater Potential of a Limestone Aquifer in Lopburi Province, Central Thailand

Wanida Piamtang and Schradh Saenton

***Abstract*—An assessment of groundwater potential in Huaykhunram subdistrict, Phattana Nikhom district, Lopburi province, Central Thailand was conducted. The study area was underlain by a fractured limestone aquifer where groundwater flow regime is complex and difficult to characterize. Groundwater is the main agricultural water source in this area and its quantity must be estimated for better planning of irrigation system. Primary study indicated that agriculture and domestic usage of groundwater in an area of approximately 100 km^2 was as large as 1.26 Mm^3/yr where the natural recharge and safe yield were approximately 3.89 Mm^3/yr. The groundwater is mainly Ca-HCO$_3$ and Ca-Mg-HCO$_3$ water types. The geochemical elements indicate quality of groundwater is controlled mainly by the dissolution of carbonate rocks. Future work will include pumping and tracers test as well as groundwater modeling using MODFLOW-CFP (conduit-flow process) to better assess groundwater resource of this area.**

***Keywords*—groundwater, limestone, potential, aquifers**

I. Introduction

An agricultural site in central Thailand is growing rapidly and has caused an increasing use of groundwater in Thailand. Lopburi is one of several provinces in central Thailand which has increasing demand of groundwater usage due to a development of industrial estates and expanding agricultural production areas. A rapidly increasing groundwater exploitation has led to several environmental consequences including water-table drop, dried dug wells, and drought [1]. This research is expected to provide better understanding of groundwater flow characteristics in limestone aquifers that can be used to improve water resource management in the study area.

A limestone or karst aquifer is a carbonate aquifer where groundwater flow dominantly occurs through bedding planes, fractures, conduits, and caves created by and/or enlarged by dissolution. Conventional groundwater modeling methods assume that groundwater flow can be described by Darcian principles where primary porosity (i.e. matrix porosity) and laminar flow are dominant in the aquifer.

Wanida Piamtang[a], Schradh Saenton[b]

Department of Geological Sciences, Faculty of Science, Chiang Mai University, Chiang Mai 50200 THAILAND
Tel. +66 5394 3418, Fax. +66 5389 2261

However, in karst aquifers this assumption is inapplicable due to the dual porosity present in karst aquifers. While Darcian principles may apply to the matrix portion of the karst aquifer, they often do not apply to flow through conduits, where flow velocities can be great enough to invalidate the applicability of Darcy's Law. Thus, different methodologies must be used to model groundwater flow in karst aquifers. Shoemaker et al. [15] and Reimann and Hill [14] developed a new subroutine for MODFLOW program [8] that enables MODFLOW to simulate flow in karst aquifers. The subroutine was tested and found to be successful in simulating flow in a sub-regional scale test site [7].

This research aims to assess hydrogeological conditions in limestone aquifers in Huaykhunram subdistrict and its vicinity. It is expected that this study will provided better understanding of groundwater flow characteristics in limestone aquifers of the study area.

II. Study area

The study area is Huaykhunram subdistrict, Phatthana Nikhom District, Lopburi Province. The study area covers an area of 100 km^2 is located 180 km north of Bangkok, capital city of Thailand (Fig. 1). This region is characterized by a tropical climate (monsoon type). The dry season begins in October to May, followed by a rainy season between June to September. The climate is very hot in the summer and cold in the winter. The mean annual temperature is approximately 27.0°C with a maximum daily temperature of 40.7°C and a minimum of 13.4°C. According to observational data from 2001 to 2010 at the Lopburi meteorological station, the mean annual precipitation in 2010 is 1,200 mm.

A. *Geology*

The study area is Huaykhonram Subdistrict, Phatthana Nikhom District, Lopburi Province. It is characterized by mountains and undulating hills related to a flat plain. Department of Mineral Resources [2] conducted a detailed geologic survey of Lopburi province. The geologic map in study area is shown in Fig. 2 and Table I. The mountainous area of the Khao Luk Mon is carbonates approximately 10 km^2, elongated in a north-south direction with the peak of 513 m above MSL. The surrounding undulating foothills and flat plain have elevation ranging from 300 to 150 m above MSL. The study area is underlain by the limestone of the Saraburi Group of Permian age [10] that identified 6 formations in Saraburi Group [11]. In stratigraphic order from oldest to youngest, namely Phu Phe, Khao Khwang, Nong Pong, Pang Asok, Khao Khad and Sap Bon formations. The Khao

International Journal of Environmental Engineering– IJEE
Volume 1 : Issue 4 [ISSN 2374-1724]
Publication Date : 27 December,2014

Khwang formation is located in the study area [16]. The type section of this formation is at Khao Khwang (late Pennsylvanian to middle Permian) in eastern Lopburi province, where 490 meter of dark to light grey, thick bedded limestone with nodular cherts has been measured [10]. The formation was deposited in a shallow-marine platform environment.

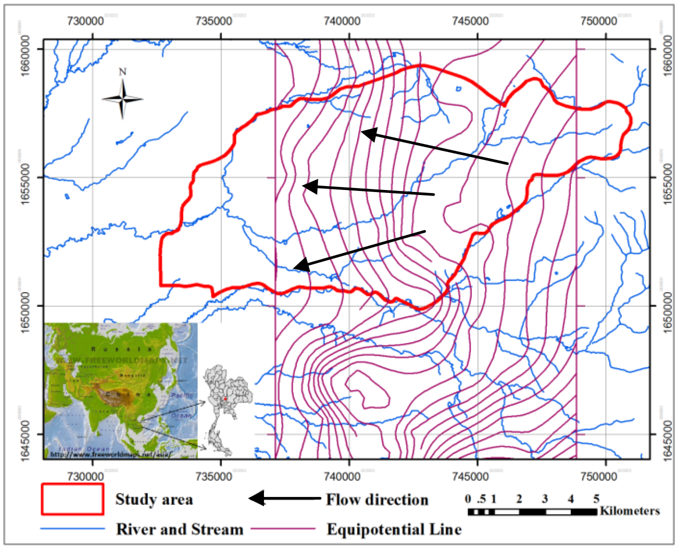

Figure 1. Map of the study area.

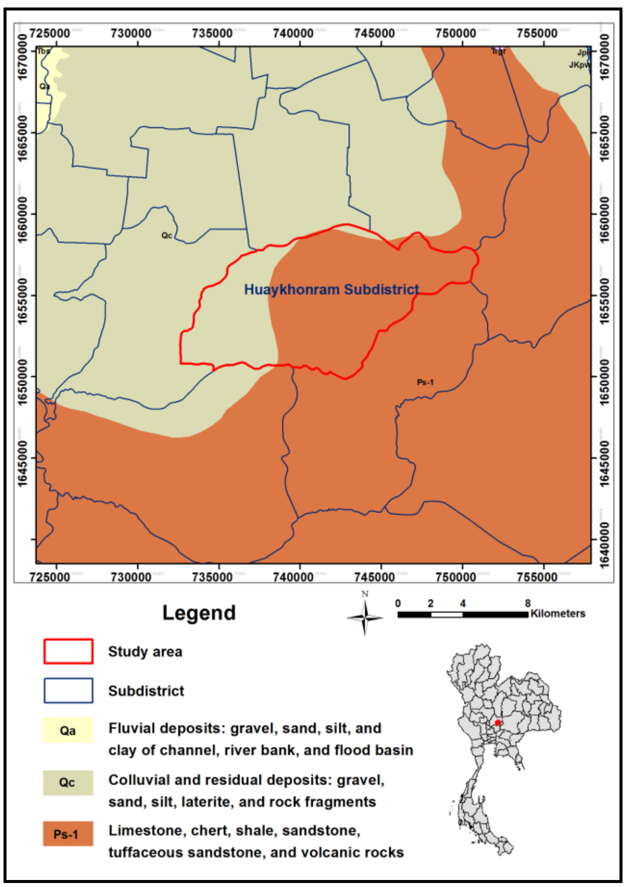

Figure 2. Geologic map of the study area.
(modified from Department of Mineral Resources, 2000)

Flat plain is covered by unconsolidated sediments of the Quaternary age. The sediments consist of colluvial deposits, and residual deposits. Colluvial deposits (Qc) are deposited surrounding foothills in north of study area. It is described as gravel, sand, silt, laterite and rock fragment.

TABLE I. GEOLOGICAL SUCCESSION OF THE STUDY AREA

Group	Formation	Lithological description
Recent	-	Colluvial and residual deposits: gravel, Sand, silt, and rock fragments.
Saraburi	Khao Khwang	Limestone: dark to light grey, thick bedded limestone with nodular cherts, chert, shale, sandstone, tuffaceous sandstone, and volcanic rocks.

B. *Hydrogeology*

The availability of groundwater in karst aquifer system of the Saraburi Group of Permian age varies widely due to complex geology [13]. This aquifer system has an expanded subsurface network of interconnected joints, fractures, and cavities. These interconnected fractures make conduits, leading water from the top of the mountains/karstic plateau to springs. The water obtain varies during two distinct seasons. During the dry season (October to May) the flow of the springs and streams reduces considerably and the mountains area the sinking streams were dry. During the rainy season (June to September) flooding occurs occasionally.

Department of Mineral Resources mapped groundwater aquifers of the Lopburi [2] and Saraburi Province [3] that can identify potential zones of groundwater in the colluvial deposits and limestone of the Saraburi group. The limestone aquifer system of the Saraburi Group is a major source of groundwater for domestic, industrial, and agriculture uses. At the mix of noncalcareous formations with karstic formations, streams are sinking underground to discharge to springs and caves [4]. The aquifer covering the entire study area is shown in Fig. 3. The average thickness of aquifers is 50 to 250 m with the yield ranging from 2 to 20 m^3/hr., water quality is generally good [5].

III. Methods

A. *Flow Characterization*

Field surveys were carried out two time from 2013 to 2014 in Huaykhunram Subdistrict, Phattana Nikhom district, Lopburi province under the Groundwater Development for Agriculture Project. The last survey has performed in September 2014. Groundwater level was measured in 28 wells to determine the equipotential line of the Limestone aquifer.

Static water levels of wells in the study area has been measured.

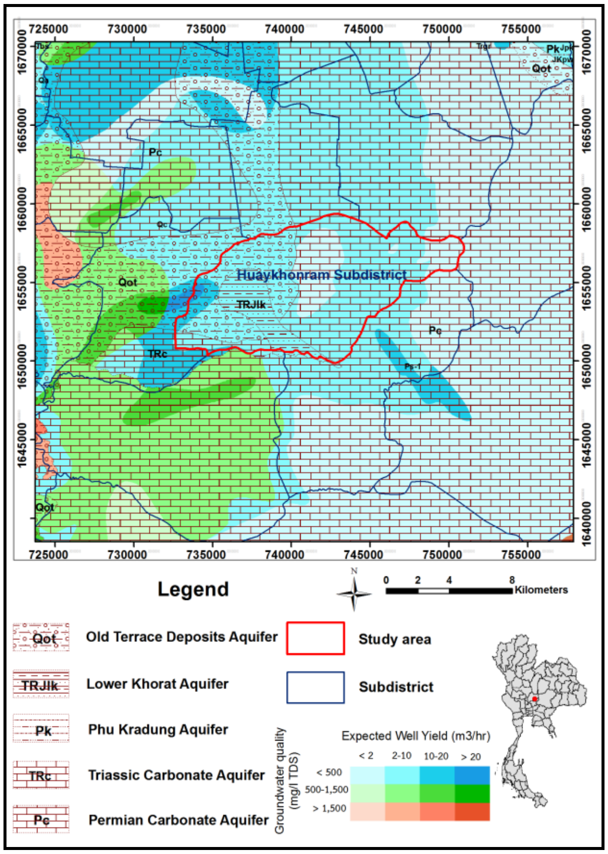

Figure 3. Hydrogeologic map of the study area.

(modified from Department of Mineral Resources, 2000)

The limestone aquifer is located at 5-60 m depth in the productive wells (4-20 m^3/h) which is connected to opening and interconnection of cave or fractures. Groundwater is abstracted from fractured and weathered limestone aquifer which is the main water-bearing formations in the study area. The depth to static water levels have been measured vary from 6 to 50 m. Groundwater level observations from different wells show that the regional groundwater flow in these aquifers is generally from the shallower aquifer (eastern part) towards the deeper part of the study area (Fig. 1). The large exploitation of groundwater is for living and agriculture. Recharge to the aquifer is possibly by direct infiltration of rainfall along the foothills of limestone. Indirect recharge might also occur generally during the dry season when fractures intercept ephemeral stream courses.

B. *Groundwater Quality*

For the study of the hydrogeochemical characteristics of groundwater in Huaykhunram Subdistrict, Phattana Nikhom district, Lopburi province. Groundwater sampling was carried out in July 2012. Twelve groundwater samples were collected and capped for major ions analyses. Temperature, electrical conductance (EC) and pH value of water samples were measured in field surveys. Chemical compositions of water samples were analyzed in the laboratory of Division of Groundwater Analysis, Department of Groundwater Resources. The chemical composition was characterized by Inductively Coupled Plasma (ICP) for cations. Sulfate, chloride, and bicarbonate ion were measured by titration.

IV. Results and discussion

A. *Groundwater storage*

Groundwater storage was calculated to quantify groundwater recharge, lateral exchange, and safe yield. Annual groundwater level changes were calculated from September 1997 through to September 2009. The data were not available for every month or seasonally averaged periods because water levels were measured manually. Groundwater level changes were converted to groundwater storage (ΔS) by multiplying water level changes by the area and specific yield:

$$\Delta S = \Delta h \cdot A \cdot S_y \qquad (1)$$

where ΔS is the average groundwater level change for the period; A is the study area; and S_y is the specific yield. In this study, an area-weighted average specified yield 0.12 was used to calculate the groundwater storage change.

Department of Groundwater Resources has preliminarily evaluated groundwater usage, groundwater recharge and safe yield in Huaykhunram Subdistrict, Phattana Nikhom district, Lopburi province in a Groundwater Development for Agriculture Project [1]. Groundwater usage in this area (approximately 100 km^2) was 1.26 Mm^3/yr. Groundwater storage in aquifer (approximately 100 km^2) was 40.67 Mm^3 where the natural recharge and safe yield were approximately 3.89 Mm^3/yr.

B. *Groundwater Quality*

Groundwater ranges in TDS from 275-410 mg/L (average 319.6 mg/L). Table II shows the hydrochemical characteristics of the groundwater. Calcium and magnesium varying from 43-85 mg/L and from 5.5-40 mg/L were the dominant cations of the groundwater. Bicarbonate was dominant anions (ranging from 190-330 mg/L). It is corresponding with general order of hydrochemical evolution in a groundwater system. The Piper plot of major ion compositions (Fig. 4) show the hydrochemistry variation in study area.

V. Conclusions

Based on the results of this preliminary study, groundwater budget of the study area shows that groundwater storage is 40.37 Mm3. Current groundwater usage is 1.26 Mm^3/yr where the safe yield is 3.89 Mm^3/yr. The groundwater is mainly Ca-HCO_3 and Ca-Mg-HCO_3 water types. The geochemical elements indicate quality of groundwater is controlled mainly by the dissolution of carbonate rocks.

TABLE II. HYDROCHEMICAL CHARACTERISTICS OF WATER SAMPLES.

Well no	pH	EC (µs/cm)	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	SO_4 (mg/L)	Cl (mg/L)	HCO_3 (mg/L)	NO_3 (mg/L)	Total hardness as $CaCO_3$	TDS
5603G001	7.7	446	68	11	16	0.9	10	<1.5	238	22	220	290
5603G002	7.6	424	71	10	16	0.9	5	8.4	238	21	220	276
5603G003	7.6	423	75	6.6	16	0.9	5	6.4	238	21	210	275
5603G004	7.6	403	68	5.5	16	0.6	5	5.6	216	22	190	262
5603G005	7.6	484	78	7.8	21	0.4	8	10	238	37	230	315
5603G007	7.5	630	77	33	21	0.4	14	35	323	20	330	410
5603G009	7.5	603	60	40	16	<0.4	18	19	322	25	320	392
5603G011	7.5	445	43	29	5	<0.4	6	6.8	243	20	220	289
5603G012	7.4	561	85	14	16	0.9	5	34	267	11	270	365
5603G013	7.5	563	54	38	21	0.9	10	27	293	22	290	366
5603G015	7.5	462	69	17	16	0.7	21	4.0	270	16	240	300
5603G016	7.4	454	79	8.4	16	0.4	10	2.8	256	22	230	295

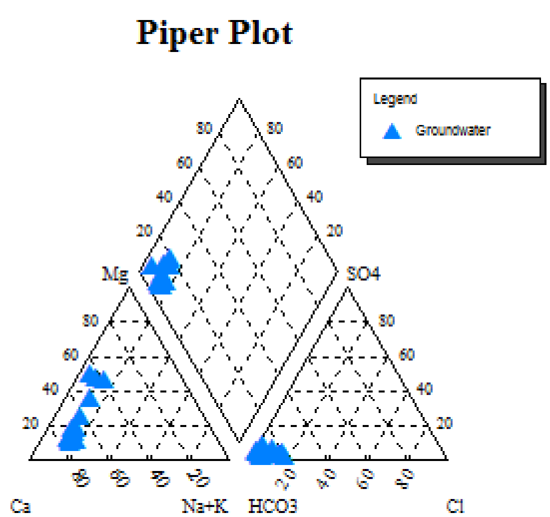

Figure 4. Piper plot for groundwaters sampled of the study area.

Acknowledgment

The study was undertaken as part of the Groundwater Development for Agriculture Project in the Department of Groundwater Resources. The authors would like to thank Assoc. Prof. Dr. Schradh Saenton for their kind provision of the groundwater modeling in limestone aquifer and also thank Department of Groundwater Resources for the groundwater compositions analysis in study.

References

[1] Department of Groundwater Resources, "The Report: Groundwater potential assessment and development for agriculture,", in Thai, 2014.

[2] Department of Mineral Resources , Geologic Map of Lopburi Province, scale 1:250,000: Ministry of Natural Resources and Environment, 2007.

[3] Department of Mineral Resources, Geologic Map of Saraburi Province, scale 1:250,000: Ministry of Natural Resources and Environment, 2007.

[4] Department of Mineral Resources, Groundwater Division, Groundwater Map Manual, Lopburi Province (A user manual of groundwater map of Lopburi Province on 1:100,000 scale), 2000.

[5] Department of Mineral Resources, Groundwater Division, Groundwater Map Manual, Saraburi Province (A user manual of groundwater map of Saraburi Province on 1:100,000 scale), 2000.

[6] Gallegos, J.J., "Modeling Groundwater Flow in Karst Aquifers: An Evaluation of MODFLOW-CFP at the Laboratory and Sub-Regional Scales," M.S. Thesis, Florida State University, 2011.

[7] Harbaugh, A.W., 2005, MODFLOW-2005, the U.S. Geological Survey modular ground-water model—The groundwater flow process: U.S. Geological Survey Techniques and Methods 6-A16.

[8] Hinthong, C., 1981, "The Report: Geology and mineral resources of the Changwat Phranakorn Sri Ayuttaya (Map ND 47-8) (In Thai)," Department of Mineral Resources.

[9] Hinthong, C., Chuaviroj, S., Kaewyana, W., Srisukh, S., Pholprasit, C., and Pholachan, S., Geology map of Thailand 1: 250,000 (Changwat Phranakorn Sri Ayuttaya ND 47-8), Department of Mineral Resources, 1985.

[10] Ponta, G., Memon, B., LaMoreaux, J., Julawong, J., and Wongsawat, S., "Karst Landforms in the Saraburi Group Limestone Thailand," Proceedings of the 13th Multidisciplinary Conference on Sinkholes and the Engineering and Environmental Impacts of Karst, 2013, pp. 299-310.

[11] Reimann, T. and Hill, M. E., 2009, MODFLOW-CFP: A New Conduit Flow Process for MODFLOW-2005: Ground Water, v. 47, p. 321-325. doi: 10.1111/j.1745-6584.2009.00561.x

[12] Shoemaker, W.B., Kuniansky, E.L., Birk, S., Bauer, Sebastian, and Dwain, E.D., 2007, "Documentation of a Conduit Flow Process (CFP) for MODFLOW-2005," U.S. Geological Survey, Techniques and Methods, Book 6, Chapter A24.

[13] Warren, J., Morley, C. K., Charoentitirat, T., Cartwright, I., Ampaiwan, P., Khositchaisri, P., Mirzaloo, M., and Yingyuen, J., "Structural and fluid evolution of Saraburi Group sedimentary carbonates, central Thailand: A tectonically driven fluid system," Marine and Petroleum Geology, 2014, pp. 1-22.

About Author (s):

Wanida Piamtang was born on December 10, 1985. She received Bachelor degree in geology, Faculty of Science (2008) from Chiang Mai University. She is geologist, practitioner level for Department of Groundwater Resources. And now, she studies in geology, Graduate School (2010-present) at Chiang Mai University.

Dr. Schradh Saenton is currently an assistant professor at the Chiang Mai University. He obtained is B.S. (Geological Engineering) and M.S., Ph.D. (Environmental Science Engineering) from Colorado School of Mines, Golden, Colorado, U.S.A. His research includes groundwater resource management, groundwater contamination, and modeling.