GW-4

Project report on

CCOP-GSJ/AIST-GA

Groundwater Phase II Project Final Meeting

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Youhei Uchida (Chief Editor)

PREFACE

Groundwater is one of the limited natural resources of the world. Because of the lack a feeling of importance of groundwater, especially, in the late 20th century, groundwater has been significantly damaged by human activities, resulting in groundwater issues, such as land subsidence, seawater intrusion, and groundwater pollution by toxic substances, that have become remarkable problems in everywhere in the world. The countries in the East and Southeast Asia have been also faced the many groundwater problems which are needed international cooperation to be solved.

Since the establishment of the organization in 1966, geological and geophysical surveys have been carried out by the CCOP under the cooperative schemes in the East and Southeast Asia for offshore natural resources. These data have been distributed to member countries as printed maps and publications. As for a groundwater project, “Groundwater database in East and Southeast Asia” had been compiled under the DCGM Phase IV project of CCOP from 2001 to 2004.

The following project, named “Groundwater Assessment and Control in the CCOP Region by CCOP-GSJ/AIST Groundwater project” from 2005 to 2008, had been started from a point of view of finding a solution of issues on an exploration and an exploitation of a groundwater resource. The final results of the project has been presented in the Special Session of the International Association of Hydrogeologists (IAH) meeting in Toyama, Japan in 2008.

The kick-off meeting of the Phase II for the CCOP-GSJ/AIST Groundwater project was held in Bangkok in October 2009. The agreement of the meeting was to release some kinds of hydro-geological map including the latest scientific information for the end-users at the completion of the Phase II project. The CCOP project should yield a data set for groundwater management. Monitoring of groundwater level， groundwater quality and temperature are the first step for groundwater management, therefore, a hydrological map is available for basic data of groundwater management and assist~~s~~ to design additional monitoring points.

The GW Phase II project had constructed database and its design, compiled data of Chao-Phraya Plain, Thailand and Red River Delta, Vietnam. We believe our final mission is to make an Asian Standard of hydrological map published from CCOP.

Moreover, new sub-project under CCOP GW Project started from April 2013. Title of the sub-project is “Development of Renewable Energy for Ground-Source Heat Pump System (GSHP System) in CCOP Regions” and this project use groundwater temperature data of the CCOP hydrological map. Chulalongkorn University (Thailand), Akita University (Japan) and GSJ have cooperation program under the CCOP sub-project and installed GSHP System on premise of Chulalongkorn University.

This is the publication which was compiled each country report presented in the CCOP-GSJ/AIST-GA Groundwater Phase II Final Meeting, 18-20 March 2014, Bandung, Indonesia. These reports have made clear the target, framework and cooperation policy of Phase II project, and conducted the agreement of the next Phase III GW Project. I believe we will be able to have some solutions about not only groundwater management but also energy problem in the CCOP member countries.

I am very grateful to the authors for their invaluable contributions and to the Organizations to which the authors belong for their permission to publish those important reports.

Youhei UCHIDA

Chief Editor

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Seawater intrusion along coastal line
in Krong Preah Sihanouk of Kingdom of Cambodia

Choup Sokuntheara

Department of Geology, GDMR, Ministry of Mines and Energy, Kingdom of Cambodia

1. Overview

1.1. Background Information

Cambodia’s official name became the Kingdom of Cambodia in the 1990s. The Kingdom of Cambodia is located in Southeast Asia in the southwestern part of the Indo-Chinese peninsula. It lies between latitudes 10’ and 15’ North and longitudes 102’ and 108’ East in the Tropical North, and covers an area of 181,035 km². The Kingdom of Cambodia shares its 2,438 km border with Thailand, Laos PDR, and Vietnam. The maximum length of the country is approximately 580 km from east to west and 450 km from north to south and it has a total boundary of 2,600 km of which approximately 5/6 is land and 1/6 is a coastline. Approximately 86% of the total land area lies within the Mekong Catchment.

1.2. Physical Geography

Cambodia's physical land features vary from region to region. A depression lake from northwest to southwest formed the old bay and the Mekong River carried sedimentation during the diluvia and alluvial epochs. Highlands and hills were then flattened and the present landscape was formed. The geologic features of mountains are Metamorphic rock in Proterozoic era, and the sedimentary rock Andesite and Basalt are formed in Paleozoic era and Mesozoic era.

The geographic characteristics of Cambodia are divided into five types: central plains, northern mountains, eastern highlands, southwestern mountains, and the southern coastal region.

1.2.1. Central plains

The central plains of the Kingdom of Cambodia are low-lying alluvial plains which surround the Tonle Sap Great Lake area; the Mekong River delta lies in the southeast section of the plain. This region occupies most of the central area and dominates the country. Transitional plains extend outward from this region, with thin forests at elevations no higher than several hundred feet above sea level.

1.2.2. Northern mountains

Along the Cambodia-Thai border to the north, the Cambodian plain borders a sandstone escarpment that marks the southern boundary of the Dangrek Mountains. A southward-facing cliff, stretching for more than 300 km from east to west, rises abruptly from the plain at a range of 180 to 550 meters.

1.2.3. Eastern highlands

East of the Mekong River, the transitional plains merge with the eastern highlands and extend forward into Laos PDR and Vietnam. This is a region of mountains and plateaus with lush forests.

1.2.4. Southwestern mountains

In the southwestern part of Cambodia, there are two distinct mountains, namely, (i) the Cardamom Mountains and (ii) the Elephant Mountains. These two mountains form another region extending between Tonle Sap and the Gulf of Thailand, and act as a physical barrier along the country's coast. Mount Oral at a height of 1,813 meters is the highest mountain in Cambodia and is located in this area.

1.2.5. Southern coastal region

The southern coastal region facing the Gulf of Thailand is narrow lowland strip, which is heavily wooded and sparsely populated. This area is isolated from the central plains with the southwestern highlands located in between.

1.3. Topography and Administrative Boundaries

Topographically, Cambodia is a large, low-lying alluvial plain that surrounds the Tonle Sap Great Lake and occupies most of the central area that dominates the country. According to the above geological characteristics and this topography, Cambodian territories are classified into categories with respective provinces (**Table 1**).

Phnom Penh is the capital of the Kingdom of Cambodia with a total land area of 290.06 km². According to the General Population Census of Cambodia of 1998, the population of Phnom Penh Municipality is 999,804, with a density of 3,745 persons per square kilometer.

1.4. Hydrology

Cambodia's unique hydrological regime is determined by the Mekong River and Tonle Sap Great Lake systems. Sections of the Mekong River, namely Khone Falls, are quite complex in its hydraulic performance. This section includes extensive floodplains, a complex delta and the well-known Tonle Sap Great Lake.

At the end of the dry season (November to April), the water flow in the Mekong River is at its

Table 1. Classification of Cambodia's natural regions and corresponding provinces

Natural Regional Classification	Number of Provinces	Names of Provinces
Plains	6	Phnom Penh, Kandal, Kampong Cham, Svay Rieng, Prey Veaeng, and Takaev.
Tonle Sap	8	Kampong Thum, Siem Reap, Bat Dambang, Pousat, Kampong Chhnang, Banteay Mean Chey, Otdar Mean Chey, and Krong Pailin.
Coastal	4	Krong Preah Sihanouk, Kampot, Krong Kaeb, and Kaoh Kong.
Plateaus and mountains	6	Kampong Spueu, Stueng Treng, Rotanak Kiri, Mondol Kiri, Kracheh, and Preah Vihear.

lowest and is contained completely within the channel. At that time, the Tonle Sap Great Lake also reaches its lowest level and is only a meter or so deep. As the monsoon rains begin, river levels start to rise and flood the wetland close to the Mekong River. Local inflow also commences. As the level of the Mekong River at Phnom Penh Municipality continues to rise, the flow in the Tonle Sap River reverses and water flows from the Mekong River to the Tonle Sap River joining with local runoff to fill the Tonle Sap Great Lake to a depth of around 10 meters.

The flow into the Tonle Sap Great Lake continues for several months until the dry season commences. The flow in the Mekong River gradually decreases step by step until the Mekong's water level at Phnom Penh Municipality is lower than the water level in the Tonle Sap Great Lake. The flow in the Tonle Sap River then reverses, and starts flowing toward Phnom Penh Municipality where it supplements the flow in the Mekong River. The flow in the Tonle Sap River continues until the end of the dry season. The depth of the Tonle Sap Great Lake again lowers to around one meter. As the Tonle Sap Great Lake fills, both from the Mekong River and local inflow, it increases in area from about 3,000 km^2 at the end of the dry season to about 16,000 km^2 at the end of the wet season (**Table 2**).

2. River Basins

Cambodia has considerable water resource potential, with abundant surface water and aquifers and a high level of seasonal rainfall. However, this potential has not yet been developed for agriculture, industrial or household use. In spite of the abundance of water sources, many areas in the central plains and plateaus lack water in the dry season and are therefore dependent on unreliable rainfall patterns.

Many rivers, streams, lakes, and their tributaries provide tremendous water resources for development. These water sources are divided into three systems: (i) the Mekong River System; (ii) the Tonle Sap River System; and (iii) the river system flowing into the Gulf of Thailand.

The Mekong River Basin stretches about 4,500 km from the Tibetan Plateau to the South China Sea and comprises some 795,000 km^2, ranking it the 21^{st} largest river basin worldwide. It incorporates the areas of six countries (**Table 3**), including six broad hypsographic regions.

The Mekong River passes Cambodia about 480 km from the border with Lao PDR in the North and Viet Nam in the South, and it has an average width of about 1.5 km in the territory of Cambodia. It crosses Stung Treng and Kratie Provinces in the upper part of the country, Kampong Charm Province, Phnom Penh Municipality--the capital of Cambodia, and flows down towards Kandal Province to the South China Sea (**Fig. 1**).

Table 2. Water sources caused flooding the Tonle Sap Great Lake

Sources of flooded water	Percent %
Mekong River	62
Local Inflow	38
Total	100

3. Sea Area

3.1. Water resources

Cambodia's coastal zone can be conceptualized as being made up two inter-related systems, namely, (i) the ecological system which includes the physical, chemical and biological environment that provides natural resources, sequesters pollutants and offers fundamental life-support functions (clean air and water, etc) for humans and other living-organisms; and (ii) the socio-economic system which depends on the many functions and products of the ecological sub-system.

Ecological systems have abundant but limited capacity to provide saline aquatic life, including fish, and clean water as well as other resources to meet the demand of the socio-economic system. It is not surprising that the final demands by society and new opportunities for multiple uses are the source of increasing conflicts within the coastal zone. Cambodia's coastline is currently being subjected to various stresses, for example, mangrove deforestation, coral reef/sea-grass destruction, marine aquaculture, and others.

Cambodia's coastal shoreline is 435 km along the Gulf of Thailand. The seaward boundary of the coastal zone has been delimited as the outer limit of the Exclusive Economic Zone (EEZ) with an area of 55,600 km². The landward boundary of the coastal zone has not yet been satisfactorily defined, but is temporarily considered to be about five kilometers from the shore. The coastal zones are situated in the Koh Kong and Kampot provinces, and in the Sihanoukville and Kep towns. Sihanoukville is the largest town on the coast that has deep seaport facilities and is considered to be one of the economic centers of Cambodia.

The coastal climate differs from other areas in the country. Its climate is also tropic monsoon with an annual rainfall between 2,000 and 4,000 mm. Generally, during the wet season from May until November the rainfall is largely derived from the southwest monsoon drawn landward from the Indian Ocean, whiles the dry season, which commences from November and lasts until April, is associated with the northeast monsoon which sends drier and cooler air throughout the region.

Table 3. Territory and water flow of the six Mekong River Basin countries within the catchments

Description	Country or Province						
	Yunnan Province, PRC	Myanmar	Lao PDR	Thailand	Cambodia	Viet Nam	Mekong River Basin
Area (km²)	165,000	24,000	202,000	184,000	155,000	65,000	795,000
Catchments as % of country or Province	38	4	97	36	86	20	
Catchments as% of MRB	21	3	25	23	20	8	100

This amount of rainfall is higher than other areas in the country. The area has average wind speeds of two to four m/s and temperatures varying from 27.5 to 28.5 degrees Celsius. Generally, the minimum temperature is 19 degrees Celsius in December while the maximum temperature is 35 degrees Celsius in April. As a natural condition, the coast has tides per day with amplitude of 1.5 m and approximate surface currents of 0.2-0.7 miles per hour. Wave amplitudes of two to three meters (during the rainy season) and 0.25 to 0.50 (during the dry season) are not uncommon.

- The mountain is formed by middle Jurassic and Lower cretaceous sandstone, conglomerate and siltstone.
- Groundwater aquifer in the area is colluvium and eluvium sand and sandstone average 30m thickness.
- Ground Water Table: 1.5-15.0m.
- Borehole depth average 30m.
- Ground water yields are between 1.0-10.0 m^3/h per an hour.
- Ground water average 2.0 m^3/h per an hour.
- Some of them were dried and salinities intrusive as at Andong Thmar, Prey Nup areas.

Fig. 1. The Coastal Plain of Southwestern Cambodia:

Alluvium important sources of groundwater supply. The bulk of the alluvium, old alluvium or young alluvium is composed of sand silt and silt clay, which has a low permeability:

- The water yield to wells at very slow about 0.7 m^3/h per an hour.
- Dug well is important as sources of domestic water supply. The sandy beds and lenses of the alluvium are one of the best water-producing horizons in Cambodia.
- Averages yield about 16 m^3/h (drilling wells). Groundwater from alluvium is generally believed to be of good chemical quality and suitable for most purpose user.

3.2. Seawater Intrusion Problem

3.2.1. Seawater Intrusion in Cambodia

Seawater intrusion has, so far, never been paid little attention. Obviously, this problem can seriously affect seawater and groundwater interactions occurred along costal lines and plains. The drilling-wells to meet saline water ave indicated in the geological map in this area and plains (**Fig. 2**).

Through a survey, we found that groundwater resources used for water supply to meet a high demand of Sihanoukville are not appropriately regulated for its real needs the future. There are totally 162,728 people equal to 30,226 families living in Sihanoukville (population statistic at 3rd quarter of 2004 of municipal HQ of Sihanoukville).

Our numerical data analysis on a total population of Sihanoukville revealed that there is only 9% of the total population has been linked to network of water supply authority of Sihanoukville and others have used groundwater for their daily life as most of them have their own wells and those private wells for their domestic needs, hotel, restaurant, and other

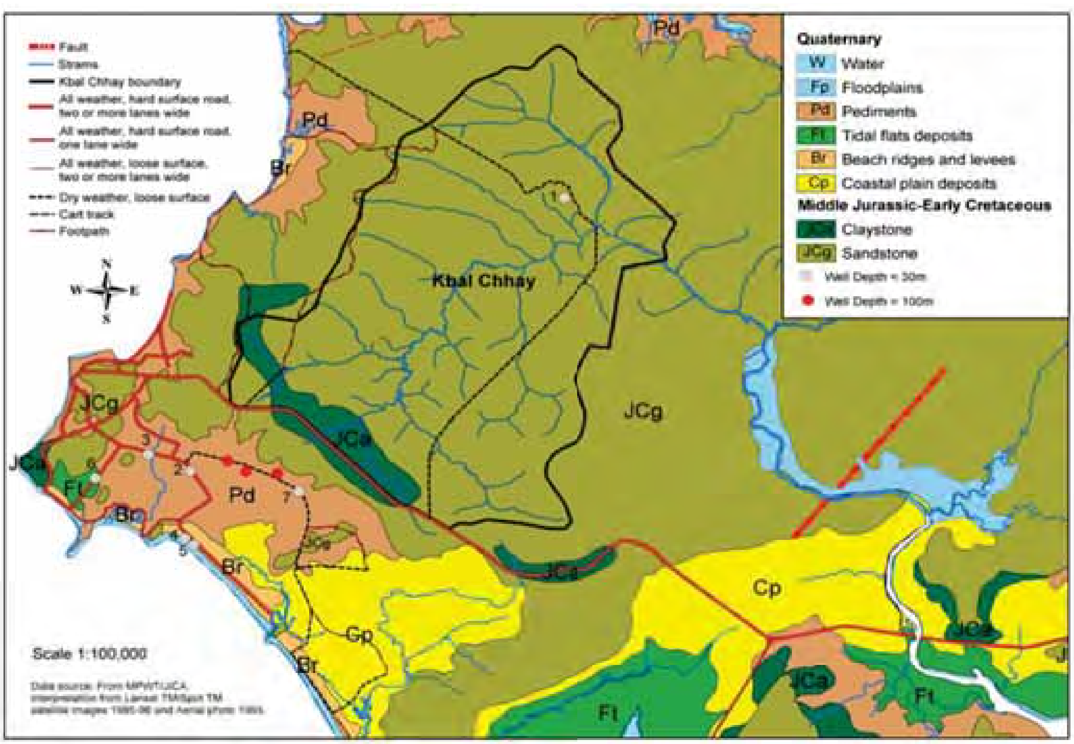


Fig. 2. Geology Map of Sihanoukville

purposes. Most of the wells are drilled in aquiferous sandy layer with a depth between 8-30 meters on the top of the sandstone or claystone rocks whereas some wells of factories and hotels are deeper (between 50-190meters which are drilled into hard rocks).

Annual findings, in dry season from January to May, are that more than 100 well with depths ranging from 8-30 meters are drilled in Sihanoukville. It is with regret that geological data relating to existing wells is not available for an assessment of groundwater resources potentials of Sihanoukville.

Groundwater is precious limited resource and vulnerable to human intervention in the environment. The main problems faced by the groundwater bodies in many parts of the world are pollution and over exploitation. In order for this resource to be available (quantity and quality) for the actual and coming generations, it is imperative to carry out a sound protection strategy.

In this paper it is presented a course of action in planning and implementing groundwater protection. The main components include aquifer vulnerability assessment, which is based on a qualitative weighting of the main factors, which may lead to contamination event.

A further step is that a protection strategy should be based upon a risk approach. This concept results from the combination of the magnitude of hazard, to which a groundwater system could be exposed to and the consequences (vulnerability) that could be derived when a specified hazard takes place. This concept results from the combination of the magnitude of hazard, to which a groundwater system could be exposed to and the consequences (vulnerability) that could be derived when a specified hazard takes place. The risk is also measured, mainly by qualitative weighting factors. This is due to the scarcity of basic data and the uncertainties attached to them.

3.2.2. General Geology and Hydrogeological Setting in Sihanoukville

The geology of the study area is characterized by thick sediments consisting of sand and little clay (**Fig. 3**). In some places of the Sihanoukville and Kbal Chhay relatively hard laterite

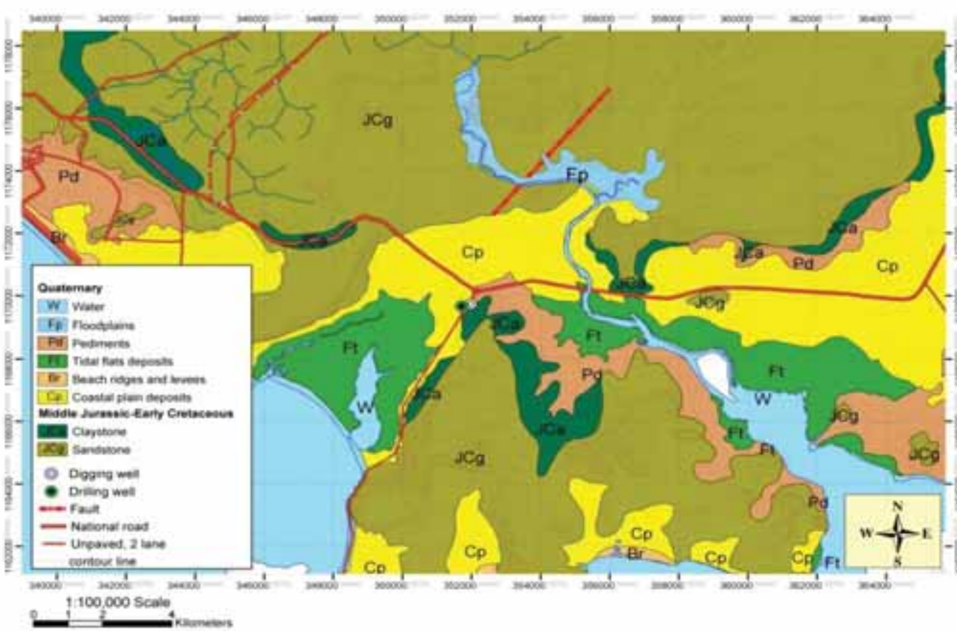


Fig. 3.

layers can be found.

The bedrock also was detected by the existing wells in Sihanoukville. However, the thickness of sediments is estimated about 30 meters deepest by national geologist during the study area.

The sandy layers of the sediments formation has occurred since Quaternary time, generally a multiple aquifer system in this area. There are generally several horizons of aquifer layers. The aquifers are generally productive and good quality. Groundwater in the aquifers is confined to semi-confined condition. As mentioned above and according to geological studies, it reveals that sandstones and claystones formation has occurred since a time of Jurassic – Cretaceous which their age is about 70 million years old. A part from that, lowland of this area is covered by alluvial recent and ancients of Quaternary time.

Pediments are also found nearby bases of the mountain existed in Sihanoukville and other areas which are not far from coastlines. Following a geological map of Sihanoukville with a scale of 1/100,000 printed out by MPWT/JICA shows that there is also a fault with a length of about 5,000 meters crossing Prek Toek Sap which is on northeast-to-southwest direction (**Fig. 4**).

3.2.3. Groundwater Monitoring

We should be express interest and good care over absorbing the groundwater utilization because it is an unavoidable source to support the livelihood of population in Sihanoukville, especially in dry season, that we all need up to 70% of total volume of water. We have seen the quick development process of benefiting from under groundwater without knowing the consequences taken place in the short future. Development process without specific

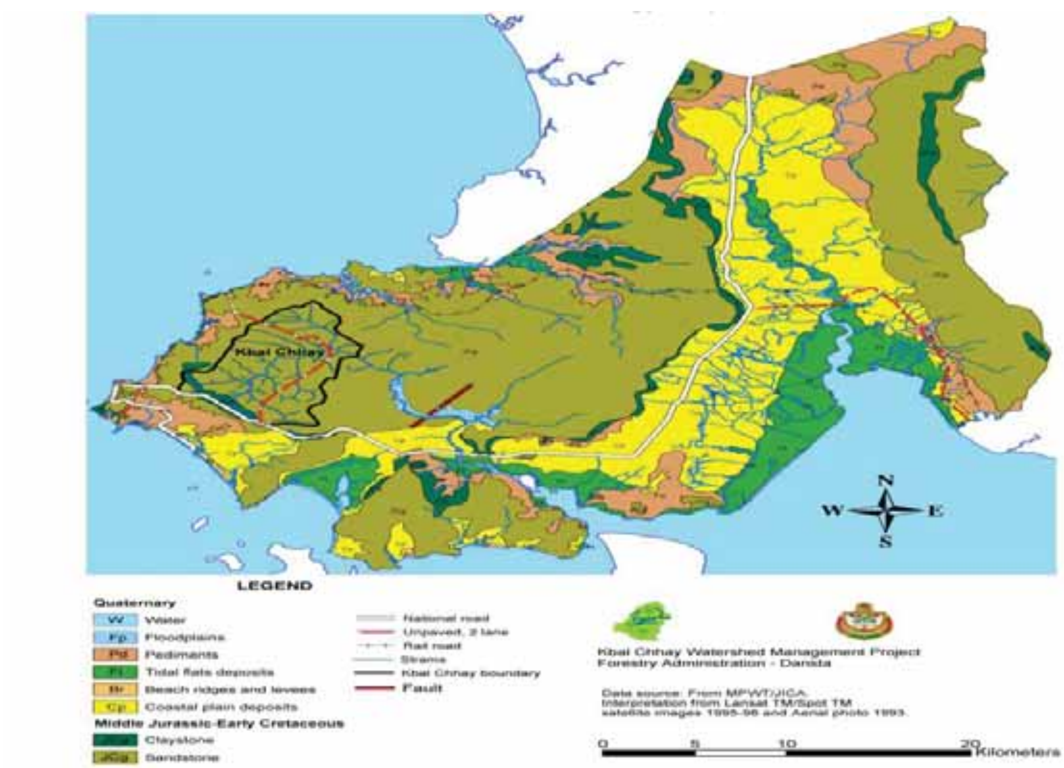


Fig. 4. Geology Map of Sihanoukville

information technology. For alert it will cause risks. Therefore, we must have groundwater monitoring to take prevents actions against such risks. It is the brief roles of the groundwater monitoring as described hereunder.

We should be express interest and good care over absorbing the groundwater utilization because it is an unavoidable source to support the livelihood of population in Sihanoukville, especially in dry season, that we all need up to 70% of total volume of water. We have seen the quick development process of benefiting from underground water without knowing the consequences taken place in the short future. Development process without specific information technology for alert it will cause risks. Therefore, we must have groundwater monitoring to take prevent actions against such risks. It is the brief roles of the groundwater monitoring as described hereunder. Groundwater is an important source of water mainly for drinking, irrigation and industrial purposes. Groundwater is also important in the preservation of ecological system.

Groundwater monitoring is necessary as it is vulnerable to depletion due to over exploitation or reduction of recharge and pollution due to human activities. Groundwater monitoring is the process of systematically collecting, analyzing, storing and using of groundwater data for proper decision making in groundwater exploration, development and management. The major reasons for monitoring of the groundwater are to determine the water quality and chemistry of a region, to determine the extent of groundwater contamination from a known source and to monitor potential sources of contamination. Monitoring process involves collection of time independent data such as geology, hydraulic properties, boundary condition and hydrochemistry and time dependent data such as water quality, water levels recharge, discharge etc.

Monitoring can be divided into background monitoring and specific monitoring. The main role of background monitoring network is to provide basic time varying information on the natural changes in aquifer storage and groundwater quality before significant development occurs. In background monitoring, observations (measurements and samples) of variables related to quantity and quality of the groundwater resources in selected locations are made. Specific monitoring is the continuous or frequent standardized measurement and observations of aquifer systems in which potential consequences of significantly exploited groundwater flow system are expected.

Further specific monitoring aims at characterizing the transient stage of ground water system during ground water development, acting as early warning system showing over abstraction of a ground water system and providing information for remedial actions, in case ground water extraction rates have been decreased after an undesirable exploitation situation. Specific monitoring provides data for groundwater managers who are responsible for identifying possible over-abstraction conditions.

Technically, in order to evaluate the groundwater resources and to identify changes in groundwater flow systems, groundwater should be monitored over continuous and long time periods. This helps to identify seasonal groundwater level fluctuations, possible groundwater depletion, water logging, groundwater, salinity and water contamination.

3.2.4. Groundwater Occurrence in Sihanoukville

Groundwater occurs in geological formations know as aquifers. An aquifer may be defined as a geologic formation that contains sufficient permeable materials to yield significant quantities of water to wells and spring; this implies an ability to store and transmit water. The nature and distri -bution of aquifers in a geologic system are controlled largely by the lithology, stratigraphy and structure of the geologic deposits and formations. Lithology is the physical make-up including, among other thing, the mineral composition, grain size and packing. Stratigraphy relates to the spatial and age relations between the various geologic formations. Structural feature includes fractures, faults and folds. Various geological formations can act as aquifers and these can be broadly grouped under:

- Alluvial deposits
- Limestone and other carbonate rocks
- Sandstone and other sedimentary rocks
- Crystalline and metamorphic rocks

Depending on Geological feature in Sihanukville proved Sandstone have been covered almost this area. Thus, we detail only geologic formation of Sandstone and other sedimentary rock in aquifer.

3.2.5. Assessment of the Groundwater Resources of Sihanoukville

In fact, an assessment of groundwater resources in Sihanoukville depends upon not only private wells but also SWSA's wells have been used. It is very difficult to do a technical analysis due to a lack of geological survey data. Actually, evaluation on groundwater resources in Sihanoukville is to be based on necessary geological database. Unfortunately, the existing wells in Sihanoukville as the current ones, people drilled for immediate consumption purpose without consequential consideration resulted from such consumption.

Whereas it is very important and necessary for geological exploration is out of their consideration (**Fig. 5**).

A recovery of groundwater of 2nd well from -30m up to about 4m above sea level takes a course of about 48 hours or 2 days (**Fig. 6**).

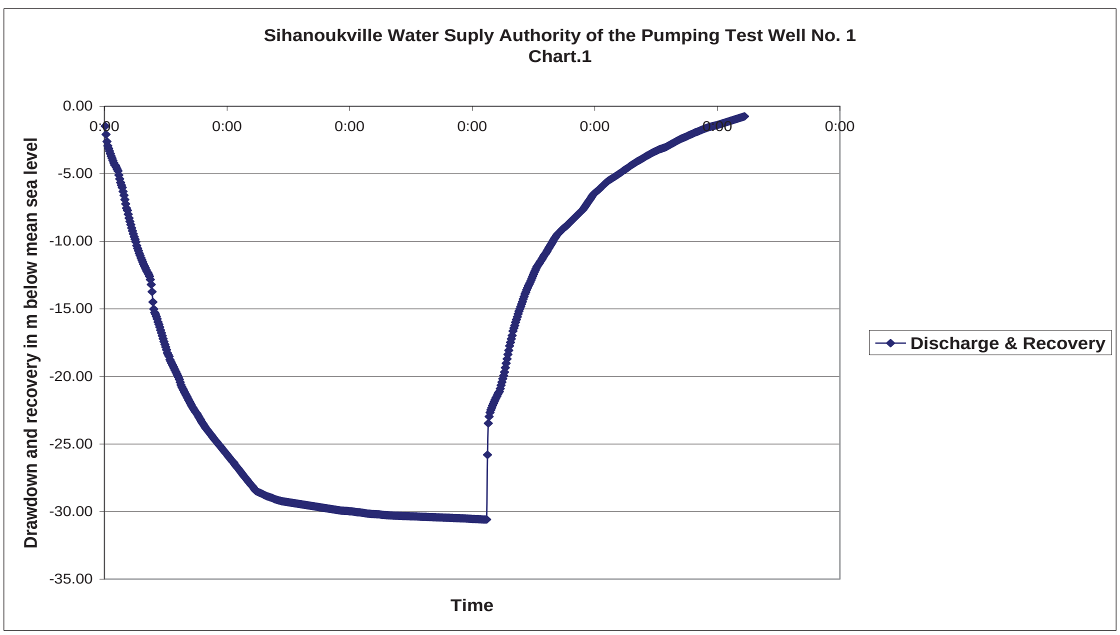


Fig. 5.

A recovery of groundwater of 3rd well from -33m up to about 4m above sea level takes a course of more than 72 hours or 3 days (**Fig. 7**).

Previous studies have also revealed that groundwater resources are scarce, as the most developed geological formation is sandstone, which proves little fissured, especially in the deeper strata. Furthermore, a number of existing wells in Sihanoukville, which confirmed that abstraction from the groundwater would be limited and could at best constitute a complement to surface water, with daily pumping limited to a few thousand cubic meters a day. However, the groundwater reserves could supply some sub-urban villages lacking wells, where the groundwater may be available (**Table 4**).

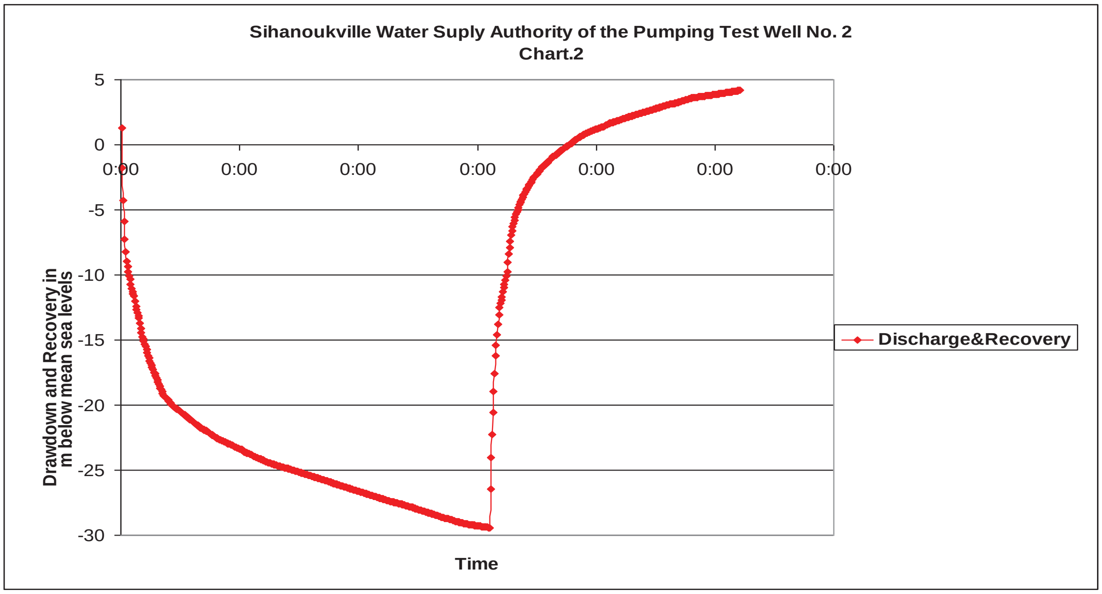


Fig. 6.

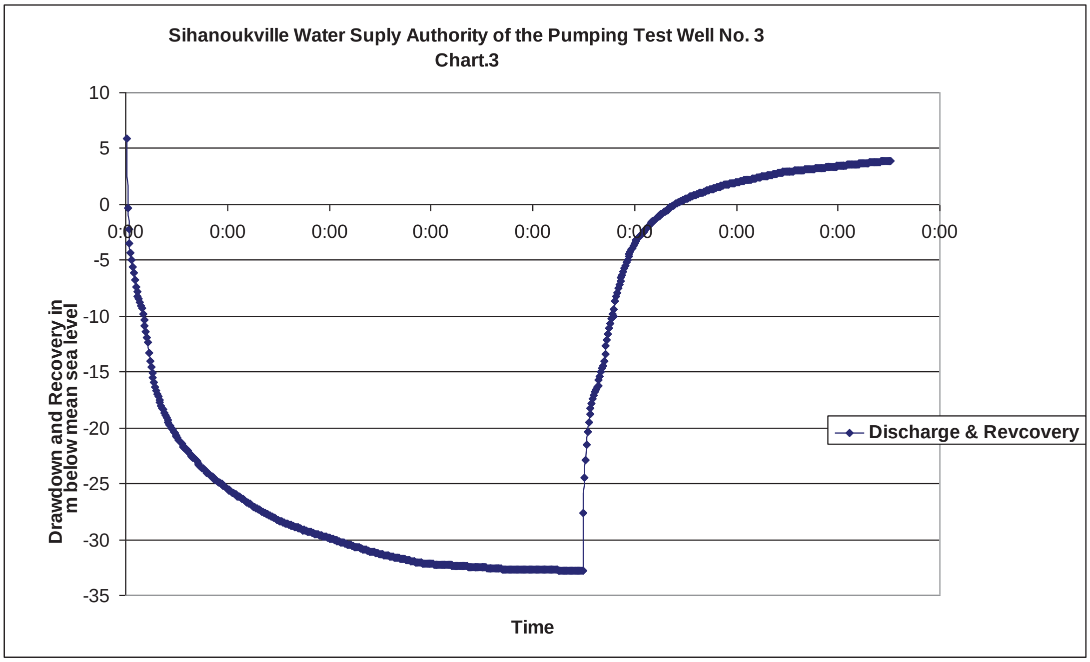


Fig. 7.

3.2.6. Problem Statement

A Sihanoukville has a domestic water deficiency of 3,500 cubic meters per day and although the current water supply demand is at 6,000 cubic meters per day, we still foresee that the future water demand will increase more and more due to a number of reasons (population growth, delays of dry season, industrial growth, and other relevant factors). Consequently, we have a concern of capacity of water resources that we have to make our active effort so we can find all possibilities to constitute supplement water with other water sources (both naturals and artificial such as a dam construction scheme at Kbal Chhay for supplying water to Sihanoukville and its vicinity in the future).

3.2.7. Solution

Hydrogeological investigation identified this area is underlain by dense sandstone strata. Therefore, there is unfavorable to occur to the groundwater resources such as sandy layer overlying it. A dam will be contracted in Kbal Chhay watershed area across a Preak Toek Sap to store water to be used as artificial recharge for the sand and sandstone strata. A well field will be developed in the aquifer from which the water demand could have been significantly improved.

Moreover, surface water in Kbal Chhay's basin is one of the most important sources of water supply to Sihanoukville and surrounding agricultural associations of Kbal Chhay area in the future.

As the hydraulic head of groundwater ensures seawater that cannot migrate landwards and impacted interaction. However, a delicate balance exists between the sea and groundwater, with over-abstraction resulting in saline intrusion and deterioration in groundwater quality.

Messrs Ghyben and Herzberg study the hydrostatic relationship between less dense groundwater and heavier seawater independently. It was found that the interface between the two water bodies occurred at a depth below sea level equivalent to about 40 times the height of the water table above mean sea level.

During groundwater abstraction, the groundwater level is lowered. This induces a shift in the position of the freshwater – seawater interface. The Ghyben-Herzberg approximation allows for the potential of inducing saline intrusion during abstraction to be assessed (**Fig. 8**).

Table 4.

Sihanoukville Water Supply	**Total pumped out**		**Remarks**
	m^3/day	l/sec	
Real water production	2500	24	Insufficient amount
Current water supply demand	6000	70	More than carrying capacity

4. Geological Base For Dam Construction Site at Kbal Chhay

The Kbal Chhay watershed covers the inner area of the Sihanoukville peninsula. The watershed has the form of a flat basket, bordered by hilly ridges (100-200m above sea level).

The watershed drains to the sea by the Prek Toek Sap River and the Kbal Chhay waterfall. The height of the waterfall is approximately 45 meters above sea level.

More importantly, its catchment's area covers 6,020 ha. The Kbal Chhay Watershed is a state reserved area for public benefit which is in a favorable condition for a dam construction to supply water to Sihanoukville municipality and its vicinity.

According to the geological formation is underlying a study area of Kbal Chhay is sandstone basement at Jurassic-Cretaceous, that is overlaid by sandy layer Quaternary.

These are covered in some places by thin laterite and clay. Depending on the geological and geo-morphological map reveals that is no geological fault in it.

Thereby dam site in Kbal Chhay Watershed is stationed at Catchment areas which should not be worried by a falling foundation away of the dam. In the case of land types and stone layers existing in this area can be determined for an appropriate location for a dam construction.

However, consideration's a specific data should also be made available before constructing a dam, through a thorough study by drilling the ground in order to get sample of each layer and its depth for a technical data analysis at any qualified laboratory (**Fig. 9**).

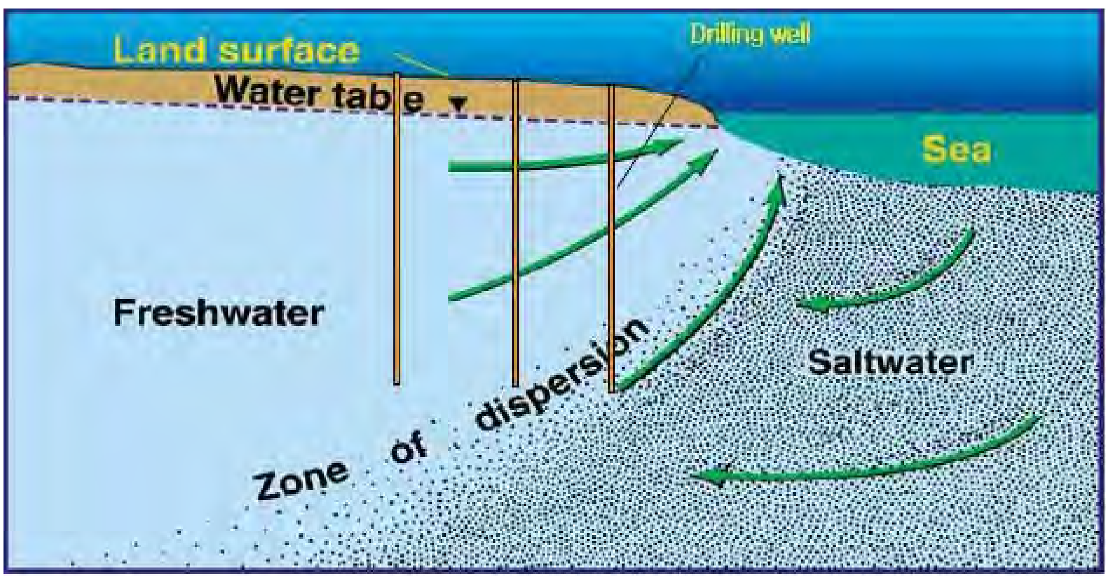
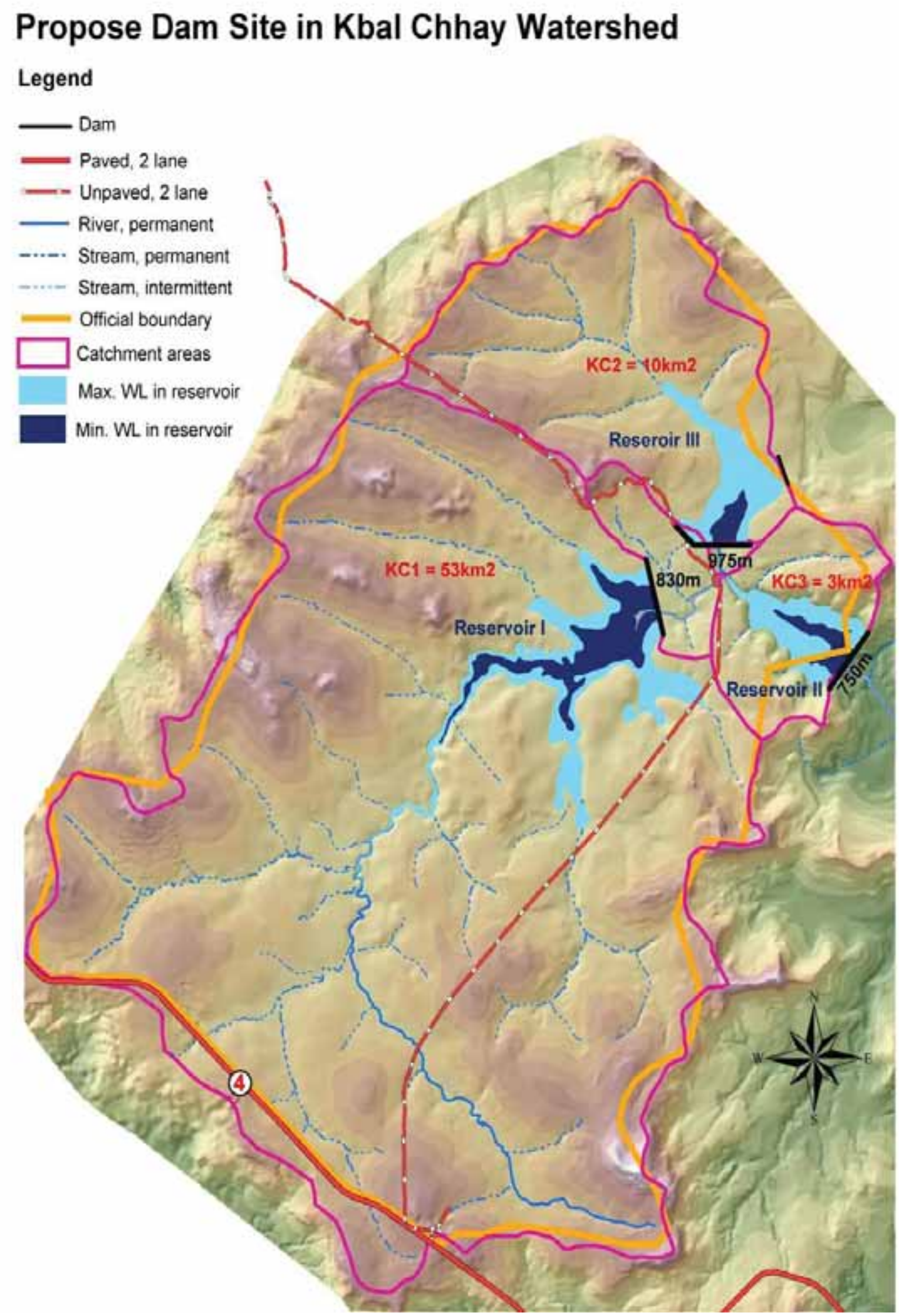


Fig. 8.


Propose Dam Site in Kbal Chhay Watershed
Legend
Dam
Paved, 2 lane
Unpaved, 2 lane
River, permanent
Stream, permanent
Stream, intermittent
Official boundary
Catchment areas
Max. WL in reservoir
Min. WL in reservoir
KC2 = 10km2
Reseroir III
975m
830m
KC1 = 53km2
KC3 = 3km2
Reservoir I
Reservoir II
750m
4
N
W
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S

Fig. 9.

5. Summary and Recommendation

The report has briefly elaborated the importance of groundwater monitoring. Integrated monitoring networks, which include meteorology, surface water, and groundwater integrated databases, should be introduced as one of the strategies for better and sustainable long term water resources planning and management.

For a proper management of water supply, the following factors should be taken into account:

- Groundwater resources
- Abstraction monitoring
- Monitoring of groundwater levels
- Groundwater quality monitoring
- Monitoring groundwater recharge
- Measuring of rainfall soil moisture content measurements
- Monitoring stream flow
- Risk management

Seawater intrusion:

- Geological surveys on coastal zones and estuaries (seawater and groundwater interactions)
- Risk management

Dam construction site:

Thorough geological study in the review available drilling, well records, structural geology and stratigraphy (Finding samples for chemical analyses and quality determination).

Hydrogeological Survey of China

WU Aimin

Department of Hydrogeology and Environmental Geology, China Geological Survey
e-mail : waimin@mail.cgs.gov.cn

Abstract

China is one of the earliest countries where people developed and used groundwater in the world. For example, Hemudu Well with wood guardrail was built in Yuyao town, Zhejiang province before BC 3700; Jiaozhuang Well with artificial stone-well-wall was built in Donghai county, Jiangsu province before BC 1000; Karez Well was built in Tulufan basin, Xijiang autonomous region in around 1 century; Zhuotong Well was built in Sichuan province in 11 century; and Rotating Drilling Well was built in Shanghai, Beijing and Tianjin in early period of 19 century.

In ancient time, Chinese people wrote some literatures and documents that described the mountains, rivers, lands, soils, floras, karst and groundwater such as *Land Chapter of Guanzi* in BC 7 century, *Commentary on the Waterways* by Li Daoyuan in 6 century, and *Xu Xiake Diary on Expedition* by Xu Xiake in 1613～1639.

Organized and scientific hydrogeological survey in China did not begin until 1949 when the People Republic of China was found. Hydrogeological survey of China may be divided into 2 stages, the period of Ministry of Geology and Mineral Resources and the period of China Geological Survey, Ministry of Land and Resources.

In the period of Ministry of Geology and the Ministry of Geology and Mineral Resources, the following hydrogeological works were implemented: (1) regional hydrogeological investigation for standard map sheet (mainly in scale of 1:200 000); (2) regional hydrogeological investigation for agricultural and stock raising regions (mainly in scale of 1:100 000); (3) hydrogeological exploration for important planning development regions (mainly in scale of 1:50 000); (4) detailed hydrogeological exploration for water supply of important cities and industry regions (mainly in scale of < 1:50 000); (5) dynamic monitoring, balance experiment and scientific research on groundwater.

In the period of China Geological Survey, Ministry of Land and Resources, the following hydrogeological works were carried out: (1) investigation and assessment on groundwater resources and environmental issues of main plains and basins (in scale of 1:250 000); (2) investigation and assessment on national groundwater quality and pollution (in scale of 1:250 000); investigation and assessment on hydrogeology and environmental geology in south-west karst regions (in scale of 1:50 000); (5) investigation and assessment on hydrogeology for the energy development bases (in scale of 1:50 000); (6)groundwater exploration and water supply demonstration for serious water shortage regions and endemic disease regions; (6) investigation and assessment on shallow geothermal energy in provincial capital cities and evaluation on national geothermal resources potential; (7) research on groundwater management and geological environmental protection.

A series of important progress was gained in the above works. For assessment of national groundwater resources in 2000-2003, a lot of groundwater data was updated. For example, total amount of groundwater resources in China was 923.5 billion m^3/yr.; total fresh groundwater resources 883.6 billion m^3/yr.; total exploitable amount 352.7 billion m^3/yr.; real exploitation 111.5 m^3/yr. in 2000. The ratio of groundwater supply to total water supply in the whole country was 20％ and the ratios in North China were 66%-72%.

For investigation and assessment of groundwater in North China Plain, 31 hydrogeological cross-sections were made; a hydrogeological structure model and groundwater numerical simulation model of the whole plain was constructed; researches on C, H, O isotopes were implemented; and main environmental issues related to groundwater development were monitored and studied. In North China Plain, total depletion of groundwater was more than 100 billion m^3; the deep groundwater level

cone 70 000 km^2; the land subsidence areas 64 000 km^2. The components of groundwater pollution mainly included N, some heavy metals, and a few organic compounds.

For groundwater exploration in Ordos Basin, a hydrogeological structure model was made; 161 groundwater well fields were discovered; 18 large groundwater source zones were explored. Total groundwater recharge amount of 10.48 billion m^3/yr, exploitable amount of 5.79 m^3/yr and exploitable potential of 4.74m^3/yr were calculated. Especially, multi-layer groundwater levels in heavy thick aquifers were measured by using a packer system; and therefore, a regional groundwater flow model was constructed.

For investigation and assessment on karst hydrogeology in South-West China, China Geological Survey has sponsored 80 geological projects in this century, spending 500 million yuan RMB. Hydrogeological survey of 77 karst water catchments have been completed; hydrogeological mapping of 200,000 km^2 in scale 1/50,000 have been finished; and total drilling footage reached 52,000 m. During emergency action for resisting drought and providing disaster relief in 2010, 2600 people and 300 drilling rigs attended the action. 2703 boreholes were completed. Karst water of 360,000m3/d was extracted to provide drinking water for 5.2 million people.

China Geological Survey has formulated a seven-year plan on hydrogeological works for the years 2014-2020. The main works are focused on 4 aspects of the following: (1) regional hydrogeological survey and mapping; (2) hydrogeology for environment protection; (3) hydrogeology for poverty eradication; and (4) hydrogeology for exploration and exploitation of energy and resources.

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Presentation on CCOP – GSJ/AIST - GA Groundwater Phase II Meeting, Bandung

China Country Report: Hydrogeological Survey of China

Aimin Wu

China Geological Survey

March 18, 2014

Outline

I. Brief History of Hydrogeology in China

I. Brief History

China is one of the earliest countries in the world to develop and use groundwater

Hemudu Site

◆The earliest well was built

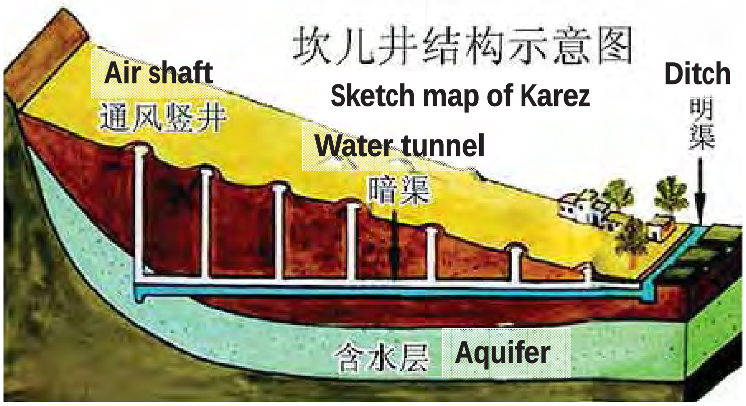
5700 years ago.

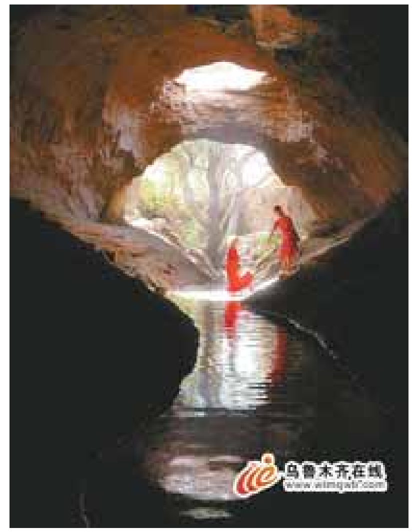
◆in Yuyao town, Ningbo, Zhejiang province.

I. Brief History

Karez（坎尔井）

◆ distribute in Tulufan basin, Hami basin, etc., Xinjiang.
◆ built 2000 years ago.





I. Brief History

Ancient Chinese people wrote some literatures and documents that described the mountains, rivers, lands, soils, floras, karst and groundwater

◆ Guanzi-Land Chapter (管子-地员篇）in BC 7 century

◆ Li Daoyuan-Commentary on the Waterways （郦道元-水经注）in 6 century

◆ Xu Xiake Diary on Expedation（徐霞客游记）in 1613～1639

I. Brief History

Organized, scientific hydrogeological survey in China did not start until 1949 when the People Republic of China was found.

◆**China's hydrogeological survey may be divided into 2 stages:**

___Period of Ministry of Geology and Mineral Resources;

___Period of China Geological Survey.

I. Brief History

◆ The Period of the Ministry of Geology and Mineral Resources

1949

↓

1998

◆**1. Regional hydrogeological mapping (in scale of 1:200 000; 1:100 000; 1:50 000)**

◆**2. Groundwater well field exploration for water supply of cities and industries (in scale of > 1:50 000)**

◆**3. Groundwater monitoring, water balance experiment and scientific research**

I. Brief History

- Period of the China Geological Survey, Ministry of Land and Resources

1999 → **Now**

- **1. Hydrogeological mapping in karst regions and energy bases (in scale of 1:50 000)**
- **2. Investigation and assessment on groundwater resources and environment in main plains and basins (in scale of 1:250 000)**
- **3. Groundwater exploration and water supply pilot for water shortage regions and endemic disease regions**
- **4. National groundwater quality Investigation**
- **5. National geothermal resources investigation**
- **6. Groundwater management and protection research**

II. Advance in Hydrogeological Survey of CGS

II . Advance

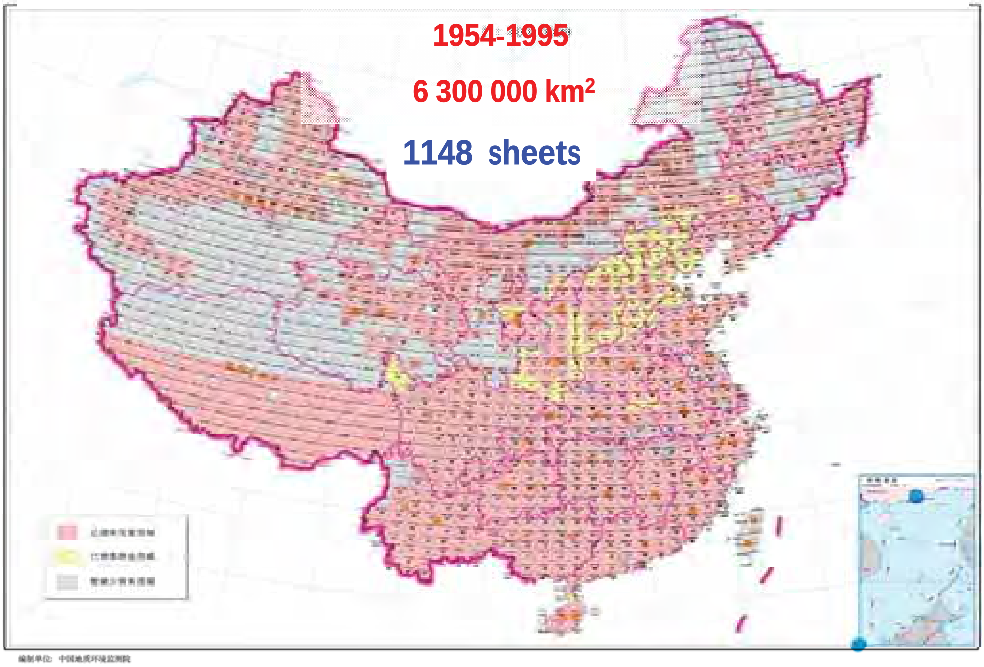
1. National Hydrogeological Mapping and Database

In scale of 1:200 000

1954-1995

6 300 000 km^2

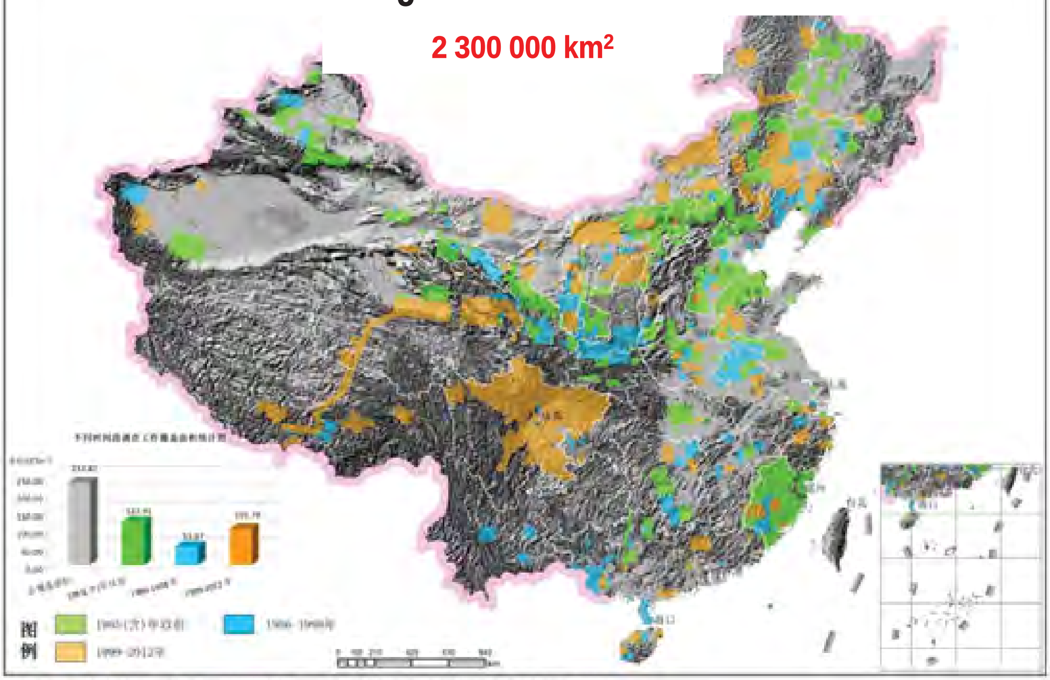
1148 sheets



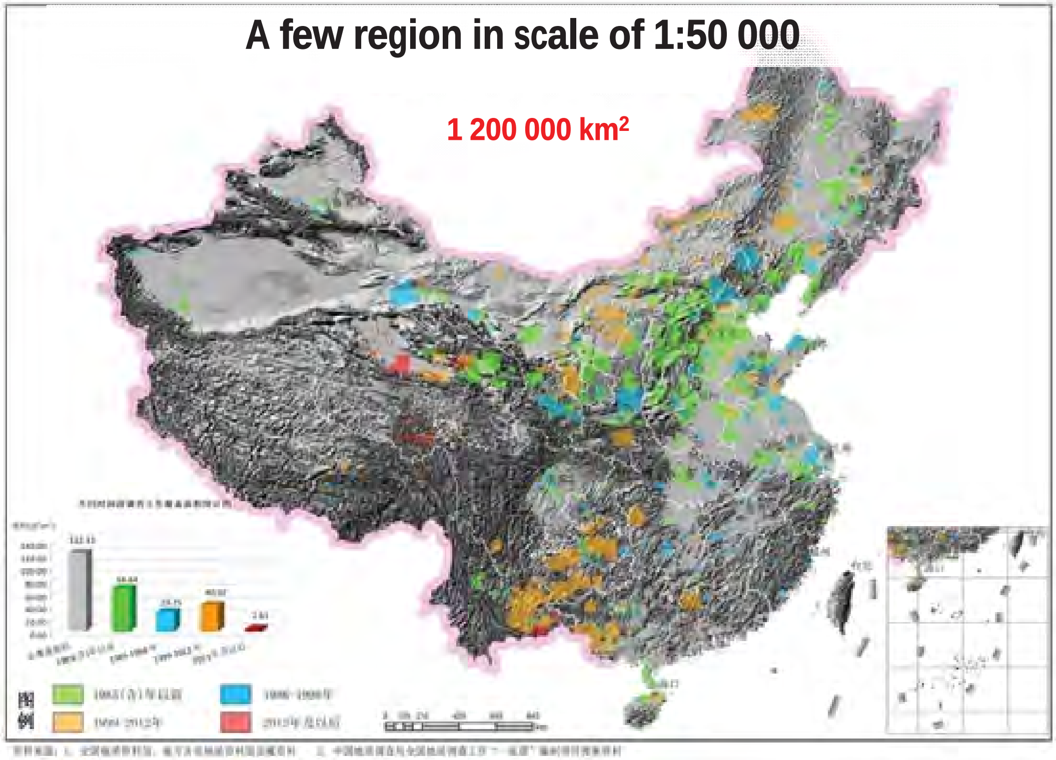
II . Advance

Some region in scale of 1:100 000

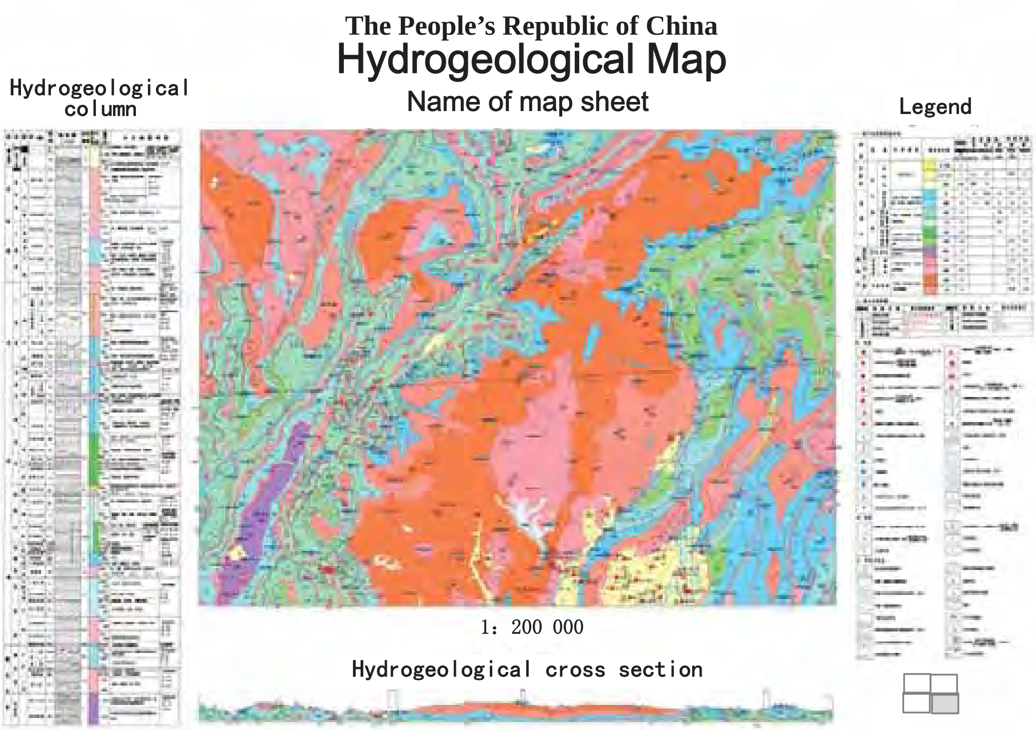
2 300 000 km^2



II . Advance

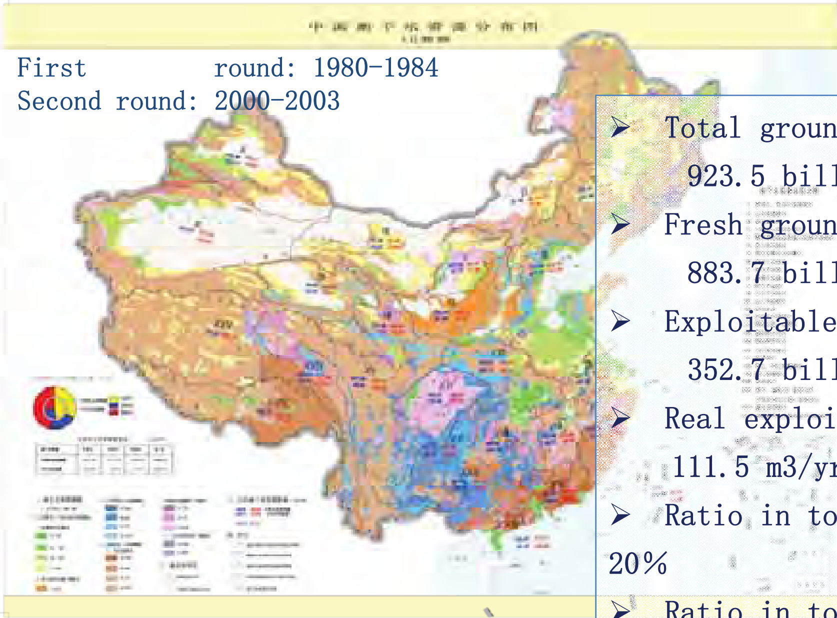


II . Advance



II . Advance

2. National Groundwater Resources Assessment



First round: 1980-1984
Second round: 2000-2003

- Total groundwater resources: 923.5 billion m3/yr.
- Fresh groundwater resources: 883.7 billion m3/yr.
- Exploitable amount : 352.7 billion m3/yr.
- Real exploitation in 2000: 111.5 m3/yr.
- Ratio in total water supply: 20%
- Ratio in total water supply in cities of North China: 66%-72%

II . Advance

3. Investigation and assessment on groundwater resources and environment in main plains and basins

(in scale of 1:250 000)

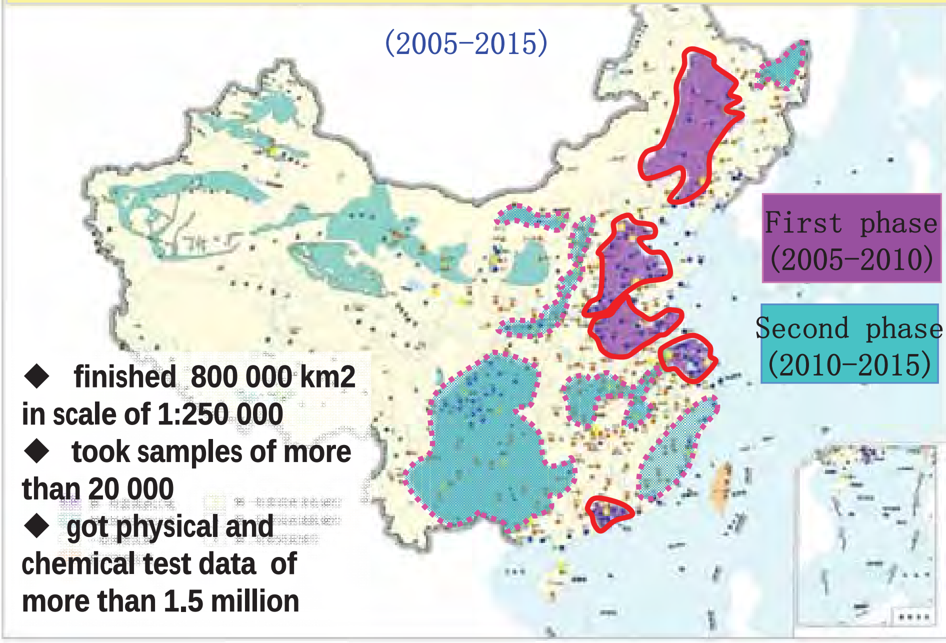
finished areas : 2 000 000 km^2

Eleven plains and basins

II . Advance

4. National Groundwater Quality Investigation

Deploy of National Groundwater Quality Investigation Plan



- **finished 800 000 km2 in scale of 1:250 000**
- **took samples of more than 20 000**
- **got physical and chemical test data of more than 1.5 million**

II . Advance

5. National Geothermal Resources Investigation

- **In 1970s,** Yangbajing geothermal field was discovered , having temperations between 150-200 ℃.
- **In 1980s,** Yangyi geothermal field was discovered, having the same temperatures with Yangbajing
- **Since 1999,** typical regional geothermal investigation has been completed in Guanzhong basin, Yinchuan plain, zone along Qinghai-Xizang etc.
- **Since 2010,** shallow geothermal energy investigation has been carried out in 31 provincial capital cities.

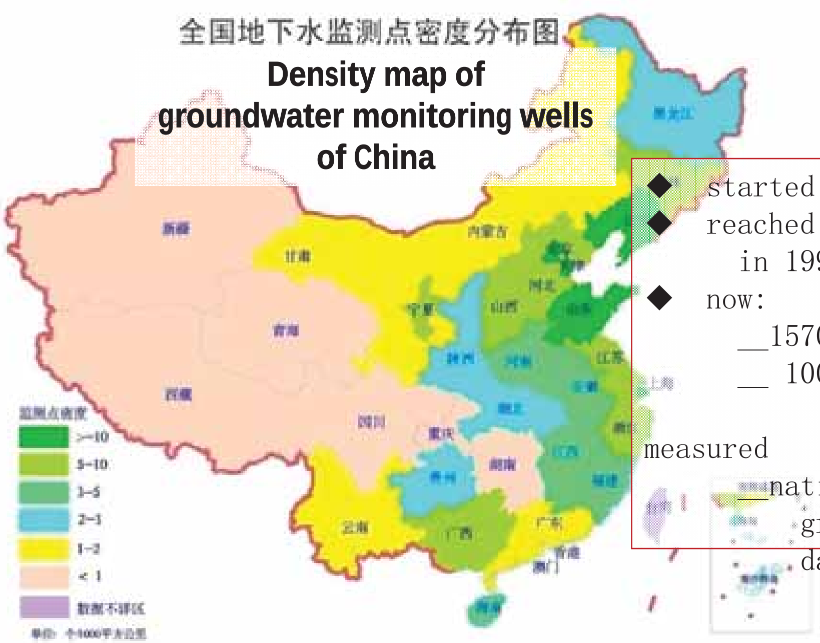
II . Advance

6. Groundwater exploration in water shortage regions and Drilling well emergency action for resisting drought

- ◆ CGS has completed exploration and construction of more 6000 deep wells in 560 counties since 1999
- ◆ completed 2 million micro-wells in Sichuan and Congqing
- ◆ provide clean drinking water for 20 million people

II . Advance

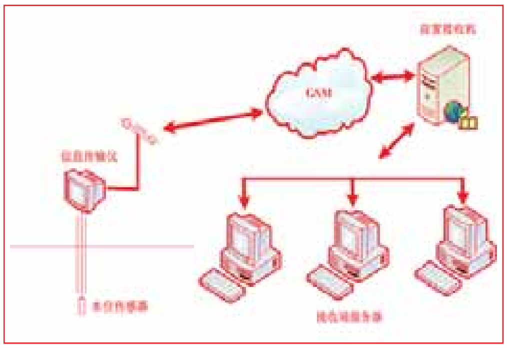
7. National groundwater monitoring network



- ◆ started in 1950s
- ◆ reached 23800 wells in 1990s
- ◆ now:
  - __15700 wells
  - __ 1000 wells auto-measured
  - __national groundwater database

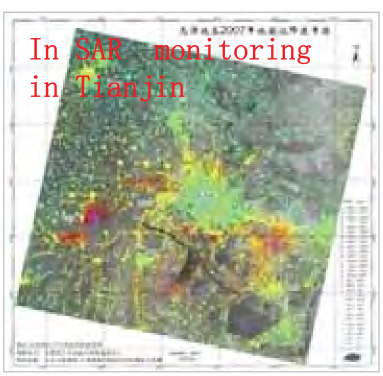
II . Advance

Groundwater Auto-Monitoring System

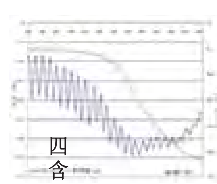


II . Advance

Land Subsidence Monitoring System



Subsidence curve



III. Plan for Next 8 Years (2013-2020)

III. Plan for Next 7 Years (2014-2020)

- 1. Detailed Regional Hydrogeological Mapping
- 2. Hydrogeology for Environment al Protection
- 3. Hydrogeology for Poverty Eradication
- 4. Hydrogeology during Energy and Resources Exploration and Development

Ⅲ. Plan for Next 8 Years (2013-2020)

- China Geological Survey sincerely welcome geological experts and organizations at home and abroad to joint us for handing in hand to create more glorious achievement.

Ⅳ. Case Study of Typical Groundwater Systems in China

Ⅳ. Case Study-NCP

2.2 Case Study in North China Plain

According to *CGS* , WU Aimin et al.,2013, *Report on Dynamic Assessment of Groundwater in North China Plain*,. ZHANG Zhaoji et al., 2009, *Report on Sustainable Utilzation of Groundwater in North China Plain*,.

Ⅳ. Case Study-NCP

North China Plain

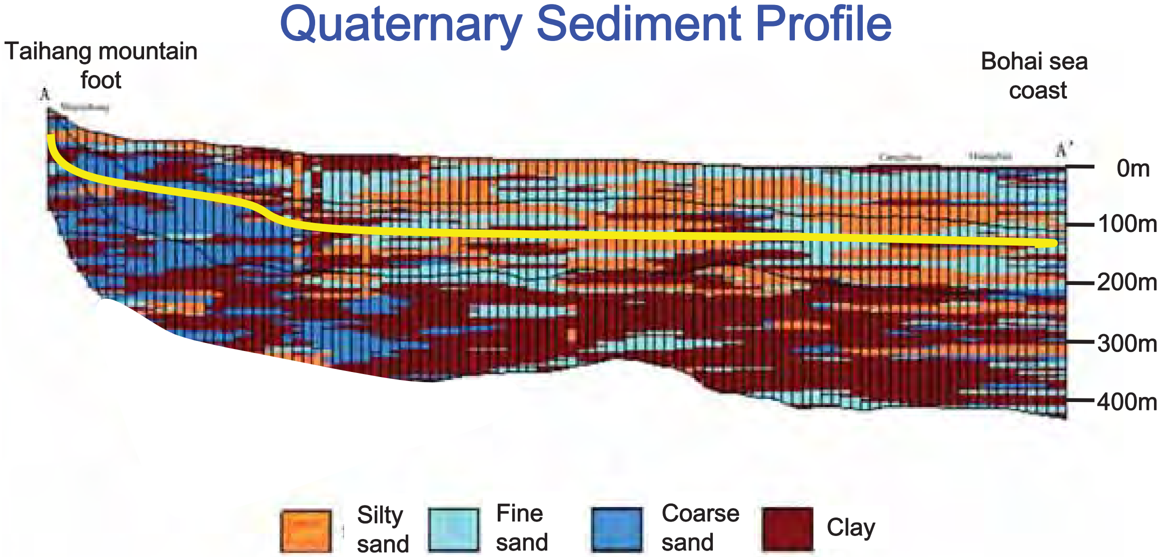
- in the north part of China
- neighbouring the west coast of Bohai Sea
- areas of 139 000 km^2
- latitude of 34°46'N - 40°25' N & longitude of 112°30' E - 119°30' E
- precipitation of 500-600mm/yr.

Ⅳ. Case Study-NCP

- 31 hydrogeological cross-sections
- hydrogeological structure model
- Research of C, H, O isotopes
- groundwater isotope age distribution model
- groundwater numerical simulation model
- main environmental issues:
  --over-exploitation: 100 billion m^3;
  --deep groundwater level cone: 70 000 km^2;
  --land subsidence: 64 000 km^2;
  --groundwater pollution。

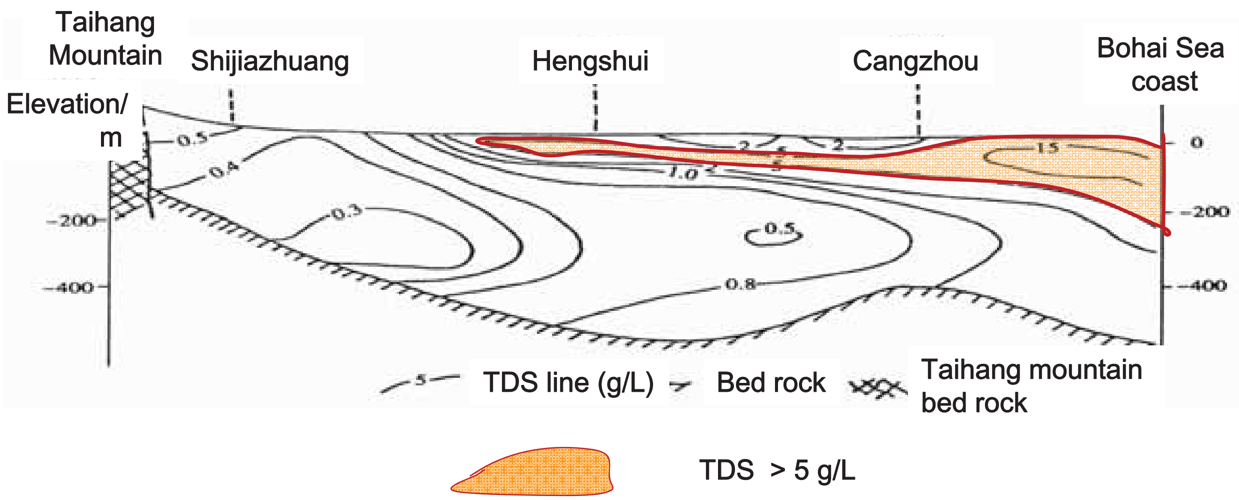
Ⅳ. Case Study-NCP

North China Plain Quaternary Sediment Profile



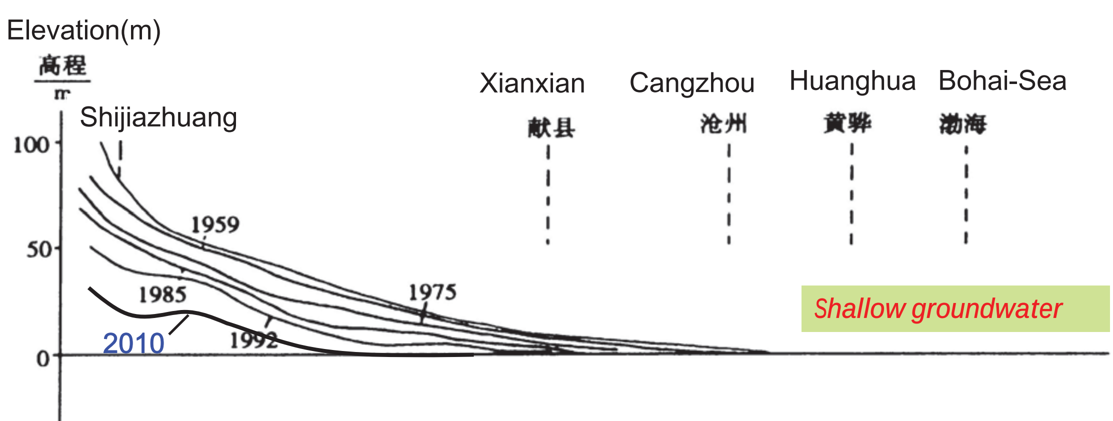
Ⅳ. Case Study-NCP

TDS Profile of North China Plain
From Tanghang Mountain Foot To Bohai Sea Coast



Ⅳ. Case Study-NCP

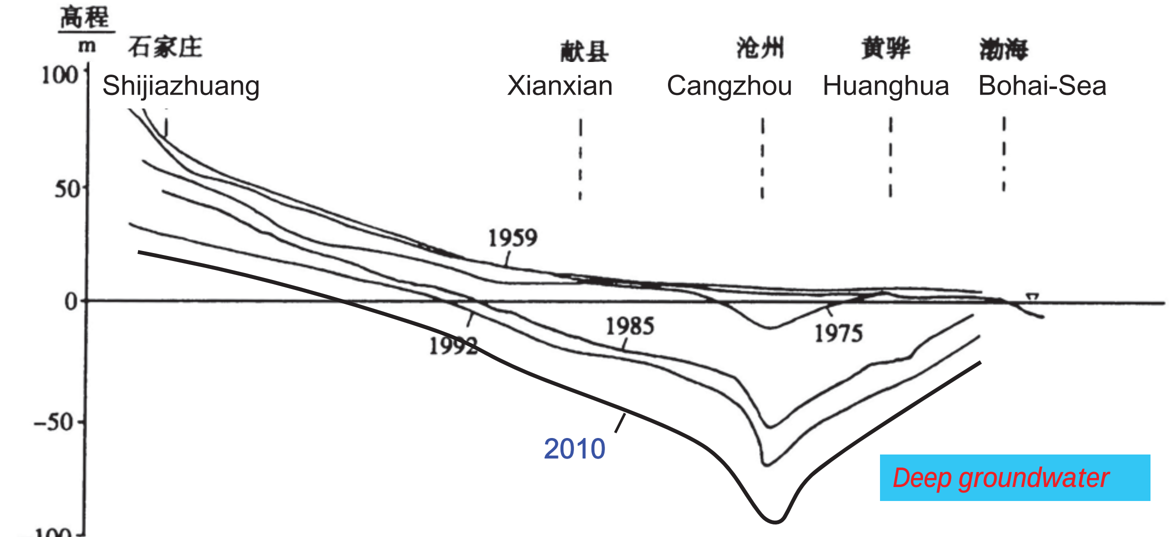
Shallow groundwater levels of North China Plain drop down with time (in profiles)



The depth to groundwater level in Shijiazhang declined from 3 m to 45 m between 1960 and 2010,declining rate by 1.05 m/a.

Ⅳ. Case Study-NCP

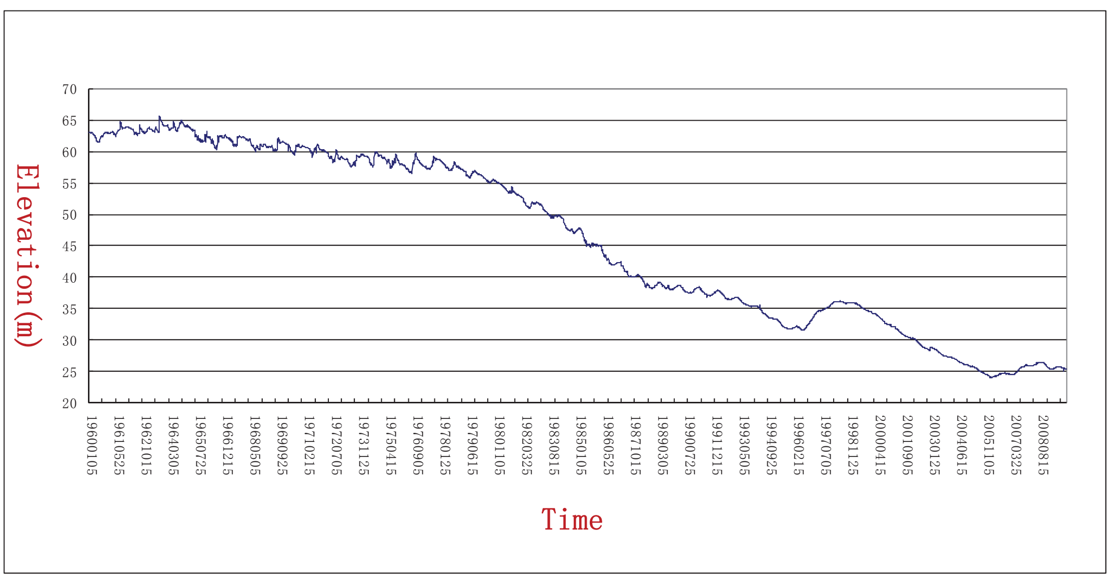
Deep groundwater levels of North China Plain drop down with time (in profiles)



The depth to groundwater level in Cangzhou declined from 6 m to 96 m between 1960 and 2010, declining rate by 2.25 m/a.

Ⅳ. Case Study-NCP

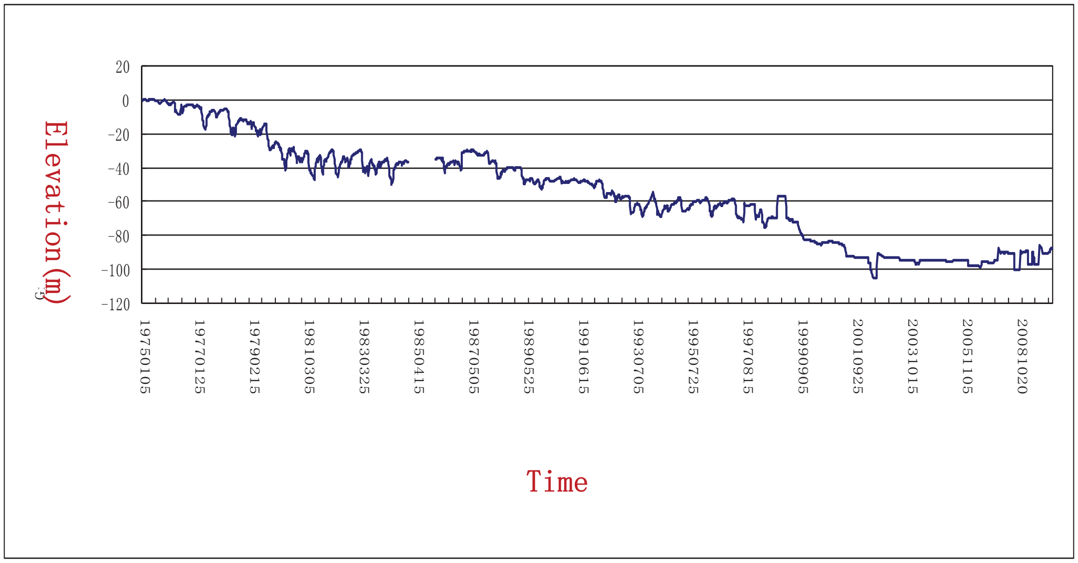
Grounder water level changes with time in Well Shi60 in shallow groundwater



The depth to groundwater level from 3 m drops down to 45 m from 1960 to 2010, declining rate by 1.05 m/a

Ⅳ. Case Study-NCP

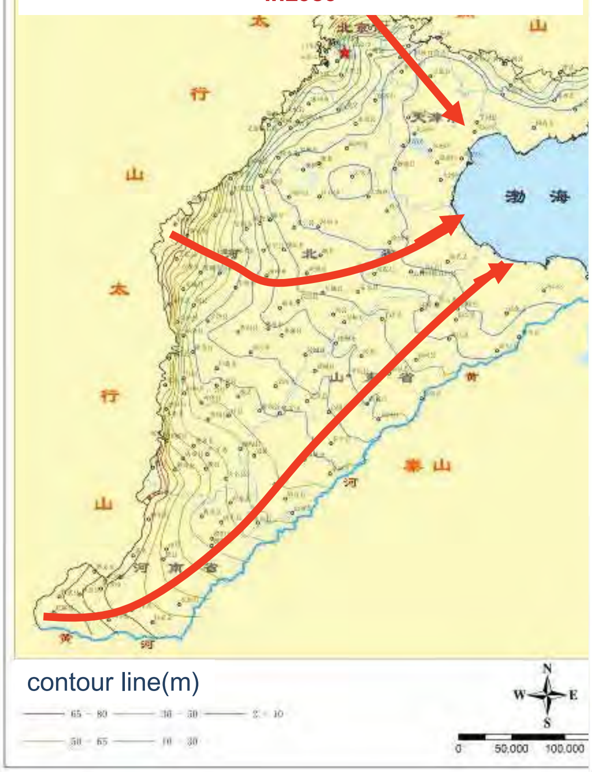
Grounder water level changes with time in Well Cang19-32 in deep groundwater



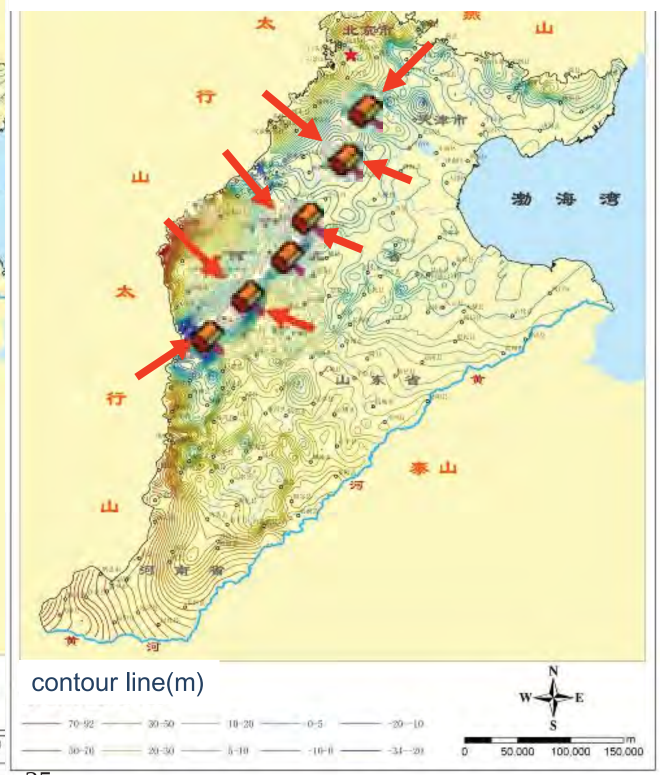
The depth to groundwater level from 6 m drops down to 96 m from 1960 to 2010, declining rate by 2.25 m/a

Groundwater flow pattern changes

Contour map of shallow groundwater levels in1959

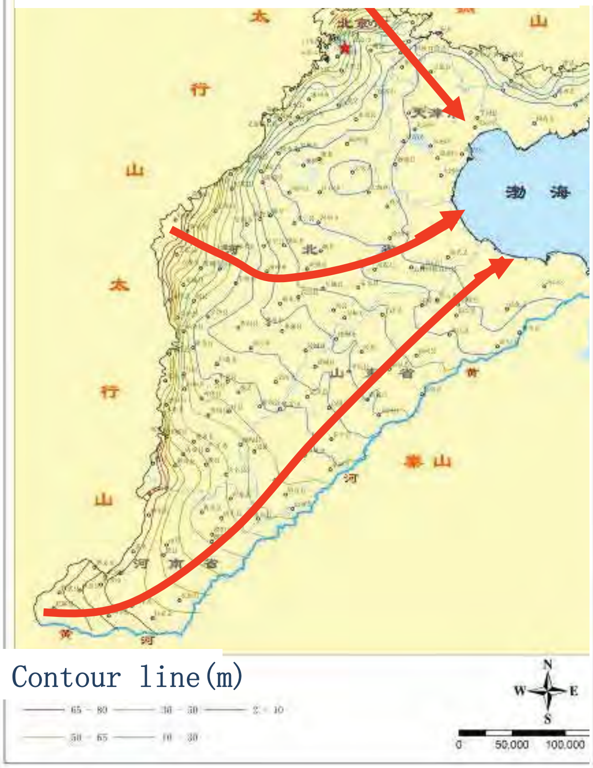


Contour map of shallow groundwater levels in 2007

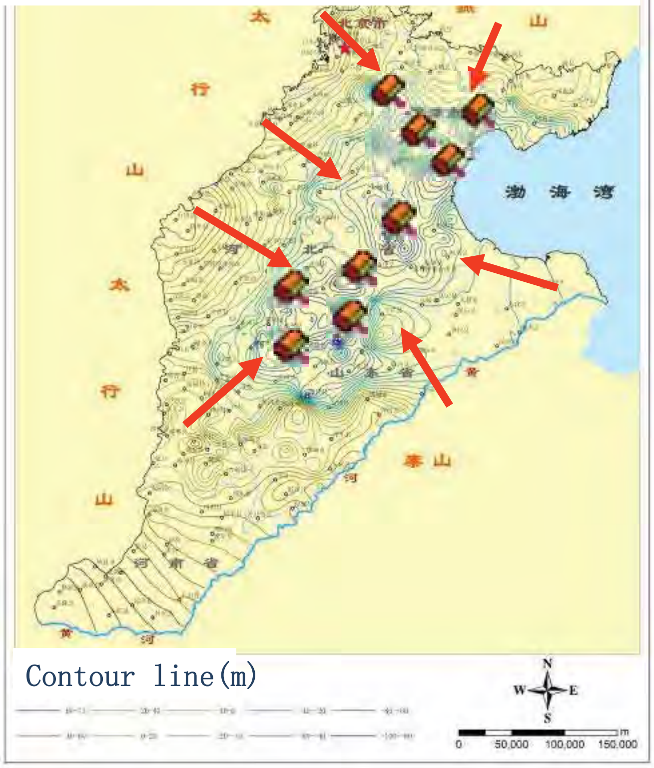


Groundwater flow pattern changes

Contour map of deep groundwater levels in1959



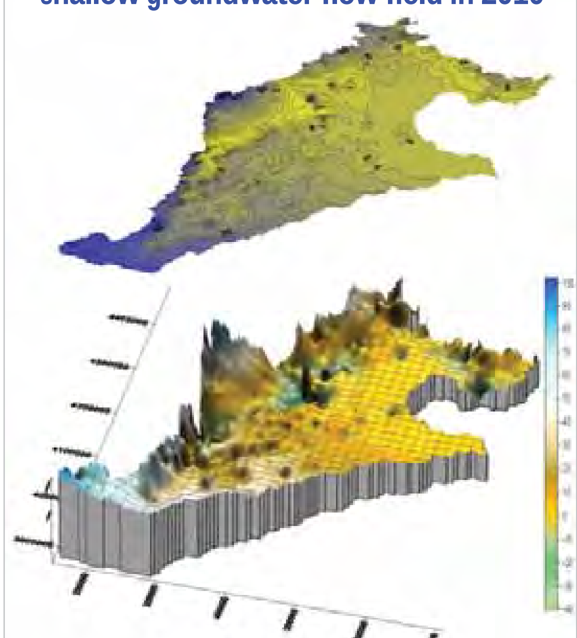
Contour map of deep groundwater levels in 2007



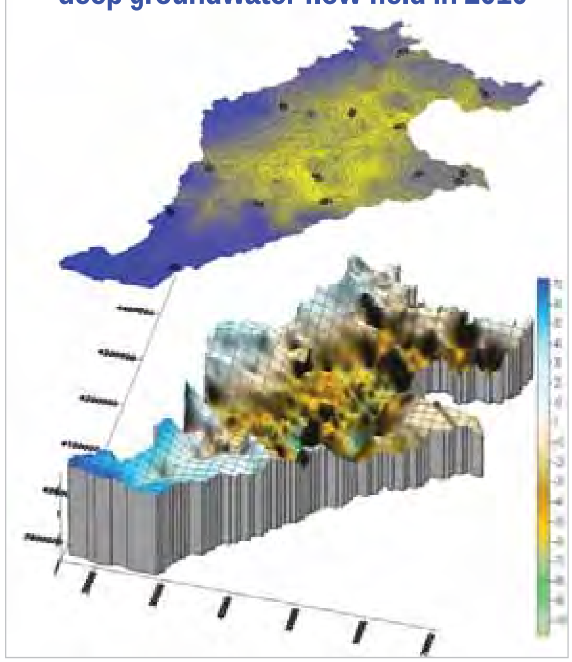
Ⅳ. Case Study-NCP

3D groundwater flow field

shallow groundwater flow field in 2010

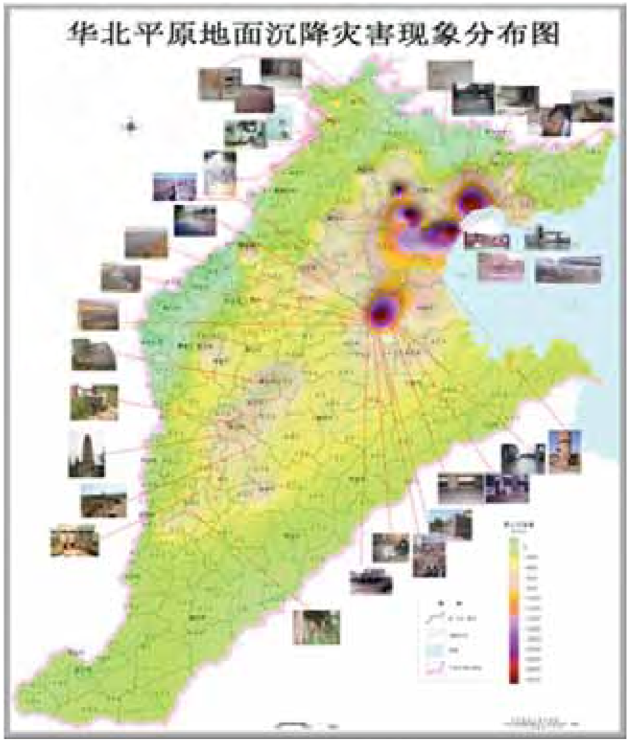


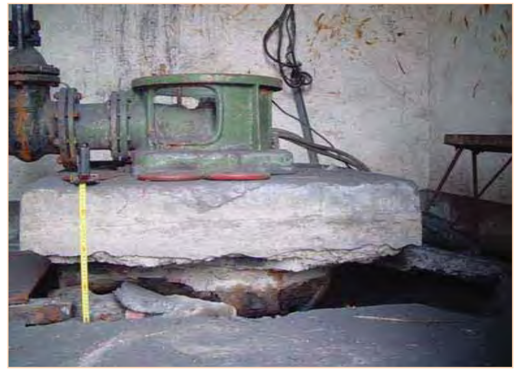
deep groundwater flow field in 2010



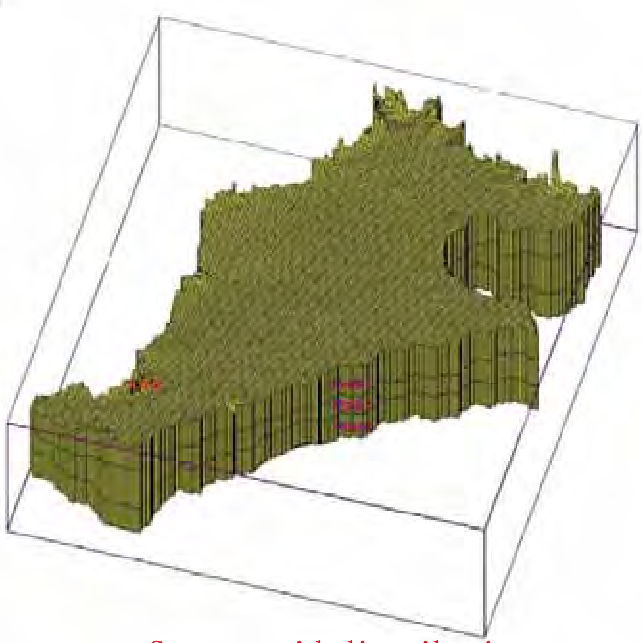
Ⅳ. Case Study-NCP

Land subsidence and ground fissure of North China Plain

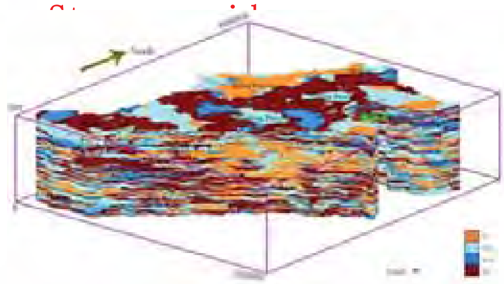




According to Groundwater Modeling



Software: GMS 6.0
Grid pattern: Square grid
Grid width : 4 km
Modeling perid: 2006-2010



Square grid distribution

Geological structure model

By a series of identification and calibration of the numerical model of North China Plain, the following results were gotten.

Groundwater Resources Assessment (2006-2010)

Item		Amount ($10^6 m^3/a$)	Proportion (%)
Recharge	rainfall	15898	79.60
	Yellow River	162	0.81
	Rivers in the region	247	1.24
	Irrigation infiltration	2796	14.00
	Boundary near Mountains	719	3.60
	Boundary near Bohai Sea	150	0.75
	Total	*19.97 billion*	*100*
Discharge	Exploitation	22229	81.88
	Evaporation	4380	16.13
	Yellow River	56	0.21
	Rivers in the rigion	29	0.11
	Bohai Sea	454	1.67
	Total	*27.14 billion*	*100*
Groundwater Budget		-7.17 billion	

An influence of geological processes to coastal development on northern coast of central Jawa (Pantura), Indonesia
A case study: Kendal Coastal plain, Central Jawa, Indonesia

Ungkap M.Lumban Batu

Geological Survey Institute of Indonesia
e-mail : ungkap1951@gmail.com

Abstract

The studied area are situated on Kendal regency west Jawa Province, located at 109 ° 40 '- 110 ° 18' E and 6 ° 32 '- 7 ° 24' S. This area is part of the PANTURA which is situated on the northern coast of Jawa. Pantura is a highway linking western and eastern Java. Thus, this area is very important and therefore the progress of development is very rapid once

A Coastal plain is interface between terrestrial and marine, therefore coastal plain areas are very dynamic and has a high possibility to changes from time to time. In that circumstances development processes of coastal plain area is influenced by several agents such as tectonic activities, sea-level changes, and sediment suplay as well as wave, and current**.** Therefore a study of Quaternary geology dynamic in the coastal plain area are interested to be carried out since the area are changeable from time to time. Understanding of Quaternary Stratigraphy is an important rule to explain an occurrence of geological processes during development of the coastal plain.

Stratigraphic succession of study area mainly consists of surface sediments and sedimentary rocks of Upper Tertiary to Quaternary age. Surface sediments, are commonly composed of alluvium. Alluvium can be found on the coastal plains, rivers and lakes. Coastal plain is in generally covered by clay and sand with a thickness of 50 meters or more. Sand generally form the delta as a water bearing layers with a thickness of 80 meters more. River and lake sediment generally, consists of pebbles, gravel, sand and silt with a thickness of about 1 to 3 meters. Boulders composed of andesite, limestone and sandstone slightly

Upper Tertiary Sediments consists of Damar Formation (Qtd) and Sandstone Member of Damar Formation (Tpds). are the oldest rocks. Damar Formation consists of tuffaceous sandstone, conglomerate, volcanic breccia. Meanwhile Sandstone member consists of tuffaceous sandstone, and conglomerate, partly cemented by calcite. The lower part consists of a conglomerate of cemented by carbonate and changes gradually to the upper part it into tuffaceous sandstone and conglomerate andesite.

In order to construct a Holocene stratigraphy, a series of shallow drilling have been carried out. However, by this method, a technical problems are found because penetration of hand drilling capability to a certain depth has limitations, if the sediment is very thick, it is not possible to reach bed rock.

The data obtaining from the drilling (32 bore holes) is then described on log sheet as a result the sediments are classified into its geological environments. As a consequently Holocene sediments of the studied area can be separated into Fluvial deposit (palaeo channel deposits, flood plain deposit and flood basin deposits) offshore deposits, nearshore deposits, , estuary deposits, , swamp deposits and soil.

Correlation of each lithological units are indeed necessary to be constructed, in order to understand well depositional processes both in vertical or in horizontal such as presence or absence of effects of changes in sea-level during the deposition process or the presence or absence of tectonic activity. It reveals that the studied area has been influenced by several geological processes such as sea-level rise and sea-level drop and Quaternary tectonic activities. Those geological phenomena are expected as the agents to change coastal plain development.

In the southern coast of P.Java, tectonic activity can be understood very well because it deals directly with the activity of the subduction zone due to the movement of the Australian plate to the north.

Meanwhile, on the north coast of P.Java there are several Quaternary basins can be found regarded as indicator of Quaternary tectonics activities.
In addition, in the area of Semarang coastal plain Quaternary tectonic movements can be explained by a correlation of sediment faces. As we know tectonics activities caused changes of environment such as shifting of a coast line or change of river flows direction.
Identification of tectonic activities have been analysed on the basis of morphotectonic, holocene lithological succession, shifting of the palaeo channel deposits as well as by sea-level changes. It reveals that tectonic activities can be distinguish into three phases so called Holocene Tectonic Phase One (THP-1), Holocene Tectonic Phase Two (HTP-2) and Holocene Tectonic Phase Three (HTP-3).
Holocene Tectonic Phase One (THP-1), is reactivation of east – west thrust fault which is represented as tectonic boundary between Damar Formation and Kerek Formation. An effect of the tectonic activities, a basement rock is subsidence as a consequently sea-level rise, and on the other hand the so called fluvio-deltaic basin was formed. Besides, it is also observed that palaeo channel one (Ch-1) shifted to be palaeo channel two (Ch-2) to the east direction.
Holocene Tectonic Phase Two (THP-2), are indicated by shifting of palaeo channel two (Ch-2) to be palaeo channel three (Ch-3). Shifting of palaeo channel is believed due to upfliting of western part of the investigated area. An indication of tectonic upfliting is expressed by the difference of drainage pattern on coastal plain area. Drainage pattern of sub dendritic – dendritic in the western part of the investigated area is likely controlled by the basement rock as a consequent of upflited.
Holocene Tectonic Phase Three (THP-3) have responsible to the development of the coast line to be northeast direction.
Based on those data it is understood well that development of the coastal plain for the future is to eastwest direction. In that circumstance, the regional development plan in this area can be laid out in accordance with existing conditions. As a result loss due to natural processes such as erosion (abrasion), or sedimentation can be reduced.

1. Introduction

Indonesia is geographically located between longitude 94º 14’ E – 141 E and latitude 06º 08’ N - 11º 15’ S. It is a huge archipelagic country extending 5,120 kilometers from east to west and 1,760 kilometers from north to south. Indonesia consists of 17.000 islands (some sources say as many as 18,000) with a total coast line length exceeding of 81,000 km. There are five main islands (Sumatra, Java, Kalimantan, Sulawesi, and Irian Jaya). Two of the islands are shared with other nations; Kalimantan (known in the colonial period as Borneo, the world's third largest island) is shared with Malaysia and Brunei, and Irian Jaya shares the island of New Guinea with Papua New Guinea. Indonesia's total land area is 1,919,317 square kilometers, roughly two third of the total area is ocean. The country borders two oceans with the sea water flows from Pacific to Indian Oceans passing the archipelago via the so called Indonesian water through flow.

Approximately 60 percent of Indonesia is forested and 41 percent is mountains, comprising two ranges; one mountain range run from the Philipines into eastern Indonesia and the other is running along the western coast of Sumatera pass through Jawa, Bali, curving north through the Sulawesi island.

The archipelago is almost entirely tropical in climate, with the coastal plains averaging 28°C, the inland and mountain areas averaging 26°C, and the higher mountain regions, 23°C. The area's relative humidity ranges between 70 and 90 percent. Winds are moderate and generally predictable, with monsoons usually blowing in from the south and east in June through September and from the northwest in December through March. Typhoons and large scale storms pose little hazard to mariners in Indonesia waters; the major danger comes from swift currents in channels, such as the Lombok and Sape straits.

Located on the equator, the archipelago experiences relatively little change in the length of daylight hours from one season to the next; the difference between the longest day and the shortest day of the year is only forty-eight minutes. The archipelago stretches across three time zones: Western Indonesian Time—seven hours in advance of Greenwich Mean Time (GMT)--includes Sumatra, Java, and eastern Kalimantan; Central Indonesian Time--eight hours head of GMT--includes western Kalimantan, Nusa Tenggara, and Sulawesi; and Eastern Indonesian Time--nine hours ahead of GMT-- includes the Malukus and Irian Jaya. The boundary between the western and central time zones--established in 1988--is a line running north between Java and Bali through the center of Kalimantan. The border between central and eastern time zones runs north from the eastern tip of Timor to the eastern tip of Sulawesi.

In Indonesia, an earthquake, landslides, tsunamis, volcanic eruptions, and floods can changes coastal line in a short period of time. Most actual samples where there is a change of coastline in a short period caused by earthquake December 26, 2004. In that event, most of the west coast of Aceh has subsidence, and partially on the Andaman coastline uplift. Although these events occurred within a short scale, but the process is a series of tectonic cycle in a long period of time. The consequences of coastal changes resulted in damage to property, such as farm buildings, fish farms, salt and other public infrastructure.

Changes in the coast line by the result of volcanic eruptions occur either directly or indirectly. Directly changes occur due to volcanic products that reach down to the shoreline like a lava flow. Changes of coast line by volcanic eruptions are related to the abundance of the volcanic material which is then transported by rivers and deposited on the beach. As a consequence of coastline will change.

A Change of the coast line in a long period of time occur by uplift and subsidence as the effect of tectonic activity. Changes in this beach will bring negative impact on socio-economic life of people living around the beach. It is also well known that Coastal area which is consists of quaternary sediments, are among the most productive and diverse ecosystems and it is intensively exploited and impacted by human activities (residential, agriculture, fisheries) that strongly modify habitats and fluxes of water, sediments and nutrients.

Sea level change could also be correlated with humidity. The change in humidity in the late Pleistocene and Holocene is generally understood as the influence of ancient monsoon activity, which is associated with the Milankovitch cycles (Kutzbach and Street-Perrot, 1985; Overpeck et, al.1996). Chappel and Polach (1991), conducted a detailed stratigraphic studies and age dating of Holocene coral where they have proved that the maximum sea level height is happening in the 9000-10000 years ago. This period can be associated with maximum climatic conditions and coincide with the peak of melting ice (inter-glacial maximum). The maximum temperature difference between glacial (18,000 ± 3000 yr. ago) and early Holocene as the climate optimum (9000 ± 3000 yr. BP) has been described by Williams et, al.(1993).

Pandarinath et, al.(2001) studied sea level changes and sedimentation in the late Quaternary period by using drilling data, they concluded that the age of wood and peat carbon is between the ages of 10,760 ± 130 to 9280 ± 150 yr. ago which included the late Pleistocene until the beginning of the Holocene. Based on global stratigraphic correlation and related to the

Quaternary basin formation and deposition processes then the age of the Quaternary sediments in the studied area are late Pleistocene until Resen.

Pantura is a term applied to called a main road which is situated along coastal area of north Jawa between Merak in the west and Banyuwangi in the east, and it has a length of about 1316 km. The main road pass through five provinces i.e. Banten, DKI Jakarta, Weast Jawa, Central Jawa, and East Jawa. It is also across a number of big cities in Java, such as, Cilegon, Tangerang, Bekasi, Cirebon, Tegal Pekalongan, Semarang, Rembang, Tuban, Surabaya, Pasuruan, Probolinggo, and Banyuangi. Therefore PANTURA has a very high economic significance.

The main purposes of the investigation is intended to study a changes near shoreline development by the geological process such as tectonic activity sea-level changes which mainly is based on Quaternary stratigraphy succession.

The investigated area belong to the Kendal district, Central Java province and is geographically located at coordinates 110 ° 00 '- 110 ° 15' E and 6 ° 50 '- 7 ° S. Nearly 90% of Kendal coastal plain and surrounding area are covered by a Quaternary sediments. It is a coastal region that is composed of coastal plains, river plains, swamps and plains of the active delta, so it is very dynamic. In a short period of time, coastline can change significantly. Therefore, the study of coastal changes need to be carried out so that the method to overcome problems can be selected and implemented to avoid greater losses in the future.

2. Methodology

In order to construct a Holocene stratigraphy, a series of shallow drilling have been carried out. However, by this method, a technical problems are found because penetration of hand drilling capability to a certain depth has limitations, if the sediment is very thick, it is not possible to reach bed rock.

During the study had been drilled as many as 32 bore holes, which was conducted in the coastal plain area of Kendal, and it has a depths ranging from 4 meters to a maximum of 11 meters. Those data are then plotted into the vertical section with the scale of 1: 100. Drilling data is then observed in detail. Each or every character of the sediment such as: changes in vertical faces boundaries, colors, composition, grain, weathering and other relevant characteristics are observed. Further drilling data are correlated to determine the composition sediment interval, so that the sedimentation processes can be understood.

A history of a changes of coastal plain development is derived by stratigraphic succession analysis of Section A-B, C-D, E-F, and Section G-H. Each section consists of several bore holes. Each bore hole has been described and plot it onto from of log bore description. The description have been made based on its colour, fossil content, clay content, organic content, grain size, structure and by other physical characters. These stratigraphic section has a direction of east-west, starting form south to north respectively. In that way it is clear to be understood the development of coastal plain both vertically or horizontally.

3. Geology and tectonic setting

Tectonically, Indonesia lies at the junction of three major crustal plates, the Pacific, the Australian, and the Eurasian (**Fig. 1**). The intersection of these plates is responsible for the creation of one of the world's most complex geological settings. Along the collision zone tertiary sediments are folded and faulted and have emerged above sea-level to form island arc.

Volcanic belt also follow the geological framework, extending from northern tip Sumatera to Jawa, Nusa Tenggara, Maluku, North Sulawesi, covering a distance of about 7000 Km. The number of active volcanoes in the world is counted about 800 in which 129 volcanoes in Indonesia and around 400 dormant are included. This condition makes Indonesia an earthquake affected area as consequently natural hazards such as landslides, volcanic eruption, earthquake and tsunami are frequently occured in Indonesia.

A large amount of geological study has been done and the main publications that stand out are the compilation of Van Bemmelen. So far, however, there are still no such comprehensive publication replaces Van Bemmelen's which utilizing modern concepts and broader amount of data.

It is generally acknowledged that two continental shelfal regions dominate the physiographic setting of the Indonesia archipelago, the Sunda shelf area on the western part and the Sahul to the east. The tectonic styles for these two regions are completely different. In the Sundaland, the predominant factors are the frontal subduction underneath Java and oblique subduction underneath Sumatra, whereas in the Sahul region, the predominant factor is the continental collision of Australian plate with the other two (Zen, 1994). Therefore the eastern part of Indonesia has more complex plate interaction, such as the Banda orogen which was formed by the collision of the Australian continental crust, mixed oceanic and continental crust of Eurasian, and the westward moving oceanic crust of the Pacific (Achmad, 1998). Therefore, this region is highly unstable except Kalimantan.

Mountains ranging between 3,000 and 3,800 meters above sea-level can be found on the islands of Sumatra, Java, Bali, Lombok, Sulawesi, and Seram. The country's tallest mountains, which reach between 4,700 and 5,000 meters, are located in the Jayawijaya Mountains and the

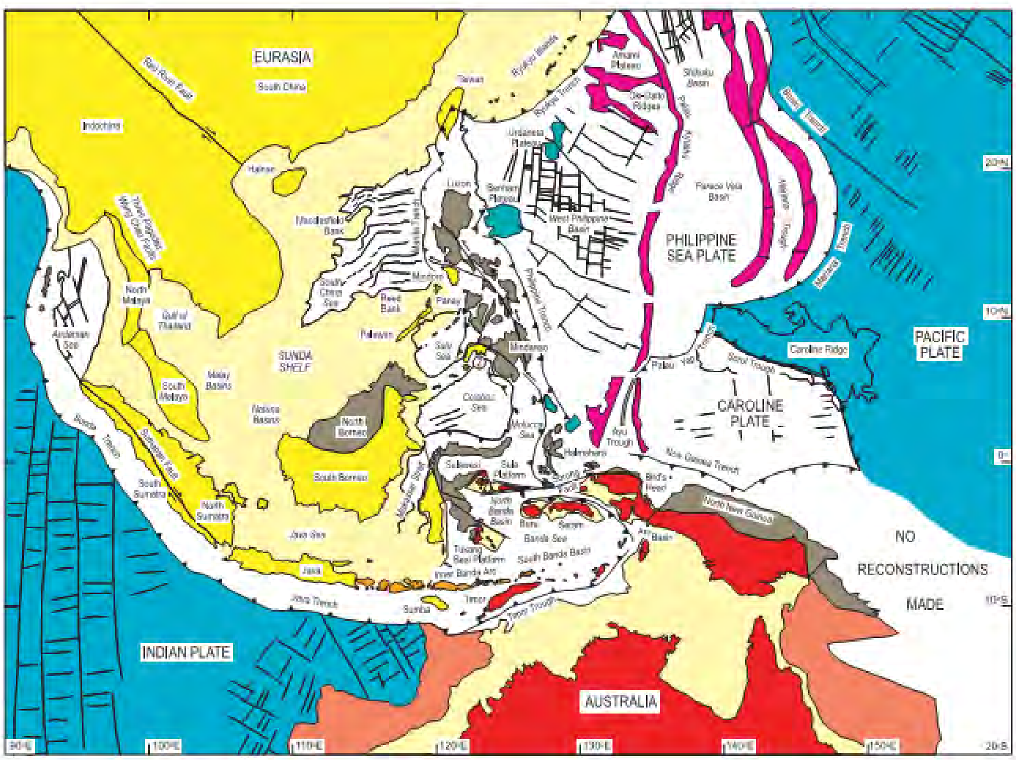


Fig. 1. Simplified Present Day Tectonic Configuration of SE Asia

Sudirman Mountains in Irian Jaya. The highest peak, Puncak Jaya, which reaches 5,039 meters, is located in the Sudirman Mountains.

Discussion of the structure and Quaternary tectonic of the investigated area has been carried out by Lumbanbatu et, al.(2007). The discussion is based on the Geological Map of Magelang, Semarang Sheet, scale 1: 100,000 (Thanden. et, al.1996). On the map it is clearly be shown a Quaternary faults line in the study area cut Damar Formastion (Plio-Pleistocene). In the vicinity of Muteran the Quaternary fault was described as thrust fault, whereas in the vicinity of the north slope of Mount Gili Kelor it was described as strike-slip fault and around the river, fault then described as a normal fault that was given notation U (up) and D (down) (**Fig. 2**). On this occasion the authors interpret that the Quaternary fault is classified as thrust fault. This opinion is based on the assumption that the main stress comes from the south to the north as a result of Indo-Australian plate movement to the north. In that circumstance, in the southern part the bedrock croupout into the surface (uplifted). On the other hand, in the northern part due to fault movements, fluvio-deltaic basin formed and subsequently filled up by fluvial and deltic sediments. The main Quaternary Fault is then cut by a fault trending to southeast - northwest. These indications prove that the fault is active, because its activity give effect to Holocene sediments.

Poedjoprajitno et, al.(2008) in the discussion of regional structural of Kendal regency recognize the existence of active fault below the surface that is Wonorejo fault, Jambe Kidul fault and Kuto fault. They identify that due to Kuto fault activities the basement rock up and

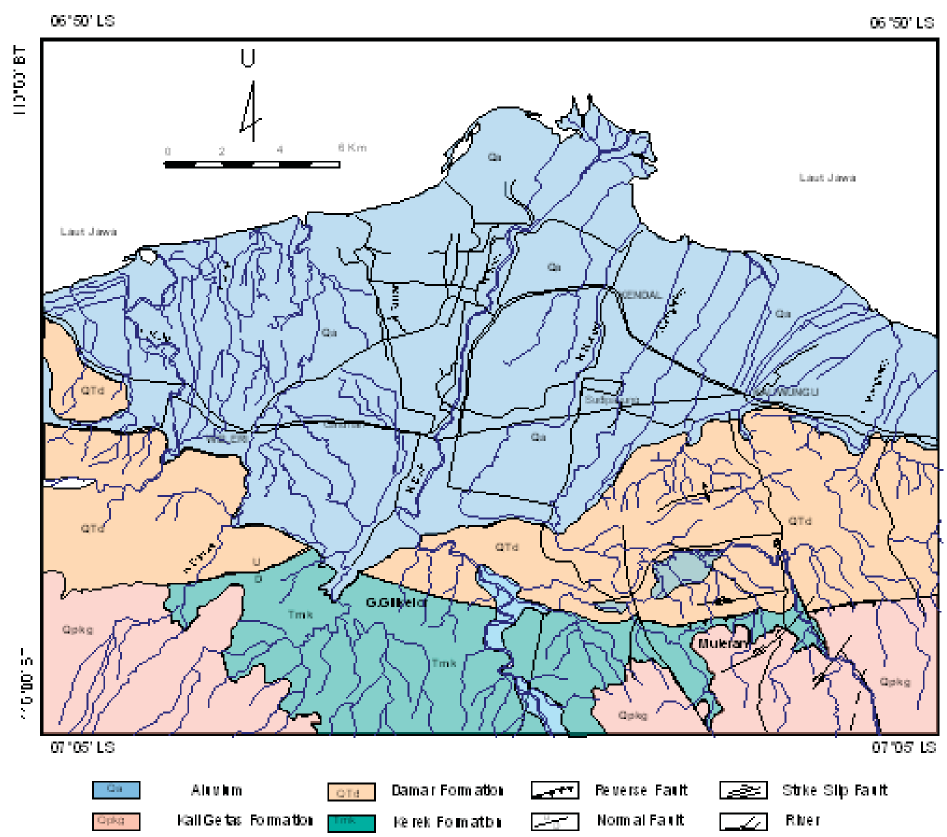


Fig. 2. Geological map of Kendal and surrounding area Central Jawa Province, showing the difference of drainage pattern on flood plain area (Thanden, dkk, 1996)

as result Damar formation croup out at surface, meanwhile on the other side it form a basin which is filled up by Holocene sediments. Kuto Fault based on analysis of measurement expressed as a thrust fault.

In general, geomorphology of Kendal regency is divided into two morphological units, namely lowlands (coast) and highland areas (hills and mountains). The northern part of Kendal region is lowlands has a height of 0-10 meters above sea level, which includes the District Weleri, District Rowosari. Kangkung, Cepiring.Gemuh District, District Ringinarum, District Pegandon. Sub Ngampel Patebon District, District and Kecamatan Kendal , Kecamatan Brangsong dan Kaliwungu. The region is dominated by low-lying areas and adjacent to the Java Sea, the climatic conditions in this areas tend to be hot with an average temperature of 27 ° C.

The southern part of Kendal Regency is a highland area consisting of hills and mountains with a height of between 10-2579 meters asl. This Hilly land covers District: Plantungan, Pageruyung District, District Sukorejo, Patean.Boja District, District Limbangan, Singorojo District, and District Kaliwungu South and climate tends to be cooler with an average temperature of 25 ° C.

Based on its genetic geomorphological of the investigated area can be grouped into the marine origin, fluviatile origin, denudation origin, structure origin and volcanic origin (Poedjoprajitno et, al.2008). Marine origin is then further more based on its landform, can be differentiated into coastal plain and Fluvio-marine**.** It is composed generally of mud (swampt), silt and gray clay containing shall fragments.

On the field it has a difficulty to draw boundary line between the unit formed by the marine and fluvial processes. However, by the interpretation of satellite images, it would be very helpful in drawing the boundaries of both morphological units. In general, morphological units in the northern part of the studied area are dominated by the marine and alluvial origin. Therefore, in this area, we can found two forms of land namely Fluvio-marine origin and Fluvial origin.

4. Fluvio-marin Origin

A simple example of Fluvio-marine origin is represented by deltaic active. Formation of deltaic active is probably occured due to supply material are much more compare to wave velocity. Delta formation can occur because the supply of material deposited on the beach is much greater than the speed of ocean waves, and currents that move material. In other words the formation of deltas in this area due to wave energy and current conditions are weak. Therefore, the formation of deltas in the study area can be classified as a delta which is strongly influenced by fluvial systems (fluvial-dominated deltas) (HG Reading, 1986**).** Bodir River, Kunto River, Blukar River, Cangkring River, Kenceng River and Kendal River **,** Kali Kanci, Kali Pengarengan, Kali Bangkaderes, Kali Cisanggarung, and Kali Kabuyutan are responsible to transport material which is then deposited on the beach formed delta.

Besides delta**,** it was found also the bay**.** There are at least three bays can be recognized in this area such as Mundupesisir Bay**,** and the Gulf Balong and Gulf M. Kluwut**.** Similar conditions are found in the Kendal (Lumban Batu**,** 2009**).** The mechanism of the process of forming this bay could be due to the supply of material to be deposited on the beach is not available, or in other words there is no river goes into the sea around the beach. Therefore, the effect of marine is more dominant.

5. Fluvial origin

The fluvial origin, occupy the northern and eastern regions (Qac). This region is the alluvial plains with an altitude of less than + 14 m covered by alluvial deposits (Qa). Characterized by flat terrain slightly undulating. Lithologically is mainly composed of gravel, sand and gray clay, which is deposited along the flood plains. Sediment thickness is estimated to <5 m (Silitonga et, al.1996).

Lumbanbatu, et, al.(2007) recognize that in alluvial plain there are a difference in density and drainage patterns. In the western part of the study area drainage pattern of subdendritic - dendritic are developed well, meanwhile in the east drainage pattern of subparallel-parallel are developing.

According to them, differences in the drainage systems in the same geological conditions (of alluvial plain), interpreted as a reflection of differences in sub surface geological conditions. The development of subdendritic - dendritic in the western part of the study area is probably due to the influence of bed rock structure. Effect of bedrock can occur because of overlaid sediment covering the bedrock are very thin. Meanwhile in the eastern part of the study area sub parallel – parallel drainage system are developed, It seems to be as an indication that the development of drainage patterns in the area are not influenced by the subsurface geological conditions. This means that alluvial sediment in the east is very thick. These facts shows that process of sedimentation in the western part has not developed well due to upflited and consequently sediment are thin. In contrast in the eastern part, sediment (alluvial) become quite thick because bed rock subsidence.

In general, the drainage pattern in this alluvial plain can be divided into three distinct patterns such as meandering pattern, sub-dendritic and subparallel-parallel. The pattern of meandering river is shown by Kali Cisanggarung. To the south, near to the hillys area, sub-dendritic drainage pattern develops well, meanwhile to the north closed to the shoreline the sub-parallel are developing.

6. Stratigraphy

According to Thanden et, al.(1996), stratigraphical succession of the investigated area started by Damar Formation (Plio-Plistocene) of non marine environment which is indicated by the prsence of vertebrate fossils. It consists of tufaceous sand, conglomerate, and volcanic breccia. Damar Formation is then overlaid unconformably by alluvial deposits. For further more alluvial deposit is able to divided into flood basin, flat plain deposits, and lacustrine deposits. Alluvial deposite distributed almost all over investigated area and it has a maximun thickness of about 80m.

Sumanang et, al.(1997) in Quaternary geology map sheets of Estuary-scale 1:50,000 Cirebon in West Java, said that, Qac categorized as BM (Beach on marine), above the beach ridge sediment deposition near shore / shallow sea. Meanwhile, Qa included in faces FM (Floodplain on marine) that is above the floodplain sediment deposition near the beach .

7. Characteristic of coastal (Coastal characteristics)

Coastal plain is an interface between terrestrial and marine, therefore coastal plain areas are very dynamic and has a high susceptibility to changes from time to time. In that circumstances development processes of coastal plain area is influenced by several agents such as wave, current, sea-level changes, and sediment supply. In Indonesia development processes of coastal plain are influenced by sea-level changes, tectonic activities, and climate. Those factors are believed as an agent to progradation and retrogradation of shore line.

Topographical condition of coastal plain area are commonly flat to gently slope. On some part formed swamp, mangrove, and beach sand. Shore line composed of mud, sand, and gravelly sand. Around river mouth commonly sediments coaster. In general, coastal characteristic usually effected by its sediment composition. Therefore coastal characteristic are commonly effected by the length of river and wide of its catchman area. There are several main rivers flows the area such as Bodri River, Kunto river, Blukar River, Cangkring river, Kencang River, and Kendal Riever.

Besides, coastal characteristic are also be influenced by its geological condition, especially on its lithological composition. Coastal plain in general, have been used as salt-field, or brackish water fish pond.

Coastal plain is a very dynamic region and susceptible to change. A changes of coastal plain occur within a short period (short term changes), medium term (medium term changes) and in the long term (long term changes) (Bird and Ongkosongo, 1980).

Coastal changes may be natural, or they may be due, at least in part, to the direct or indirect effects of Man's activities in the coastal zone and in the hinterland. Direct effects include the building of sea walls, groynes, and breakwaters, the advancement of the shoreline artificially by land reclamation, and the removal of beach material or coral from the coastline. Indirect effects include changes in water and sediment yield from river systems following the clearance of vegetation or a modification of land use within the catchments, or the construction of dams to impound reservoirs that intercept some of the sediment flow. There are many examples of such man-induced changes on the coasts of Indonesia.

Lithology of the coastal plain is mostly composed of mud, silt, sand and pebble. In the vicinity of river mouth usually consists of coarse sediment. In general, the characteristics of the coast are affected by the type of material transported by the river, then deposited on the beach. Therefore, the characteristics of the coast is strongly influenced by the length of the river and catchment area (Yinwang et, al.2003). The longer the river that flows in areas of has a very gentle slope, the more finer material that will be deposited on the beach. Therefore the influence of river activities in controlling the growth of coastal development in the studied area is strongly influenced by river activities.

Besides, geological conditions are also be considered as a main factors to control coastal characteristics.

The main rivers that flowing in this region is Kali Bodri, Kali Kunto, Kali Blukar, Cangkring Kali, and Kali Kendal Kali Kenceng. Up stream of. Kali Bodri itself is located on Mount Prahu, in the southern of studied area, that flow through the catchment area (catchman area) covering 640 km^2 (**Fig. 2**).

In study area, transported material by the river was deposited on the northern coast of Java and form the active delta. This active delta occur because the supply of material deposited on the beach is much greater than the speed of ocean waves, and currents that move material. Therefore, the delta formed in the study area strongly associated with the presence of Bodir Kali, Kali Kunto, Kali Blukar, Cangkring Kali, Kali Kali Kenceng and Kendal. Therefore, the formation of deltas in the study area can be classified as a delta which is strongly influenced by fluvial systems (fluvial-dominated deltas) (HG Reading, 1986). Based on the description can be concluded that the characteristics of the coast in the Kendal area effected by supply of material transported by the upper reaches of the river on the south and then deposited along the coast of Kendal.

8. Quaternary geology

A study related to the sedimentology and stratigraphy in the Kendal area have been carried out by Lumban Btau et, al.(2007), based on stratigraphic succession derived from the four cross-sections in east - west, directions. They concluded that the Quaternary sediments in the study area can be divided into 1). Swamp sediment, 2). Estuarine Sediment, 3). Near shore sediments, 4). Offshore Sediment, 5). Fluvial deposits and 6). Para-Holocene sediments.

Hidayat et, al.(2008) distinguish the Quaternary sediments into Damar Formation, offshore deposits, nearshore deposits, river channel deposits, estuary channel deposits, flood plain deposits, swamp deposits and soil. The study is based on five section which has a direction of north-south and northwest - southeast and northeast - southwest. It reveals that there are no difference regarding the composition of Quaternary sediments in the study area, either through cross-section trending north - south and east-west.

Furthermore, to know the sedimentation processing in the study area, the following discussion attempts to explain the Quaternary lithological succession of each section.

On cross-section AB (**Fig. 3**), a lithological succession starting from the lowest part (basement rock) consists of sticky gray clay, very dense and contain patches of yellow spots, and fragments of volcanic rocks with a diameter of 0.5 - 1 cm. These bedrock are the result of weathering of Damar Formation called pre Holocene deposit. The basement is then covered

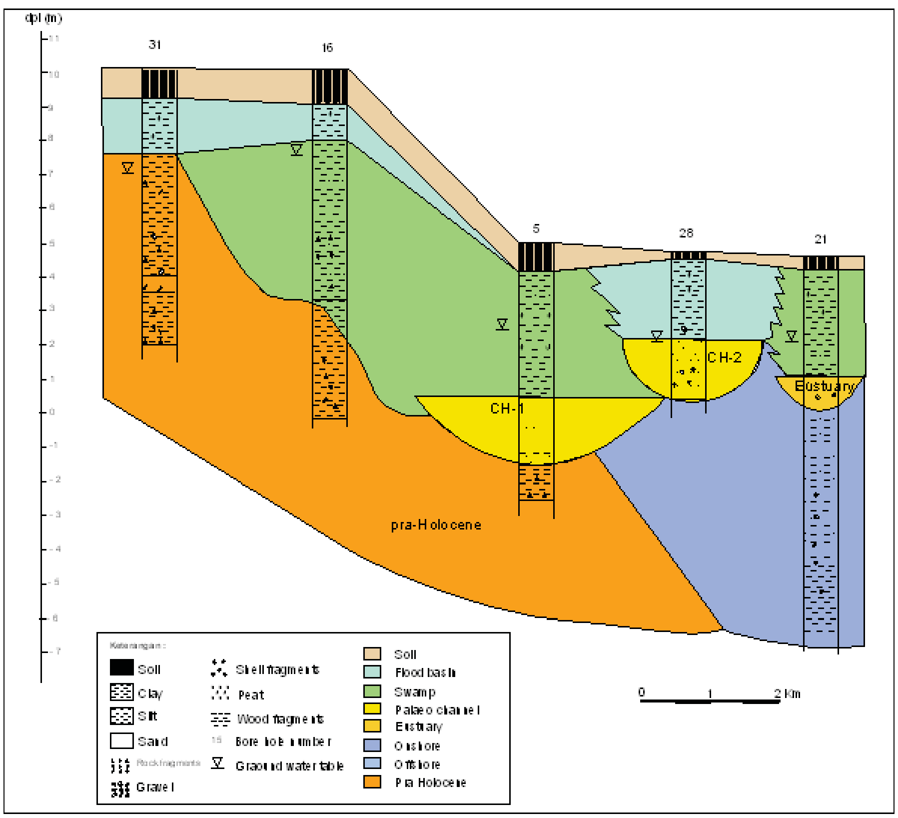


Fig. 3. Lithological correlation along A-B section

by near shore sedimen consists of dark greenish gray silt, which is intercalated by a thin layer of fine sand and many contain fragments of shellsmolluscs . The lower part consists of green clay. Furthermore the near shore sediment is then overlaid by well-developed swamp deposits which has a thickness of 8 m. This sediments are generally composed of yellowish brown clayey silt containing plant remaind, such as leaf and roof. Lumban Batu et, al.(2007) states that the formation of a thick swamp deposits can be assumed as indication of a calm depositional conditions.

They also mentioned that there was a shifting of palaeo channel to the east (Drill Point 28), but there was no explained how these palaeo channel sifting. According to the opinion of the writer, shifting of palaeo channel one (Ch-1) into palaeo channel two (Ch-2) is interpreted as the result of tectonic activity of Holocene Phase One (TF -1) shortly after calm conditions ended. This palaeo channel two (Ch-2) erodes swamp sediment covering the near shore deposits. Flood basin sediment produced by palaeo channel two (Ch-2) activities consists of clayey silt, yellowish brown, sticky , and contains roots of plants remained and leaves and residual organic brown-black in colour.

Quaternary sediments succession on the cross-section C-D (**Fig. 4**) preceded by interfingering near shore sediments with offshore sediments. It also observed estuary channel sediment, and in general consists of intercalation between thin sand layer, clay sand and in some places there are a thin layer of black sand, coarse grained - medium size with sub-angular - sub-rounded in shape. Clay-sand, medium grained and greenish to black in colour, is poorly sorted and sub-angular to sub-rounded in shape and contain the remaining shells of molluscs.

The dimensions of the estuary channel in section (C-D) is greater compare to estuary channel

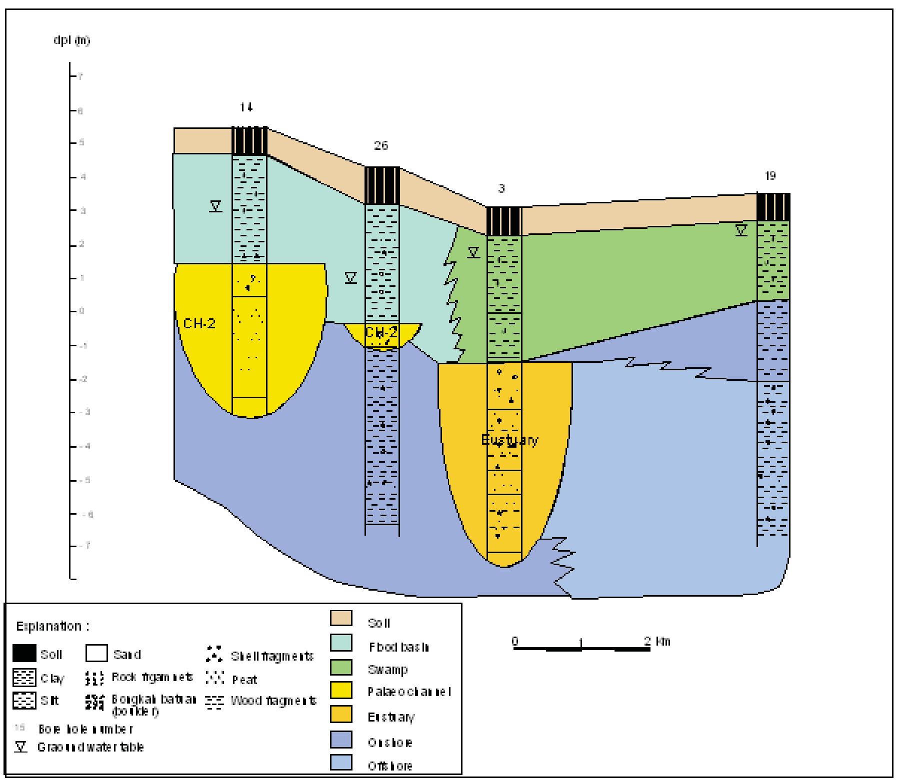


Fig. 4. Lithological correlation along C-D section

on cross-section A-B. This condition can be explained because the estuary channel position on section C-D is closer to the coastline, and it happened that sea-level is drop. An indication of sea-level drop occurred in a continuous is showed by the presence of near shore sediment that cover offshore sediment, which is then are overlaid by swamp deposits.

Lumban Batu, et, al.(2007) observed changes in dimensions of palaeo channel in this section based on changes in sediment thickness. This means that palaeo channel two(Ch-2) is more developed than the palaeo channel one(Ch-1). Another interesting point is the distribution of flood basin sediment widespread. This is possible because the dimensions of fluvial system are also increase, it can happen due to the high volume of water, which is in correlative with the greater level of wetness.

The development of flood basin sediments in this area is defined as the condition of the higher humidity caused by climate change(Hidayat DRR, 2008).

On cross-section E-F (**Fig. 5**), we observed a changes in dimension of palaeo channel two (Ch-2) become narrow. This phenomenon may be as an indication that main river branches into several small rivers channel (distributary channel) that generally occur in areas close to shore. In addition, there was a shifting of palaeo channel two (Ch-2) eastward into palaeo channel three (Ch-3) where this palaeo channel has a slightly larger dimensions. A shift of palaeo channel two into palaeo channel three is interpreted as the product of Holocene Tectonic two activity (THF-2). Palaeo channel three then erodes swamp sediments and offshore marine sediments.

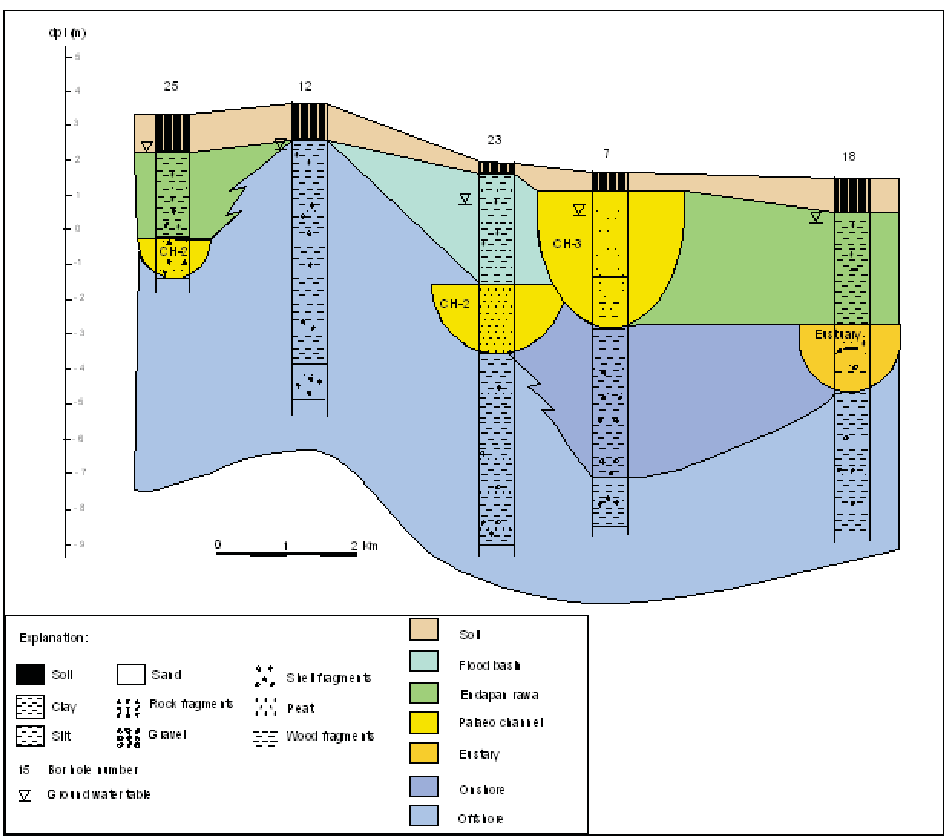


Fig. 5. Lithological correlation along E-F section

Meanwhile, sea-level tends to drop, which is showed by the formation of swamp sediments and flood basin sediment on the top of the near shore and offshore sediments. In addition to the growing dimensions of the palaeo channel three (Ch-3), is likely due to sea-level drop so that the river flow developed well in low-lying coastal areas. This condition can be correlated to tectonic activity of Holocene Phase Three (THF-3 which caused the basement rocks uplift in the southwest of studied area, and on the other hand coastal area are subsidence and as a result the direction of coastal development turned into a northeast direction. According to Hidayatat all. (2008), the peak subsidence process is expected to take place during the Holocene.

Cross-section G-H (**Fig. 6**) is the most northern section located near the recent shoreline. Lubanbatu et, al.(2007) observed that dimensions of a palaeo channel and estuary getting bigger. This condition is due to the location of palaeo channel and estuary are closer to the coastline. Another thing that is interested to point out is the presence of thick swamp deposits which covered estuarine sediment. This phenomenon can be interpreted as an indication of gradually decreasing of sea-level in long period. A presence of a thick swamp deposits is interpreted as calm depositional condition.

9. Indentification of quarternary tectonics

Identification of Quaternarry tectonic in this area have been analysed based on its geomorfological features (drainage pattern) and its Holosen litological sequences. In the studied area which is mainly builtup by coastal plain, it is interested to analysed drainage pattern, since in such area normally surface geological information are very limited. In the studied area there are two different types of drainage pattern are developed ie. sub-dendritic-dendritic and parallel-parllel. The difference of the two drainage pattern must be influence by

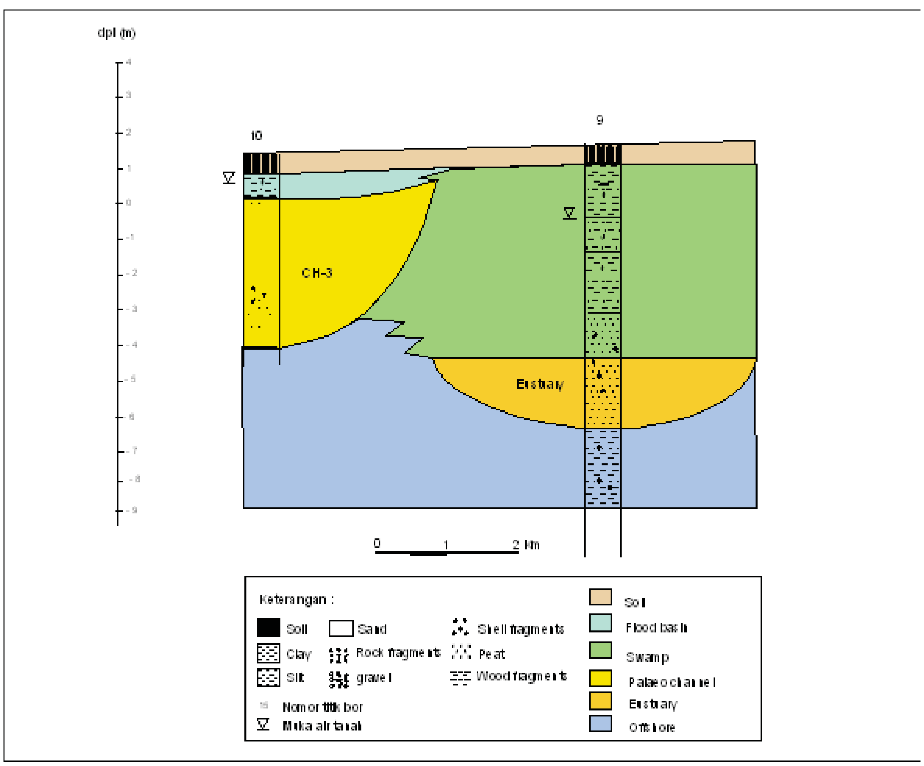


Fig. 6. Lithological correlation along G-H section

sub-surface geological condition. Normally, dendritic patterrn are developed on homo geneous rock such as mud or clay stone which has low permeability.

In the field it is difficult to obtain data to explain relationship between the drainage pattern and its litological conditions. It seems that litologic composition of all over coastal area are quite similar, composed of brownish to gray silty clay and dark gray sandy clay. On the other hand on some places it reveled that area wich is occupied by dendritic – sub-dentritic pattern are relativelly higer in topography compare with the area where parallel – sub parallel developed. It could also be interpreted that underlain sediment on sub-dendritic – dendritic are thinner compare to the other. Therefore the development of sub-dendritic - dendritic drained pattern are might be strongly influenced by the structures of underline sediment. If it is true, than we interpreted that basel level are uplifted and consequenently the thickness of sediment become thinner, on the other side the base level are subsidence so that the thickness of sediments are becaming thicker.

Based on the stratigraphic succession analysis of cross-sectional trending east-west direction a composite section was made (**Fig. 7**). This figure show that during Holocene can be observed geological event such as sea-level rise and sea-level drop as well as tectonic activities.

The same phenomenon have also been observed by Suyatman et, al.(2008) on the basis of stratigraphical succession analysis derived from geological cross section which has a trend of north-south, southwest-northeast, and southeast-northwest.

From those data mentioned it reveals that the tectonic indication can be observed by the difference of elevation of base level which suddenly changed, and irregularity of stratigraphical succession, sea-level changes, and shifting of palaeo channel deposit.

The tectonic activities within this area are initiated by formation of fluvio-deltaic basin which is produced by Holocene Tectonics phase one (HTF - 1) which is showed by subsidence of basement rocks. Holocene Tectonic Phase One is represented by tectonic line as thrust fault (Plio-Pleistocene) located in the southern part of investigated area, and have a direction of east – west. As a consequence of the basement subsidence then sea- level rise which is represented by the presence of nearshore sediments covering Damar Formation consisting of volcanic material. At the same time an palaeo channel sediments are also deposited. Another geological phenomenon is the shifting of palaeo channel one (Ch-1) into palaeo channel two (Ch-2), which is likely as the maximum tectonic HTF-1 at the time.

We can also observe a sea-level drop on small scale (local) within maximum sea-level rise. Sea-level drop is indicated by the presence of estuary sediments. This fact explains, that although the sea-level tends to rise in general, but locally followed by fluctuations in sea-level changes. After maximum sea-level rise, and then sea-level decline gradually in a regional, meanwhile deposition process of nearshore sediments and offshore sediment takes place. Other geological phenomena which indicate the existence of tectonic activity is showed by a shift of palaeo channel two (Ch-2) into palaeo channel three (Ch-3) which indicates the maximum of tectonic THF-2. Sea-level drop occurs continuously until present which is characterized by the formation of marsh sediments and flood basin sediments.

The dynamics of geological processes are also recorded in the formation and change of coastal line in the studied area. Observation of the growth of coastal development in the area of Kendal have been conducted since 1864 -1973 by Bird and Ongkosongo (1980). Based on the observations (**Fig. 8**) they have seen a change in the growth of shoreline that was originally developed to the north (1864-1910), turned into a northeast direction (1946-1973).

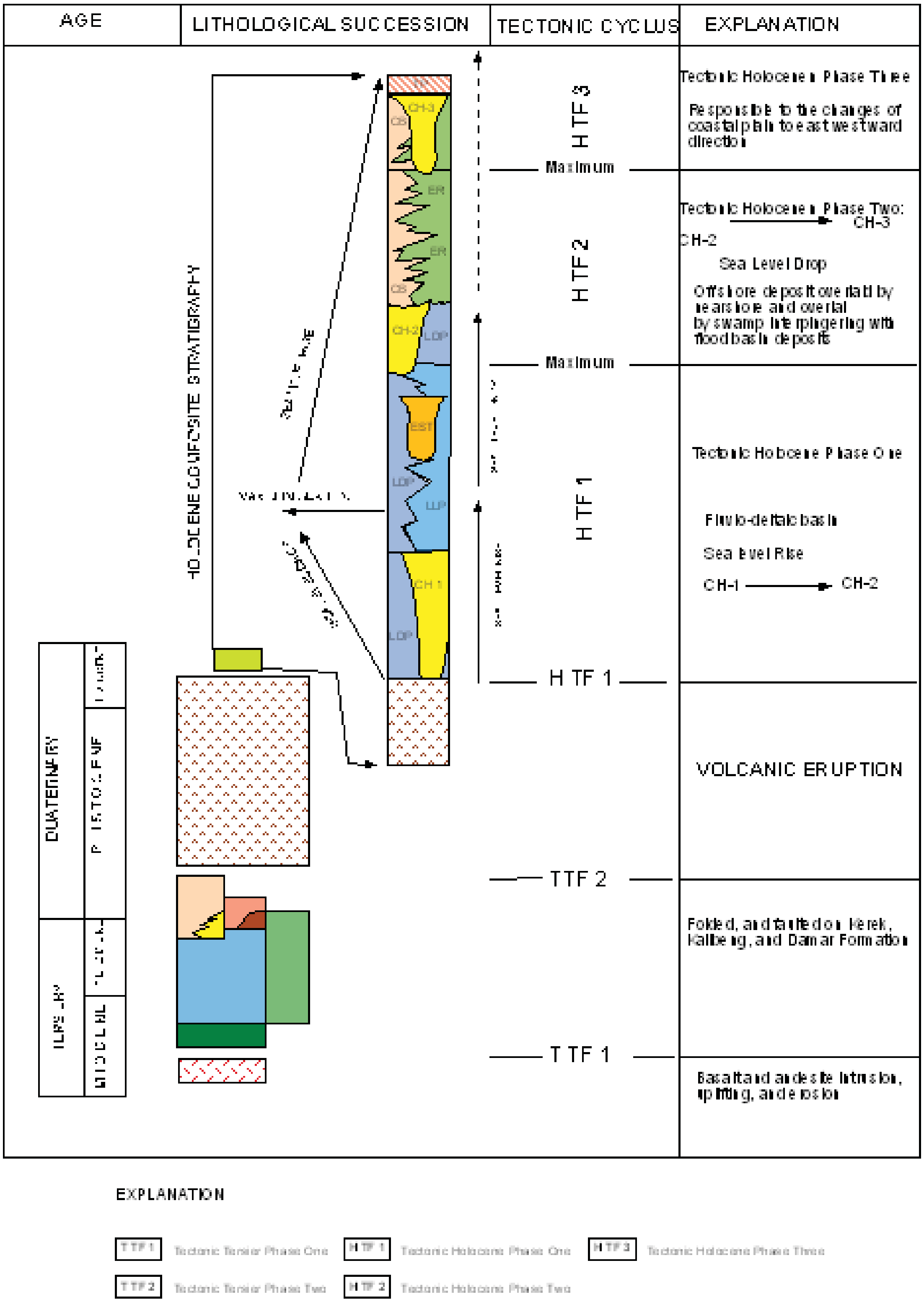


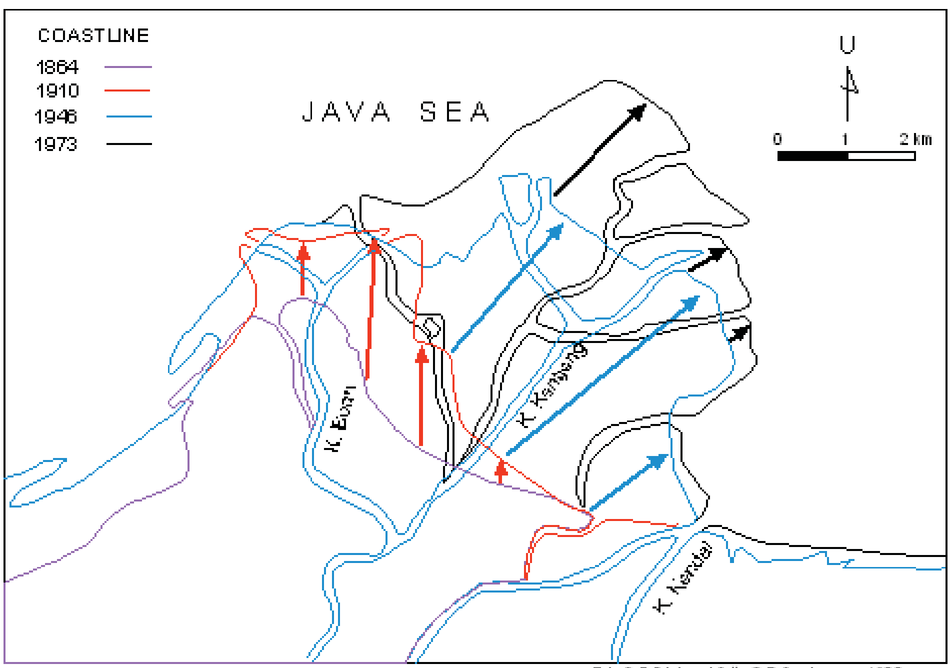
Fig. 7. Stratigraphical and tectonic holocene cyclus of Kendal Area

This fact provides information that in a relatively short period (1946 -1973) that is over 28 years the progress of coastal plain have been developed toward the northeast is much more rapid compared with the development of the coastal plain to the north during the period of 47 years(1864 -1973). This condition can be interpreted that the volume of supply of material transported by Kali Kenceng much more greater than the volume of materials transported by Kali Bodri that form the coastal plain to the north. Hidayat et, al.(2008) in Poedjoprajitno et, al.(2008) mentions that the factors controlling the process of infilling the basin can be influenced by sea-level changes, climate change and tectonic activity. Furthermore they stated that the supply of material can be influenced by the tectonic activities.

The changed of coastal plain development to wards northeast is correlative with the upflited of the western part of the investigated area which causes bedrock croupout on the surface as consequently drainage pattern are turning toward the northeast. Thus the supply of material transported by Kali kenceng deposited in the area and consequently the development of the coastal plain in accordance with the direction of development of river.

Developments of coastal plain in northeast direction are the products of Holocene Tectonic Phase Three activity (THF-3). The effect of THF-3, causes the direction of Kali Bodri as suppliers of sediment material changes to northeast. And consequently the development of coastal plain to the northeast direction is much broader when compared with coastal development to the north.

This fact is also reflected on morphology features of alluvial plain shown by the differences in the drainage pattern (**Fig. 2**). In the western part of investigated area the drainage pattern of sub dendritic – dendritic are developed well, while to the east sub parallel – parallel drainage pattern are developed. The difference of drainage patterns in the same geological conditions occupied by alluvial must be suspected due to same reason. The drainage pattern of sub



Eric C.F Bird and Otto S.R.Ongkosono 1980

Fig. 8. A changed of Coastal line in Kendal area during 1864-1973

dendritic-dendritic in the west of the studied area occurred because aluvial deposits in this area relatively thinner compared with that in the east where the drainage pattern system that develops is sub parallel - parallel. Therefore, the development of drainage patterns in the west of the studies area are controlled by its bedrock.

10. Conclusion

The study of the Quaternary deposits characters on the alluvial lowland to coastal plain of the Kendal areas was based on an analyses of the sedimentology and stratigraphy of boreholes information obtained along the east –m west section

The penetration of the bore head varied from 4.00 to 13.00 m. This study reveals seven environments which occurred above the Damar Formation (Qtd) deposited during the Lower Pleistocene age.

Quaternary sediments in the study area can be divided into 1). Swamp sediment, 2). Estuarine Sediment, 3). Near shore sediments, 4). Offshore Sediment, 5). Fluvial deposits and 6). Para-Holocene sediments

Based on its stratigraphical position, palaeo channel deposits can be separated into palaeo channel one (Ch-1), palaeo channel tow (Ch-2) and palaeo channel three (Ch-3) from yaoung to alod respectively.

Tectonic activities that can be observed in the studied area is in the form of uplift, and subsidence. It is clear be shown that Holocene Tectonic Phase One (HTF-1) is characterized by subsidence where quaternary basin occur which is filled up by quaternary sediments.

Shifting of palaeo channel two(Ch-2) into palaeo channel three (Ch-3) is an indication of the maximum of Holocene Tectonic Phase Two (THF-2.)

The changed of coastal plain development to wards northeast is correlative with the upflited of the western part of the investigated area which causes bedrock croupout on the surface as consequently drainage pattern are turning toward the northeast. Developments of coastal plain in northeast direction are the products of Holocene Tectonic Phase Three activity (THF-3).

On the basis of startigraphical sequence , it reveals the investigated area are influenced by sea-level rise and sea- level drop as well as tectonic activities. These geological event control coastal development into northeast direction.

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Groundwater and Geological Database in Japan

Youhei UCHIDA[1]

[1]Geological Survey of Japan, AIST
e-mail: uchida-y@aist.go.jp

Abstract

Geological Survey of Japan (GSJ), AIST is a public organization that carries out various geological surveys and researches. GSJ has consistently provided geological information, which is essential to build a safe and sustainable society, since its establishment in 1882. The Geoinformation Center, GJS, compiles GSJ's research outcomes in accordance with Japanese Industrial Standards (JIS) and distributes them as high-quality geoinformation and satellite information via the website and through traditional publication.

Keywords: Geological Survey of Japan, geoinformaion, geological database

1. Introduction

Geological Survey of Japan (GSJ), AIST is a public organization that carries out various geological surveys and researches (**Fig. 1**). GSJ has consistently provided geological information, which is essential to build a safe and sustainable society, since its establishment in 1882. Three research units, the Institute of Earthquake and Volcano Geology (IEVG), the Institute for Geo-Resources and Environment (GREEN), and the Institute of Geology and Geoinformation (IGG), along with the Geoinformation Center and the Geological Museum of AIST, are collectively called the "Geological Survey of Japan".

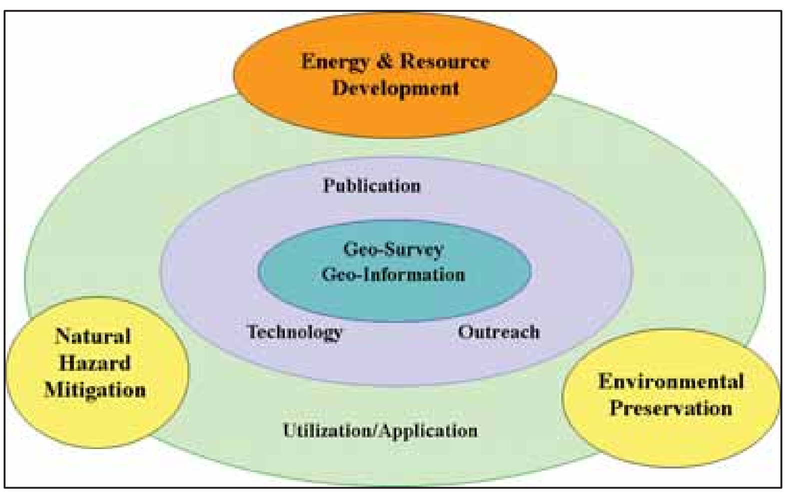

Fig. 1. Scope of GSJ Research

The mission of GREEN is to contribute to securing natural resources, effectively utilizing geosphere for a sustainable and stable energy cycle, and ensuring the safe environment. GREEN also develops and disseminates basic information based on its surveys, researches, and technical developments. The major tasks of GREEN include surveys and researches to assess the potential and understand the genesis of natural resources such as minor metals, methane hydrate and natural gas. GREEN also works for effective utilization of groundwater resources by proposing a suitable way of groundwater usage specific to each region. GREEN compiles and publishes databases and maps of soil environment, groundwater, mineral and fuel resources to develop intellectual infrastructure on resources and environment.

IGG aims to provide geological information helpful for society and contribute to environment conservation and natural disaster mitigation through its researches. Working with other foreign and domestic organizations, IGG also promotes the digitization and integration of the geological information in Asian region. IGG compiles and updates various maps and databases of geological information including quadrangle geological map series, seamless geological maps, gravity maps, aeromagnetic maps, and geochemical maps. IGG collects basic information on marine resources and environment, as well as it compiles marine geological maps and related databases around the Japan Islands.

2. Groundwater Database

2.1 Hydro- Environmental Map

The Groundwater Research Group of the GSJ/AIST have a research of national program for High-Level Nuclear Waste (HLW Program) to evaluate the stability of the deep environment including the groundwater flow mechanism. The group will provide the information of all Japanese islands, and the data is also effective in Carbon dioxide Capture and Storage (CCS) study, unknown Groundwater resources (incl. hot-springs) and Ground-Source Heat Pump Systems (**Fig. 2**).

One of main tasks of the Groundwater Research Group is to publish a series of hydro-environmental map. In this map series, we especially attempt to apply multi-tracer technique to analyze regional groundwater flow systems. The technique is based on the data combination of groundwater level, water chemistry, stable isotopes and subsurface ground temperature as tracers. Although each tracer has both advantages and disadvantages in water flow analysis, application of multiple tracers may compensate disadvantages of each tracer. The hydro environmental maps are provided in compact electronic media (CD-ROM) with database of groundwater quality and other hydrological and geological information, giving users a hint to solve groundwater problems.

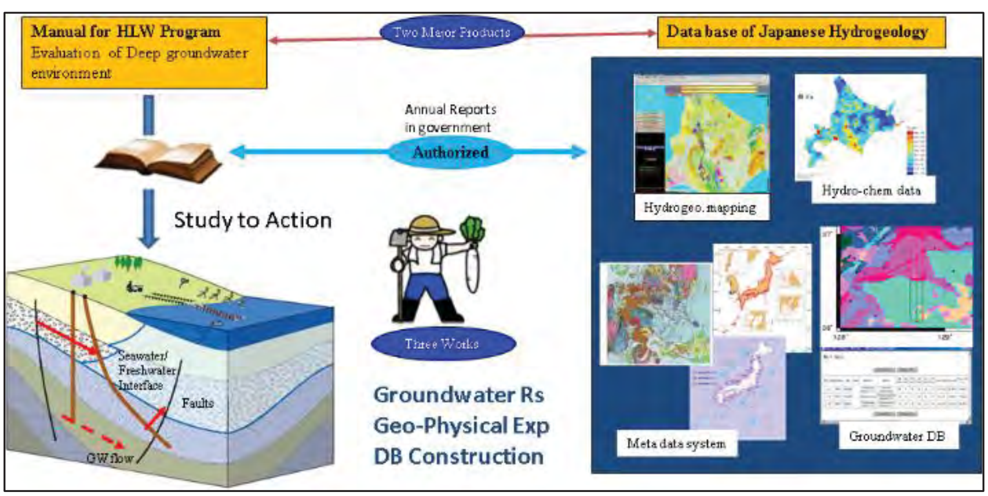

Fig. 2. Research activity of the Groundwater Research Group in GSJ

Fig. 3. Areas covered by Water-Environmental Maps (left) and main control window of the map (right)

Six water- environmental maps, entitled “Sendai Plain”, “Akita Plain”, “Kanto Plain”, “Nobi Plain” , “Chikushi Plain” and “Yamagata Basin” were already published, which will be followed by a map of “Kumamoto Plain” and “Ishikari Plain” in 2014. **Fig. 3** shows areas of water- environmental maps. The map may be useful for not only local governments and residents but also students who study hydrology.

2.2 Groundwater Survey

There are many observation wells in Japan which are used for monitoring groundwater level and land subsidence (**Fig. 4**, left). Each observation site has two or three nested observation wells, and these wells are designed for single screen well. Each screen depth is settled at the different aquifer, therefore, we can get three-dimensional distribution of chemical compositions, hydraulic head and subsurface temperatures. We have measured water level and groundwater temperature at 2m intervals in those observation wells and constructed database of subsurface temperature in Japan. The precision of thermometer which we use is 0.01℃ (**Fig. 4**).

Fig.4. Observation well for groundwater level and land subsidence (left) and digital thermistor (right)

3. Geological Database in Japan

3.1 Maps

Eight map sheets, five CD-ROMs and two DVD-ROMs have been published during the period of this report (July 2012 - June 2013). The published coverage has reached approximately 74% over the land, at scales of 1:50,000(**Fig. 5, Fig. 6**) and 1:75,000. Print-on-demand and library copy services of geological maps continue to be provided.

- 1:50,000 Geological Maps (5 sheets)
- Geological Maps of Volcanoes (2 sheets)
- 1:2,000,000 Map series no.11 Volcanoes of Japan (Third Edition) (1 sheet)
- Marine Sedimentological Maps (3 CD-ROMs)
- Marine Geological Maps (2 CD-ROMs)
- Gravity Database of Japan, DVD Edition (DVD-ROM)
- Seamless geoinformation of coastal zone “coastal zone around Fukuoka” (DVD-ROM)

(http://www.gsj.jp/Map/index_e.html)

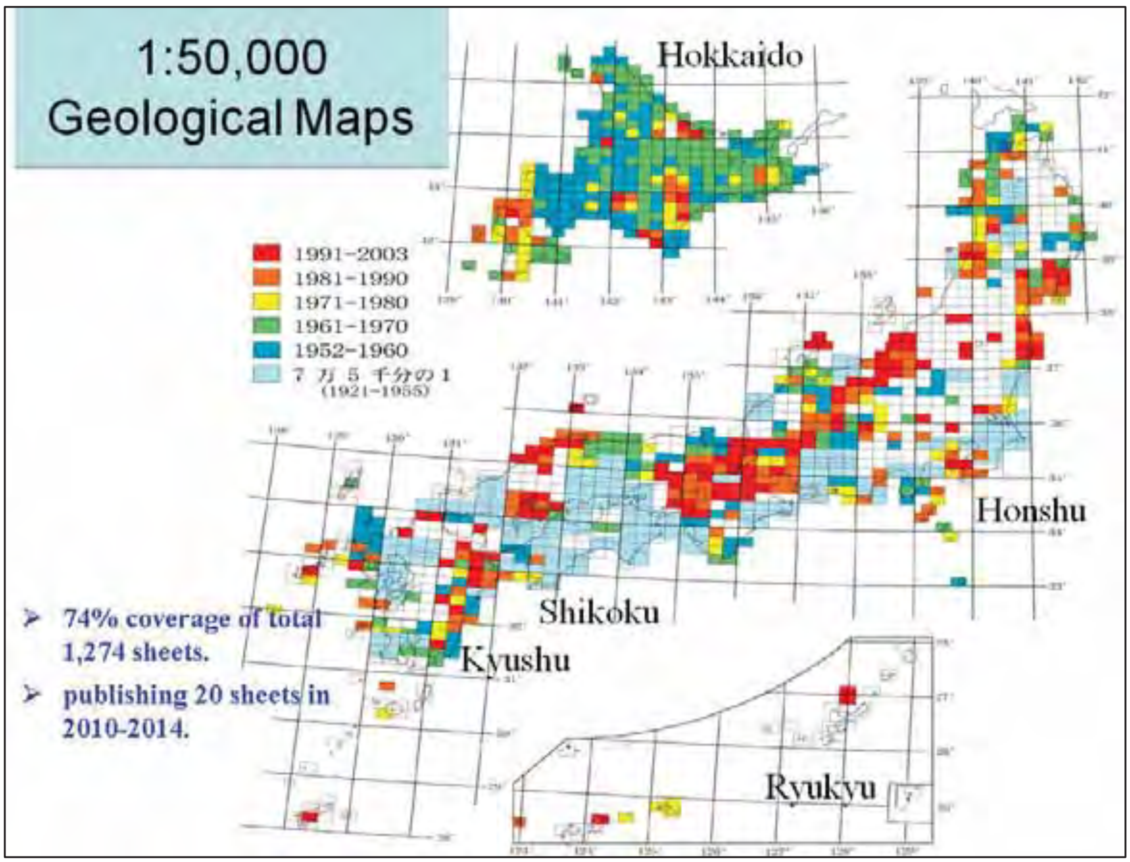

Fig. 5. Published coverage of 1:50,000 Geological maps in Japan
(https://www.gsj.jp/Map/JP/geology4.html)

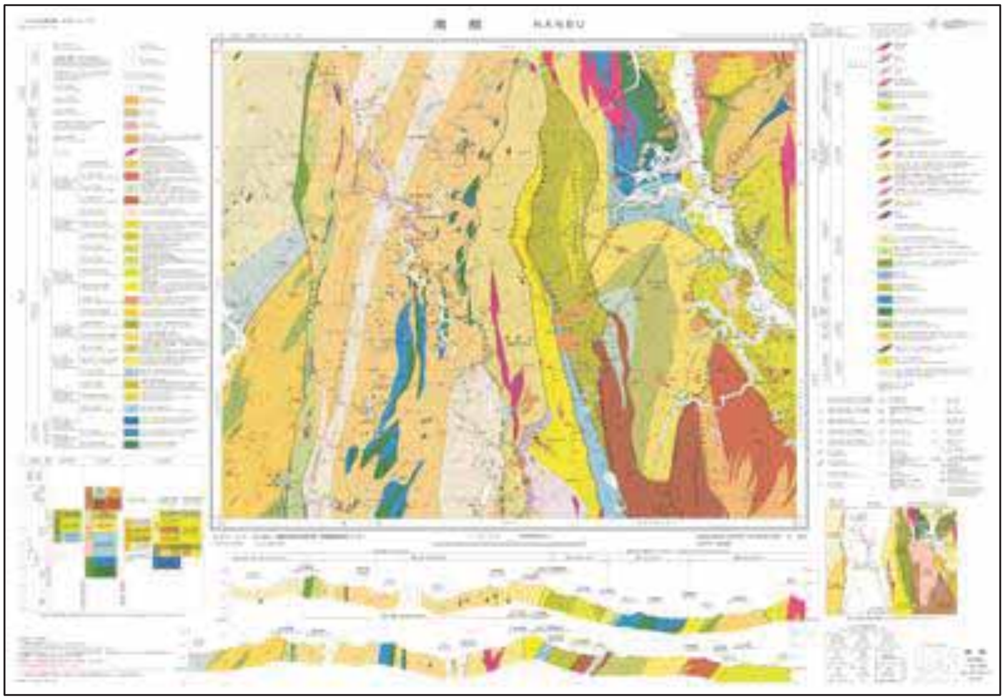

Fig. 6. Recent 1:50,000 Geological Maps “NANBU” published 2014 (Sugiyama and Matsuda, 2014)

3.2 Databases

The database systems of GSJ are now under reconstruction due to the following circumstances:

Firstly, the database servers in AIST are to close by the end of 2013FY, and will be substituted by cloud servers for the next generation services where the database software (Oracle RDBMS) is transmitted to FOSS (PostgreSQL/MySQL).

Secondly, in 2012, the Japanese Government decided to promote Open Data, triggered by the lack of the official data usability in the March 2011 earthquake, and appointed geologic data as important data for the public, along with topographic and geographic data. The newly established guideline requires the data to be machine-readable and free of charge. GSJ is revising the usage guideline carefully watching the progress of the discussions in the government. The new GSJ license will adopt the Creative Commons License (CC BY or CC BY-ND) to be equivalent and interoperable with it.

Thirdly, GSJ also has modified the internal regulations about its official publications by constructing a new database system. Previously, databases came directly from the researchers’ free ideas and not examined by referees. In order to respond to the increasing importance of the organization web services, GSJ has changed the rules as below.

- A referee system (peer review) on databases has been introduced
- Databases have become the official outcomes.

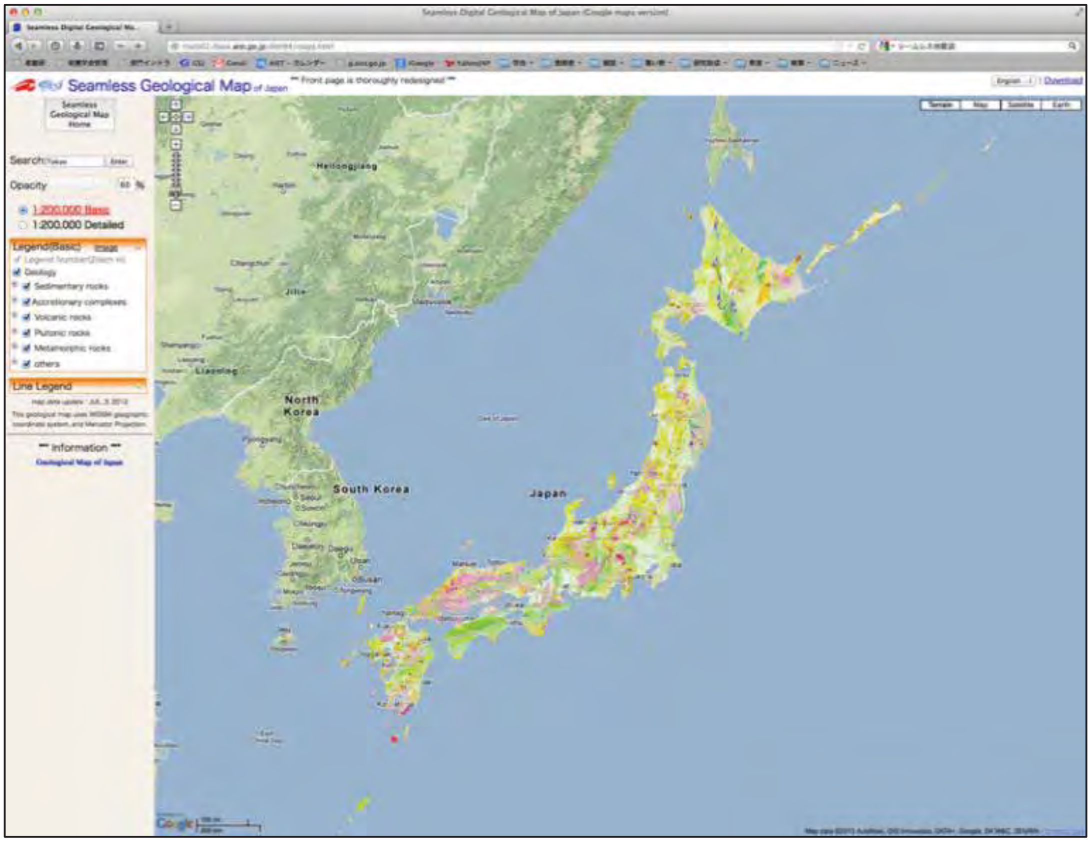

Fig. 7. Web-based seamless geological map

In order to improve the convenience for users, GSJ has integrated similar databases. For example, the “Quaternary Volcanoes in Japan” and “Active Volcano Database of Japan” have been combined into “Volcanoes of Japan”.

A renewed portal site, in which all the users can access the GSJ’s data they want to see, is scheduled to be launched in FY 2013 (**Fig. 7**). As a part of the portal function, a viewing system “Geomap Navi” was newly developed and released (https://gbank.gsj.jp/geonavi/). This system enables the users to overlay several geologic maps, data and contours in a single browser window like GIS software.

3.3 One Geology

The OneGeology project is an international initiative of the geological surveys of the world. The initiative aims to create a web-accessible dynamic geological map data of the world. GSJ has been actively participating in the project through the OneGeology-CCOP project in the East and Southeast Asian region. GSJ also provides cloud servers which are hosting the web mapping service (WMS) of geological maps of Japan and the following Southeast Asian countries: the Philippines, Indonesia, and Malaysia. It is also currently preparing the geological maps of Vietnam, Papua New Guinea and Myanmar.

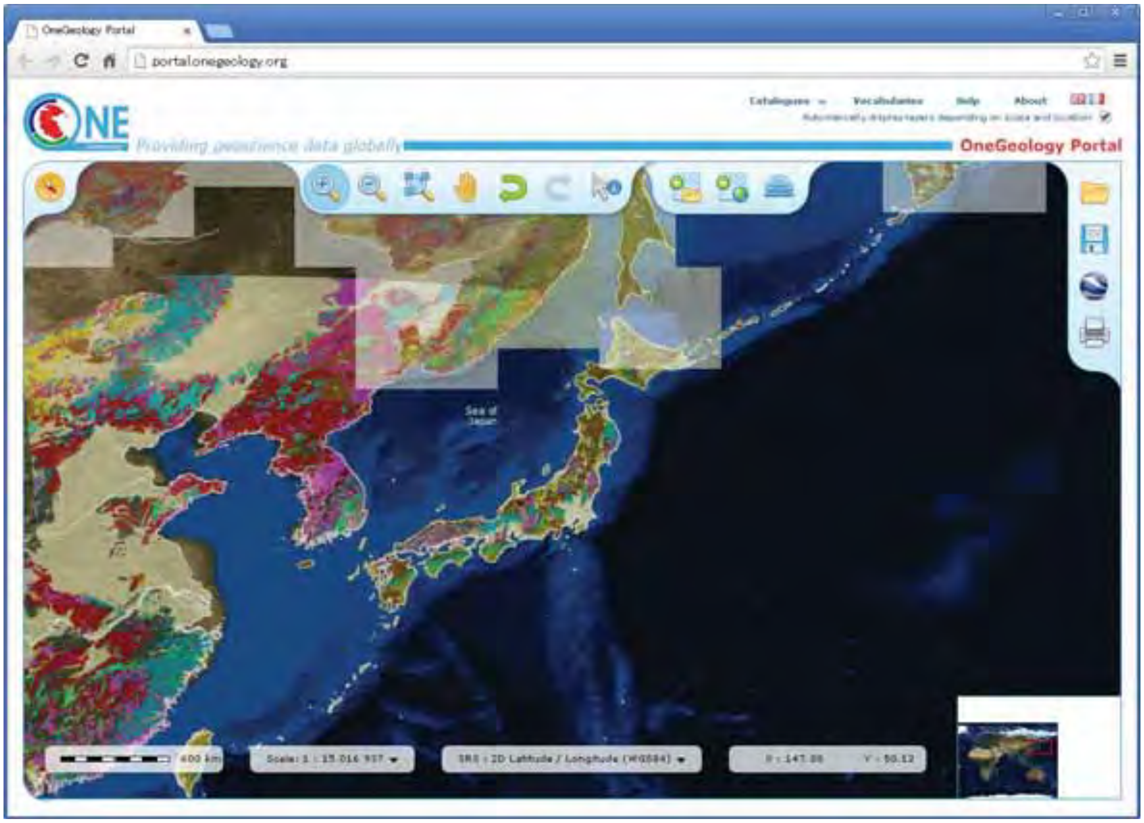

Fig. 7. One Geology Map of Japan (http://www.onegeology.org)

4. Conclusions

The Geoinformation Center, Geological Survey of Japan, compiles GSJ's research outcomes in accordance with Japanese Industrial Standards (JIS) and distributes them as high-quality geoinformation and satellite information via the website and through traditional publication. Geo-scientific databases contribute for not only management of natural resources but also environment protection and natural hazard mitigation. GSJ will compile various geo-scientific information, and construct a database on an open Web, using the world standard formats and GIS.

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Groundwater monitoring networks in Korea

[1]Lee, J.Y. and [2*]Ha, Kyoochul

[1]Kangwon National University, Korea
[2]Korea Institute of Geoscience and Mineral Resources(KIGAM)

Abstract

There are two primary nationwide groundwater monitoring networks and a few secondary (auxiliary) monitoring networks in Korea (Table 1). The first primary network is the National Groundwater Monitoring Network (NGMN), which has been managed by the Ministry of Land and Transport, and the Korea Water Resources Corporation (K-Water) since 1995, and it mainly monitors groundwater quantity nationwide (Kim et al., 1995; Lee et al., 2007). As of 2011, there were 336 monitoring stations (497 monitoring wells) under NGMN, covering the whole country including Jeju Island. Many of these stations have two monitoring wells, one for shallow groundwater and the other for deep bedrock groundwater. The monitoring equipment installed in each well measures groundwater level, electrical conductivity, and water temperature every hour. The measured data are automatically transferred to K-Water. Using the monitored data, K-Water analyzes trends in groundwater parameters (Park et al., 2011), which are then reflected in the national management plan for groundwater resources.

The other primary monitoring network is the Groundwater Quality Monitoring Network (GQMN), which mainly monitors changes in groundwater quality, and it is managed by the Ministry of Environment. The GQMN is comprised of the National Groundwater Quality Monitoring Network (NGQMN), the Regional Groundwater Quality Monitoring Network (RGQMN), the NGMN, and the Seawater Intrusion Monitoring Network (SIMN). In 2011, a total of 2,579 wells were examined for groundwater quality. In the monitoring, groundwater sampling and subsequent chemical analyses were conducted two times (April-May and September-October) per year. A total of 20 parameters were analyzed including contents of nitrate, chloride, total coliform, TCE, and PCE.

The secondary groundwater monitoring network includes the Subsidiary Groundwater Monitoring Network (SGMN) operated by local governments such as Seoul, Busan, Daegu and Incheon, and Jeju island (Lee et al., 2005; Kim et al., 2007; Choi and Lee, 2012; GIMS, 2013). The SGMN surveys groundwater level at one to three times per month and groundwater quality two times per year.

Other secondary groundwater monitoring networks like the Seawater Intrusion Monitoring Network (SIMN) and the Drinking Water Monitoring Network (DWMN) have specific goals. The SIMN, operated by the Ministry of Agriculture, Food and Rural Affairs and the Korea Rural Community Corporation, is mostly comprised of multi-level wells installed in islands and coastal areas, especially facing the Yellow Sea and the South Sea (Song et al., 2007). As of 2012, a total of 117 monitoring wells were operating (MIFAFF and KR, 2012; Park et al., 2013).

All this monitoring data facilitates the understanding of the groundwater condition in Korea. Using this data, we found various facts about the condition of the domestic groundwater which are

1) The groundwater level was generally decreasing during 1996 to 2008,

2) The majority of ground water temperatures recorded during 1996 to 2008 showed increases at rates of 0.04 to 0.09℃ per year due to global warming or climate change (Lee et al., 2006; Park et al., 2011),

3) 41 to 50% of the coastal groundwater was affected by seawater intrusion (Park et al., 2012). It has been shown that groundwater in some urban areas is severely contaminated with various organic compounds (Park et al., 2005; Lee et al., 2010; Baek and Lee, 2011).

Table 1. Summary of groundwater monitoring networks (stations) in Korea (Lee and Lee, 2013)

Monitoring network	Number of wells	Management/operation
National Groundwater Monitoring Network (NGMN)	497	Ministry of Land and Transport/K-Water
Groundwater Quality Monitoring Network (GQMN)	2,579	Ministry of Environment/KECO
Subsidiary Groundwater Monitoring Network(SGMN)	10,000 (target number)	Local governments like Seoul and Jeju
Seawater Intrusion Monitoring Network (SIMN)	117	Ministry for Food, Agriculture, Forestry and Fisheries/KR (as of 2012)
Drinking Water Monitoring Network (DWMN)	not known	Ministry of Environment

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Groundwater Monitoring Networks in Korea

Kyoochul Ha

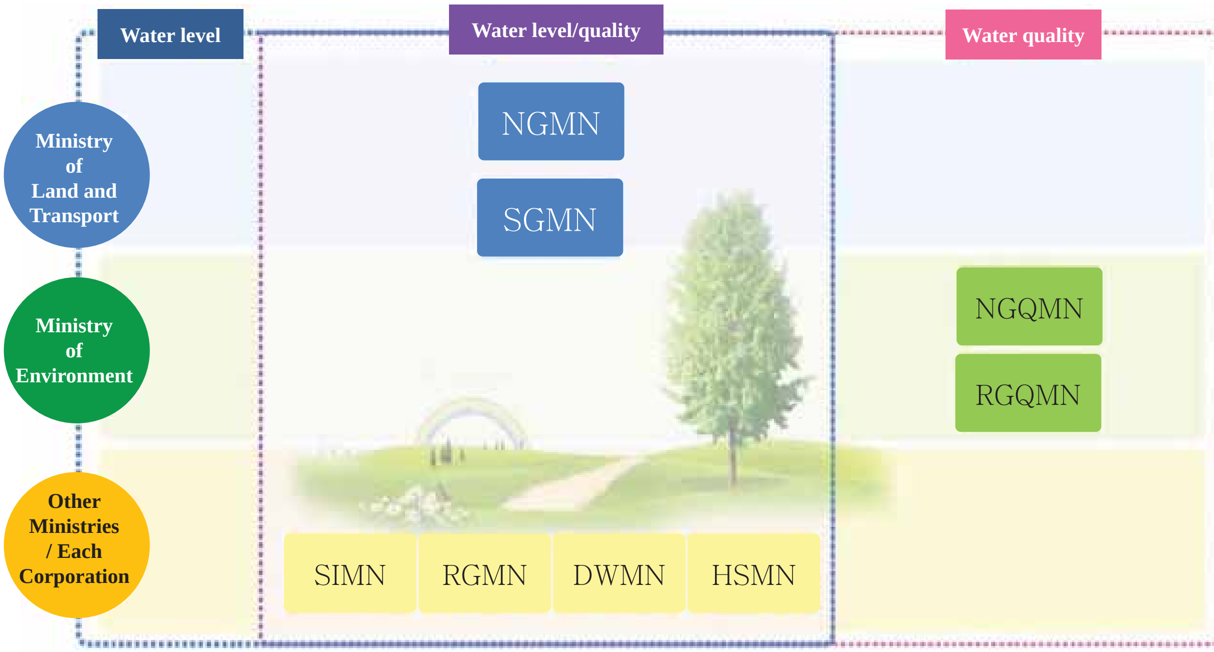
hasife@kigam.re.kr

Korea Institute of Geoscience and Mineral Resources

Groundwater Law and Master Plan

- In 1994, the government established the '**Groundwater Law**'
  - Contains regulations with respect to construction and management of groundwater monitoring networks.
  - In 2001, the concept of **public water (not private water) for groundwater** was adopted and obligation for remediation of contaminated groundwater was newly established.
- Ministry of Construction and Transportation (MOCT) issued a '**Master Plan for Groundwater Management**' in 1996
  - Included long-term groundwater monitoring plans, hydrogeological survey projects.
  - Revised every 5 year.
- Based on both the law and master plan, the National Groundwater Monitoring Network (NGMN) was constructed and has operated since 1995

Types of Groundwater Monitoring Networks



NGMN: National Groundwater Monitoring Network, **SGMN**: Subsidiary Groundwater Monitoring Network, **SIMN**: Seawater Intrusion Monitoring Network, **RGMN**: Rural Groundwater Monitoring Network, **DWMN**: Drinking Water Monitoring Network, **HSMN**: Hot Spring Monitoring Network, **NGQMN**: National Groundwater Quality Monitoring Network, **RGQMN**: Regional Groundwater Quality Monitoring Network

Groundwater Monitoring Networks in Korea

Monitoring network	Number of wells	Management/operation
National Groundwater Monitoring Network (NGMN)	497	Ministry of Land and Transport/K-Water
Groundwater Quality Monitoring Network (GQMN)	2,579	Ministry of Environment/KECO
Subsidiary Groundwater Monitoring Network(SGMN)	10,000 (target number)	Local governments like Seoul and Jeju
Seawater Intrusion Monitoring Network (SIMN)	117	Ministry for Food, Agriculture, Forestry and Fisheries/KRC (as of 2012)
Drinking Water Monitoring Network (DWMN)	not known	Ministry of Environment

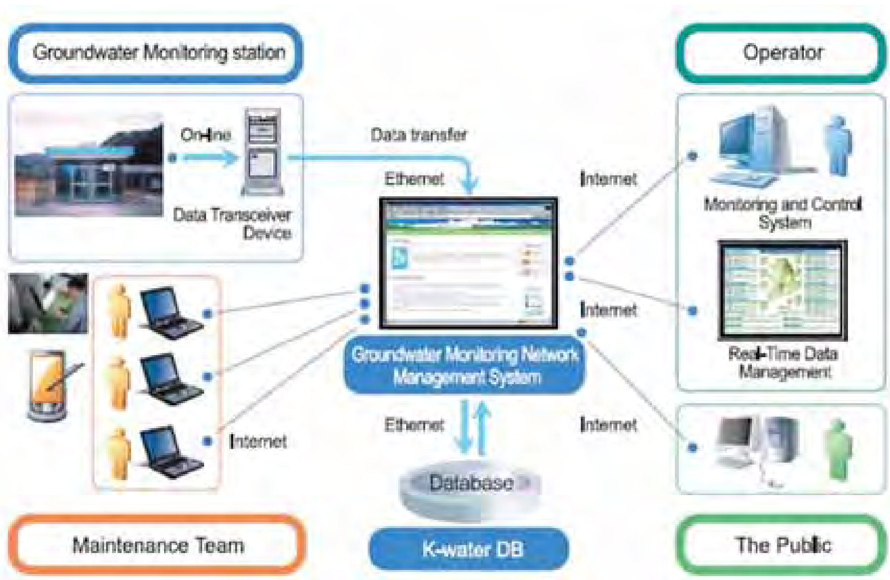
(Lee and Lee, 2013)

Development of the NGMN

- For each monitoring station, two separate groundwater wells were newly installed.
  - One well, with an average well depth of 20 m, is used to monitor **shallow groundwater (alluvial aquifer)** and the other well, with an average depth of 70 m, is used to monitor **deep groundwater (bedrock aquifer)**.
  - The well depths are dependent on the hydrogeological strata in the area of the monitoring station.
- The wells were drilled with a 350 mm diameter, in which monitoring wells with a 200 mm outside diameter were installed.
- To protect the groundwater wells and monitoring devices, an outer facility (building) using bricks or steel was constructed.
- Monitor **groundwater level, water temperature, and electrical conductivity(EC)** automatically.

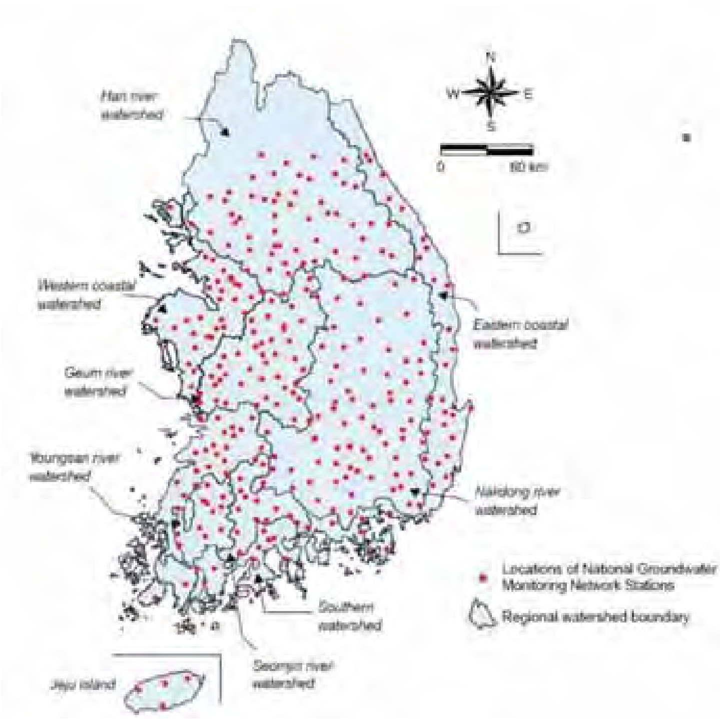
Management System for the MGMN

- Establishment of the monitoring data remote transceiver system
- Improvement of reliability of observed data and minimization of missing data by regular check ups
- Analysis of real-time monitoring data by the National Groundwater Monitoring Network Management System and provision of it through the internet



(Source : www.gims.go.kr)

Location of the NGMN



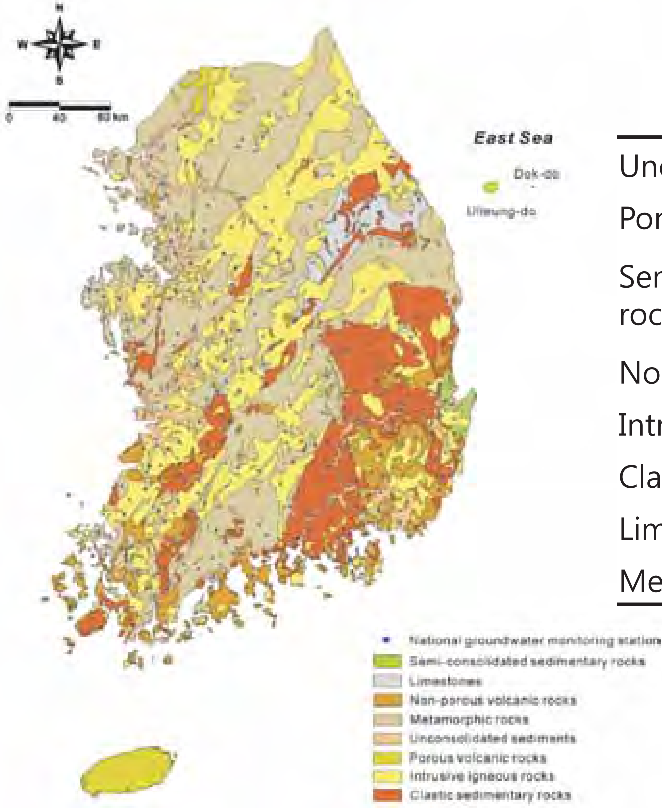
(Kim, 2012)

Hydrogeologic Units

Hydrogeologic unit	Geologic ages and units	Lithology	Topography
1. Unconsolidated sediments	Quaternary sediment	Clay, silt, sand, gravel	Plain, valley
2. Porous volcanic rocks	Quaternary volcanic rocks	Basalt, trachybasalt, tuff	Plateau, hill
3. Semi-consolidated sedimentary rocks	Quaternary marine sedimentary rocks Tertiary sedimentary groups	Semi-consolidated shallow marine–non marine sedimentary rocks with interbedded volcanic rocks	Hill
4. Non-porous volcanic rocks	Tertiary to Cretaceous volcanic rocks	Rhyolite, andesite, basaltic andesite, tuff	Mountain
5. Intrusive rocks	Cretaceous Bulguksa granites Jurassic Daebo granites Palaeozoic to Triassic intrusive rocks	Granite, diorite, gabbro, foliated granite, hypabyssal rocks	Hill, mountain
6. Clastic sedimentary rocks	Cretaceous Gyeongsang groups Triassic to Jurassic Daedong groups Carboniferous to Triassic Pyeongan groups	Shallow marine–non marine sedimentary rocks	Mountain
7. Limestones	Cambro-Ordovician great limestone group	Marine carbonate rocks with interbedded clastic sedimentary rocks	Karst, mountain
8. Metamorphic rocks	Carboniferous to Permian Pyeongan groups Cambrian Yangdeok group Okcheon group	Schist, quartzite, phyllite, slate	Mountain
	Precambrian schist and gneiss complex	Gneiss, schist, granitic gneiss, basic plutonic rocks	Hill, mountain

(Source : Lee et al., 2007)

Hydrogeologic Units and NGMN installation

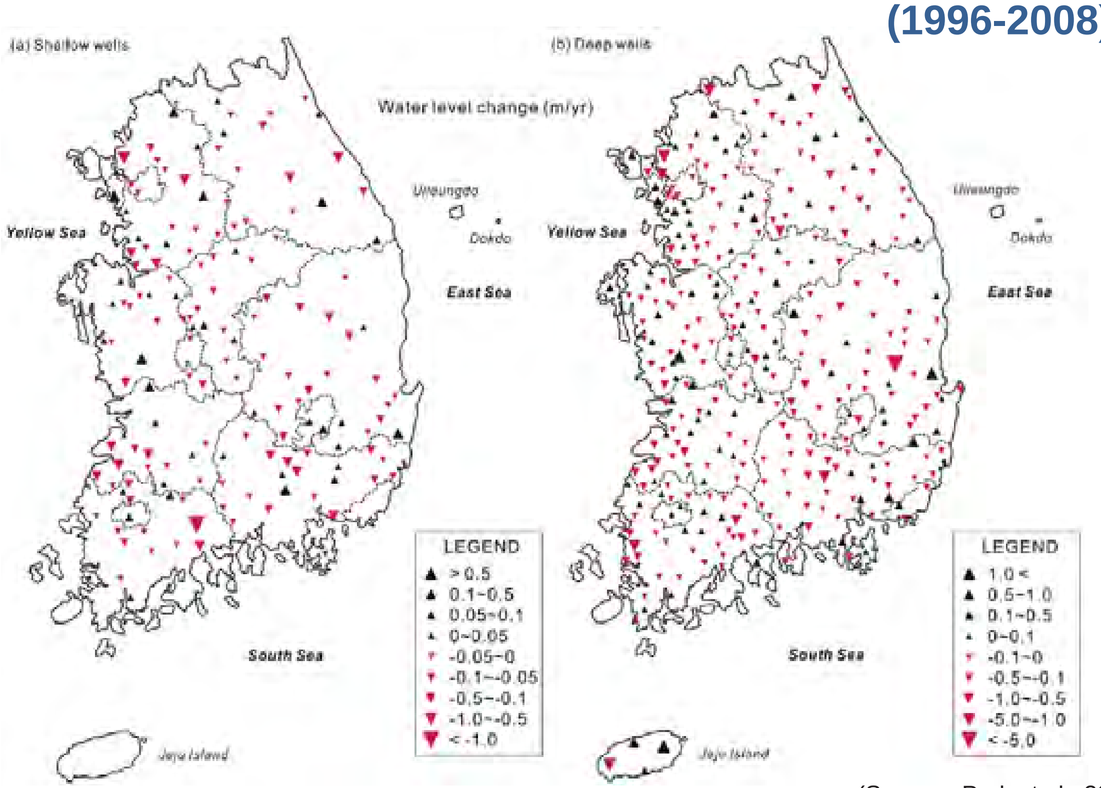


Unconsolidated sediments	1%
Porous volcanic rocks	1%
Semi-consolidated sedimentary rocks	2%
Non-porous volcanic rocks	6%
Intrusive igneous rocks	44%
Clastic sedimentary rocks	16%
Limestones	3%
Metamorphic rocks	27%

(Source : Lee et al., 2007)

Long-term Groundwater level trend

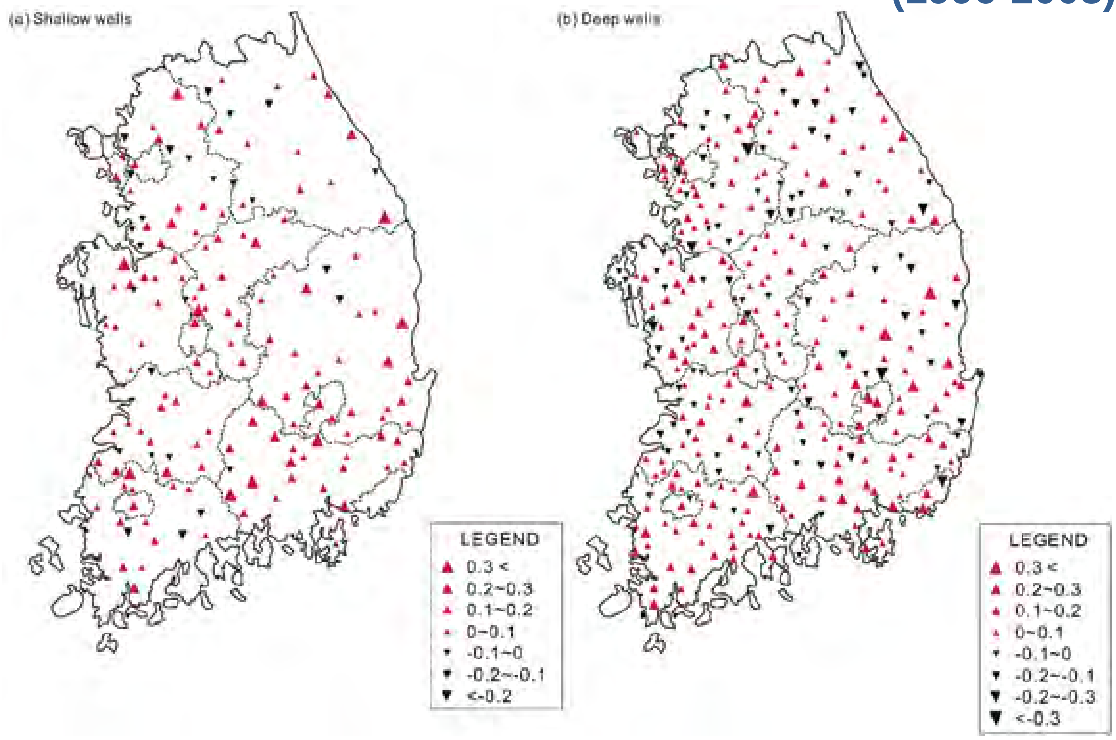
(1996-2008)



(Source : Park et al., 2011)

Long-term Groundwater temperature trend

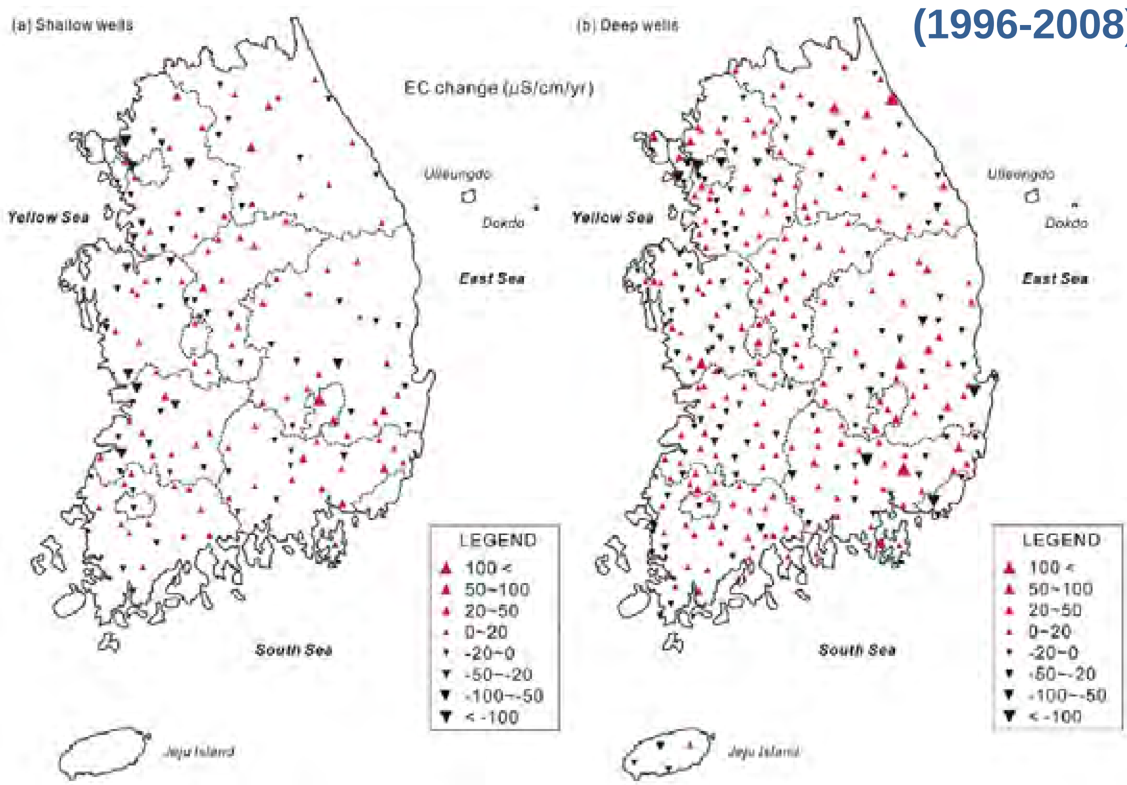
(1996-2008)



(Source : Park et al., 2011)

Long-term Groundwater EC trend

(1996-2008)



(Source : Park et al., 2011)

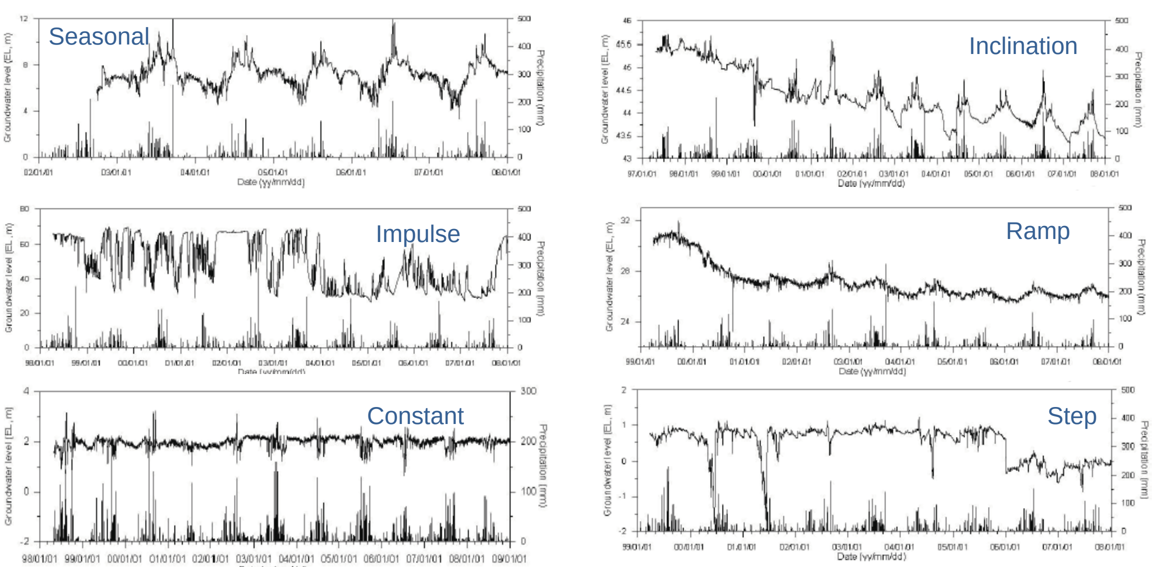
Long-term Trend Analyses for the NGMN

- The groundwater levels were generally decreasing and most of this decrease was attributed to increased pumping nationwide.
- The groundwater temperature variation was the most striking.
  - The majority of the monitored shallow and deep groundwaters exhibited increasing trends at mean rates of 0.04–0.09 ˚C/yr.
  - The widespread and prevailing increase in groundwater temperature nationwide, with increasing air temperature, is strongly indicative of the effect of global warming.
- The electrical conductivity (EC) values of groundwaters were very high in metropolitan and industrial areas, which were indicative of anthropogenic groundwater contamination and progressive groundwater quality deterioration

(Source : Park et al., 2011)

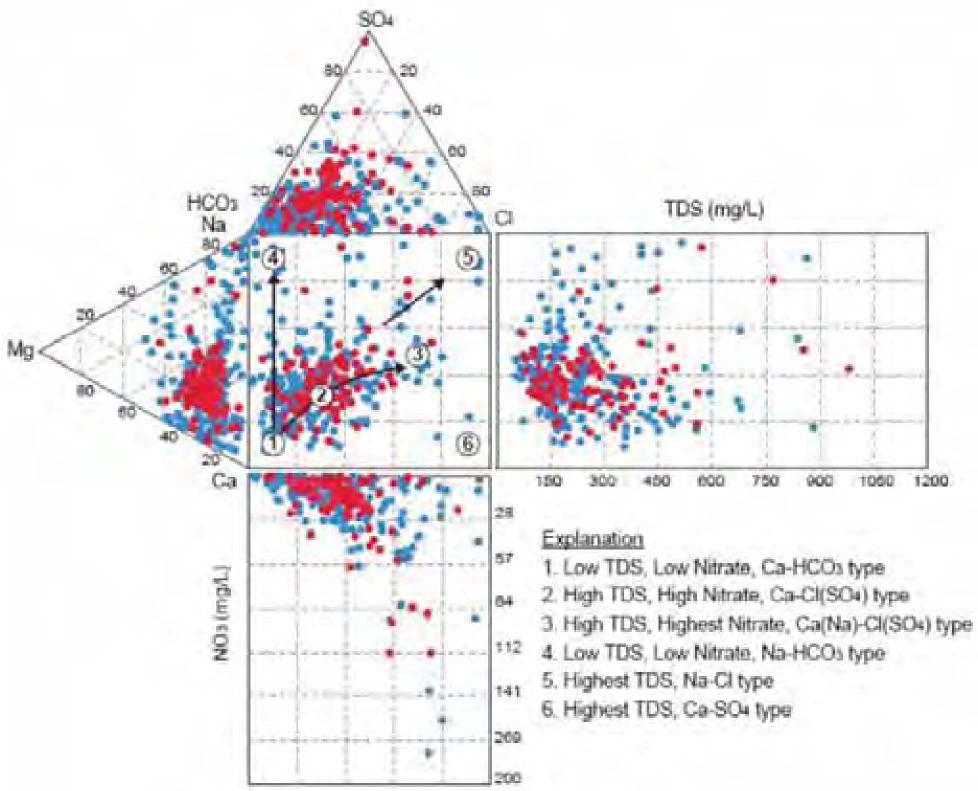
Water level variation types of the NGMN

- Seasonal type occupied 66.8% of the whole monitoring wells
  - Impulse 12.4%, constant 11.8%, ramp 4%, inclination 3.2%, and step 1.7%, respectively.
- Additionally, 72.5% of monitoring wells were sensitive to rainfall and 24.6% were affected by pumping at neighboring well.



(Source : Kim, 2012)

Water quality types of the NGMN



(Source : Kim, 2012)

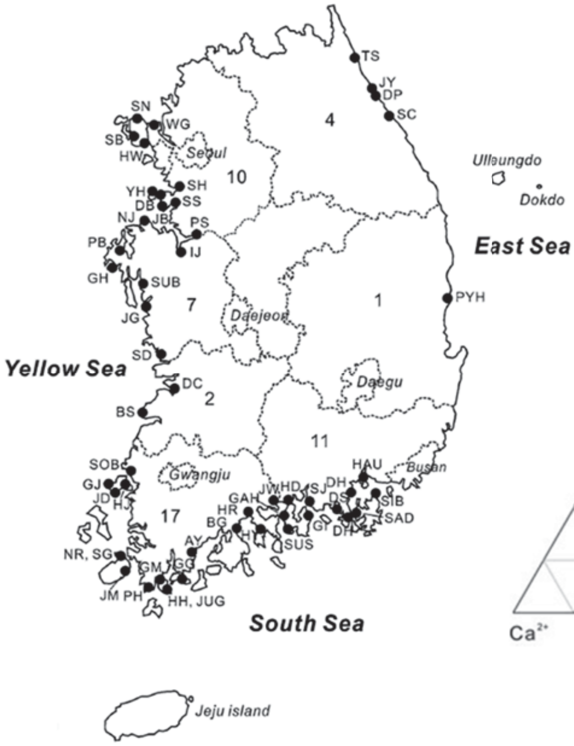
Seawater intrusion Monitoring Network

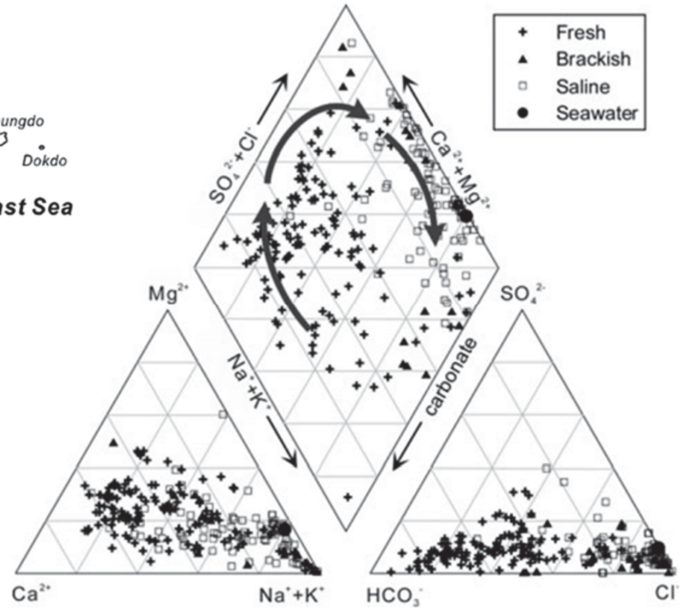
- The Korea Rural Community Corporation (KRC) has installed 92 seawater intrusion monitoring wells since 1998.
  - Each monitoring station had 1–3 wells located in the western and southern coastal areas.
  - All the monitoring wells are within 2 km of the coastal line.
  - The depths of the monitoring wells range from 30 to 200 m.
  - The mean groundwater levels of the monitoring wells ranged from -19.7 to 16.2 m above mean sea level.
- The chemical compositions of groundwater had been analyzed every year.
- In each monitoring well, water level, electrical conductivity (EC), and water temperature had been measured hourly using a multi-probe equipped with a data logger in each monitoring well.

(Source : Park et al., 2012)

Seawater intrusion Monitoring Network

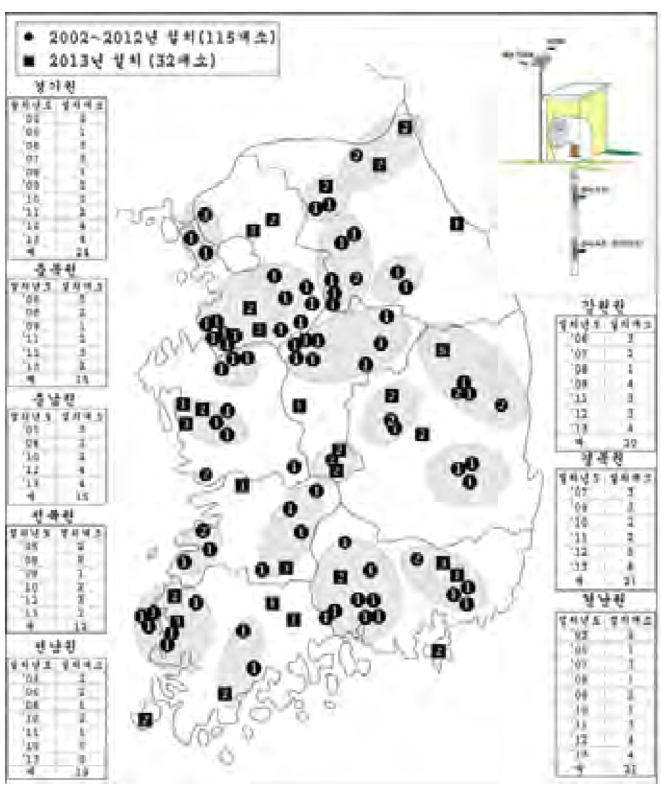
❖ Chemical composition analysis results





(Source : Park et al., 2012)

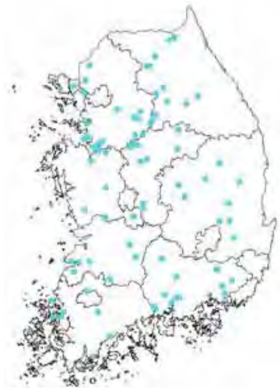
Rural Groundwater Monitoring Network



(Source : Song's presentation, 2014)

Rural Groundwater Monitoring Network

❖ Drought Impact on Groundwater system



- **Groundwater level variation in 2012 compared to average over the last 3 years**

Month	Average	GG(10)	KW(9)	CB(8)	CN(5)	JB(3)	JN(5)	GB(5)	GN(8)
January	0.60	0.66	-0.06	0.30	-0.05	0.51	0.69	0.15	1.26
February	0.26	0.58	-0.15	0.20	-0.38	0.15	0.55	0.04	0.71
March	0.18	0.33	-0.27	0.18	-0.35	0.06	0.66	-0.04	0.67
April	0.50	0.74	0.04	0.35	-0.14	0.24	1.22	0.23	1.07
May	0.31	0.66	-0.07	0.25	-1.00	-0.45	1.56	0.23	0.59
June	0.03	0.36	-0.12	0.04	-1.98	-0.41	0.93	-0.05	0.44
Compare to Jan.	**-0.57**	**-0.30**	**-0.06**	**-0.26**	**-1.93**	**-0.92**	**0.24**	**-0.20**	**-0.82**

(Source : Song's presentation, 2014)

Summary and conclusions

- The national groundwater monitoring station serves as a baseline and primary station to monitor long-term general trends in water-level fluctuations and groundwater quality in Korea.
- A consensus was formed that an evaluation of the present NGMN and its monitoring capability was needed to enhance the efficiency of the groundwater monitoring work and to meet altered societal conditions.
- Extension of groundwater monitoring data utilization
  - Detection of groundwater problems and prevention (depletion, and water deterioration, etc)
  - Drought, stream dryness
  - Land subsidence
  - Hydro-seismology
  - etc

Thank you for your attention !!

Groundwater Management in Lao PDR

Introduction

- Groundwater information is limited available in Lao PDR.
- In Lao PDR groundwater is however and important source of water for water supply and also for cottage and small-scale industries.
- In rural area groundwater is a sources of water of well and borehole for cooking and drinking purposes of household.
- The authority involve in groundwater in Laos mainly are: Ministry of Public Health (National of Environmental Health and Water Supply), Ministry of Energy and Mining (Department of Mining and Department of Geology) and Ministry of Agriculture and Forestry (Dept. of Irrigation).

Law related to groundwater

- Mekong Agreement in 1995 and other procedure related to water usage in Mekong River Basin by Mekong River Commission.
- Water and Water Resources Law in 1996
- Environmental Protection in 2007
- Decree on Management of Drinking Water and Water Usage Quality Standard in Household in 2005
- Decree on Environmental Impact Assessment in 2010
- Agreement on National Standard of Environment in 2010

Status of available usage of groundwater

- Groundwater is probably remain the main source of rural and small town water supply.
- Lao population access to the sources of drinking water both surface and ground water.

In 2006:

- 11.7% people use tubewell / borehole
- 10% people use of protect well or spring
- 27% people use of unprotected well or spring
- 15.3% people use of surface water
- 11.2% people use of bottled water
- 8.9% people use pipe into dwelling, and
- 6.2 % people use of other unimproved

(Cooking and drinking purposes)

Groundwater issues

- In generally, quality and quantity of ground water is still good. And there is no serious impact to environment in the short term.
- The development of groundwater is mainly for domestic use such as well and borehole construction.

Groundwater issues (Cont.)

- Risk to groundwater can be caused by upstream user and also local communities themselves through overuses or contamination of less understood on groundwater management.
- Risk to groundwater quality is petty due to low intensity of settlement and low industrialization.

Groundwater issues (Cont.)

- There are some significant local risks particularly from mining activities in some river basins and around industry zones.
- There is especially important where such pollution could occur near wells being used for drinking and other domestic used.

Conclusion

- There is limited information on groundwater and there is no specific agency carry out on groundwater management in recent year.
- Groundwater sources is use for domestic purpose only (cooking and drinking) in Lao PDR.
- Quality and quantity of ground water is still good. And there is no seriously impact to environment in the short term.
- The result of National Workshop on River Basin Management on 17-18 Oct 2011, Vientiane, Lao PDR. The Department of Water Resources is going to strengthen on the water resources management both surface water and ground water in clouding establish the database system.


Thank you for your kind attention

Geological and Groundwater Database of Malaysia

Asminah Rajuli

Minerals and Geoscience Department, Malaysia

1. Introduction of the country

1.1. General Status

The Federation of Malaysia comprises of Peninsular Malaysia, and the states of Sabah and Sarawak on the island of Borneo. Situated between 2º and 7º to the North of the Equator line, Peninsular Malaysia is separated from Sabah and Sarawak by the South China Sea. In the northern part of Peninsular Malaysia lies Thailand and bordering Singapore in the south. Sabah and Sarawak are bordered by Indonesia while Sarawak also shares borders with Brunei. Malaysia has a total area of 329,758 square km and a population of 28.3 million. The capital city is Kuala Lumpur (**Fig. 1**).

1.2. Politics and Economics

Malaysia has its origins in the Malay Kingdoms with the head of state is the Yang di-Pertuan Agong while the head of government is the Prime Minister. The government system is closely modelled on the Westminster parliamentary system and the legal system is based on English Common Law.

The largest ethnic groups are the Malays, Chinese and Indians and many other ethnic groups have lived together in Malaysia for generations. All these cultures have influenced each other; creating truly Malaysian culture.

Fig. 1. Malaysia location map.

2. Status of minerals and geoscience department Malaysia

2.1. Summary

The department was established on 1st July 1999 with the merging of Mines Department and the Geological Survey Department. The headquarters office is situated in the center of Kuala Lumpur. In the whole country, the department has 10 state offices to provide advisory services to the state authority, government agencies and the private sectors related to the geosciences and mineral sector.

The core business of the department is to deliver mineral and geosciences information for supporting the economic activity of the private sectors, as well as to assist in the overall planning and decision-making by the government.

The senior management department consists of the Director General and assists by the Deputy Director General of Corporate and Mineral Economics, the Deputy Director General of Operations, the Director of Technical Services Divisions and the Director Mineral Research Centre. Currently, the department strength consists of 1,140 staffs including of 324 professional and management officers and 816 support staffs.

3. Status of groundwater in the country

3.1. Introduction

One of the objectives of groundwater developments in the country is to reduce dependency on only one source of water and to provide reliable source of water supply. The need rise sharply especially during water crisis e.g. drought season or in area where source of clean reliable surface water is scarce. Minerals and Geoscience Department is the lead agency in groundwater research and development in the country. The department provides advisory and professional services to the state authority, government agencies and the private sector related to the development of groundwater. The vision of the department is to act as the national depository for all information related to geoscience and mineral resources of the country includes groundwater.

3.2. Geological Settings

3.2.1. Peninsular Malaysia

Tectonically, Peninsular Malaysia forms part of the Sunda Shield. Its Triassic fold-mountain belt, the spine of the Peninsula, continues from eastern Burma through Thailand, Peninsular Malaysia, the Banka and Billiton Islands, and eastwards into Indonesian Borneo. All the systems, ranging from the Cambrian to the Quaternary, are represented in Peninsular Malaysia. The Triassic and older strata are essentially marine whereas the post- Triassic rocks are characteristically non-marine. Sedimentation was continuous throughout the Paleozoic and Mesozoic. Granitoids occupy almost half the peninsula, commonly forming topographic highs, notably in the Main Range. The main episode of granitic emplacement coincides with the culminating late Triassic orogenic event during which all the older strata were folded and deformed (**Fig. 2**).

3.2.2. Sabah

Sabah, situated at the northern tip of Borneo Island, is geologically complex. The oldest rocks are the Early Triassic metamorphic rocks of the Crystalline Basement, found mainly in eastern Sabah. Large bodies of granite, granodiorite, tonalite, ultramafic and mafic rocks intrude into the metamorphic rocks. The ultramafic bodies are distinctly elongated and commonly aligned east-west along the general metamorphic foliation trend (**Fig. 3**).

3.2.3. Sarawak

In Sarawak, the oldest formations go back only some 300 million years, and so barely one-sixth of the world's recorded geological history is represented here. These ancient rocks form part of the West Borneo Basement which is the exposed part of the Sunda Shield in Southwest Borneo, and is thus related to continental South-East Asia. The Basement is built up of Palaeozoic and Mesozoic rocks. Most of Sarawak, however, is underlain by younger Tertiary sedimentary rocks especially the region northeast of the Lupar river (**Fig. 4**).

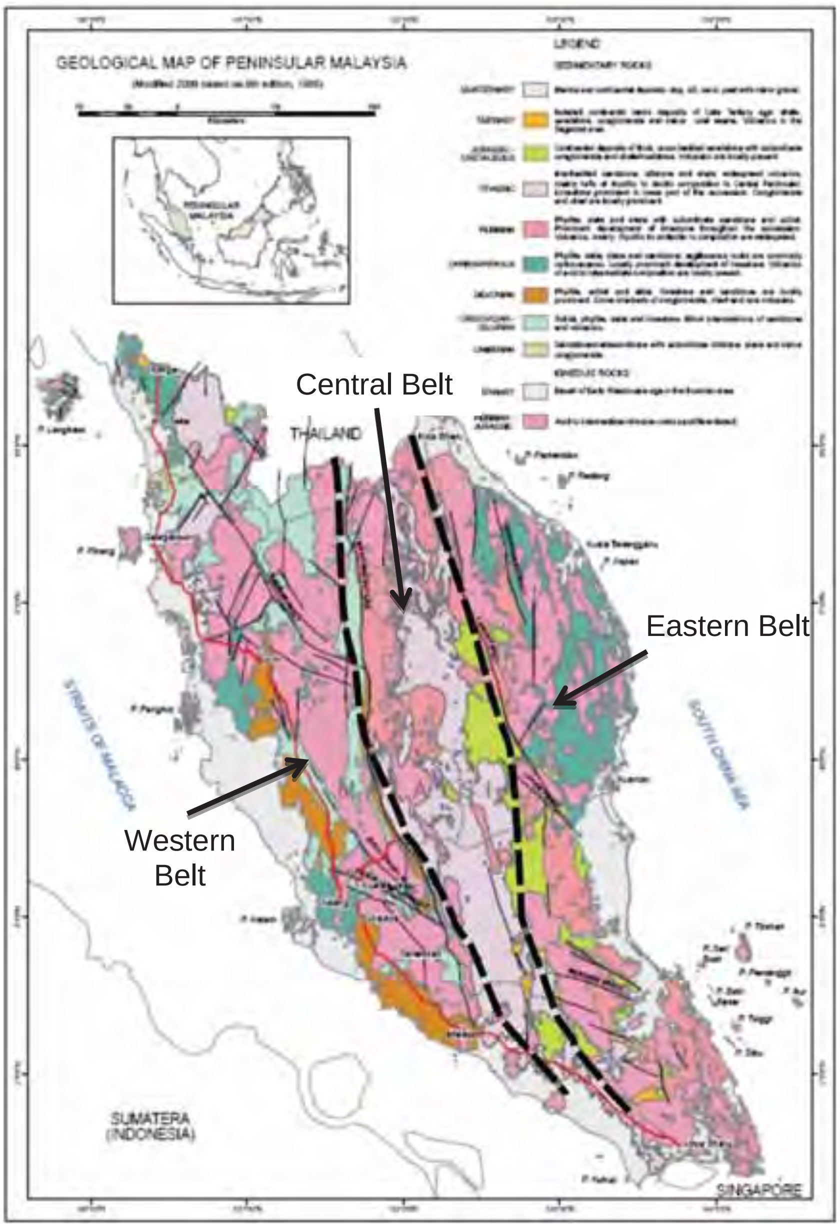


Fig. 2. Geological map of Peninsular Malaysia

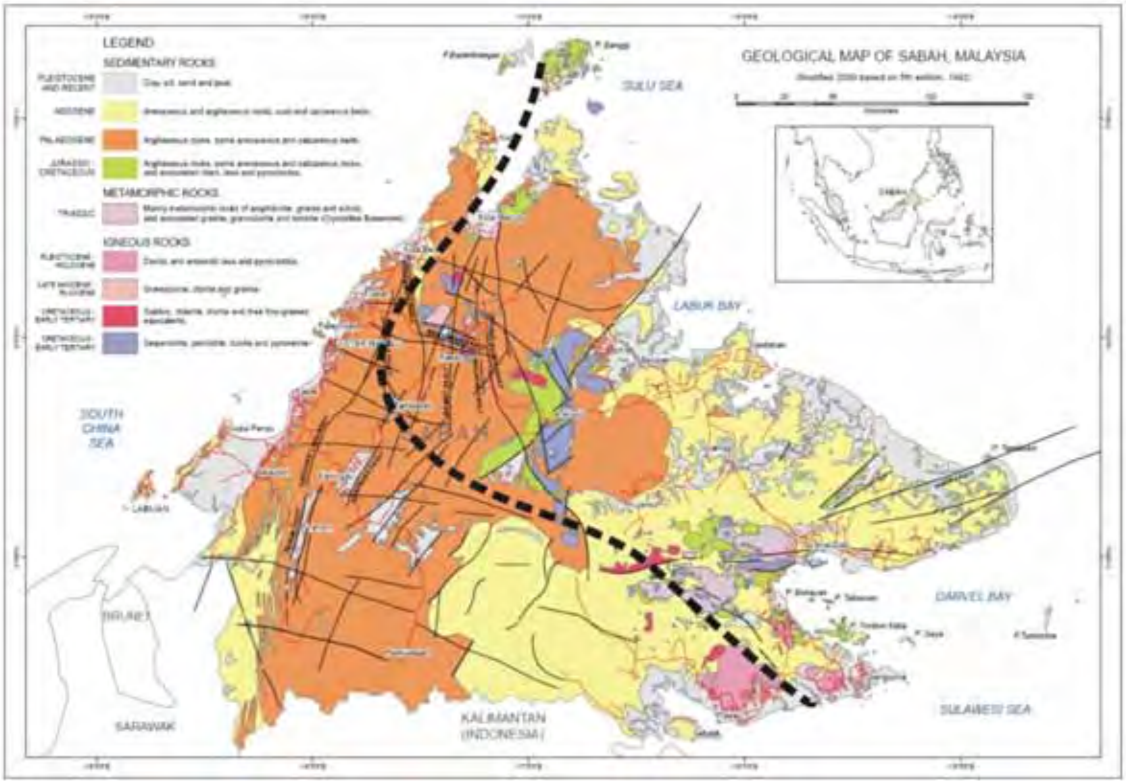


Fig. 3. Geological map of Sabah, Malaysia.

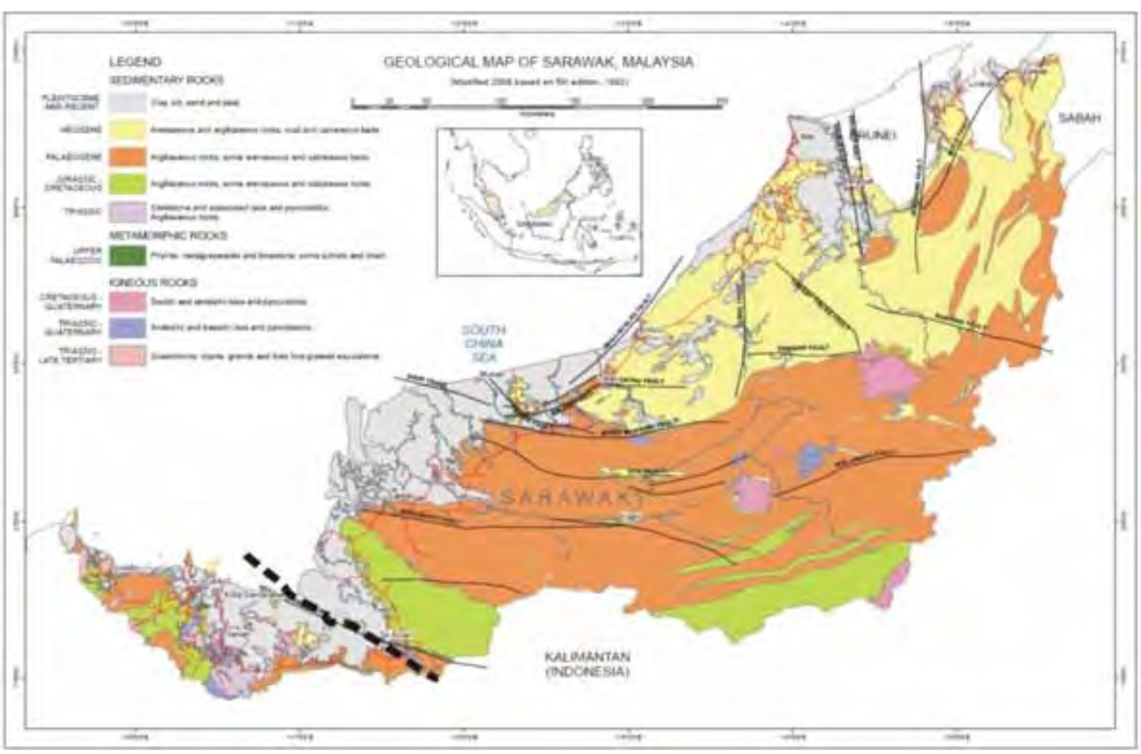


Fig. 4. Geological map of Sarawak, Malaysia.

3.3. Types & Occurrences of Aquifer

Groundwater is water that is found underground in cracks and spaces in soil, sand and rocks. Types of groundwater resource in Malaysia include shallow alluvial aquifer, deep alluvial aquifer, hard rock aquifer, peat aquifer and island aquifer.

Much of aquifer in Malaysia is formed from sedimentary rocks that were created by accumulation and compaction of loose sediments. Limestone is one of the main Palaeozoic sedimentary rocks which are found in thick layers. Heavy erosion of easily eroded limestone is found in Sabah and Sarawak. Sandy beaches are found primarily on Malaysian tropical islands.

3.4. Potentials and Productions of Groundwater Resources

Groundwater development starts in Peninsular Malaysia since early 1900s in Kelantan. 60% is use for domestic purposes, 35% for industrial supply while the other 5% is for agriculture. In Peninsular Malaysia, groundwater resources can be divided into 4 potential categories; i) the most productive aquifers are the alluvium which can yield up to 100m^3/h per well, ii) limestone is the most productive aquifer in hard rock which can produce up to 50m^3/h per well, iii) Fractured sand stone, their metamorphic equivalent and volcanic rock aquifer can produce up to 30m^3/h per well, iv) the least productive aquifer is made up of fractured igneous rocks which can give 20m^3/h per well.

Groundwater investigations and development in Sarawak has been started since the 1970s. Three categories of aquifers in Sarawak are shallow aquifers (sand, gravel and peat), deep aquifers in sedimentary basins and deep aquifers in fractured hard rocks. Groundwater is presently the main source of water supply in several coastal villages in Sarawak.

Groundwater in Sabah has been developed in the shallow aquifer. The most productive aquifer so far is the Sandakan Formation (thick bedded sanstone). Since the 1980s most of the coastal villages of Sabah have been exploiting groundwater resource by digging shallow wells as a main source of water supply.

Generally, about 0.2 million m^3/d of groundwater is being exploited in Peninsular Malaysia, 0.05 million m^3/d in Sarawak and 0.02 million m^3/d in Sabah. Mostly are used for domestic purposed while others are for industry and agriculture.

4. Status of groundwater database in the country

4.1. Introduction

The Minerals and Geoscience Department Malaysia is a lead agency in the country in implementing a groundwater management framework as well as the groundwater database information. Groundwater database development has been started since early 1980s with various series of the groundwater data management system. The latest is the MINGEODAT (Minerals and Geoscience Database) system which is an integrated system that has been developed for the department in order to manage the groundwater information. MINGEODAT is centralized database and consist of 10 other different systems includes HYDROdat that holds groundwater information on approximately 5,000 boreholes. Currently, the HYDROdat application is the country repository of groundwater bore information managed by Minerals and Geoscience Department Malaysia (**Fig. 5, 6, and 7**).

Fig. 5. Website Minerals and Geoscience Department Malaysia shows the link of groundwater database in MINGEODAT system

Fig. 6. The example of interface display of HYDROdat

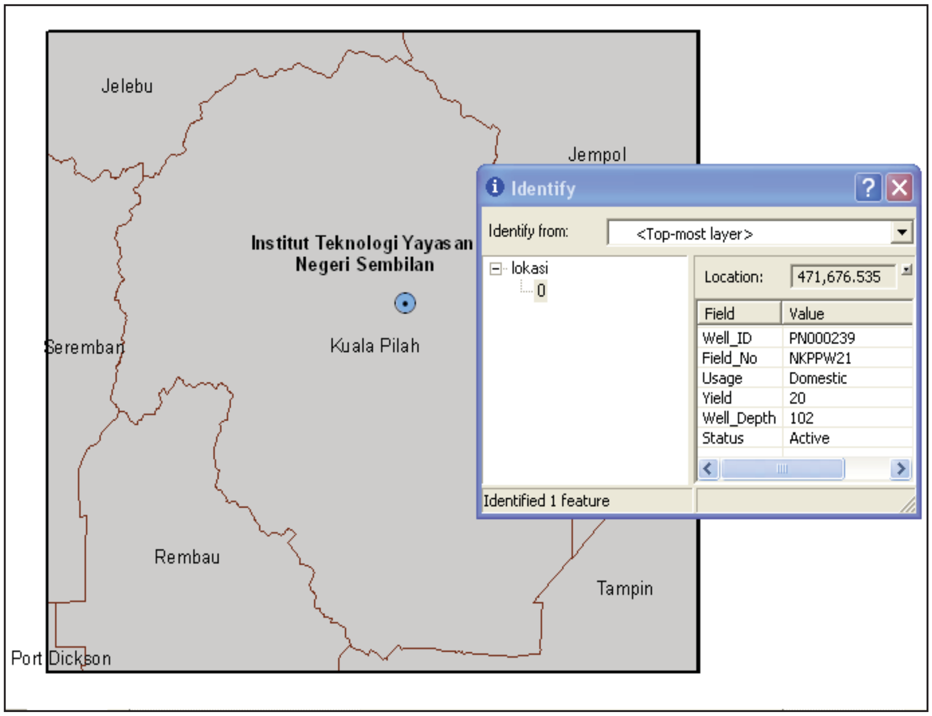


Fig. 7. The search results display in map form

4.2. Database Management

The HYDROdat combines data from a wide variety of sources including the data from other government departments, industry and private. This database securely stores a collection of hydrological, geochemical (sampling and chemistry), and geological data collected throughout country. This includes the data from Groundwater Monitoring Programme database, information from industrial sector and past and present research and consultancy project data. All the data from outside were submitted to Minerals and Geoscience Department Malaysia and will be entered to the system by the staff. The HYDROdat is automatically system linked to the ArcGis map, therefore only the data with complete latitude and longitude coordinate could be entered into HYDROdat. The other basic water-well data in the system includes information such as location, usage, total depth, static water level, casing and lithology.

4.3. Database Accessibilty

The data can be accessed via website of Minerals and Geoscience Department Malaysia with appropriate security access for confidential data. The data can be accessed online at no charge for outsiders but only for certain parameters and does not include all of the fields of data. Viewers are allows to enter search criteria and all search results can be displayed as a report or any text files or displayed in map form such as digital geological map. The map server also allows the viewer to view and query any of the data near the point of interest.

4.4 Future Directions and Programs

The future plan to enhance the groundwater database in the country is to measure and deliver the real time data of groundwater level and quality continuously. This needs the budget to set up network of monitoring stations and the application system for accessing real-time water data.

The application should allow the staff to receive groundwater level and publishes daily water level data whereas the water users are able to instantly access information of groundwater interactive map showing the real time data on groundwater level and groundwater chemistry data. All these data is very important to be used in managing groundwater, including groundwater access, allocations and extraction, protecting aquifers and providing data for the development of groundwater sharing plans throughout the country. As a conclusion, the role of Minerals and Geoscience Department as a leading agency in the field of groundwater is very important in managing the efficient groundwater database for the future development of water supply in Malaysia.

Ground water resources of Myanmar and case study in central Myanmar

Aung Myo Win

Department of Geological Survey and Mineral Exploration, Ministry of Mines, Myanmar

1. Introduction

Myanmar is endowed with resources of arable land, water resources, natural gas, mineral deposits, fisheries, forestry and manpower. Myanmar is situated in South-East Asia between latitudes 9° 32’ and 28° 31’ N and longitudes 92° 10’ and 101° 11’ E and has a total land area of 676,577 sq.km (261,227 Sq mi). It extends 1931 km (1200mi) North to South and 925km (575 mi) East to West. It has a total coastline of 2,276km (1,414mi) and total international land borders of 5,858km (3,641mi) with five countries, China (2,185km, 1357mi), Thailand (1799km,1,118mi), India(1,403km, 872mi), Laos DPR (238km,148mi) and Bangladesh (233km,145mi). There are divided 7 States and 7 Regions.

2. Topography

Myanmar has mountain ranges in the North, East and West. Lengthwise, it stretches about 2200 Km North to South and approximately 950 Km East to West. Myanmar also has a long coastal line of 2200 Km in the South. Sea frontier comprises Rakhine coast line 710 Km, Delta coast line 430 Km and Tanintharyi coast line 1070 Km. The highest lands are at the North of the country and it inclines towards the South, resulting in most of the rivers flowing from the North to the South. Most of the land frontiers are defined by mountains. The country is divided into five topographic regions as follow

1. The Western and Northern hilly regions
2. Shan plateau (Eastern part)
3. The central dry zone or central semi-arid regions
4. The deltaic zone
5. The Rakhine and Tanintharyi coastal strips and mountainous regions

3. Morpho- tectonic belts of Myanmar

Tectonically and geomorphologically Myanmar can be divided into 4 belts from East to West as follow;

1. The Eastern Highlands
2. The Central Lowlands of Central Cenozoic Belt
3. The Western Ranges or Indoburman Ranges
4. The Rakhine Coastal Belt

3.1. The Eastern Highlands

The Eastern Highlands which include the northern and eastern mountainous tract of the Kachin State in the north, the Shan Plateau in the middle, and the Tanintharyi ranges in the south. The presence of Precambrian orthogneisses and low-grade meta-sedimentary rocks

(Chaung Magyi Group), Paleozoic and Mesozoic carbonates, clastics, and igneous rocks enable this province to remain as a highland, locally with Karst topography in the limestone areas. The Chaung Magyi sediments were laid down probably in a eugeosyline, the Paleozoic carbonates and clastics in a shallow sea, and Mesozoic clastics and evaporates in enclosed and intermontane basins. The province had undergone at least four times of deformation before it was uplifted by the epirogenic movements at the end of Mesozoic. Since then, it has been a fairly stable block. Large linear granitoid plutons of mainly Upper Mesozoic and Lower Tertiary ages intruded along the western marginal zone of this province. These plutons were subduction-related igneous bodies that intruded along the weak junction zone between the tectonic provinces during late Mesozoic and Early Tertiary.

3.2. Central Lowlands or Central Cenozoic Belt

The Shan Plateau and Western Mountains were uplifted during late Cretaceous and Early Tertiary times. The Central Belt was then a subsiding trough which was gradually in filled with vest thickness of sediments possibly exceeding 75,000 feet. Fluviatile and deltaic sedimentation continually advanced to the south .In general, the northern portion of the Central Belt is characterized by continental sedimentation whereas the southern part is marine. In the late Tertiary , tectonic movements resulted in broad folding and occasionally thrusting of the Tertiary sediments (general north-north-west strike for folds; north- north-west and north-east fault systems); the Bago Yoma hills were uplifted during this period and divided the southern part of the Central Belt into two alluvial valleys. Recently, the Ayeyarwaddy/ Chidwin system has built up a huge alluvial delta to the Andaman Sea. Earth movements have continued and have affected the deposition of the Quaternary alluvium.

The General type area for the Tertiary sediments is the Minbu Basin in Central Myanmar. Here, the Eocenes, Peguan and Irrawaddian Series are separated from one another by unconformities. The Central Volcanic Line has divided this province into two halves since about Miocene. This igneous line starts from the Jade Mines area in the north, through the Wuntho igneous mass, Lower Chindwin Volcanoes, Salingyi, Shinmadaung, Mt.Popa, east of Zegon and Tharyarwady, to Myaungmya area in the south. The well-known Sagaing Fault, a right-lateral strike-slip fault that runs north-south for a distance of nearly 600 miles is located near the eastern edge of the province.

3.3. Western Ranges or Indo-Burma Ranges

It comprises Naga Hills, Chin Hills and Rakhine Yoma. They are underlain by a thick, mildly deformed, tightly folded and weakly metamorphosed sequence of flysch type deposits, which apparently were deposited in a subduction trench that lay between the Eurasian plate and northeastward-subducting Indian plate. Exotic limestone ranging in size from tiny blocks to mappable units, ophiolites and metamorphic tectonites are locally present within the disrupted flysch deposits. The Western Ranges arose as the results of folding, over thrusting and uplifting during the Early Himalayan Orogeny at the close of Eocene.

3.4. Rakhine Coastal Belt

The Rakhine Coastal lowland is underlain by Upper Cretaceous type deposits and lower Tertiary rocks in the south and by Upper Tertiary clastic sedimentary rocks of molasses character in the north. The strata are tightly folded and form chains of low hills. It is the southern continuation of the Assam Basin in northeastern India where a thick Tertiary succession is also present. The Minbu and Assam Basins are fairly similar not only stratigraphy and lithology, but also in the occurrence of oil and gas, especially in the

Oligocene and Miocene formations.

4. Water resource potential in Myanmar

There are four major river systems, namely, the Ayeyarwaddy, the Thanlwin, the Chindwin and the Sittoung. Besides there are some river systems in Rakhine State and Thanintharyi Region. These river systems contribute for the surface water resources of the country. Due to favourable climatic condition and physiographic features, there are eight river basins those cover about 90% of the country's territory. Total surface and groundwater potential of Myanmar are approximately 828 km^3 and 495km^3 per year respectively (**Table 1**). However, in many cases the usefulness of groundwater resources is limited due to their being non-renewable, saline or brackish, and hence not suitable for irrigation. If only renewable groundwater suitable for irrigation development is considered, the potential is reduced to 28.3 billion m^3.

The assessment of water resources potential both for surface and groundwater is carried out on the basis of river basins. In terms of water resources, Myanmar stands the 14th position at global level and 5th position at Asia region (Ref: WRUD).

5. Groundwater resources in Myanmar

On the basis of stratigraphy, there are eleven different types of aquifers in Myanmar (**Table 2**). Depending on their lithologies and depositional environments, groundwater from those aquifers have disparities in quality and quantity. Of these groundwater from Alluvial and Irrawaddian aquifers are more potable for both irrigation and domestic use. Groundwater are also extracted from Peguan, Eocene and Plateau limestone aquifers for domestic use in water scared areas, even though these are not totally suitable for drinking purposes.

The groundwater resources of Myanmar by administrative region can be summarized as follows.

5.1. Kachin State (Northern areas)

Groundwater is found mainly in Oligocene- mid- Miocene and Eocene rocks. It is mainly

Table 1. Myanmar's annual average water resources potential by river basin

Region / river basin	Surface water (mcm /Yr)	Groundwater (mcm /Yr)
Region 1. Chindwin	104720	57578
Region 2. Upper Ayeyawady	171969	92599
Region 3. Lower Ayeyawady	229873	153249
Region 4. Sittoung	52746	28402
Region 5. Rakhine	83547	41774
Region 6. Tanintharyi	78556	39278
Region 7.Thanlwin	95955	74779
Region 8.Mekong	10580	7054
Total	**827946**	**494713**

brackish and rarely fresh. In the valley areas, groundwater from alluvial deposits is fresh and yield may be high, but it is found only in localized areas.

5.2. Sagaing Region (North-Western area)

In the northern part of the Division, groundwater is situated in Oligocene to mid- Miocene rocks and is brackish in quality. Groundwater in the Chindwin Basin is of mid-Pliocene age and occurs in a contained area. The water is suitable for drinking and irrigation purposes. Groundwater in the southern part of the Region is suitable mostly in alluvial beds of Quaternary age, mainly fresh water, and has a good yield. The water is also suitable for drinking and irrigation purposes.

5.3. Shan, Kayah, Kayin and Mon States and Tanintharyi Region (East and South-Eastern area)

Groundwater occurs mainly in limestones of the Carboniferous-Permian age. In the eastern part of the area, it lies in beds of Mesozoic and Precambrian ages. Groundwater in volcanic rocks is found in the southeastern part. Generally, it is fresh and mostly suitable for drinking and irrigation. To exploit economically, drilling method may be limited.

5.4. Rakhine and Chin States (Western area)

In the eastern part of the states, groundwater occurs in Eocene rocks. The groundwater is mainly brackish and fresh water is rarely encountered in this area. On the Western side groundwater is of Oligo-mid-Miocene and is brackish in quality. Natural reserves of fresh water are limited and seawater intrusion may be encountered.

5.5. The Central Area (Mandalay and Magway Regions)

Fresh groundwater is found in Quaternary and Mio-Pliocene rocks. But salinity of groundwater in Mio-Pliocene beds increases with depth. It is suitable for drinking and irrigation purpose. Small supplies of groundwater have been achieved from boreholes tapped in Upper and Lower Peguan in some areas. They are of Miocene and Oligocene ages. Groundwater in these sediments is mostly saline and rarely fresh.

5.6. The Delta Area (Yangon and Ayeyarwady Region)

Groundwater occurs in alluvial beds of Quaternary age. It is mostly fresh and in some parts brackish and suitable for drinking and irrigation purposes. In coastal area the water quality may be saline.

5.7. Bago Region (Southern area)

The central area of the Region is Bago Yoma and it has the rocks of Oligo- Miocene age bearing mainly brackish water. Natural reserves of fresh water are limited. In the eastern and western parts of the Region, groundwater of alluvial beds is exploited. Groundwater reserves are considerable and suitable for drinking and irrigation purposes.

Table 2. The Major Aquifers in Myanmar

Sr.No	Name of Aquifer	Major rock units	Area of occurrences	Remark
1	Chaungmagyi Aquifer (Precambrian)	Low grade metamorphic rocks	Eastern Highland	To be study in detail
2	Cambrain- Silurain Aquifer	Molohein Group Pindaya Group Mibayataung Group	Eastern Highland	To be study in detail
3	Lebyin- Mergui Aquifer	Graywecke , quartzite, argillite, slate, mudstone, gravel etc;	Western boundary of Eastern Highland and Taninthari ranges	To be study in detail
4	Plateau Limestone Aquifer	Limestone & dolomite	Eastern Highland	GW is being extracted in some places
5	Kalaw- Pinlaung- Lashio Aquifer	Loi- an Group & Kalaw Red Beds	Western boundary of Eastern Highland and Tanintharyi ranges	To be study in detail
6	Cretaceous Aquifer	Flysch units and limestone units	Western Ranges	To be study in detail
7	Flysch Aquifer	Interbedded units of sand, siltstones, shale and mudstone	Western Ranges	Probable GW source area
8	Eocene Aquifer	Sandstones, siltstones and shales	Periphery of Central Lowland	Probable GW source area
9	Pegu Group Aquifer	Sandstones, siltstones and shales	Central Lowland and Rakhine Coastal Plain	Mostly saline & brackish water, some fresh water in recharged areas
10	Irrawaddian Aquifer	Mainly sands, sandstones with gravels, grits, siltstones and mudstones	Central Lowland and Rakhine Coastal Plain	Thick aquifer fresh GW with high iron content
11	Alluvial Aquifer	Sands, gravels and muds	Major river basins and its tributaries, base of mountains and ranges	Fresh GW, seasonal water table changes

6. Occurrence and quality of ground water in Myingyan- Nathogyi- Taungtha area, central Myanmar

The Myingyan-Natogyi-Taungtha area is situated at the center of the dry zone of Burma, where the tropical and sub-tropical steppe climate (BSh) is prevailing. The agricultural and economic development of this region is therefore much dependent upon the surface and underground water resources. The surface water resources which are mainly temporary streams, tanks and reservoirs cannot meet water requirements beyond the rainy season and the beginning of winter. In the other seasons of year, the water supply for agricultural and domestic use has come mainly from tube wells and dug wells. Hydrological division of the Department of Geological Survey and Mineral Exploration had conducted the hydrology field survey in Myingyan- Nathogyi and Taungtha area in 1976.

During the investigation, the electrical conductivity of ground waters was measured and 78 water samples were collected from various aquifers and analyzed in the chemical laboratory of the Department of Geological Survey and Mineral Exploration. All the dug wells and tube wells were surveyed and recorded and well logs of tube wells studied in conjunction with the data on the chemical characteristics of the ground waters.

6.1. Aquifers in Myingyan- Natogyi -Tauugtha area

Although the problem of the water shortage in the Myingyan-Natogyi-Taungtha area is solved by the local people by sinking tube wells and dug wells, hydrogeologic characteristics of the various aquifers have not yet been studied. M.M. Ivanitsin (1959 & 1962) and Maung Thin (in press) classified several aquifers of dry zone of central Burma. Their classification was based upon the lithology and stratigraphic position of the local geological formations of central Myanmar. In accordance with their classification aquifers can be grouped in Myingyan-Natogyi-Taungtha area as follows:

1. Alluvial aquifer
2. Irrawaddian aquifer
3. Peguan aquifer

The alluvial and Irrawaddian aquifers arc more important for the agricultural development of the area because they contain considerable ground water of good quality and all the cultivated lands are situated on these aquifers. Peguan aquifer is found only as a source of ground water fit for local water supply.

6.1.1. Alluvial aquifer

From Sarmeikkon in the north to Sindewa valleys in the southwest about 270 square miles of alluvial sediments occur as a narrow strip on the left bank of Irrawaddy River. The thickness of individual aquifers varies from place to place and generally, the upper horizon of aquifers where dug wells are usually, constructed is situated at the depths of 5 to 30 feet. The lower aquifers are tapped at the depths of 100 to 180 feet.

The alluvium occurs as layers of unconsolidated sands and clays. The water table upper horizon is shallow, at places near to surface water resources becoming deeper away from them. This suggests that the ground water of upper horizon is entirely replenished by surface water. The water table of lower horizon usually lies at 20 to 75 feet below the surface and sometimes exceeds 100 ft. From the beginning of the monsoon season gradual rise of water table occurs and this rise is more pronounced in the upper horizon than the lower one although both are totally replenished by the infiltration of surface water during the rainy season.

Similar replenishment of ground water only at the sites of surface water resources is also usually found in the other parts of the dry zone (Mauug Thin, Tin Maung Nyunt, Ant Pe and Maung Thin).

The waters of upper horizons are slightly saline sulphate-bicarbonate sodium and saline sulphate-bicarbonate sodium and saline sulphate sodium water, while those of lower ones are fresh bicarbonate-chloride, magnesium-calcium and bicarbonate- sodium waters and saline sulphate bicarbonate sodium water with total dissolved solids (T.D.S) ranging from 670 to 1760 ppm. The conductivity measurement of waters of lower aquifer which is situated at 150-160 ft. is 850 micromhos and that of upper aquifer (25-30 feet deep) is found to be 3250 micromhos. It shows that the ground water of upper horizon bears more soluble salts than the lower one. Such unusual enrichment of ground water by soluble salts is generally found in semi-arid and arid regions where the influence of high temperature leads to the concentrations of salts in shallow ground waters. The wells which penetrate the alluvial aquifer discharge 500 to 5000 gallon per hour.

6.1.2. Irrawaddian aquifer

The Irrawaddian rocks arc extensively exposed on the east of Natogyi and Yonzingyi area. The other exposures are generally elongated and narrow and their total area of distribution is about 530 square miles. The Irrawaddian aquifer is comprised of thick layers of sands and clays, sandy layers being more abundant at the lower portion.

The depth of the aquifer varies from place to place. East of Natogyi it lies at 100-120 feet below the surface and the water table rises up to the depth of 30-70 feet , whereas in Minyin Kyaukphu area, the aquifer and water table are situated at depths of 680-790' feet and 230-290 feet respectively.

The ground waters of Irrawaddian aquifers are mostly fresh bicarbonate sodium, bicarbonate calcium and bicarbonate magnesium waters with T.D.S. ranging from 330 to 170 ppm, saline bicarbonate sulphate sodium with T.D.S. of 2650 to 2690 ppm and brackish sulphate bicarbonate sodium with 5460 ppm of T.D.S. Waters of high sulphate content are also found at the few localities such as Nyaungbintha and Petpinaing. It is probably local concentrations derived from the sulphide minerals or formed after leaching of the rocks by the ground water. The discharge of the wells of Irrawaddian aquifers varies from 700 to 4500 gallon per hour depending upon the type of well and pump.

6.1.3. Peguan Aquifer

Extensive exposures of Peguan rocks are found southwest of Welaung, Taungtha range, Natogyi and Mingon range. The thickness of this aquifer is not known and the wells which penetrate up to 150 feet depth are found to be water producing. The Peguan rocks are composed of sandstones interbedded with clays, shales and siltstones. Generally the Peguan aquifers are confined ones but the shallow ground water is sub artesian. The water table rises up after tapping the aquifer and usually stays at the depth interval of 105 to 32 feet below the surface. East of Natogyi along a fault line, brackish waters seep out to the surface through spring and after drying up due to high temperatures form.

In some areas ground waters of the Peguan aquifer are fresh bicarbonate magnesium water with 380 ppm of T.D.S. and some are slightly saline bicarbonate sodium magnesium and sulphate- bicarbonate sodium magnesium waters with 1130 to 1560 ppm of T.D.S. In some places ground waters are found to be brackish sulphate magnesium water with 9690 to 10700 ppm of T.D.S. In some areas near to the temporary surface water resources where water-exchange can occur easily, fresh waters are usually found. For example at Palangon village where streamlets arc found, the ground waters have been found to be fresh bicarbonate waters with low T.D.S. Predominant concentration of Mg has been noticed in the ground waters. Mg is usually derived from sea water trapped in the pores of sediments during deposition under marine condition (B.D. Hem, 1959). As Peguan rocks are of marine origin higher content of Mg may be due to the leaching of Mg salts from these rocks. Enrichment of SO_4 may be due to gypsum which is abundant in Peguan rocks. Wells penetrating the Peguan aquifer give low yields, the discharge varying from 850 to 1500 gallons per hour.

6.2. Quality of ground water for agricultural use

Instead of surface waters, ground waters are widely used in irrigation because of natural advantage; *e.g.* nearness to the irrigated lands, constant yields (discharge), lack of suspended materials, etc. However, if they contain a lot of soluble salts, the soil will gradually become saline and harmful to the plants. Therefore, their chemical compositions are very important in considering their possible application in irrigation.

If the T.D.S. is greater than 1700 ppm, the ground water is generally regarded as water unfit for irrigation, but sometimes water containing 1700-3000 ppm of soluble salts is allowed. Depending upon the type of dissolved salts, the nature of soil and the kinds of plants, ground water composing of 5000 ppm T.D.S. can be used to irrigate land in arid and semi-arid regions (Priklonskii and Laptev, 1949). The T.D.S. in the ground water of Myingyau-Narogyi-Taungtha area is usually less than 3000 ppm, but at places it exceeds 5000 ppm. Hence majority of the ground waters can be preliminarily considered as fit for irrigation.

The ground waters of alluvial aquifer fall in the classes of good qua1ity, fair quality and poor quality. The poor quality waters are usually found in the upper horizon s of the aquifer. Good quality waters are usually produced from the lower horizons.

The ground waters of the Irrawaddian aquifer have been found in the classes of poor quality, fair quality, good quality and excellent quality. Good quality waters are usually observed in the synclinal areas and poor quality waters are found on the limbs of anticlines where contamination by saline water from Pcguan aquifer is probable.

The ground waters of the Pcguan aquifer generally fall in the classes of poor and fair quality or fair quality

Ground water of excellent quality can be used without precaution. However, irrigation with water of good and fair quality necessitates special measures to prevent the gradual accumulation of alkali in the soil and consequent decreased fertility.

6.3. Conclusion

Among the three types of ground waters, waters alluvial and Irrawaddian aquifers are found to be promising for future utilization in agriculture. These aquifers are extensive, lie at shallow depths below the surface, and their waters are generally of goad quality. The ground waters of Peguan aquifer are more or less saline and can be used for livestock and domestic use.

An Overview of Groundwater and Geological Data Base in the Philippines

Clarissa G. Villanueva

Mines and Geosciences Bureau,
Department of Environment and Natural Resources, Philippines
e-mail : clarissa_villanueva2000@yahoo.com

Abstract

The Philippines' water related agencies which include the Mines and Geosciences Bureau (MGB) have, for many years, been collecting data as they discharge their function to fulfil their mandate of conducting scientific research and assessment programs. Groundwater assessment is just one of the major thrust of MGB's activities where set of data are collected and used for analysis and afterwards set aside for archiving. Owing to the importance and usefulness of pertinent water related data collected over time, it has been recognized that there is a need to organize and systematize these data whereby not only the collecting agencies but also the general public will benefit. Although the agencies have different mandate and objectives, data sharing is one common objective that pushes for the development of water information sharing system. Information on water quality, quantity and other relevant data are managed using appropriate data format. Geological database include the index of geologic quadrangle, mineral resources and geo-hazards quadrangle maps.

Keywords : groundwater assessment, data sharing, water information sharing system, geological database

1. Introduction

Rapid population growth and industrial development had brought about a tremendous increase in the need and demand for water resources both in the rural and urban areas. The need for water by the general population and industries had to be satisfied that the sustainability and protection of the groundwater resources had been given limited attention. The rapid reduction, depletion, degradation and critical condition of the groundwater resources should be recognized and its management should be initiated.

There are different water related agencies that collect and generate water data based on their mandate, responsibility and specific objectives with a common objective of developing a water information sharing network. Several efforts on the management of water resources and the creation of water resources database had been recognized and had shown a big leap in its development and progress.

Among the different water related and data collection agencies, the National Water Resources Board (NWRB) had been recognized as a central repository of all water related data including streamflow, water quality, groundwater, rainfall, rivers, water permits, dam and project programs and publications (**Fig. 1**).

2. Groundwater Database

2.1. The Data Collection Agencies

The following are the primary data collection agencies with the information shared:

1. National Water Resources Board (NWRB), lead agency - Water Permit, Groundwater
2. Bureau of Research and Standard (BRS) - Streamflow Data
3. Environment Management Bureau (EMB) - Water Quality
4. Mines and Geosciences Bureau (MGB)– Groundwater
5. Local Water Utilities Administration (LWUA) - Groundwater
6. National Irrigation Administration (NIA)– Dams, Groundwater
7. National Economic Development Authority (NEDA)– water policies
8. Philippine Atmospheric, Geophysical, Astronomical Services Administration (PAGASA) - Rainfall data
9. Water Supply Program Management Office (WSPMO) of the Department of Interior and Local Government (DILG)– groundwater data

2.2. Lands Geological Survey, Mines and Geosciences Bureau, Department of Environment and Natural Resources

The Lands Geological Survey Division (LGSD) of the Mines and Geosciences Bureau (MGB) has the following general functions and services:

- Formulate, develop and coordinate the adoption/implementation of national geological mapping programs, field survey and laboratory research technologies and geostandards and georeference materials;
- Conduct specialized researches in geology, petrology ore genesis mineralogy and other related scientific disciplines , including the conduct of hydrogeological, geohazards and geoenvironmental site assessments;

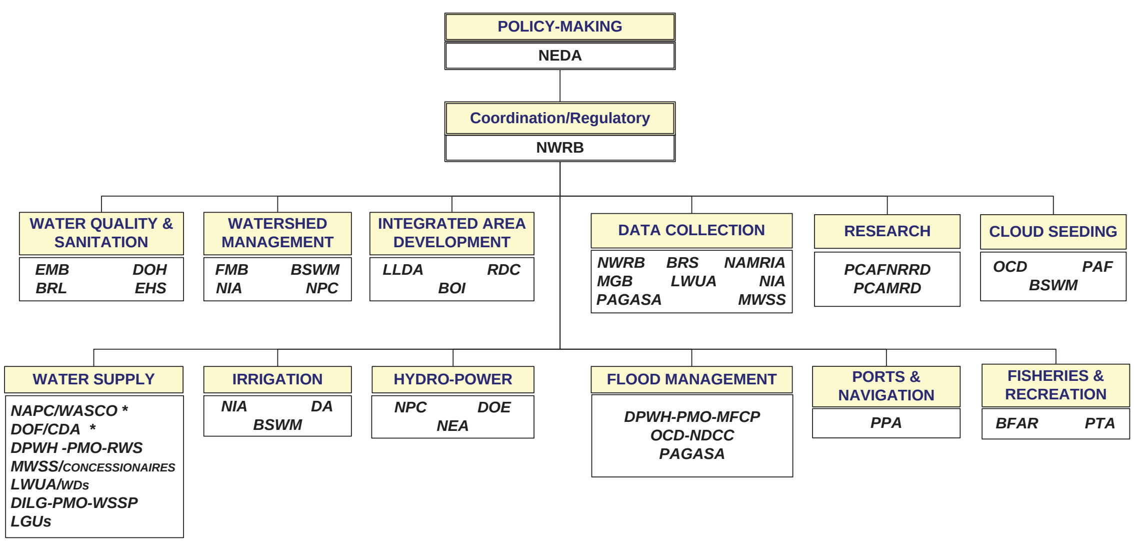


Fig. 1. Functional Chart of Water Related Agencies in the Philippines
(Adopted from the Presentation of Susan P. Abano, Engineer IV, Water Resources Assessment, Policy and Program Division, NWRB)

- Provide technical support services to the Regional Offices, other government agencies, mining contractors/permittees and the general public.

The specific functions and services of the LGSD include Geological Survey Research, Environmental Geology and Hydrogeology Research, Mineral Deposits and Ore Genesis Research, Geological Database and Information Systems, Geological Laboratory Services and Urban Geology.

The Environmental Geology and Hydrogeology Research Section is responsible for the conduct of hydrogeological assessment and geophysical surveys in relation to mineral exploration, groundwater assessment, structural and engineering geological evaluation and geo-environmental studies.

2.3. Efforts on Groundwater Database Development

The MGB and NWRB, both under the DENR have on a continuing basis conducted projects and studies on the national level. The MGB particularly conducts researches, investigations and assessment of the groundwater resources. The technical output produced had been utilized as management tools for the authorities, planners and decision makers to properly manage the groundwater resources.

2.3.1. Groundwater Resources of the Philippines (1970-1980)

The Groundwater Availability Map of the Philippines had been realized with the extensive hydrogeological data gathered by the early geoscientists at the MGB.

The First (1st) Edition of the Groundwater Availability Map was published by the MGB in 1982. The legends used were based on UNESCO/IAH Legend (1970) Classification of Hydrogeologic Units. The map projected the regional environment, characteristics and quantifies groundwater regimes suitably. It also represented a synthesis of all available

Fig. 2. Groundwater Availability Map

information on geology, structure, geomorphology, climatology and hydrology relevant to the hydrogeology of the country.

The groundwater availability map of the Philippines (**Fig. 2**) shows the availability of groundwater based on the water bearing capacity of various lithologic units covering the entire Philippine archipelago. Included is the characterization, extent, and location of groundwater sources (i.e. extensive/highly productive aquifers, fairly productive aquifer, less productive aquifers, and rocks with limited or low potential capacity to produce water). This was partly based on the hydrogeological and groundwater assessments survey, studies, and investigations made in different areas of the Philippines since the early 1960's.

2.3.2. Rapid Groundwater Assessment (1982)

In 1982, the NWRB had embarked on a project to roughly assess the country's groundwater resources at the municipal and provincial levels. This provided a comprehensive guide to water supply planners and designers and local officials. The output of the project was a Regional Rapid Groundwater Assessment and Regional Well Classification Maps (**Fig. 3**).

2.3.3. National Water Data Collection Network (NWDCN)

Spearheaded by the NWRB together with the MGB for groundwater, EMB for water quality and BRS/DPWH for surface water, the project is a groundwater, surface water and water quality database designed for the purpose of water resources planning.

2.3.4. National Water Information Network (NWIN)

The NWIN, an offshoot of the NWDCN is a computer-based system linking databases of water resources agencies. It includes stream flow data, water quality data, groundwater data, rainfall data, river systems data, water subscribers, project programs and publications. The computer data input was provided by the participating agencies.

2.3.5. Philippine Groundwater Databank (1991-1994)

It is the most widely used groundwater database (PGDB-GIS) developed under the UNDP

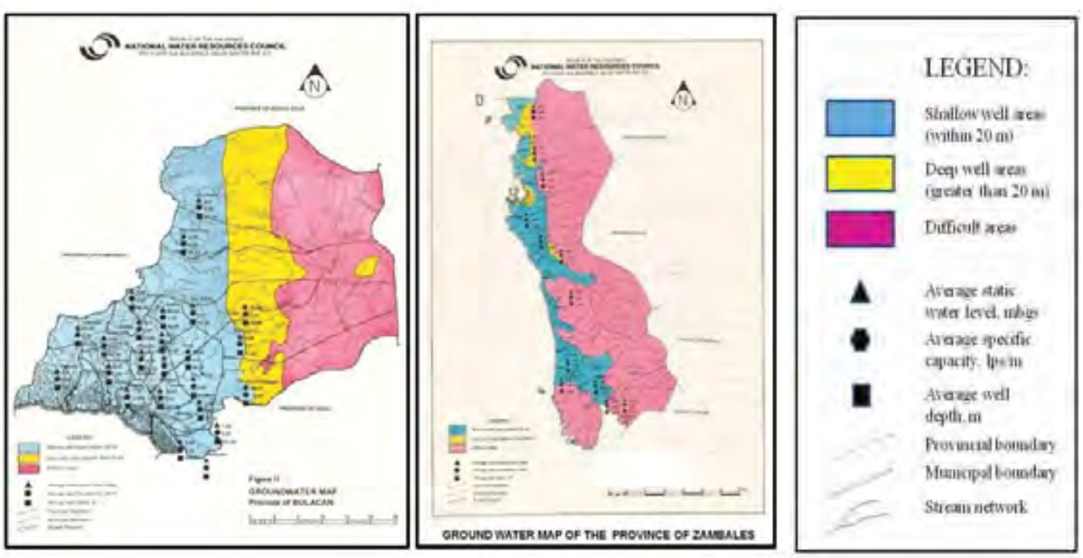


Fig. 3. Provincial Level Groundwater Maps of Bulacan and Zambales Provinces

Project (PHI/88/028) “Strengthening Water Sector in Groundwater Databanking and Dissemination” between the period 1991 to 1994. It was developed to systematize data collection and databanking in the groundwater sector. The database consists of well database and spring database. It was installed at the NWRB, LWUA and NIA and can still be accessed at present through the LWUA Research Division website.

2.4. Issues and Challenges

Database development in the Philippines faced many challenges including outdated hardware, software and network technology. Database developed for streamflow data, groundwater and water quality had not been properly maintained and updated.

The computer hardwares for NWIN are already unserviceable and the servers are outdated. Fiber optic network is very expensive and there are already new network technologies available in the market. The website is not available most of the time due to the problems on webhosting services.

There was no clear cut policy on the propriety of data. Data generating agencies were not able to update and upload the data. Personnel/staff trained are already gone, had either transferred, been promoted or retired.

As per the memorandum of agreement, the roles and responsibilities defined therein had been forgotten and had not been realized. Changes in leadership and the technical working group are constant.

There had been identified overlaps and gaps in the management system. Duplication of entry had been common. But mostly, the lack of fund and institutional weaknesses had been blamed as the common reason in attaining sustainability, continuous operation and maintenance of the database.

2.5. Current Programs and Initiatives

The Groundwater Resources and Vulnerability Assessment Program had been initiated by the MGB pursuant to Republic Act No. 9275 or the Clean Water Act of 2004. Chapter 3, Section 19, Item (d) thereof required “the preparation and publication of a national groundwater vulnerability map incorporating the prevailing standards and methodologies…” (MGB News Item, September 12, 2011).

The Program aims to generate critical information and database on groundwater resources availability and vulnerability in the various regions and areas of the country, and make the information available to authorities responsible for water resources management and development, physical framework and land use planning, land classification and allocation by Local Government Units, and regional as well as developmental projects.

For 2011, the MGB had targeted fifteen (15) municipalities and four (4) provinces as project areas.

The main activities for the Program had been data compilation, remote sensing studies, geologic and water well inventory, resistivity surveys and the identification, characterization and assessment of groundwater reservoirs and aquifers. The expected outputs are hydrogeological maps and groundwater vulnerability maps at 1:50,000 and 1:10,000 scales, and groundwater resources inventory database.

In 2012, the MGB enhanced the implementation of the program by increasing the target areas to include the twenty (20) provinces and urban growth areas.

2.5.1. Groundwater Resources Assessment

For the Groundwater Resources Assessment, the following will be undertaken:

1. Assess the Availability of Groundwater within the Various Sections of the Watershed/area
2. Establish the Groundwater Quality Baseline of a Specific Watershed Area
3. Establish the Potentials and Limitations of Available Groundwater Within the Given Watershed /Area

2.5.2. Groundwater Phase II

The Project with the Geological Survey of Japan/National Institute of Advanced Industrial Science and Technology (GSJ/AIST) was a contribution to the Groundwater Project Phase II to conduct assessment of water resources in Metro Manila and Metro Cebu.

The specific objectives of the project are inventory and updating of water related data and information, mapping of updated water resources data and information and evaluation of available water in prioritized critical areas of rapid growth expansion using modern technique for evaluation.

2.5.3. Solutions to Groundwater Problems in the CCOP Region

The participation in recently started project with KIGAM (2013-2017) through the Intensive Training Course on Groundwater Theory and Applications in Daejon, Korea on June 24-July 9, 2013 and the Technical Workshop in Thailand on October 6-9, 2013.

The highly urbanized areas should be considered as case study areas.

2.5.4. Groundwater Vulnerability Mapping

The Groundwater Vulnerability Mapping had be a contribution to the implementation of a provision of the clean water act stipulated in Chapter 3, Section 19-D, to wit: prepare and publish a national groundwater vulnerability map and monitoring and remediation of areas seriously affected by groundwater degradation and depletion.

2.5.5. IWAVE Project

The MGB was part of the project that was implemented with the International Atomic Energy Agency (IAEA) in cooperation with the Philippine Nuclear Research Institute (PNRI) and the NWRB. The undergoing projects being implemented include Groundwater Vulnerability Assessment and Surface Water and Water Quality Assessment.

2.5.6. Establishment of an Integrated 3D GIS-Based Water Resources Management Information System in the Provinces of Pampanga and Bulacan (KOICA)

The project had a kick-off Meeting on March 13, 2014.

3. Geological Database

The Geological Database Information System (GDIS) is responsible for the generation of geohazards and geologic maps in digital format as well as the archiving of the data related to geohazards and geologic quadrangle mapping of the LGSD. In addition, the GDIS maintains, updates and disseminates geohazards and geologic information through its database system.

3.1. Geological Maps Database

The index to the 1:50,000 geological quadrangle maps shows the distribution of the printed maps, reproducible maps and scanned/digital maps.

3.2.Geohazard Maps

The geohazard maps are more accessible to the public in an effort to further raise awareness on responding to disasters. The move is to broaden public access to the geohazard maps, which have become an important tool in disaster risk reduction and management (**Fig. 4, 5**).

3.3. Geohazards Web Portal

The interactive and downloadable geohazard maps are now available online through the Mines and Geosciences Bureau website at www.mgb.gov.ph

4. Conclusion and Recommendation

There is a need for a National Database for Groundwater Resources to be able to:

- Develop an effective planning and management tool for an informed policy and decision making strategies.
- Improve data management to ensure sustainability of data collection and processing of data and information
- Generate data for sharing of information through the use of science based models and tools
- Improved capacity in terms of water resources assessments by concerned institutions/ agencies

With the various projects and activity with regards to groundwater resources, an integrated data management system should be made operational. The use of a common database for easy sharing should be developed.

Fig. 4. Index to 1:50,000 Scale Geological Maps

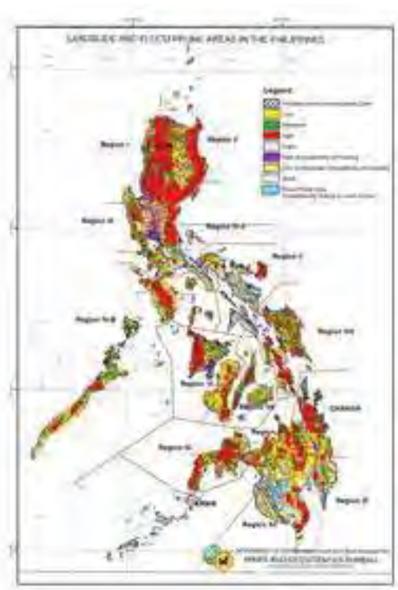


Fig. 5. Seamless Geohazards Maps Available in 1:50,000 Scale

Various stakeholders are also encouraged to visit the web portal of the MGB to be able to appreciate and understand the various hazard maps and other information/data available for the public.

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Groundwater In Papua New Guinea

Nadia Kuman

Geological Survey Division, Papua New Guinea
e-mail : nkuman@mra.gov.pg

1. Introduction

Papua New Guinea (PNG) is a Pacific Island Nation with a total land mass of 462,840km^2 and a total population of about 6million people. PNG shares it border with Australia to the south, Indonesia to the west and Solomon Island to the east.

PNG is very diverse culturally with 841 different indigenous languages with the three official languages being English, Pidgin and Motu. It is still a developing nation with about 80% of the population being uneducated with subsistence farming as the main means of survival.

2. Mineral Sector of Papua New Guinea

Since the 70's the mineral sector of PNG has provided over 65% of the country's gross national income. To date there are eight mines which are in production and several others that are in different stages of development.

Prior to 2012, the main mineral commodities were gold, silver and copper. However, towards the end of 2012 this changed to include nickel, cobalt and chromium. Exploration companies have also begun looking for coal and coal seam gas (CSG) as well as lateritic nickel, hydrothermal nickel sulphide and rare earth elements (**Table 1**).

Table 1. Summary of production of mineral commodities.

Commodity	Quantity	2007	2008	2009	2010	2011	2012
Copper (Cu)	Tonnes	169, 184	159,652	166,700	163, 717	119, 194	125, 348
Gold (Au)	Tonnes	1,710,920.39	1,982,975	1,786,327	2,095,080	1,869,181	1,771,070
Silver (Ag)	Tonnes	1,687,920.84	1,547,468	846,727	2,728,746	2,826,759	2,614,871
Nickel (Ni)	Tonnes	0	0	0	0	0	4758
Cobalt (Co)	Tonnes	0	0	0	0	0	473
Chromium (Cr)	Tonnes	0	0	0	0	0	3630

2.1. Mines in Operation

(1) Hidden Valley Mine

The Hidden Valley mine is an open cut gold and silver producing mine that is located within the Morobe Province of PNG. In 2012 it produced 4.53 tonnes of gold and 46.58 tonnes of silver. It has a ten year mine life with a potential to increase.

The mineralization is hosted within the Morobe Granodiorite of the Owen Stanley Metamorphic Complex. It is Cretaceous in age with the deposit itself being a porphyry related epithermal carbonate base-metal deposit (**Fig. 1**).

(2) Lihir Gold Mine

Lihir Gold Mine which is located in the New Ireland Province of PNG is a massive gold producing open cut mine which produced 16.92 tonnes of gold by the end of 2012. It has a 40 year life span with the potential to increase. Lihir is an epithermal high sulfidation deposit that is hosted within hydrothermal breccia of Pliocene age (**Fig. 2**).

Fig. 1. Aerial view of Hidden Valley Mine

Fig. 2. Aerial view of Lihir mine pit

(3) Ok Tedi Gold Mine

Ok Tedi which is located in the Star Mountains Region of the Western Province of PNG is one of the largest open cut gold, copper and silver producing mines in the world. By the end of 2012, it produced 11.5 tonnes of gold, 23 tonnes of silver and 125,348 tonnes of copper. It has mine life of 22 years which has now been extended to 2025, with new discoveries. It mines a hydrothermal skarn deposit which is hosted in monzonite porphyry of the Fubilan Stock. It is Miocene of age (**Fig. 3**).

(4) Porgera Gold Mine

Following Ok Tedi in size is the Porgera Gold Mine which is located in the Enga Province of PNG. It is a massive gold and silver producing mine which produced 12.48 tonnes of gold and 2.56 tonnes of silver by the end of 2012. it is both an open cut and underground mine with a mine life of 30 years and potential to increase.

The deposit is hosted within the Porgera Intrusive Complex of a calcareous shale formation of Miocene age. The deposit itself is an intrusive related epithermal carbonate base-metal deposit (**Fig. 4**).

Fig. 3. Aerial view of Ok Tedi mine.

Fig. 4. Aerial view of Porgera mine.

(5) Ramu Nickel-Cobalt Mine

The Ramu Nickel-Cobalt mine is the first of its kind in PNG and is located on the Krumbukari Plateau in the Madang Province of PNG. It produces nickel, cobalt and chromium of which 4758 tonnes, 473 tonnes and 3630 tonnes were produced respectively by the end of 2012. The estimated resource is about 143 million tonnes at 1.01% nickel and 0.1% cobalt.

The deposit is hosted within a laterite host rock within the Papuan Ultramafic Formation of cretaceous age. It is a residual nickel-cobalt-chromium deposit.

(6) Simberi Gold Mine

The Simberi Gold mine is located on the eastern side of the Simberi Island. This Island is part of the Tabar Group of Islands within the New ireland province of PNG. Its commodities are gold and silver of which 1.61 tonnes and 0.29 tonnes were produced respectively by the end of 2012. It is an open cut mine with a 12 year mine life and potential to increase. The deposit is hosted within hydrothermal breccia of Pliocene age and is a structurally controlled low sulfidation deposit (**Fig. 5**).

Fig. 5. Aerial view of Simberi mine.

Fig. 6. Aerial view of Sinivit Gold Mine

(7) Sinivit Gold Mine

Sinivit mine is situated on the south-western part of Rabaul in the East new britain province. It is a medium scaled gold and silver producing mine. By the end of 2012 it had produced 0.06tonnes of gold and 0.04 tonnes of silver. It is an open cut mine with a 28 year life span and potential to increase this.

The deposit like Lihir and is also hosted in hydrothermal bresccia of Pliocene age. The deposit itself is a epithermal carbonate base-metal deposit with an oxide gold cap (**Fig. 6**).

(8) Tolokuma Gold Mine

Tolokuma mine is located within the Goilala District of the Central Province of PNG and is a large gold and silver producing mine. By the end of 2012 it had produced 0.61 tonnes of gold and 1.35 tonnes of silver. It is and underground mine with a life span of 18 years with the potential to increase mine life.

The deposit is hosted within andesite volcanics of the Kagi metamorphics of Middle Miocene age. The deposit itself is generally a low sulfidation epithermal gold deposit.

3. Upcoming Prospects

Currently in Papua New Guinea, there are about 92 prospects in the country. This number includes major and minor prospects both active and inactive as well as abandoned prospects. For this report, a brief description of only the active prospects in advanced stages will be given.

(1) Amazon Bay Iron Sands Prospect

The Amazon Bay Iron Sands project is a massive project that is now in its feasibility stages and hopes to go into production by 2016. With reserves estimated at 445 million tonnes, and a life span of about 200 years it has the potential to become a world class operation. The ore will be extracted from mechanical beach deposits spanning 75 kilometers along the southern coastline of PNG. Once into production it will export vanadium rich magnetite concentrate to an expanding Chinese market.

(2) Bulolo Gravel Project

This project is located in the Bulolo region of the Morobe Province and aims to produce gold on a large scale along with silver on a smaller scale. The minerals are hosted in conglomerates of the Otibanda Formation of Pliocene age with the deposit itself being an intrusion related gold deposit.

(3) Frieda River Prospect

The Frieda River Prospect which is now in its prefeasibility stages will be one of the world largest gold and copper producing mines. From the three different deposits within the same area, reserves have been calculated as;

- Nena deposit - copper resource (51Mt @ 2.43% Cu, 0.57 g/t Au), and gold resource (18mt @ 1.4 g/t Au, 0.1% Cu);
- Horse Ivaal / Trukai deposit (2,090 Mt @ 0.5% Cu, 0.3 g/t Au); and Koki deposit (620 Mt @ 0.37% Cu, 0.25 g/t Au) ;

It is a planned open cut mine that will mine a high sulfidation porphyry copper gold system that is hosted in diorite porphyry rock of the Frieda Complex. The complex had been dated to be of Pliocene in age. Production is expected to begin in 2017.

(4) Frieda River Nickel Laterite

This is an active project which is run by Redstone Metals Ltd. It is a medium sized project with the size defined at 25000-500,000. The deposit is hosted in laterites of the April Ophiolite AFormation of Cretaceous age. It is a residual nickel-cobald deposit.

(5) Gameta Prospect

This is a medium sized gold project located on the northern coast of Fergusson Island in The Miline Bay Province that is currently in advanced stages of development. The Cretaceous ore is hosted in peridotite of a metamorphic core complex. It is a carbonate base metal gold mineralization and low sulfidation epithermal mineralization deposit. The prefeasibility study has been completed and will soon commence bankable feasibility study.

(6) Kereminge

Kereminge is a medium sized gold project containing about 5-50 tonnes of gold. Located 9kmsouth of Wau in the Morobe Province, the deposit is hosted within dacite porphyry of the Owen Stanley Metamorphic Formation. It is an epithermal carbonate base-metal deposit.

4. Groundwater

4.1. Groundwater Distribution in Relation to Geography and Climate

The geography of Papua New Guinea consists of the eastern side of the island of New Guinea

Fig. 7. General geography of Papua New Guinea

together with the islands of New Ireland, New Britain, Manus, Bougainville and the D'Entrecasteaux Islands. The main land has a distinct central mountain range which is called the Owen Stanley range that runs through the center of the country with relatively flat plains on either side of it. The mountains are covered with vast rainforests while the plains consist mostly of savannah grasslands and of swamp vegetation. There are many rivers that flow through the lands with the Sepik river to the north and the Fly River to the south being the two largest (**Fig. 7**).

The distribution of the vegetation is also an indication of the rainfall distribution across the country. The climate is generally tropical with northwestern monsoon winds from December through to April and southeastern monsoon from May through to October. These winds dictate the rainfall distribution. However, the southern part of the country which is just off the northern tip of Australia receives the least amount of rainfall year round resulting in a semi-arid climate with savannah vegetation. The rainfall distribution is shown in the map below while the map after that shows the distribution of vegetation (**Fig. 8, 9**).

Having stated all this and from looking at the maps, it can be seen that groundwater is mostly utilized in the areas to the north and south of the central mountain range as well as on the smaller islands and coral atolls. The towns which use groundwater for their water supply systems are Kiunga, Daru, Alotau, Kerema, Lae and Namatanai. These are places where bore holes have been constructed, the water is then pumped to treatment facilities and later distributed for consumption. Apart From this there are many villages along the coastline and on the islands that obtain water from hand dug wells for household consumption. Most other areas which are mostly situated in higher altitudes use surface waters.

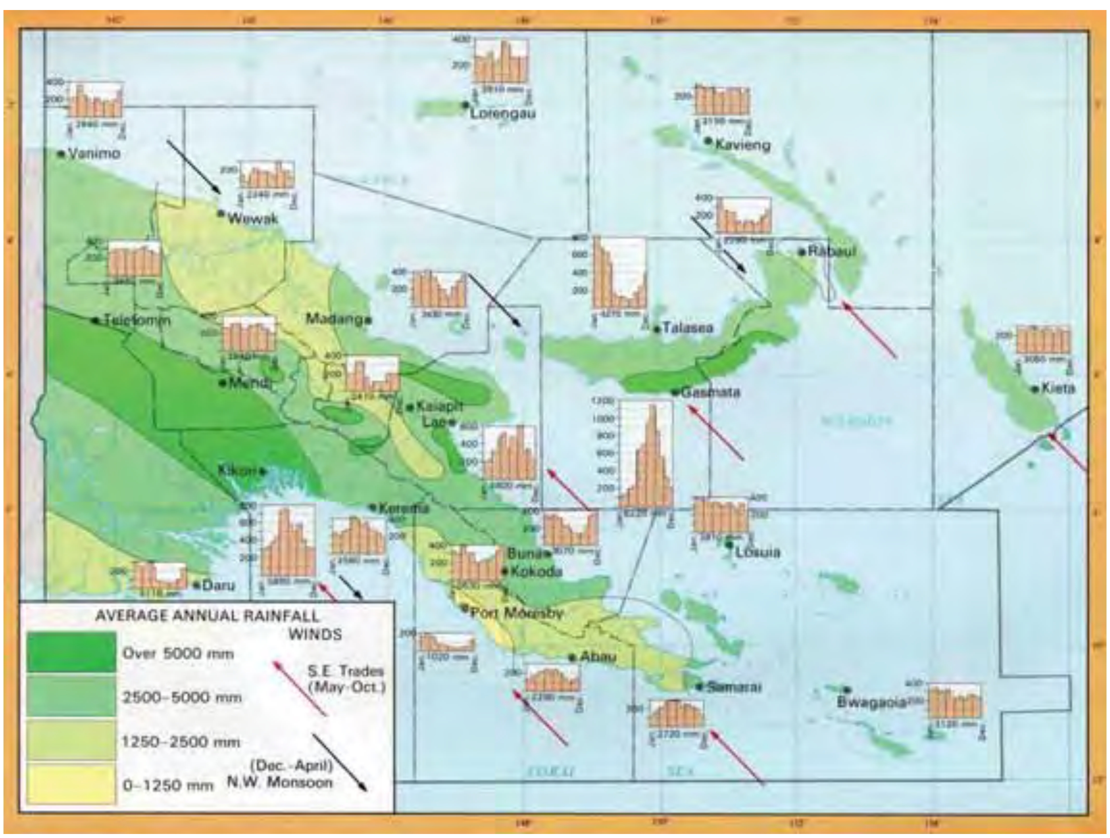

Fig. 8. Rainfall data of Papua New Guinea.

4.2. Groundwater Data in Papua New Guinea

Though there are many places in Papua New Guinea that rely on groundwater, there is not much information regarding the topic. The main reason for this being the lack of funding.

When the former Department of Mines was converted to the now Mineral Resources Authority, everything had to be moved to the new office (MRA) which we are now located in. During that shift, the old Hydrogeology database that had been created was misplaced. As a result of this we are now attempting to create a database using what little information we have available and from that we hope to produce a Regional Groundwater Resource Map of the country. The information is being gathered from old reports from borehole construction and borehole rehabilitation. This consists mostly of pumping test results, standing water levels, recharge rates and others collected from borehole log sheets.

A sample of the borehole information for the Madang Province has been indicated in **Fig. 10**. This is an example of the type of information which we will be able to extract from the old reports. As you will see, there is not much information given on the water quality. This information is scarce because in most cases, funding would have been inadequate to pay for water samples to be fully analysed.

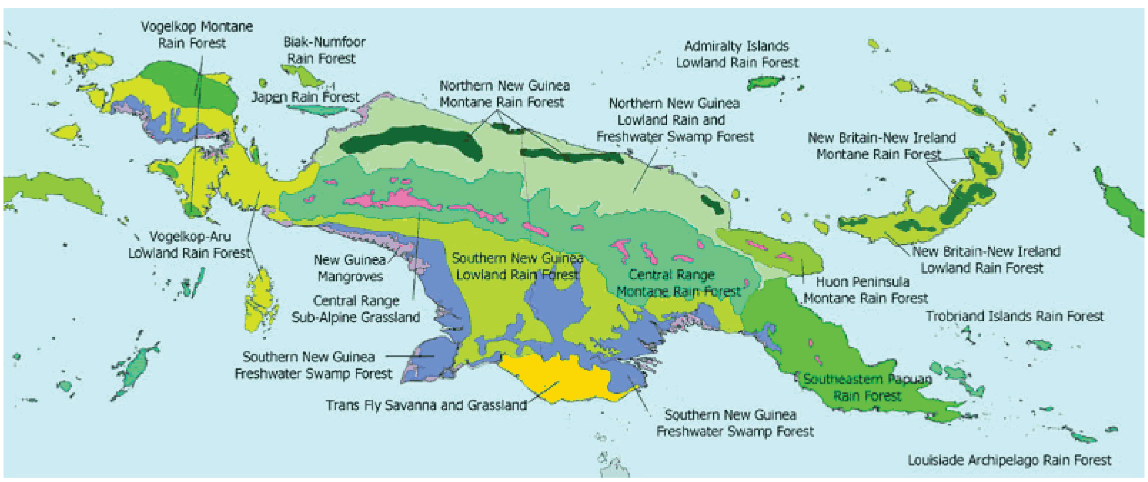

Fig. 9. Vegetation distribution across New Guinea.

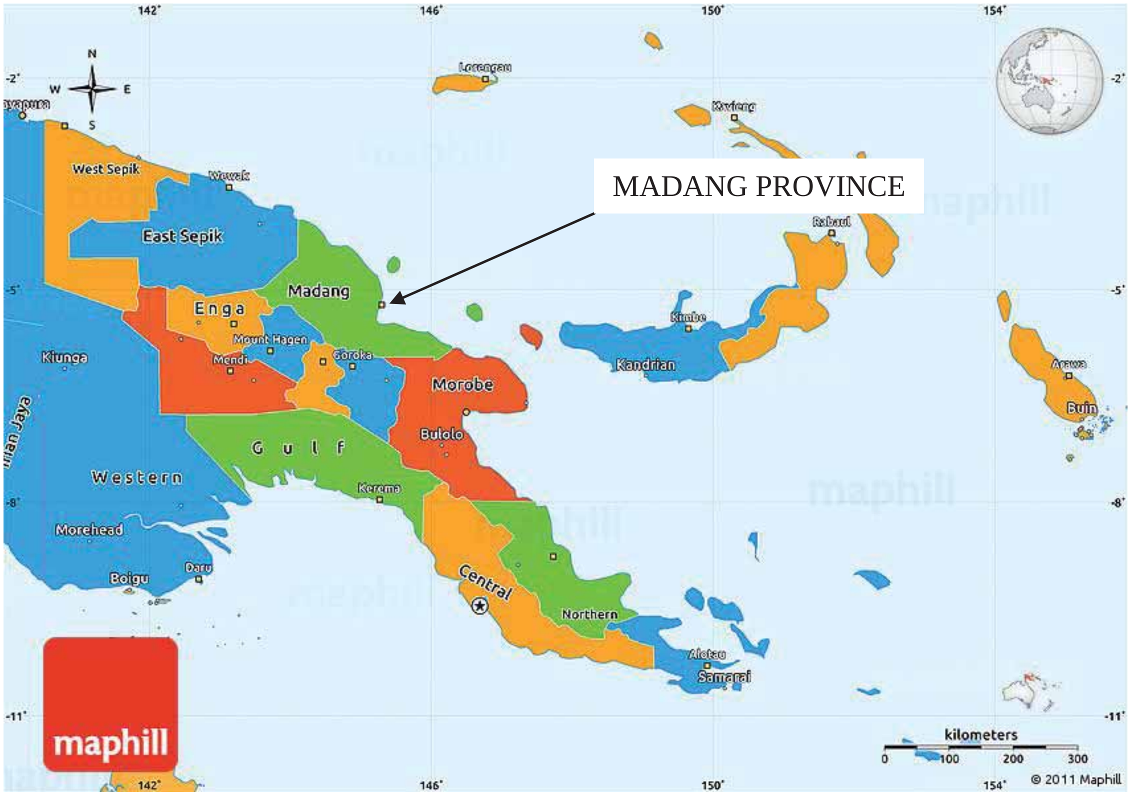

Fig. 10. Madang province: summary of borehole information map showing location of Madang province

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Groundwater Exploration and Detailed 1:50,000 Mapping, Upper Chao Phraya Basin

Aranya Fuangswasdi and Phuangchat Chantawongso

Department of Groundwater Resources, Ministry of Natural Resources and Environment, Thailand

Abstract

Demand for groundwater and its development has been dramatically increased to serve the need of water supply as a consequence of rapid growth of population and economic expansion. The responsibility in finding and supplying groundwater lies with various government agencies, private entities and local administration bodies. Under the decentralized administration policy, the local administration bodies are directly responsible for providing water sources for community consumption. To effectively manage this valuable resource, a set of accurate and most-updated basic groundwater technical data, shall be available for detailed project planning for optimal and sustainable development.

The Royal Decree B.E. 2545 was promulgated with authority given to the local administration bodies to procure and dispend water resources for population consumption within their administrative boundary. Groundwater Resources Department is the role governmental agency dealing with groundwater resources, including effective management, prepare and provide accurate and most updated groundwater sources, as part of the basic information for infrastructure development. To ensure successful handover and cooperation, a complete database of nationwide groundwater sources and maps must be developed. The first step was to generate the regional groundwater maps, 1:500,000 scale, in conjunction with the production of 1:1,000,000 of Groundwater Resources Map of Thailand. The project was completed in 1978. The 1:100,000 groundwater resources provincial maps project was in the second phase, completed during 1989-2001. These sets of map provide both quantitative and qualitative groundwater potential which could be instantaneously used for drilling water wells. Nevertheless, these maps were not for groundwater resources and water works system development, partly due to its large scale which could not contain accuracy and precision to a very detailed level. The two pilot projects were initiated to generate the groundwater resources map of 1:50,000 scale, one for Nan Province in2008 and another for Upper Chao Phraya Basin in 2010-2011.

The important outcome of the detailed groundwater mapping of the Upper Chao Phraya Basin in 1:50,000 scale, provides sufficient details for the classification of hydrogeologic units, both in unconsolidated and consolidated aquifers. For the unconsolidated aquifers, the Chiang Rai aquifer unit (Qcr), mapped as a single unit under the previous provincial groundwater map, was remapped with two distinctive hydrostratigraphic sequences namely Quaternary alluvial fan deposit aquifers (Qaf) and the underlying Quaternary younger terrace deposit aquifers (Qyt). The Qaf unit contains 2 aquifers, the younger Qaf1 and the older Qaf2. Likewise for the Qyt; the overlying younger Qyt1 is underlain by the older Qyt2. Similarly, the older aquifer system known as Chiang Mai aquifers (Qcm) was remapped and renamed as Quaternary older terrace deposit aquifers (Qot) which comprises of 3 hydrostratigraphic sequences; overlying Quaternary older terrace deposit aquifers Qot1, the middle unit Qot2, and the underlying Qot3. Additional hydrogeological details of this latest effort, including groundwater usage and need, details of aquifers and their hydraulic properties, flow system, aerial extent of the recharge and discharge areas, have become much more valuable for sustainable development of groundwater resources, quantitatively and qualitatively.

1. Overview

1.1. Background

Department of Groundwater Resources (DGR) is the only core agency whose mission is to provide a unified groundwater resources management at maximum efficiency. The duties and responsibilities included the preparation, compilation, and update groundwater information to ensure that both Hydrogeological and Groundwater maps are accurate and current at all times. All this information is to be used, by private and government organizations as well as the general public, as the basic for the development of groundwater for consumption, agricultural, and industrial.

DGR as a core agency responsible for preparing such information needs to create a groundwater resources database and groundwater maps for each groundwater basin throughout the country. The studies should explore groundwater potential for each groundwater basin both in quantity and quality. This is because the original groundwater resources database used in provincial groundwater maps scale 1:100,000 does not have enough detailed information. Recently, the groundwater information has increased substantially. Due to academic studies and researches, as well as the drilling and construction of new groundwater wells by DGR, local administrations, and other agencies. Thus, DGR has established the Project to Study, Exploration, and preparation of Groundwater Maps Detailed scale of 1:50,000 for all 27 groundwater basins across the country. The Upper Chao Phraya basin has been selected as a pilot project. Because the area has many problems and obstacles in groundwater resources development, such as neglected groundwater yield, some areas cover with a thick clay layer which results in higher investment for well construction, some areas have water quality problems such as saline or brackish water, iron, fluoride, chloride that exceeded the “World Health Organization Drinking Water Standards”. In addition, the demand for groundwater is increasing rapidly due to the expansion of the community, either for domestic, agricultural, or industrial uses. These made both public and private sector organizations, that responsible for providing water, have to meet with increasing water demand, and turn to groundwater as solution. But many agencies which responsible for supplying water to the consumer, especially local administrations, still lack of the knowledge and information to make decisions on groundwater wells to meet with new water demand in a timely manner. If the Groundwater Maps detail scale at 1:50,000 are completed DGR can help solving quoted problems by distribute them, along with guide book and training on how to use the new groundwater map, for the merit of private and government organizations, local administrations, and general public.

1.2. Objective

The main objective of the Project of Groundwater and Hydrogeological Detail Mapping scale 1:50,000 of Upper Chao Phraya Basin that summarized as follows.

1) To identify potential sources of groundwater both quality and quantity for preparation of Hydrogeological and Groundwater maps detailed scale 1:50,000 covering the Upper Chao Phraya Basin.
2) To optimize the groundwater management by using the Hydrogeological and Groundwater maps detailed scale 1:50,000 to tackle with the problems, and to save the budget for groundwater development.
3) To prepare the groundwater data for GIS database of DGR.
4) To publicity, distribute, and conduct training workshops for practical using of Groundwater Maps to all local administrations in the country.

1.3. Goal

This project has the following goals.

To have Hydrogeological Maps that complied with IAH (International Association of Hydrogeologists) standard, and Groundwater Maps detail scale 1:50,000 that are useful for management, and development of groundwater resources in efficient and sustainable ways. The area cover Upper Chao Phraya Groundwater Basin which consists of nine provinces include Uttaradit, Sukhothai, Lampang, Phetchabun, Phitsanulok, Phichit, Nakhon Sawan, Tak and Kamphaeng Phet.

1.4. Area

Project's areas for this contract is Area, consist of three provinces, covering 53,196.14 square kilometers (**Fig. 1)**, includes 77 sheets of topographical maps scale 1:50,000 from the Royal Thai Survey Department.

1.5. Scope of works

According to the contract details for Project of Groundwater and Hydrogeological Details Mapping Scale 1:50,000 of Upper Chao Phraya Basin. Activities to be carried out are as follows.

1) Study and collection of secondary data.
2) Study of groundwater usage and demand.
3) Field works exploration to verify Hydrogeological data.
4) Analyze interpret and process the data acquired.
5) Preparation of Hydrogeology GIS layers.
6) Preparation of Hydrogeology and Groundwater maps detail scale at 1:50,000.
7) Preparation of Hydrogeological Geographic Information System (HYGIS).
8) Generate the reports.
9) Conduct the conferences, seminars and training for those involved.
10) Publicity and distribution of Projects result

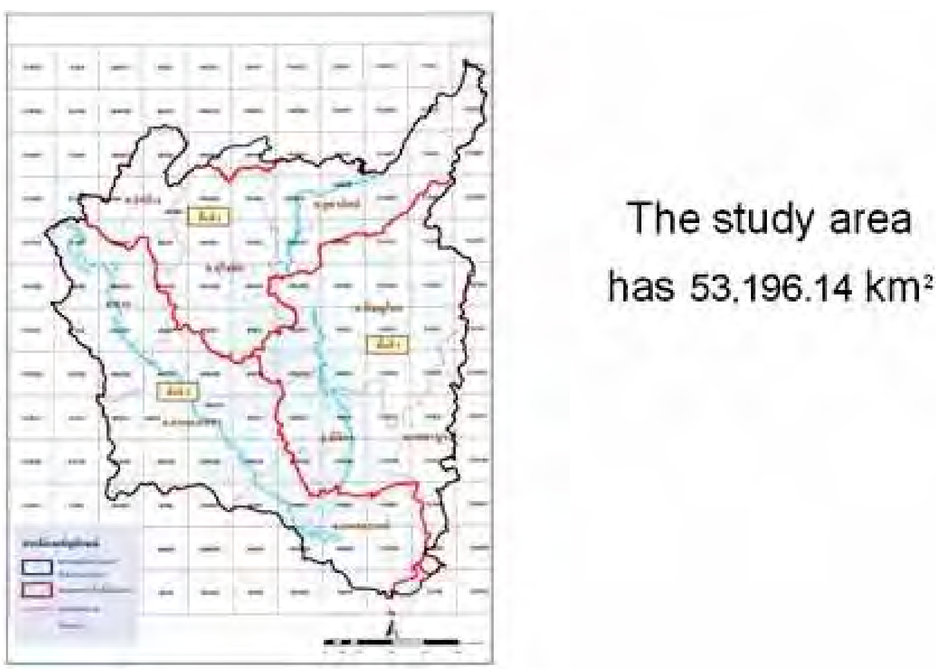


Fig. 1.

1.6. Excepted Benefits

Benefits derived from the project operation will consist of academic and data interest as show below.

1.6.1. The academic benefits

The Decentralization Act of 2002 requires that the local administrations are responsible for providing and developing water sources for public consumption. Hence, they will have Groundwater Maps which show details of groundwater sources up to the village level. Local leaders will have guide book for Groundwater Maps which enable them to create plan and construct groundwater wells more efficiently according to the groundwater potential in their area. Further, farmers in the area can utilized the shallow groundwater to support their farm either within or outside of the irrigation area. These will increase farmers' income, resulting in a more stable economy and stimulate the gross national product (GDP).

DGR will has new Hydrogeological and Groundwater Maps detail scale of 1:50,000, Hydrogeological Geographic Information System, or HYGIS of the Upper Chao Phraya Basin. This is the first groundwater basin out of 27 basins around the country, which have been study and exploration for preparation the 1:50,000 scale maps, plus gathering information for database system. All these are essential tools to enable DGR to manage groundwater resources in the Upper Chao Phraya Basin with efficiency.

1.6.2. The database benefits

- Groundwater Maps detailed scale 1:50,000 for Upper Chao Phraya Basin will be available and publish in sheets according to the Royal Thai Survey Department.
- Hydrogeology detailed scale 1:50,000 for Upper Chao Phraya Basin will be available and publish in sheets according to the Royal Thai Survey Department.
- Hydrogeological Geographic Information System, HYGIS will be up date for the Upper Chao Phraya Basin.

2. Upper Chao Phraya Groundwater Basin

2.1. Geography

The Upper Chao Phraya Groundwater is located on the Lower Northern part of Thailand. The terrain is mostly river plains, flood plains, staircase plain, and plains alternating with corrugated hills that caused by the action of major rivers in the North, Ping, Wang, Yom, and Nan rivers. These rivers have brought sand, gravel, and rock fragments deposits accrued for several million years and made the area as most important crop growing plains of the North.

2.2. Meteorology and Hydrology

2.2.1. Climate

The climate of the North and the Upper Chao Phraya Groundwater Basin are under the influence of the Southwest and the Northeast monsoon. As a result, three seasons existing here.

Summer is around mid-February to mid-May. Total time about 3 months, due to weaking Northeast monsoon in February. The East, and Southeast wind increasing their power. Summer storms in the North will happen from time to time during March to April. In general, temperatures is higher and the weather is warm.

The rainy season is around mid-May to mid-October. The rain caused by Southwest monsoon winds from the Bay of Bengal hit the mountains in the north. Another part has been influenced by the clash between the two air currents, the South wind of the Southwest monsoon and North winds of the Northeast monsoon. This causing rain in June and September.

Winter is around mid-October until about February. Because, the Northeast wind blows pass through the high pressure area of Central Asia in China. This made the North colder that other part of Thailand.

The weather data from weather stations of the Meteorological Department in the project area can be summarized in average annual values as follows (**Table 1**).

2.2.2. Amount of Rain and Volume of Runoff

Amount of rainfall in the North is varying a lot in each area. With an average annual rainfall in the range of 800 – 2,400 mm per year. Specially, in the Upper Chao Phraya Groundwater Basin the annual rainfall is between 900 to 1,700 mm, and rainfall usually occur in May to October.

The amount of watershed runoff from Ping Wang, Yom and Nan rivers, which flow together into the Chao Phraya River Basin, on the average volume of 26,790.79 million cubic meters per year (**Table 2**).

2.3. Soils and Landuse

Land use in the Upper Chao Phraya Groundwater Basin area can be classified into five categories according to the Land Development Department as follows.

- Forest Area is 39.98 percent of the Upper Chao Phraya Groundwater Basin. Most are located in the upper rim of the basin. This is mostly a hilly area with steep hills, non deciduous forest, deciduous forest, and cultivated forest.
- Farmland Area is 50.74 percent of the Upper Chao Phraya Groundwater Basin. Most are located in the middle and lower part of the basin. The area is mostly rice field, followed by fruit orchards and perennial crops including corn, sugarcane, cassava, citrus fruits, and Lychee etc.
- Residential Areas is 4.18 percent of the Upper Chao Phraya Groundwater Basin. The majority of the population lives in dense areas within the city, or district in the municipality, and some will be distributed in agricultural areas.

Table 1.

Climate Variables	**Average Annual Values**	
Average Annual Temperature	26.2	degrees Celsius
Average Annual Humidity	74.6	Percent
Average Annual Wind Speed	1.4	Nut.
Average Annual Cloud Covered	5.4	Units (0-10)
Average Annual Amount of Evaporation	1,551.2	Mm.

- Water Resources, the area is 1.74 percent of the Upper Chao Phraya Groundwater Basin. The water resources are both natural and man-made ones, such as rivers, lakes, reservoirs and irrigation canals, etc. The important rivers, Nam Yom and Nam Nan rivers, flowing in the middle of the basin. This is why the Upper Chao Phraya Groundwater Basin is mostly farmland.
- Other Areas is 3.36 percent of the Upper Chao Phraya Groundwater Basin. Land use cannot be classified in group. As most of them are wilderness areas, areas of marsh and meadows, grave yard, rocky outcrops, and gravel pit, etc.

Land Development Department has identified the suitability of the soil for land development in the Upper Chao Phraya Groundwater Basin, detailed as follows.

- Class 1: Suitable Soils. The soil is well to medium suited. There are limitations that affect the growth of plants at rare to medium (The area is approximately 60.50% of the Upper Chao Phraya Groundwater Basin), and divided into three sub class.
  - Soil suitable for rice.
  - Soil suitable for seasoning crops.
  - Soil suitable for fruit orchards.
- Class 2: Less Suitable or Unsuitable Soils. The soil has severe limitations such that plant growing is difficult (Around 0.10% of the Upper Chao Phraya Groundwater Basin), such as the sandy soil, very thin soil, high density of rock fragments. This soil type should be used for reforestation, faster growing plants, or perennial trees.
- Class 3: Unsuitable Soils. The soil has very severe limitations for cultivated crops (About 39.39% of the Upper Chao Phraya Groundwater Basin), such areas are steep terrain with very high slope causing a severe washed down of topsoil. These areas should be maintained as an upstream forest, or economic forest.

- **Table 2.** Amount of Watershed Runoff for each River Basin

Item	**Basin**	**Rainy Area (sq.km.)**	**Average Run Off Per Year (Million cubic meters)**			**Annual Run Off Average per unit area (l/sec/sq.km.)**
			Rainy Season	**Dry Season**	**Annual**	
1	Ping	34,856	6,873.31	2,170.46	9,043.77	8.23
2	Wang	10,791	1,310.71	271.53	1,582.24	4.65
3	Yom	23,616	3,461.11	504.05	3,965.16	5.32
4	Nan	34,140	9,368.40	2,831.23	12,199.63	11.33
Total		**103,403.00**	**21,013.53**	**5,777.27**	**26,790.80**	**29.53**

- Note: 1) The study of Meteorology and Hydrology in the project area dividing the Basin according to the Committee of the National Hydrology.
- 2) Report from The project of master plans preparation for water resources development and irrigation projects improvement for the Plan 9 (RID, 2003).

Soil permeability is divided into five levels

- Good permeability. The permeable rate is 18.750 cm / hr covered about 30.41% of the Basin area.
- Relatively good permeability. The water is 9.375 cm / hr covered about 31.02% of the Basin area.
- Moderate permeability. The water is 4.125 cm / hr covered about 3.35% of the Basin area.
- Relatively slow permeability. The water is 1.250 cm / hr covered about 27.12% of the Basin area.
- Slow permeability. The water is 0.313 cm / hr covered about 8.10% of the Basin area.

2.4. Geology and geologic Structure

Geologically, the central plains or Upper Chao Phraya Groundwater Basin is the vast sedimentation basins, consisting of the alluvial plains of Ping, Wang, Yom and Nan. This is the result from movement of large fault during Tertiary period. The fault systems including the Mae Ping, the Nam Pad, and the Jedi Sam Ong fault. These create Normal fault in North-South arrays arising from the release of the continent after the collision of India tectonic plates which causing the expansion of the fault systems. These expansions turn the area to be vast sedimentation basin and pull-apart basin from the open access to the Gulf of Thailand. Thus, create the Tertiary vast sedimentation basin of the North.

Upper Chao Phraya Groundwater Basinis a large sedimentation area.

Particularly, the alluvial plains of Phitsanulok – Phichit, which has accumulated the unconsolidated sediment since Tertiary period. this sedimentary basin is a large groundwater storage. Hydrogeology has classify unconsolidated sediment into 7 different types as, Floodplain deposits Aquifers, Coluvial Deposits Aquifer, Younger alluvial fan aquifer (Qaf1), Older alluvial fan aquifer (Qaf2), Younger Terrace Deposits Aquifer, Old Terrace Deposits Aquifer, and Sedimentary Aquifers. The East and Northeast rim of Upper Chao Phraya Groundwater Basin, which is the boundaries between Phitsanulok and Phetchabun provinces, most of consolidated rocks in this area is Korat group, except the Southeast of Phitsanulok in Nern Maprang district, Saraburi group can be patchy seen. The Northeast of Phitsanulok, rock from Cretaceous – Tertiary period covered wide area of Nakhonthai and Chatrakan districts.

Important Geological structures in the area are the 3 fault systems as described following.

- The Nam Pad Fault systems is a NE-SW fault which begin from Dien Beien Phu Fault Zone in Vietnam passes through Chaiburi Laos to Thailand follow the Nam Pad river, and Upper Chao Phraya Groundwater Basin most of them fall in Korat group.
- The Mae Ping Fault systems is a NW-SE fault, begin from Sagaing Fault in Shan State of Myanmar cut through to Thailand along Mei River and enter to Upper Chao Phraya Groundwater Basin.
- The Phetchabun Fault systems is a NS fault begin as continuous line from Nam Pad Fault in Pak lai, Llaos. Then cross to Thailand along the Pa Sak River in Phetchabun Basin and cross with Mae Ping Fault in Souhtern area of Nakhon Sawan.

2.5. Hydrogeological Rock Units

As the Upper Chao Phraya Groundwater Basin is a large sedimentation basin. Most of the deep well there, getting groundwater from unconsolidated rock. Hydrogeology has classify unconsolidated sediment into 7 different types as, Floodplain deposits Aquifers, Coluvial Deposits Aquifer, Younger alluvial fan aquifer (Qaf1), Older alluvial fan aquifer (Qaf2), Younger Terrace Deposits Aquifer, Old Terrace Deposits Aquifer, and Sedimentary Aquifers. Such aquifers may be divided into shallow aquifer which the groundwater wells (not exceed 30 m). tend to get groundwater from the alluvial fan aquifer, and the flood plain deposit, while the deep well tend to get groundwater from Old Terrace Deposits Aquifer. The Coluvial Deposits Aquifer, Younger Terrace Deposits Aquifer, and Sedimentary Aquifers tend to give very little groundwater yield.

For consolidated rock aquifers, they often give low groundwater yield, except the area with Limestone or Carbonate rocks which give high groundwater yield from large cavity in Limestone. Groundwater in other rock type, only accumulate along the continuous crack or large Fault zone.

2.5.1. Hydrogeological

Upper Chao Phraya Groundwater Basin in area 2 consisting of both unconsolidated and consolidated rock aquifers as follows.

Aquifers in unconsolidated rock is divided into 5 types as

1) Floodplain deposits Aquifers consist of alternating layers of gravel sand sediment and clay, which placed parallel to the Yom River, Nan River Ping River and the Phichit River. The average sedimentary thickness is around 30-100 m. The aquifer depth is around 20-80 meters, and the groundwater yield in the rank of 10 to more than 20 cubic meters per hour with good water quality.
2) Coluvial Deposits Aquifer composed of gravel sand sediment, and clay, the depth of aquifer in the range of 10 to 40 meters. This is found in the area of Muang district of Tak province; Banphot Phisai, Muang, Chum Saeng, Khao Liao, Tha Tako, Nong Bua, and Phaisali district of Nakhon Sawan. In general, the groundwater yield is less than 5 cubic meters per hour, but in some areas yield may be more than 10 cubic meters per hour. The water quality is good to brackish.
3) Younger Terrace Deposits Aquifer composed of sedimentary clay, silt, sand and gravel deposits in the Western plain of Phitsanulok province, in Bang Rakam, and part of Maung, Phrompiram district, Phitsanulok. The area is parallel with the Yom River from Satchanalai district, Sukhothai, down to Phichit and Kamphaengphet. The depth of aquifer is in the range of 30-80 meters, groundwater yield is 5-15 cubic meters per hour, the water quality is good.
4) Alluvial fan aquifer is the older aquifer next to the Floodplain deposits Aquifer, and underlying the Floodplain deposits Aquifers. They have thick clay layer as foundation, and disperse itself cover the plains on both side of Ping River. The Alluvial fan aquifers can be divide in to 2 sub aquifers, namely, Younger alluvial fan aquifer; Qaf1 and Older alluvial fan aquifer; Qaf2. These can be describe as follow.
5) Older alluvial fan aquifer is aged in mid Pleistocene period, consist of. coarse sand and gravel sediments. The sediment grain size is from coarse sand to over 20 mm. The coverage extends from the lower West of Muang Khumphaengphet district, toWest side Plain of Ping River, in Maung Khumphaengphet, Klong Khlung, Pangsila Thong, Khanu Woralaksaburi districts, Kamphaengphet province. This aquifer

continued into the Western area of Nakhon Sawan in Lat Yao district. The aquifer depth is about 10-45 meters from the surface.

Fan aquifer: Qaf1 is aged between mid to end of Pleistocene period, consist of. coarse sand and gravel sediments. The sediment grain size is from coarse sand to over 20 mm. The coverage extends from West of Phran Kratai and Muang Kamphaengphet districts until Eastern rim of the project area in Phran Kratai, Muang Kamphaengphet, Larn Krabuo, Sai Ngam, Klong Khlung, Sai Thong Wattana, and Bung Samakee districts of Kamphaengphet. This aquifer continued into upper part of Nakhon Sawan in Bunpot Phisai district. The aquifer depth is in the range of about 5-35 meters from the surface.

Both aquifers are very similar in hydrogeology term. The different are only the age and origin of the sedimentation. They are also represents as a significant sources for groundwater in the project area.

Old Terrace Deposits Aquifer consist of gravely sand, clay and silt sediment. Aquifers depth in the range of 40-80 meters, and groundwater yield is 5-15 cubic meters per hour, water quality is good. This aquifer type is found on Western hill area from Sri Satchanalai, down to Sawankhalok ,Thung Saliam and Ban Dan Lan Hoi districts of Sukhothai, Klong Khlung Phran Kratai. Khanu Woralaksaburi, and Muang Kamphaengphet districts of Kamphaeng Phet province.

2.5.2. Aquifers in consolidated rock

Sedimentary Aquifers can be separated into 8 aquifers type as

1) Phu Thok Aquifers: KTpt. compose of, sandstone, reddish brown to purplish brown, alternate with siltstone and sandstone, show large cross-bedding, with aquifer depth around 20-50 meter. The groundwater yield is less than 2 cubic meters per hour, water quality is good, found in Chat Trakan, and Nakhon Thai districts Phitsanulok Province.
2) Upper Khorat Aquifers: Kuk. compose of, sandstone color brown, reddish brown, dark red, gray have the mica mixes with shale, and siltstone, conglomerate with calcium grain. The depth of aquifer is around 20-50 meter, water quantity is less than 2 the cubic meter per hour, water quality is good, found in Nampad district, Uttaradit; and Nakhon Thai district, Phitsanulok Province.
3) Middle Khorat Aquifers: Jmk, compose of, sandstone , and round conglomerate color is yellowish gray to grayish pink, Phu Phan Formation, shale and siltstone color reddish brown, Sao Khua Formation, and sandstone color reddish gray to white, Phra Wihan Formation, found from Ban Khok district, Uttaradit Province, pass through Chat Trakan, Watbot, Wangtong, Nurn Maprang districts, Phitsanulok Province, and ended in Khao Kho district, Phetchabun Province. The aquifer depth is between 30-120 meter, water quantity is less than 2 cubic meters per hour, water quality is good except high iron content in some area.
4) Lower Khorat Aquifers: TR-Jlk. compose of, sandstone, siltstone, shale and conglomerate, water quantity is between 2-10 cubic meters per hour, water quality is good, found at Khao Kho , Mueang Phetchabun, Wang Pong , Chon Daen, and Bueng Sam Phan districts, Phetchabun Province.
5) Lampang Aquifers: TRlp. compose of, alternate sandstone, siltstone and shale, water quantity is less than 2 cubic meters per hour, water quality is good, found at Nam Pat district, Uttaradit Province, Si Satchanalai and Thung Saliam districts, Sukhothai Province.

6) Triassic Limestone Aquifers: TRls. compose of, limestone, water quantity is less than 2 cubic meters per hour, water quality is good, found at Nam Pad, Tha Pla districts, Uttaradit Province, and Si Satchanalai district, Sukhothai Province.
7) Permian Permo-Carboniferous Carbonate aquifers: PCcn. compose of, gray limestone, black chert, gray shale, white gray sandstone and conglomerate, water quantity that is less than 2 cubic meters per hour water quality is good, found split patchy at Wang Pong, Chon Daen districts, Phetchabun Province, Phayuha Khiri, and Tak Fa districts, Nakhon Sawan Province.
8) Ordovician Limestone Aquifers: Ols. This is limestone show thickness character found at Pong Nam Ron village, Khlong Lan district, Kamphaeng Phet Province, water quantity is between 3-5 cubic meters per hour, the depth of aquifer is around 30-40 meter, water quality is good but with high hardness, found at Mae Phrik district, Lampang Province, Sam Ngao, Wang Chao districts, Tak Province and Khlong Lan district, Kamphaeng Phet Province.

Metasediment Aquifers. can classified aquifers 2 unit e.g.

1) Permo-Carboniferous Meta-sedimentary Aquifers: PCms. compose of, half sandstone to quartzite, half slate to shale and conglomerate, the depth of aquifer around 10-60 meter, water quantity is between 2-10 cubic meters per hour, found at Tap Khlo district, Phichit Province, Chon Daen, Wang Pong district, Phetchabun Province, Tha Pla, Mueang Uttaradit, Laplae districts, Uttaradit Province, Si Satchanalai district, Sukhothai Province and Thoen district, Lampang Province.
2) Carboniferous Meta-sedimentary Aquifers: Cms. compose of, fine-grain sandstone alternate with shale and conglomerate, water quantity is between 2-5 cubic meters per hour, found at Thung Saliam, Si Satchanalai, Khiri Mat and Mueang Sukhothai districts, Sukhothai Province.

Metamorphic Aquifers can further classified to 4 aquifers e.g.

1) Silurian-Devonian Metamorphic Aquifers: SDmm. Compose of, phylitic tuff, ryolitic tuff, and greywacke some area alternates with quartzite, water quantity is between 2-5 cubic meters per hour, water quality is good, found at Tha Pla, Mueang Uttaradit districts, Uttaradit Province, Thung Saliam, Si Satchanalai districts, Sukhothai Province, Mueang Kamphaeng Phet , Khlong Lan, Pang Sila Thong and Khanu Woralaksaburi districts, Kamphaeng Phet Province.
2) Cambrian-Devonian Metamorphic Aquifers: DEmm. compose of, quartzite, schist, phyllite and gneiss, the depth of aquifer average is between 40-70 meter, water quantity that is less than 2 cubic meters per hour, water quality is good, found at Sop Prap, Thoen and Mae Phrik districts, Lampang Province.
3) Cambrian Metamorphic Aquifers: Emm. compose of, brownish yellow quartzite show the character of thickness and arkosic sandstone, water quantity that is less than 2 cubic meters per hour, water quality is good, found at Mueang Tak, Wang Chao districts, Tak Province and Khlong Lan district, Kamphaeng Phet Province.
4) Precambrian Metamorphic Aquifers: PEmm. compose of, gneiss, biotite schist, cale silicate somewhere has a trace touches with granite, water quantity that is less than 2 cubic meters per hour, water quality is good, found at Sam Ngao, Mae Ramat, Mueang Tak districts, Tak Province, Khlong Lan and Pang Sila Thong districts, Kamphaeng Phet Province.

Igneous Aquifers can further classified to 2 aquifers e.g.

1) Volcanic Aquifer: Vc. compose of, Andesite, Ryolite and Tuff, water quantity is less than 2 cubic meters per hour, found at Thoen district, Lampang Province, Mueang Tak district, Tak Province, Khiri Mat district, Sukhothai Province, Chon Daen, Wang Pong, Bueng Sam Phan districts, Phetchabun Province, Nong Bua, Phaisali and Tha Tako districts, Nakhon Sawan Province
2) Granitic Aquifers: Gr. compose of, granite the most biotite granite and tourmaline granite, water quantity is less than 2 cubic meters per hour, found from Sam Ngao district, Tak Province, Thoen district, Lampang Province end in Pang Sila Thong district, Kamphaeng Phet Province, and found patchy in Chon Daen, Wang Pong districts, Phetchabun Province, Nong Bua, and Phaisali districts, Nakhon Sawan Province.

At the Basaltic Aquifer Bs,. the underground water was stored stay to the fracture, and soft rock, water quantity is less than 2 cubic meters per hour, found at Ko Kha district, Lampang Province.

2.6. Groundwater Potential

Upper Chao Phraya Groundwater Basin is considered as the country's second largest, groundwater basin. The largest one is the Lower Chao Phraya Groundwater Basin. Groundwater Potential in the Upper Chao Phraya Groundwater Basin, especially in the plains, total area approximately 10,000 square kilometers consists of 4 high potential groundwater aquifers. These are Flood plain deposit aquifer (depth less than 20 m), and Alluvial fan aquifers (depth from 0-20 m and in some area 20-40 m). Other 2 layers are line deeper below, Younger Terrace Deposits Aquifer and Older Terrace Deposits Aquifer. All these aquifers have groundwater yield more than 10 cubic meters per hour.

The overall potential for groundwater quality of the Upper Chao Phraya Groundwater Basin is good to excellent. However, some area may have relatively high iron content exceeds drinking water standards, and brackish water also scattering in cetral plain of the Basin. The Northeast of the Basin in Chat Trakan, and Nakhon Thai districts Phitsanulok Province, mostly in Phu Hin Rong Kla National Park is a wide area of salty water. Beside this, some of the Phaisali area of northern Nakhon Sawan province also have salty groundwater.

3. The Aquifers in the Project

The detail analysis of aquifers start from identify each aquifer and plotting them in Hydrogeological cross section map from North-South and West-East. This is to show the aquifers layer, and their horizontal expansion.

3.1. The Main Aquifers in the Project

The aquifers in Upper Chao Phraya Groundwater Basin (Area 2: Phetchabun, Phitsanulok, and Phichit provinces), specially 3 aquifers that emerged above ground, are Flood Plain Aquifer (Qfd), Younger Alluvial Fan Aquifer (Qaf1), and Younger Terrace Aquifer, Upper Part (Qyt1) The rest are aquifers that have been covered by the first three. These are Younger Terrace Aquifer, Lower Part (Qyt2), Old Terrace Aquifers (Qot), and Semi-Consolidated Aquifer (Tsc). All these aquifers are expanded in Phetchabun, Phitsanulok, and Phichit provinces.

3.2. The Thickness of Main Aquifers in the Project

The alluvial aquifers are the most important aquifers in Upper Chao Phraya Groundwater basin. Thus, the groundwater management in the basin will be better managed, if the aquifers thicknesses are known. Therefore, the Consultants have made the map shown aquifers thickness of the main aquifers.

1) Flood Plain Aquifer (Qfd) in Upper Chao Phraya Groundwater Basin (area 2) has aquifer thickness less than 20 m, except small areas in Pha MaKarb and Pak Tang sub districts of Muang Phichit district, and Pho Pratubchang sub district of Pho Pratubchang district, Phichit province and area in the South adjacent to Area 3.

2) Younger Alluvial Fan Aquifer (Qaf1) Upper Chao Phraya Groundwater Basin (area 2) has aquifer thickness between 20-40 m, except in central Basin area in Nong Kula, Pun Sao sub districts of Bang Rakum district, Phitsanulok Province; Wang Mok, Ban Na, Bung Bua sub districts of Wachirabharame district, Nuen Pao sub district of Sam Ngarm district, and Phai Laom sub district of Pho Pratubchang district, Phichit province.

3) Younger Terrace Aquifer, Upper Part (Qyt1) Upper Chao Phraya Groundwater Basin (area 2) has aquifer thickness between 40-60 m., except in central area of map sheets number 5041I, 5041III, and 5042II. These consist of Mae Raka, Nong Phra sub districts of Wang Thong district, Tha Tarn, Nong Kratum, Nakorn Phamak, Wat Ta Yom, Nuen Khum, Phai Laom, Sanarm Khle sub districts of Bang Kratum district, Phitsanulok; Phai Kwang, Tha lao, Pak Thang, Nai Muang, Tha Laung, Pha Makha, Muang Khao, Dong Khlang sub districts of Muang Phichit district, Pho Pratubchang, Wang Jik, Phai Laom, Phai Tha Pho sub districts of Pho Pratubchang district, Wang Samrong, Wang Wha, Khlong Koon, Tub Mun sub districts of Ta Pan Hin district, Bang Lai, Bung Naram, Hauy Kaew, Pho Sai Ngarm sub districts of Bung Na Ram district, Wat Kwang, Tai Nam sub districts of Pho Thalay district, Phichit province

4) Younger Terrace Aquifer, Lower Part (Qyt2) Upper Chao Phraya Groundwater Basin (area 2) has aquifer thickness between 30–60 m, except the East side of Area 2, which is the central plain, cover area of Taluk Tiam, Sri Phirom, Wang Won, Nong Khaem Prom Phiram, Tha Chang, Matum sub districts of Prom Phiram district, Phai Kor Don, Ban Krang sub districts of Muang Phitsanulok district, Keang Nang Ngarm, Chum Saeng Songkram, Kui Muang, Bang Rakum, Bung Kho, Nikom Patana, Nong Kula sub districts of Bang Rakum district, Phitsanulok province.

3.3. The Main Aquifers Characteristics

The water management of Upper Chao Phraya Groundwater Basin should be able to manage for each aquifer continuously follow aquifer identification, the analysis of aquifers expansion, and aquifers thickness. The Consultants have analyzed the coefficient of transmissibility of main alluvial aquifers and interpreted them into 3 layers of coefficient of transmissibility maps for Younger Alluvial Fan Aquifer, for Younger Terrace Aquifer, Upper Part, and for Younger Terrace Aquifer, Lower Part.

The coefficient of transmissibility for each aquifer can be summarized as follow : -

1) Younger Alluvial Fan Aquifer (Qaf1) the map shown transmissibility, (T), in 3 ranks, namely , less than 100 m^2/day, between 100 – 1,000 m^2/day, and more than 1,000 m^2/day, which will appeared scattering from the central down to the South of Area 2 and continue south to Area 3. The area cover Pho Pratub Chang, Wachirabarame, Bang Mun Nak, PhoThalay, and Dong Chareong districts, Phichit province.

2) Younger Terrace Aquifer, Upper Part (Qyt1) the map shown transmissibility, T, in 3 ranks, namely , less than 10 m^2/day, between 10 – 20 m^2/day, and more than 20 m^2/day. The area with T more than 20 m^2/day, lined along North to South between Yom and Nan Basin.

3. Younger Terrace Aquifer, Lower Part (Qyt2) the map shown transmissibility, T, in 3 ranks, namely , less than 10 m^2/day, between 10 – 20 m^2/day, and more than 20 m^2/day. The area with T more than 20 m^2/day, lined along North to South of Western rim of the Area, which is center of Upper Chao Phraya Groundwater Basin, but the Northern part still lined between Yom and Nan Basin.

The Flood Plain Aquifer which lying above Younger Alluvial Fan Aquifer, or Younger Terrace Aquifer, Upper Part is only a thin layer with thickness less than 20 m. The groundwater wells of this aquifer are usually set the perforated pipes in this aquifer and the one below. Thus, the data cannot be analyzed to show transmissibility layer in the map.

4. Groundwater Potential

The study of groundwater potential in term of quantity, quality, and dynamic of Upper Chao Phraya Basin in the area of Phetchabun, Phitsanulok and Phichit Provinces are summarized as follow : -

4.1. Groundwater quantity potential

Consultants group has classified groundwater quantity potential map of unconsolidated aquifers into 3 main aquifers. The groundwater available yield map of Younger Alluvial Fan Aquifer (Qaf1), the groundwater available yield map of the Younger Terrace Aquifer, Upper Part (Qyt1), and groundwater available yield map of the Younger Terrace Aquifer, Lower Part (Qyt2). The groundwater available yield of those aquifers can be summarized as follows:

1) **Younger Alluvial Fan Aquifer (Qaf):** Area which available yield exceed 20 m3/hr., in the Upper Chao Phraya Groundwater Basin (Area 2) located in center part of the Basin, and lying along Nan and Yom flood-plain. The area also covered, Northern part of the Basin extended to the West, from Maung district to Sam Ngam district and Vachirabarami district of Phichit province then continue to Lan Kra Bue and Sai Ngam district of Kamphaengphet province.

2) **Younger Terrace Aquifer, Upper Part (Qyt1):** Area which available yield exceed 20 m3/hr., in the Upper Chao Phraya Groundwater Basin (Area 2) also lying in center part of the Basin between Yom and Nan rivers, with Northern part extended continuously up to Sukhothai province.

3) **Younger Terrace Aquifer, Lower Part (Qyt2):** Area which available yield exceed 20 m3/hr., in the Upper Chao Phraya Groundwater Basin (Area 2) covered most part of the Basin in sedimentary area except at the Eastern peripheral of the Basin and small spot area West of Sam Ngam and Pho Pra Thab Chang district of Phichit province.

4.2. Groundwater potential in term of quality

Groundwater quality potential have been classified into 2 categories, Total Dissolve Solids (TDS) and the main dissolve solids which concludes as follow : -

1) **Younger Alluvial Fan Aquifer (Qaf)**: The area which total dissolve solids (TDS) is entirely less than 500 mg/l, except in spot area scattering at the South of Pho Ta le ,Ta

Phan Hin, Thab Klho ,Bang Mun Nag, and Dong Cha Roen districts of Phichit province, showing TDS between 500-1,500 mg/l.

2) **Younger Terrace Aquifer, Upper Part (Qyt1)**: The area which total dissolve solids (TDS) is entirely less than 500 mg/l, except the area South of Muang, Bang Mun Nag, Thab Kho, and Dong Cha Roen districts of Pichit province and some area scattering in central of basin which shows TDS between 500-1,500 mg/l.

3) **Younger Terrace Aquifer, Lower Part (Qyt1)**: The area which total dissolve solids (TDS) is also entirely less than 500 mg/l, except the area South of Muang, Bang Mun Nag, Pho Pra Thab Chang, Ta Phan Hin, Thab Kho, and Dong Charoen districts of Phichit province which shows TDS between 500-1,500 mg/l.

4) **Consolidated Aquifers**: The area which total dissolve solids (TDS) is also mainly less than 500 mg/l, except the area South-East Thab Kho district Pichit province, Wang Pong, Chon Daen, Nong Phai, Bung Sam Phan and Wichian Buri districts of Phetchabun province showing TDS between 500-1,500 mg/l and TDS more than 1,500 mg/l scattering in spot at North-East area of Wang Pong, Chon Daen, Bung Sam Phan and Wichian Buri districts of Phetchabun province.

5. Hydrogeological and Groundwater Maps

Database supporting the Hydrogeological and Groundwater Maps is composed of 15 main coverage as follow : -

- Coverage of Fundamental Data
- Coverage of Geological Data
- Coverage of Hydrogeological Data
- Coverage of Groundwater Well Data
- Coverage of Water Level and Groundwater Flow Systems
- Coverage of Groundwater Available
- Coverage of Groundwater qualities
- Coverage of Groundwater Utilizations
- Coverage of Groundwater Potential
- Coverage of Hydrochemistry Data
- Coverage of Groundwater Balance and Groundwater Potential Vulnerabilities
- Coverage of Data from Field Investigations
- Coverage of Groundwater Discharge / Recharge Areas data
- Coverage of groundwater replenishments
- Coverage of Hydrogeological cross section data layer

The database is systematically divided into 2 main parts, as database of Hydro-geological Geographic Information System and groundwater Geographic Information System. All of the data are collected in each topographic map sheet of Royal Thai Survey Department scale 1:50,000

For compilations of Hydrogeological and Groundwater Maps, hard copies, only some important data layers are selected and overlain the data layers to show important data for each map sheet of hydrogeological and groundwater maps scale 1: 50,000 The usage of both type maps are summarize as follow. The details of map preparation and usage is present in the main report and using manual book of hydrogeologic map and detailed groundwater map.

Map users can either connecting all of these map sheets to build up as one large map to show the continuous groundwater information of the investigated are or use any individual map sheet to show the data of any village. The index map of every map sheet shown the administration boundary, to make the search easier and more convenience. However, map users should carefully study to understanding the character of data as mention above so that to interpret and use data from each map correctly.

Public and private agencies that are responsible for groundwater development can use this groundwater map as guide line to develop groundwater. The map already indicates the water yield, water quality, rock aquifer, the depth of aquifer, water level and others data.

The map shows blue color, when compare with groundwater quantity index, indicates well yield of 10-20 m^3/hr, good quality with total dissolved solid (TDS) < 500 mg/l

For the rock type of aquifer, one can look at rock legend which in this area showing the Younger Alluvial Fan Aquifer (Qaf1). It composes of gravel, sand and clay sediment which deposits along river bed forming a fan shape at the edge of groundwater basin. Groundwater is accumulated in the void of sediments, depth mostly less than 40 meter. The details to develop groundwater can be found in the map conclusion table which stated the rock type and the expected well depth.

Groundwater and Geological Database of Timor-Leste

Abstract

Timor-Leste currently has no groundwater or geological database but there are plans to develop one for the nation's groundwater resources during 2014. In recent years a large volume of new data sets have been generated from projects and programs focussed on improving Timor-Leste's water resources data and information knowledge base to support better decision making and improved water resources management outcomes. There are now many disparate datasets covering groundwater quality, geochemistry, groundwater height and flow directions, recharge, seawater intrusion and classification of the hydrogeology. Developing a database system to allow the effective collation, management and use of this data is both difficult and important for resource management in Timor-Leste.

East Timor's economy and its communities are heavily dependent on access to safe and reliable water resources for their households and livelihoods. Groundwater is the primary water source, and is increasingly relied upon throughout the year and particularly during the dry season and periods of drought. With increasing water demand from investments in water supply systems and economic development and increasing data and information requests from other Ministries, NGO's and researchers, the need to turn attention to the development of an effective groundwater database is real.

The National Directorate for Water Quality and Water Control (DNCQA) has responsibility for the management of surface and groundwater in the Government of Timor-Leste. With the assistance of the donor country, Australia, DNCQA are currently scoping the development of a Microsoft Access database that is georeferenced, linked to other Government planning, and government and non-government water supply systems through P-Codes and reference numbers. Initially, this database will contain data on groundwater and surface water quality and heights, the location of springs, and the location and basic information on bore holes developed for groundwater extraction.

The database will have a user friendly interface through Google Earth and Microsoft Access. In Access, there will be automated data entry from some sources, such as results from the local water quality laboratory, and simple manual input from other sources. There will also be functions to easily retrieve and export data for third parties and report writing. The georeferencing of all data will enable the database to be viewed via Google Earth. Icons will identify locations with different categories of data and by clicking on these you will view site specific information and details of the many different types of data available at that location related to the water resource.

The development of a geological database for Timor-Leste is also very important for the effective resource management into the future however there are no plans for developing one at this stage. Currently, there are many geological and hydrogeological GIS datasets created by DNCQA from a project to create the Hydrogeological Map of Timor-Leste. This project was supported by AusAid and Geosciences Australia undertook considerable work to harmonised previous geological survey's conducted during the 1960's and 1970's, and then update and categorised them according the current international standards in geology and hydrogeology. This work has created significant volume of new GIS datasets for the Timor-Leste's geology and hydrogeology, becoming an important tool for the water and geological sectors.

Effective management of a nation's natural resources is not only as good as the data and information underpinning the management decisions on how it is used, but also on the systems and processes that are designed to effectively collate, management and use the data and information. This is a challenge for all countries, including Timor-Leste and it is one that we are addressing.

COUNTRY REPORT

GROUND WATER AND GEOLOGICAL DATABASE IN TIMOR LESTE

By
Gregorio deAraujo
National Directorate of Water Resource Management
in Tmor Leste

WELCOME

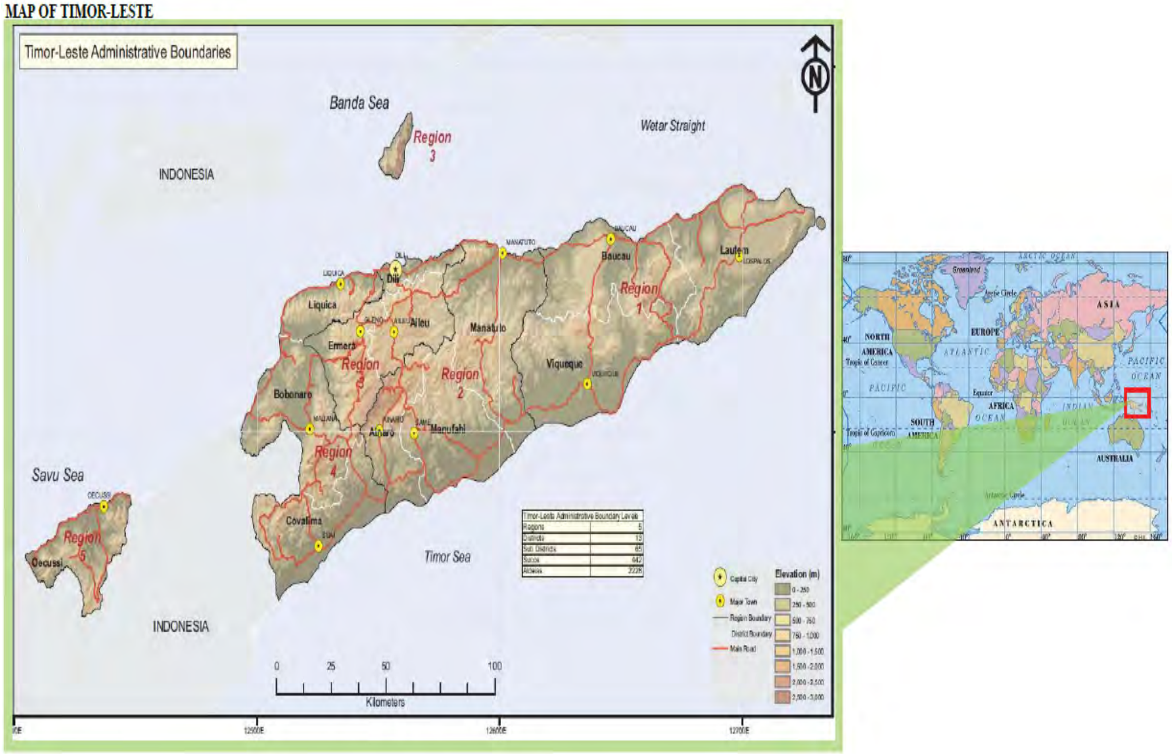
REPUBLICA DEMOCRATICA DE TIMOR LESTE

INTRODUCTION

- Characteristics of TL
- Climate
- Water resources and orientation
- Geology and Hydrogeology
- Expected Project outcomes

Location of Timor-Leste

MAP OF TIMOR-LESTE



CHARACTERISTIC OF TIMOR LESTE

- Eastern half of Timor island located in south Pacific 400 km north Of Australian Continent .
- About 1.2 million people with 3.2% annual growth rate
- 14,610 km2 , Latitude 8º and 9º 30' South, Longitude 124º and 126º 30' East.
- Generally mountainous characterised by rugged terrain & small narrow valleys.
- Highest mountain (Ramelau Mountain) extending from west to east has a altitude of 3,000 metres

Climate

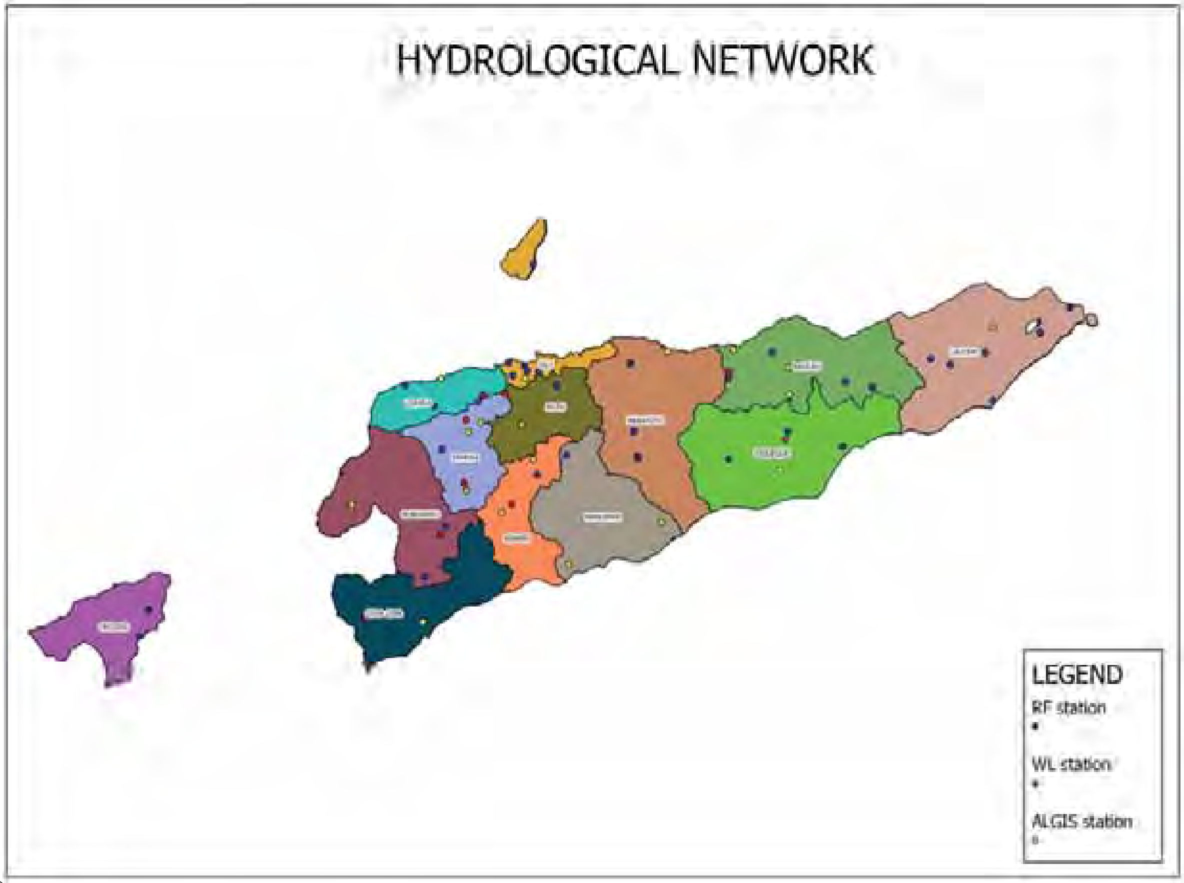
- There are 2 season (wet and wet seasons)
  - Wet season between November and April
  - Dry season between May and October
- Rainfall intensity and duration in East Timor varies from place to place.
- Cold in mountainous areas to very hot in low lying areas (10 to >34^{o}C)

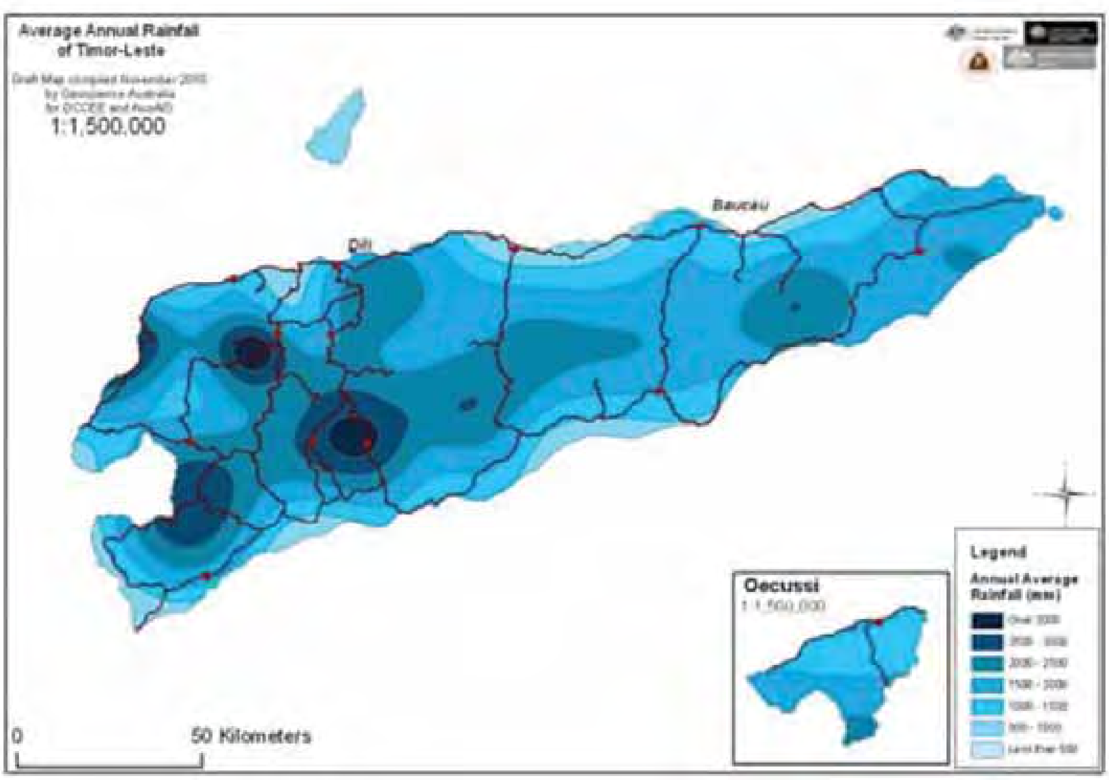
RAINFALL

- **Average annual rainfall** 1,600 mm
  - August is the driest month 20 mm rainfall
  - January records highest precipitation average of 234 mm
- Most places have no rainfall gauges
- No data for may years
- Currently government is reestablishing stations

WATER RESOURCES

- Small lake in Eastern part – Iralalaru (Area 383Km2)
- Very few perennial springs
- Most springs supplying drinking water to rural communities
- Ground water resources in low lying areas 886 m cm/year recharge
- Very minimal groundwater resources in upland areas


HYDROLOGICAL NETWORK
LEGEND
RF station
WL station
ALGIS station


Average Annual Rainfall
of Timor-Leste
1:1,500,000
Dili
Baucau
Oecussi
Legend
Annual Average
Rainfall (mm)
0
50 Kilometers

Summary Report on Groundwater and Sensitivity to Climate Change

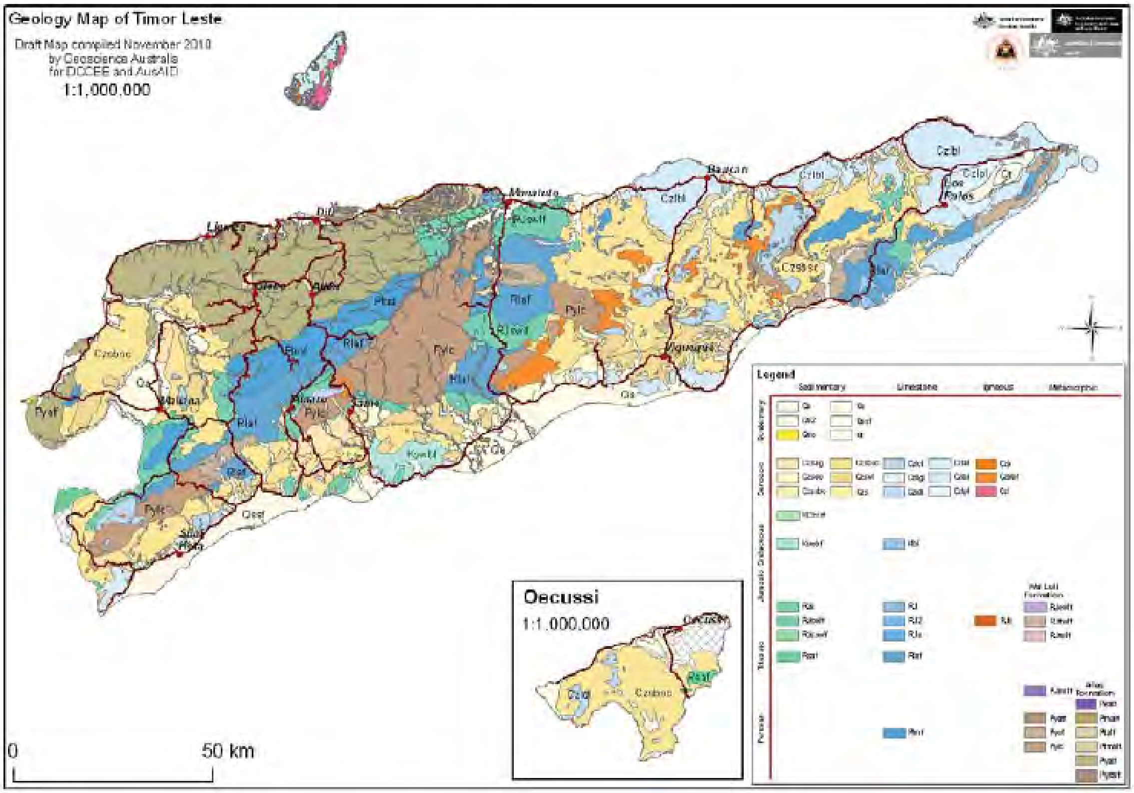
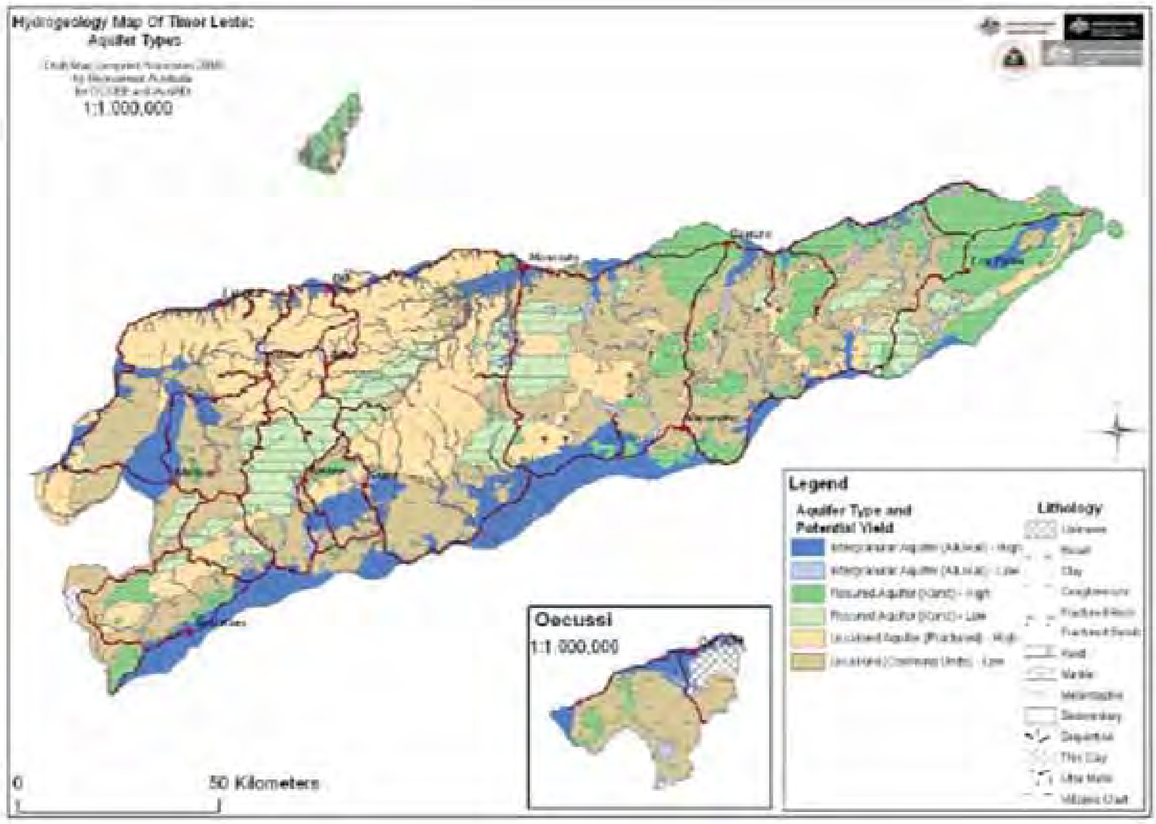
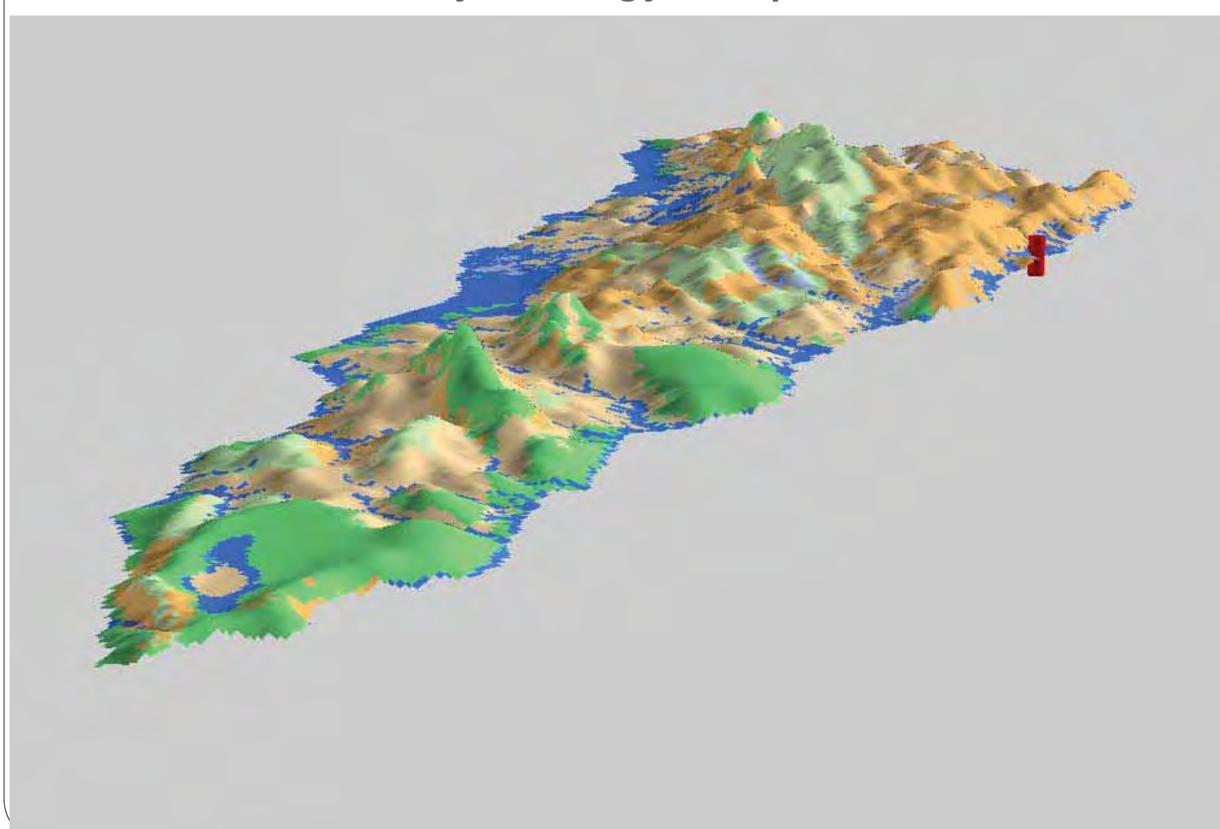


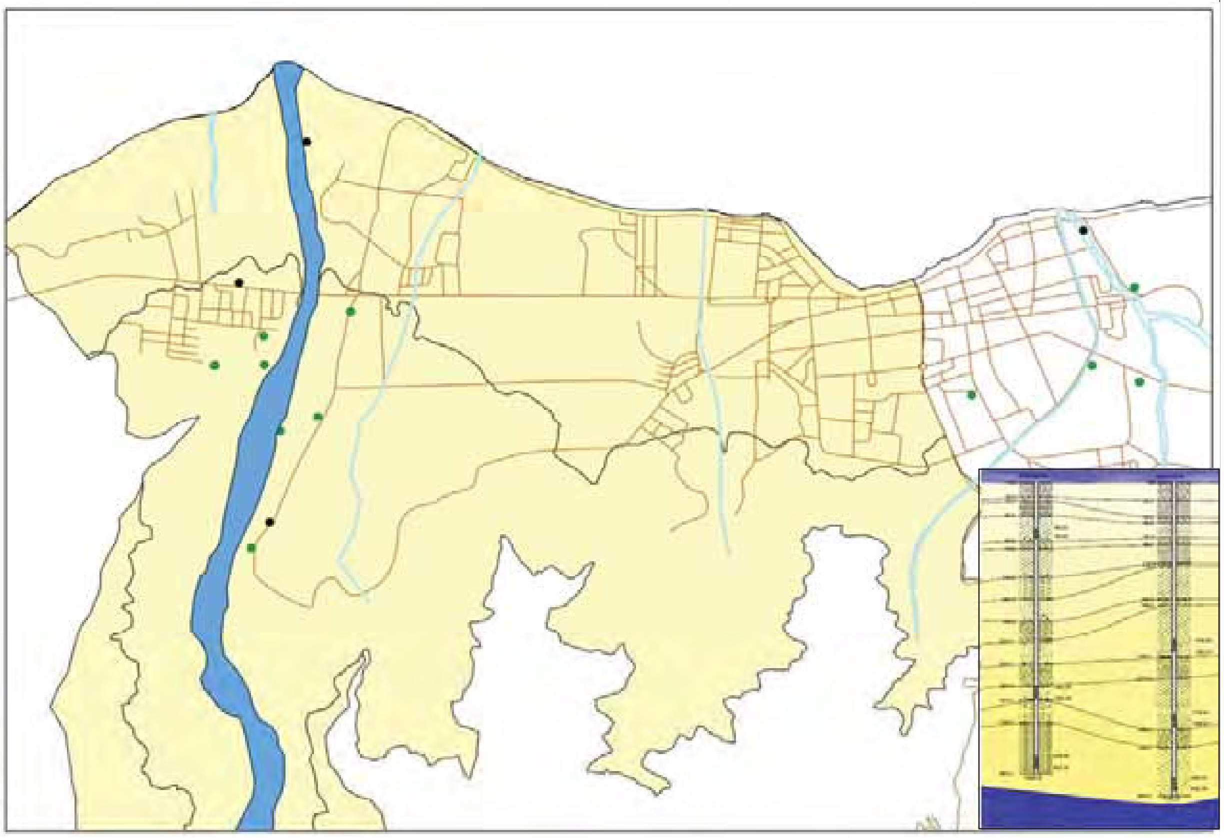
Figure 3: Geology of Timor-Leste (Wallace et al., 2010)



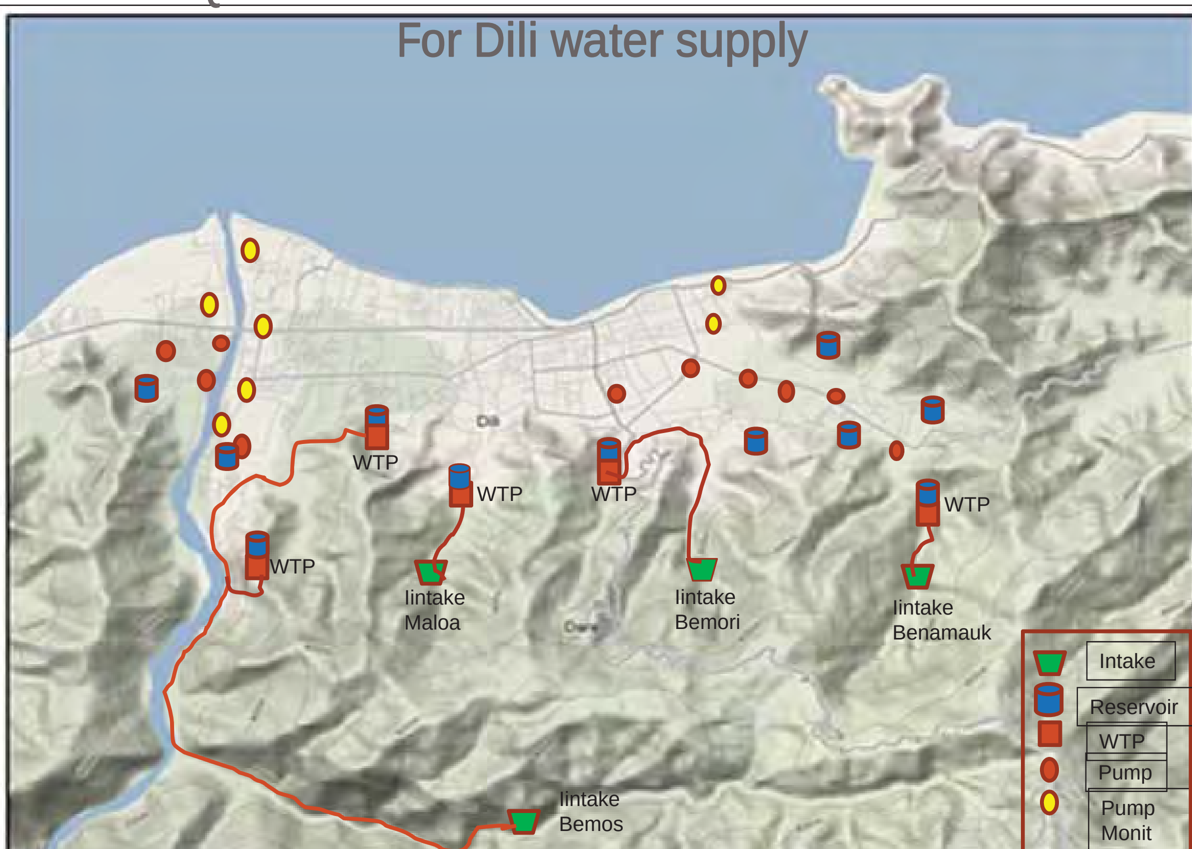
Hydrology Map



Location of Deep well in Dili Capital



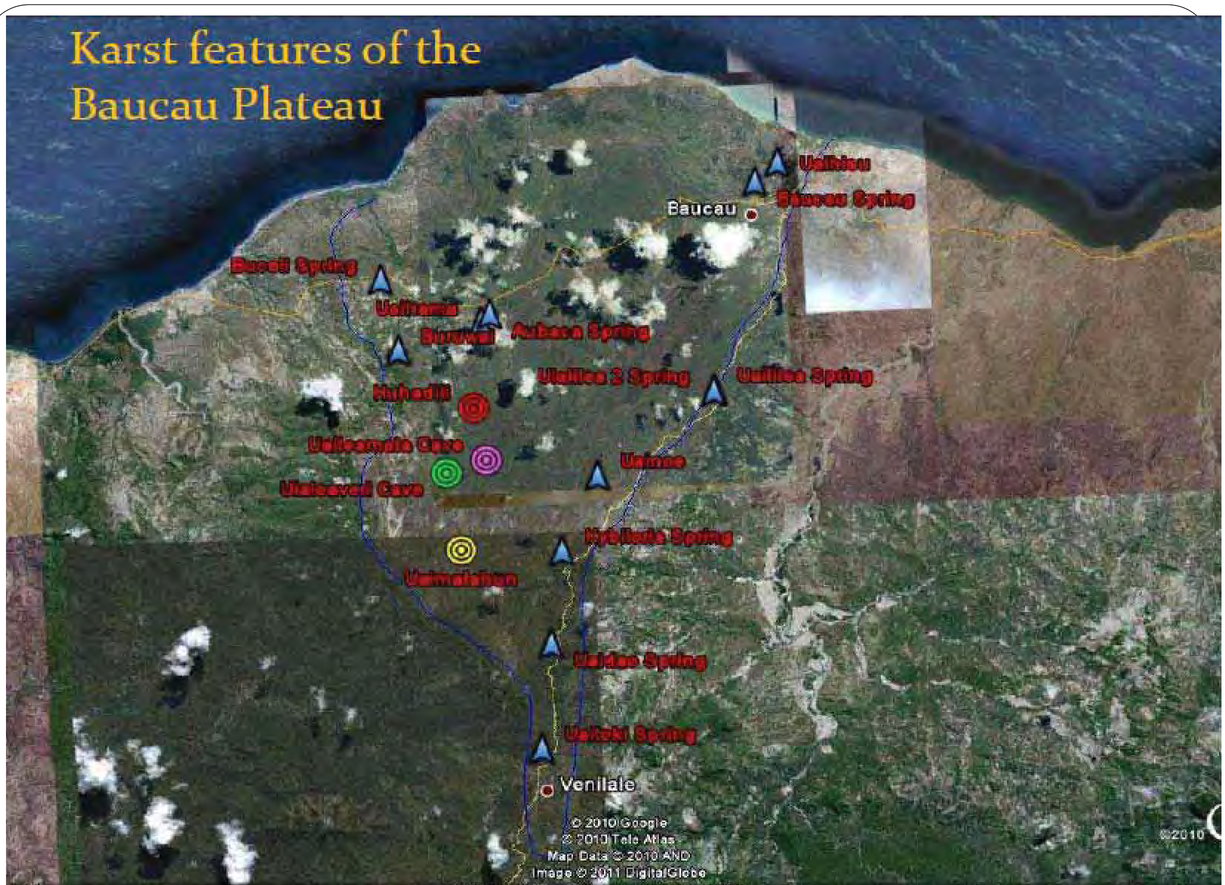
Quantities of Ground water and surface For Dili water supply



Ground Water usage

Groundwater as a source potable water use since 1999 in Dili .

- The demand on groundwater has risen over the last 12 years with growth of population. Increased of groundwater production from 15,240 M3/D (2000) to 19,728 M3/D (2012)
- Total capacity 19,728 m3/d from 14 well-fields and 4 WTP in Dili

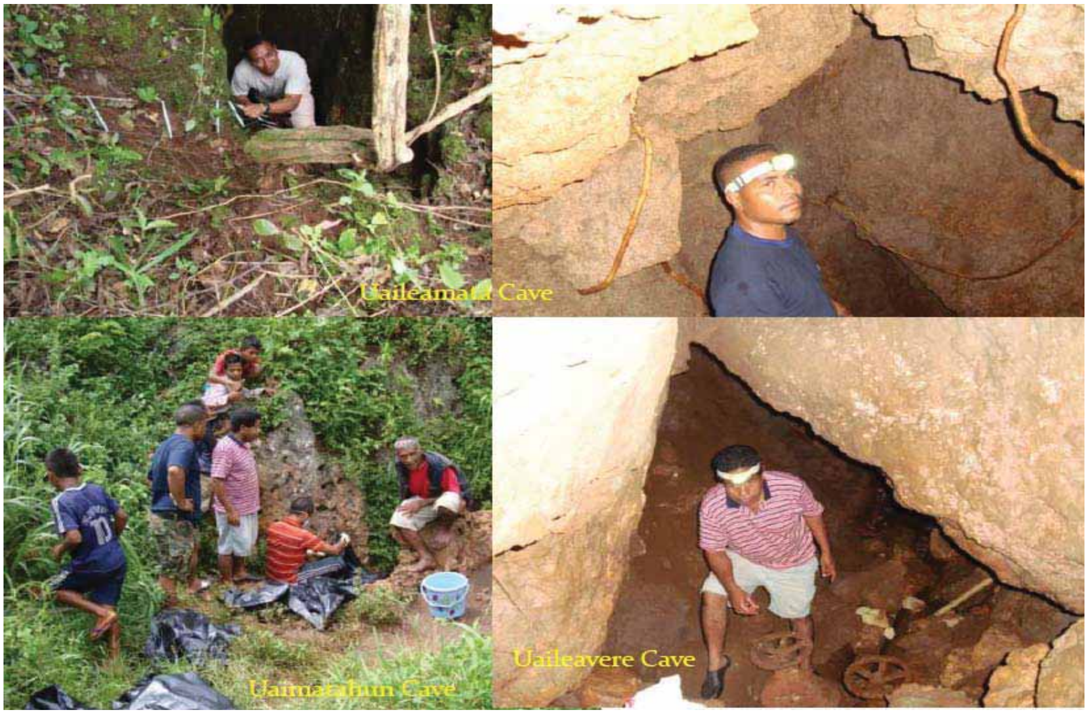


two of the springs are very large in Baucau

UaiLia & Uaisarake Springs

200 L/s

50 L/s


Uaileamata Cave
Uaimatahun Cave
Uaileavere Cave

Flow Net


?
Baucau
Venilale
Google

Dye Tracing Method

- Three basic questions commonly encountered in groundwater hydrology are:

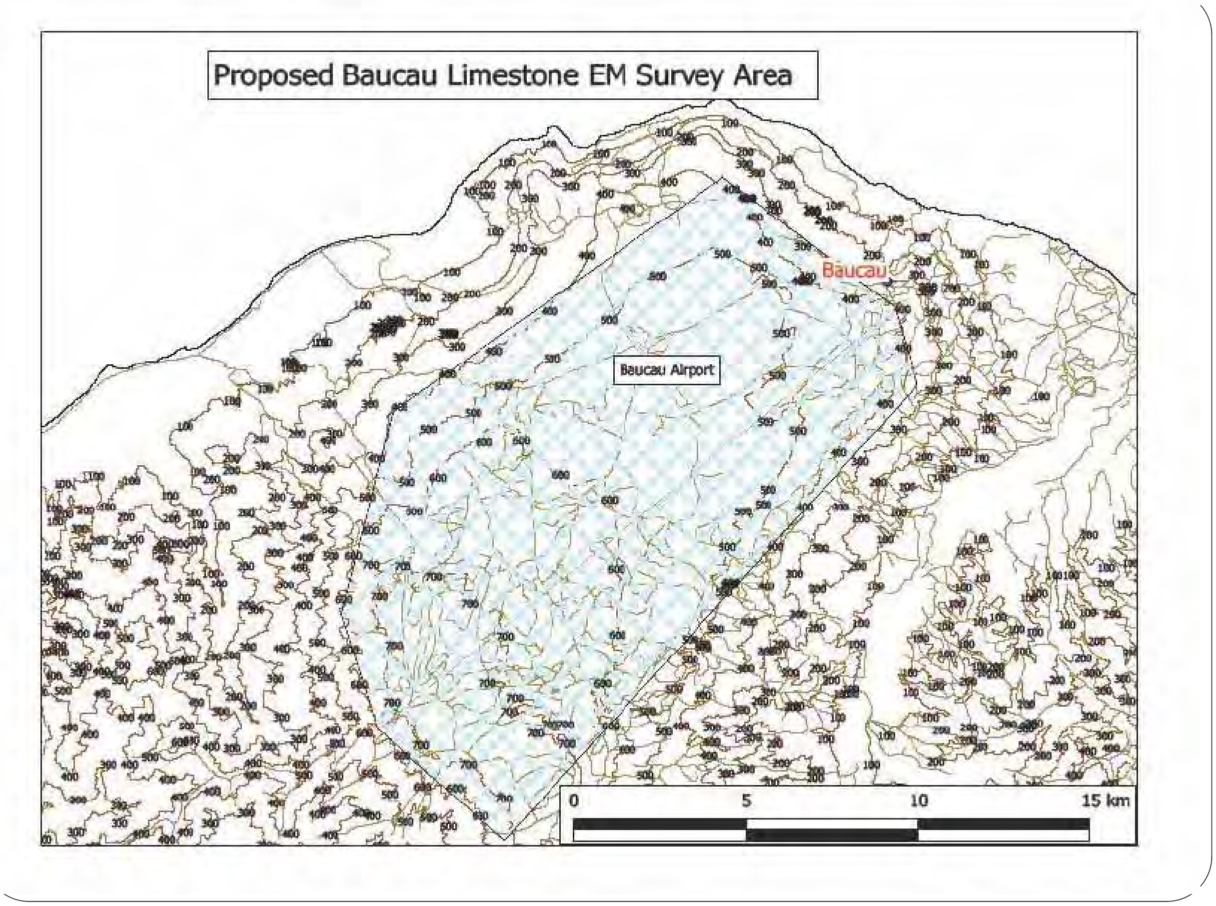
- • Where does the water go?
- • How long does it take to get there?
- • What happens along the way?

Sampling for dye using activated carbon granules

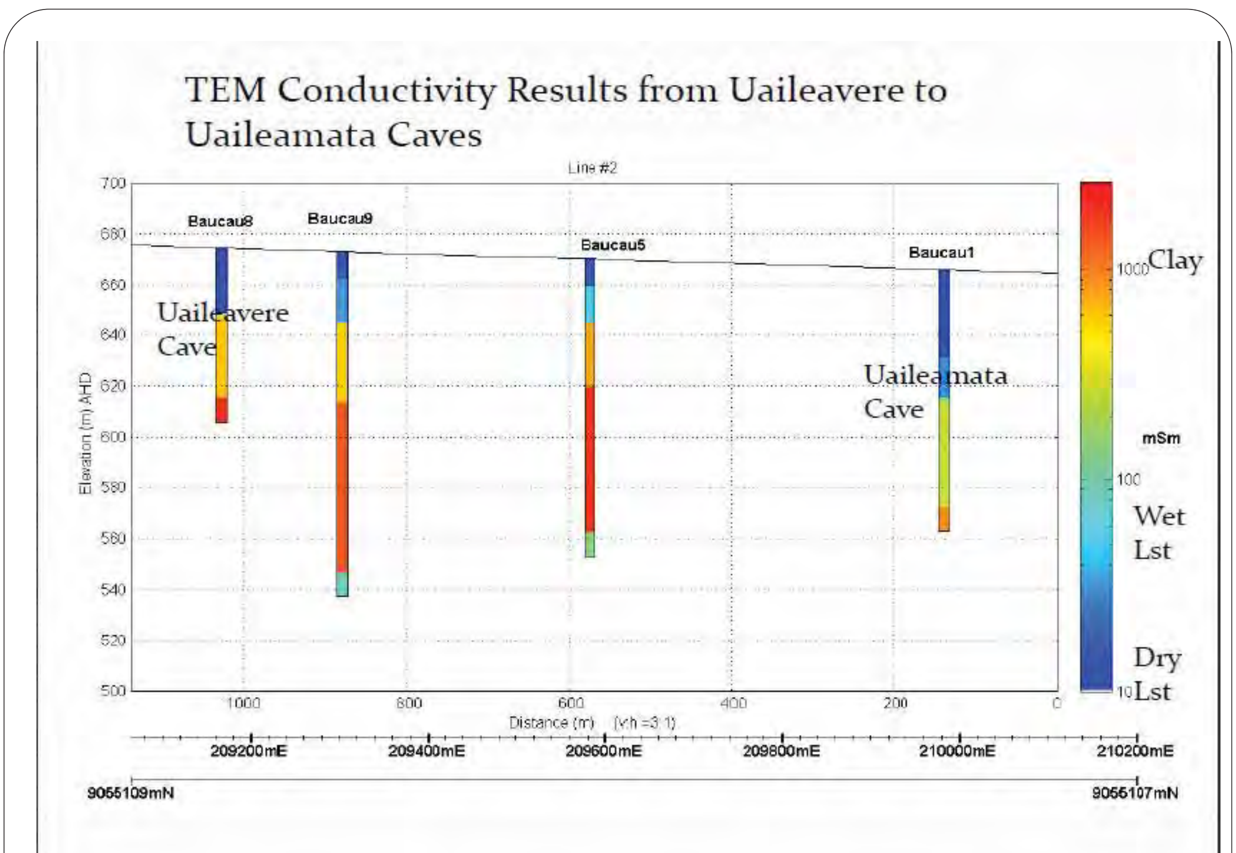
Anchor used to hold sampler

Aubaca Spring sample site

Results Showing Dye Travel Direction and Breakthrough Curves



Proposed Baucau Limestone EM Survey Area
Baucau
Baucau Airport
0
5
10
15 km



TEM Conductivity Results from Uaileavere to Uaileamata Caves
Line #2
Baucau8
Baucau9
Baucau5
Baucau1
Uaileavere Cave
Uaileamata Cave
Elevation (m) AHD
Distance (m) (v:h =3:1)
Clay
mSm
Wet Lst
Dry Lst
209200mE
209400mE
209600mE
209800mE
210000mE
210200mE
9055109mN
9055107mN

General Site Data logging sheet

- We are testing logging sheets like this one to consistently collect site data in the field.
- Details are entered or cells are circled.

General Data

AGENCY	DNCQA	RECORDED BY		PROJECT	Liquica Water Resources Assessment			
Bore	Well without pump	Well with pump	Spring	Lake	Lowland river	Mountain stream	Underground stream	Sinkhole
Connected to public water supply system	Connected to private water supply system	Not connected to a water supply system	DGAS System Name	DGASP				
District		Subdistrict		Suco		Aldeia		
STATION NAME		SITE ID						
LATITUDE		LONGITUDE		LAT/LONG DATUM		ALTITUDE (M)		
RIVER CATCHMENT								
HYDROGEOLOGY	Intergranular	Fissured Karst	Localised	Fractured Confining Unit	High Potential Yield	Low Potential Yield		
AQUIFER NAME		Comments						

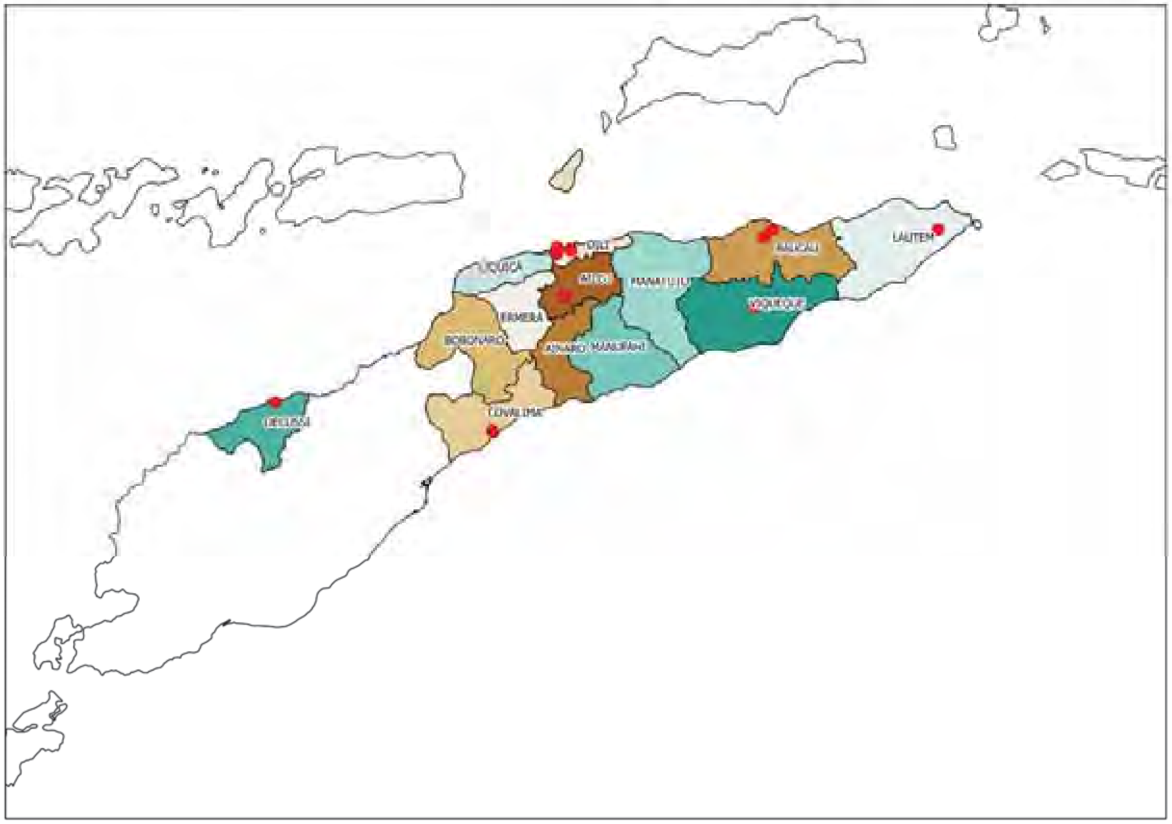
Data logging sheet is for bore holes and wells.

- Logging sheets for spring locations and water monitoring sites also being developed.
- Currently testing these logging sheets in a water resources assessment project in Liquica.
- Eventually these logging sheets will look exactly the same as the MS Access database to improve manual entering of data.

Bore / well data

CONSTRUCTION INFORMATION	ACTUAL YEAR		<5 YEARS	after 2000	1995	1985	Drilling Contractor					
Bore / Well DEPTH (M)		Screen Depth (m)		Water Level (m)		Bore Yield (lps)						
BOREHOLE DIAMMETER		¾" (20mm)	1" (25mm)	1 ¼" (32mm)	1 ½" (38mm)	1¾" (45mm)	2" (50mm)	3" (75mm)	3 ¼" (81mm)	3 ¾" (95mm)	4" (100mm)	
PRIMARY USE OF WATER		Bottling	Industry / Commercial	Mine dewatering	Mining	Domestic	Irrigation	Stock (animals)	Public Supply	Aquaculture	School	Clinic
SECONDARY USE OF WATER		Bottling	Industry / Commercial	Mine dewatering	Mining	Domestic	Irrigation	Stock (animals)	Public Supply	Aquaculture	School	Clinic
		No. of Households (service area)		Reliability of supply		All Year A	Wet season only B					
TYPE OF PUMP		Hand Pump	Electric	Diesel / Gasoline								
BORE OWNERSHIP		PRIVATE	PUBLIC		Comments							

GROUND WATER LEVEL MONITORING



Orientation & Monitoring of Water Resources

Hydrological data collection (springs, river, rainfall)

- *Continue the on-going data collection – but need to have a system where all data are stored and updated and shared among the users (integrated data bank of rainfall, river and spring flow).*
- *Need proper coordination with other agencies concerned (NWRM, Agriculture, DNSAS/infrastructure, Public works).*
- *Formulate a plan to expand measuring stations, upgrade and maintain equipment.*

Orientation & Monitoring of Water Resources

Groundwater Monitoring and Control

- *Registration of wells (production) – owner, location (coordinate), purpose, max volume of water to be withdrawn from the ground; technical data: total well depth, thickness and type of aquifer, well screen location.*
- *Permit /license for new well drilling – location, purpose, conditions and requirements (well log, driller's log, pumping test, water quality) - data can be used to determine groundwater characteristics.*
- *Water charges – should be based on:*
  - *Intended use of water*
  - *Quantity/rate of extraction in relation with other users and water bearing capacity of the source*
  - *Environmental effects*
  - *Extent to which water withdrawal will affect other wells, sea-fresh water balance*
  - *Development cost of bringing water from the source.*

Orientation & Monitoring of Water Resources

- *Monitoring well points (to be identified based on land use/zoning) – water level, water quality and capacity recorded & kept at WRMD*
- *Regulations on proper groundwater extractions and development*
  - *Distance between wells (well siting), depth, capacity (safe yield)*
  - *Standards – drilling methods, design and development*
  - *Records of operation – water level (drawdown) and daily discharge, checking water quality on regular basis (weekly)*
  - *Well protection – pollutants control, sanitary seal, recharge and abandonment*
  - *Environmental assessment for large production wells (urban, rural and commercial)*

Basins and Trans-basins Boundaries

- *Review and adopt previous studies' recommendations (e.g. ADB – TA)*
- *Determine resource/basin capacity (recharge) within the basin (long term)*
  - ***Can start with critical areas where future groundwater extraction is planned, and industrial estates and urban expansions are proposed.***
  - ***Established the supply-demand relationship (with population and location, etc)***
- *West and East Timor boundaries – identify and study areas and recommend actions - (need high level government action for international agreement)*

Expected Project outcomes

- T-L government is better informed about the impacts of climate change on WRM and support provided to the NAPA
- Technical agencies in T-L have improved skills and knowledge on WRM monitoring and management
- T-L water agencies have a better understanding about the impacts of climate change on water resources

Thank you

Vietnam Groundwater monitoring review and database

Nguyen Chi Nghia, Bui Du Duong

Department of Water resources monitoring, Nawapi, Vietnam

1. Introduction

Vietnam national water resources monitoring network is one part of the national monitoring network system of resources and environment. At the present, the National Center for Water Resources Planning and Investigation (NAWAPI) management and operation of 710 groundwater monitoring stations include 206 stations in the Bac Bo delta, 26 stations in the north central region, 46 stations in the central region, 212 stations in the Tay nguyen highlands and 220 in the Mekong delta. The monitoring database was used for more research. This article is intending to sum up the statute of the Vietnam groundwater monitoring network in 2013 year.

2. Current operation of vietnam's groundwater monitoring network

2.1. Northern delta area

2.1.1. Current situation of the network

The region comprises 206 active stations implementing the monitoring task with 10 surface water stations and 196 groundwater stations (**Fig. 1**).

The groundwater monitoring stations are set at the aquifer of Quaternary deposits (qh and qp) and fractures aquifer (n, cp, t2, os). The number of stations installed in the aquifer comprises 95 stations (qh2 and qh1), 86 stations (qp2 and qp1), 9 stations (n), 3 stations (t2), 2 stations (c-p) and 01 station (o-s).

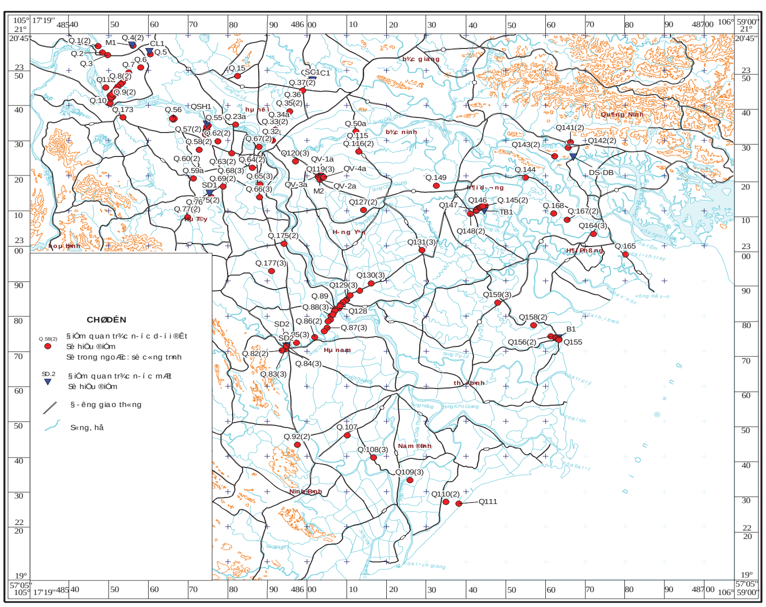


Fig. 1. Monitoring network in Northern delta

2.1.2. Assessment of water level change in Northern delta area

- *Aquifer qh:* water level usually decreases in the dry season and recovers during the rainy season with fluctuation range from 0.26 to 2.5 m. Dynamic change depends on hydro-meteorological conditions.

- *Aquifer qp:* across the delta, water level in this aquifer tends to decline for several consecutive years (1995-2013) (**Fig. 2**). This phenomenon is supposedly resulted of groundwater overexploitation, leading to the adverse reduction of water level with loss of recover ability; consequently, an adjustment dealing with rational exploitation is vitally essential. The trend of water level in some areas are below:

- *Hanoi area:* the concentration of water extraction, water level keep decreasing to an allowable threshold in the aquifer; as a result, some factories have to adjust water extraction capacity, leading to slow decline of water level in the Pleistocene aquifer. Some areas are recovering gradually.
- *Thai Binh area:* water level compared with previous years has unceasingly decreasing trend to an unusual depth of 5.39 m (Q.159b). Average declined water level exceeds 0.27 m matched with 2012 and 4.73m with 1995. Decline rate of water level in the area is about 0.26 m/year.
- *Nam Dinh area:* lowest water level is 12.14 m (Q.109a). Water level in 2013 is declined 0.57m lower than 2012 and 10.07m than 1995. Decline rate of water level in the aquifer is about 0.61 m/year.

Temperature of groundwater in the aquifers (qh, qp, etc.) of the Northern delta does not change considerably and remains approximately stable in the range of 22.6^{0}C to 27.82^{0}C, averaging 25.18^{0}C.

2.2. North Central Plain

2.2.1. Current situation of the network

The groundwater resources monitoring network in North Central region is currently set in two provinces: Thanh Hoa and Ha Tinh (**Fig. 3, 4**).

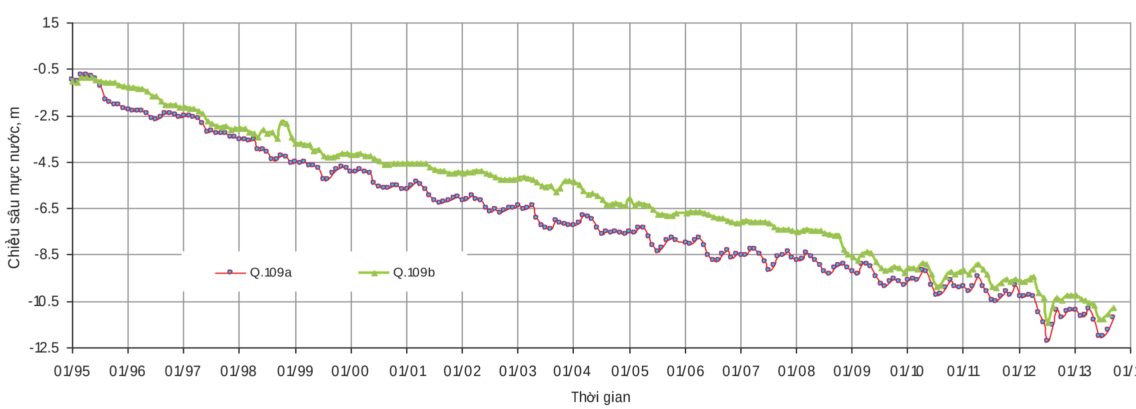


Fig. 2. Water level fluctuation in Truc Phu, Truc Ninh, Nam Dinh

Network monitoring groundwater resources in North Central region has a total of 26 monitoring stations, with 4 single purpose stations in Thanh Hoa and 02 in the area of Ha Tinh. For 2-3 purposes monitoring station, there are 10 stations being active in Thanh Hoa and 10 in Ha Tinh. The task is primarily monitored by automatic recording; some are recorded manually due to broken automatic device.

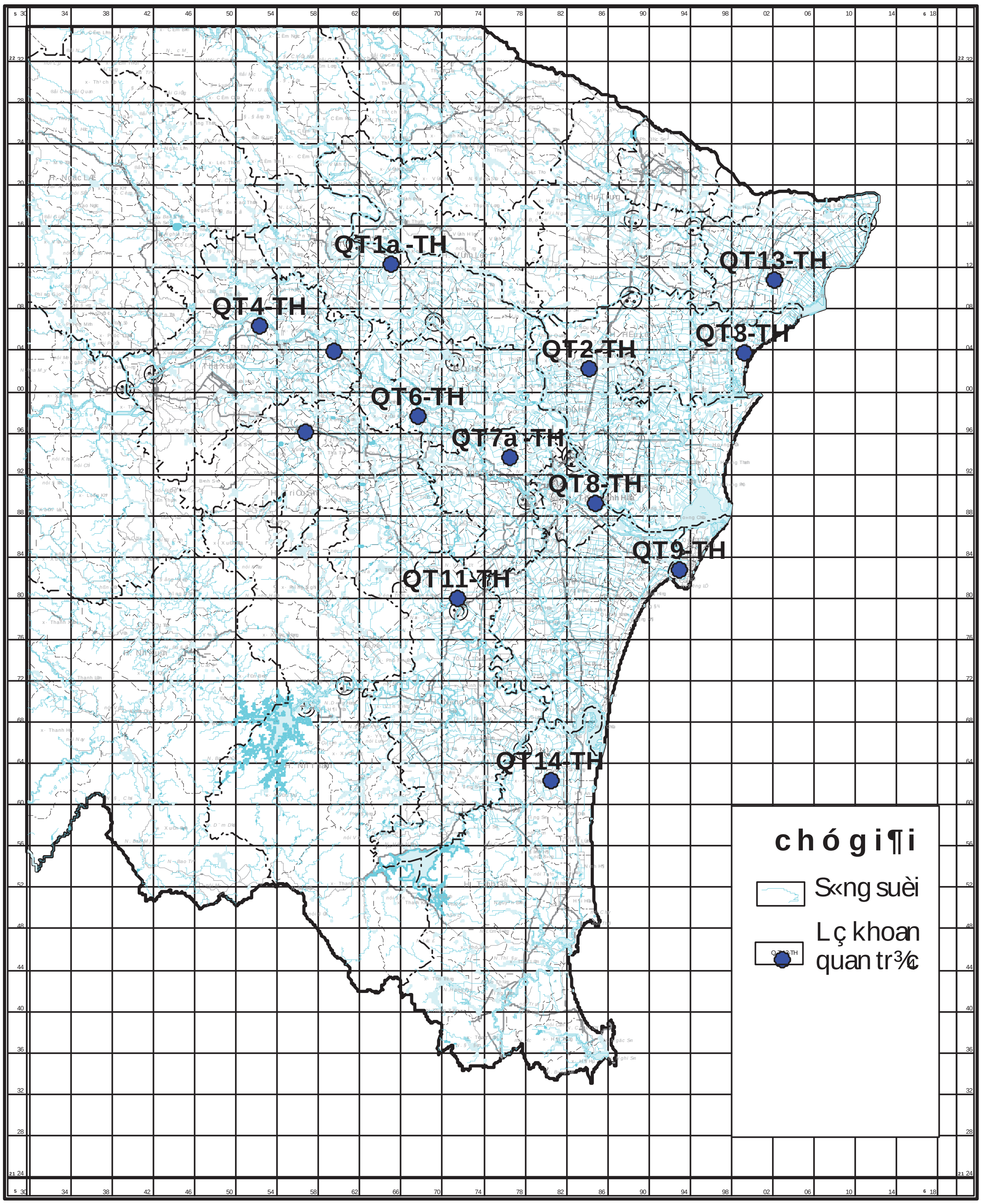


Fig. 3. Groundwater monitoring network in Thanh Hoa Province

The groundwater monitoring stations are installed at the aquifer of Quaternary deposits (qh and qp) and fractures aquifer (t2). The number of stations set in the aquifer consists of: qh aquifer with 11 stations (Thanh Hoa region) and 6 stations (Ha Tinh Province); qp aquifer with 23 stations (Thanh Hoa region) and 09 stations (Ha Tinh province); t2 aquifer has 07 stations.

2.2.2. Assessment of water level change in North Central Plain

- *Aquifer qh:* water level in qh of Thanh Hoa Province fluctuates from 0.6 to 2.86 m. Margin ranges is from 0.69 to 1.20 m, 3.09 m in some areas (QT8-TH). Water depth in aquifer of Ha Tinh province fluctuates from 1.57 to 5.46 m, the margin is highly ranged from 1.19 to 2.11m. In general, the water level of aquifer is seasonally fluctuated during the year due to hydro-meteorological influences. In addition, water level fluctuation of qh and qp aquifer has lightly tight relationship expressed through cophasal fluctuation in Q.6 (qh) and Q.6a (qp) (**Fig. 5**).

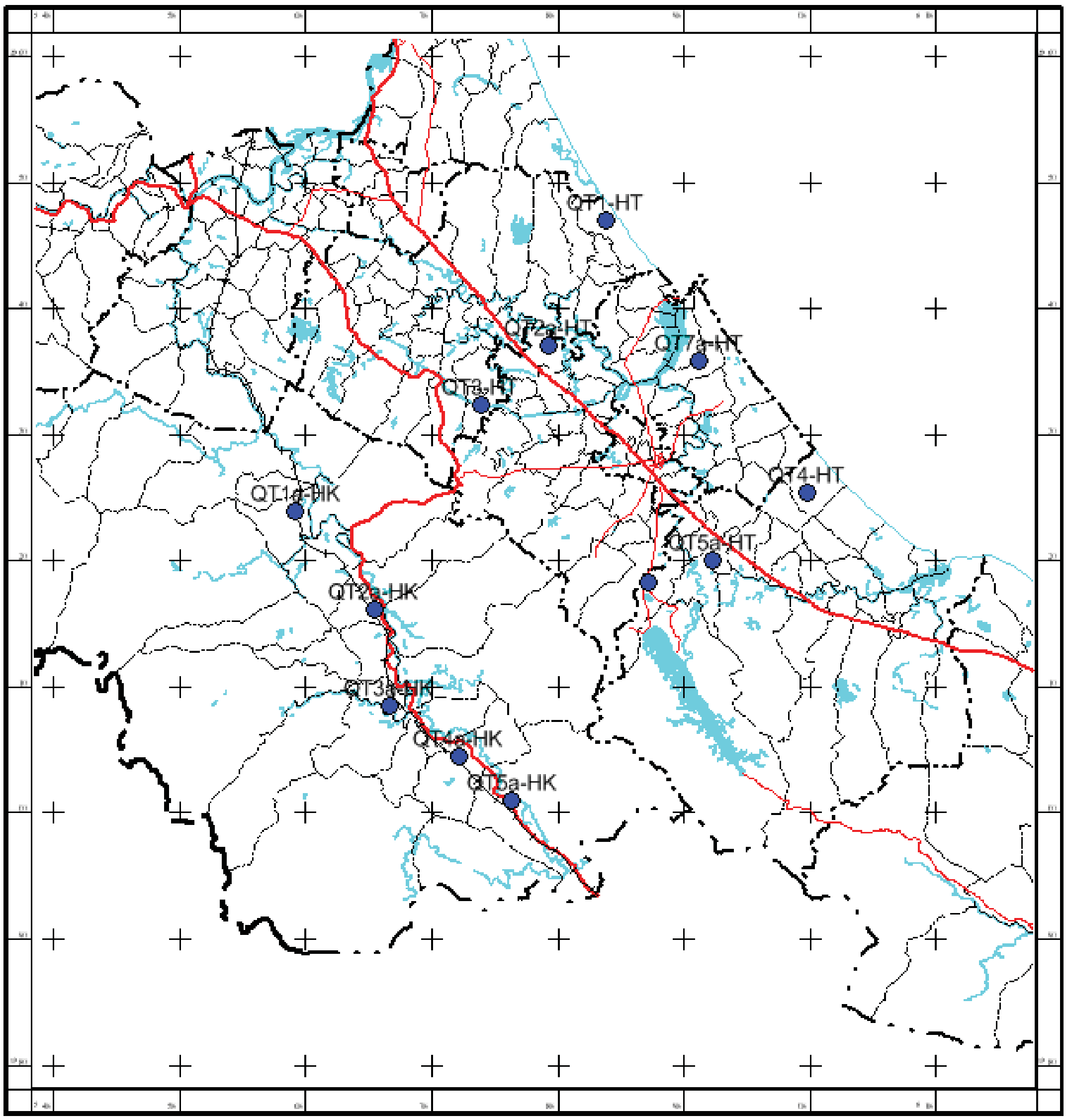


Fig. 4. Groundwater monitoring network in Ha Tinh Province

- *Aquifer qp:* water depth in aquifer of Thanh Hoa Province fluctuates from 1.62 to 7.02m, fluctuation margin is about 0.69 to 2.48 m. For areas of Ha Tinh province, water level fluctuates from 1.60 to 1.87 m and margin range is from 0.37 to 1.06 m (**Fig. 6, 7**).

- *Aquifer t_2*: water depth in the aquifer ranges from 1.83m- 2.02m. In the rainy season, heavy rainfall affects to the water level of the aquifer, causing the lightly high fluctuation margin from 1.73 m - 2.21 m. Water level fluctuation in aquifers qp and t2 has a closed hydraulic relationship shown in water level fluctuation diagram (**Fig. 8 , 9**).

Temperature of groundwater in the aquifers (qh, qp, etc.) of the North Central Plain (Thanh Hoa, Ha Tinh) remains approximately stable in the range of 22,64^{0}C to 28,51^{0}C, averaging 25.180^{0}C.

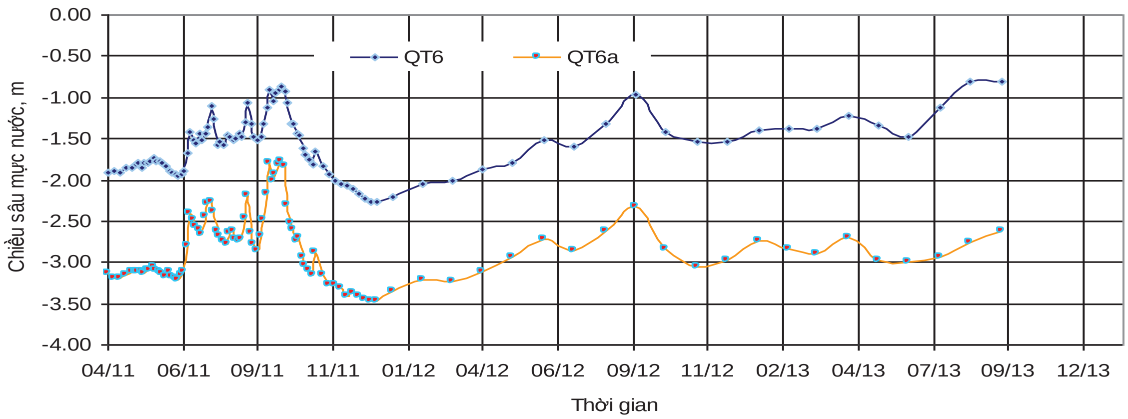


Fig. 5. Water level fluctuation in Thieu Vien, Trieu Hoa, Thanh Hoa

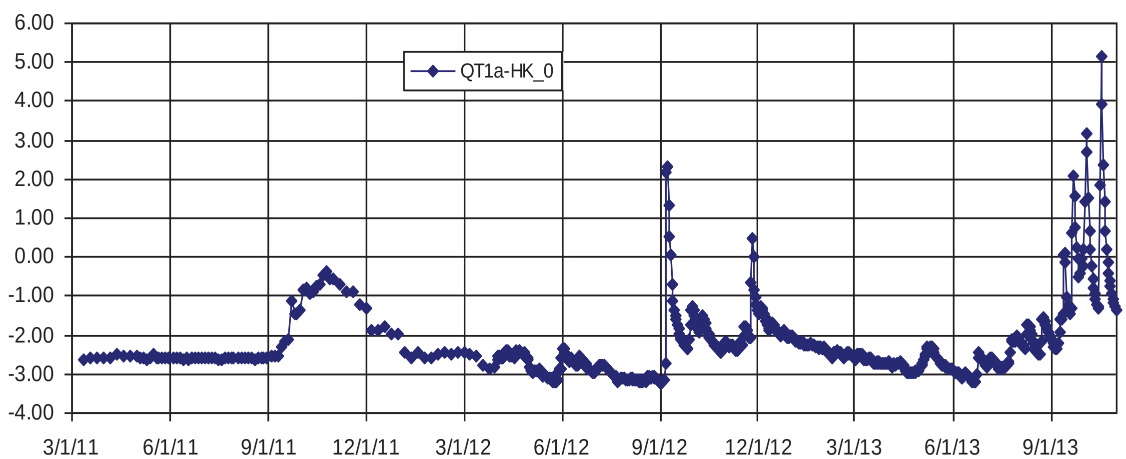


Fig. 6. Water level fluctuation in Phuong Dien, Huong Khe, Ha Tinh

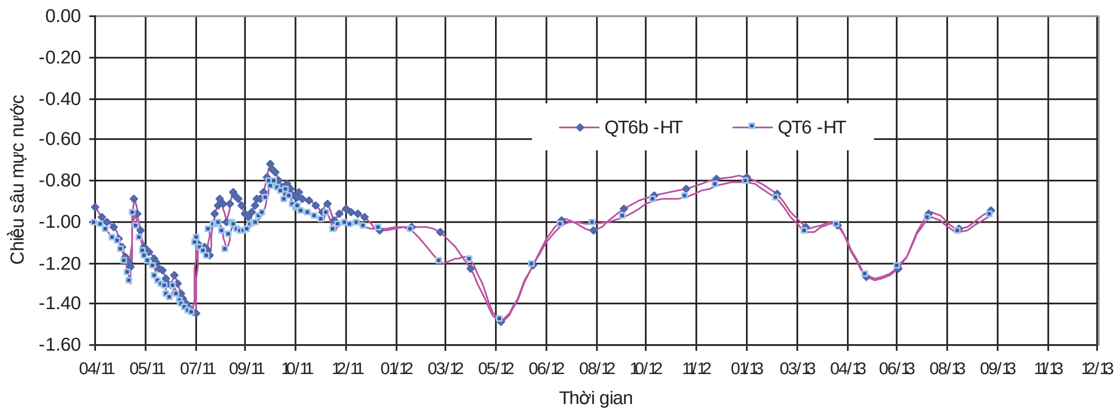


Fig. 7. Water level fluctuation in Cam Thach, Cam Xuyen, Ha Tinh

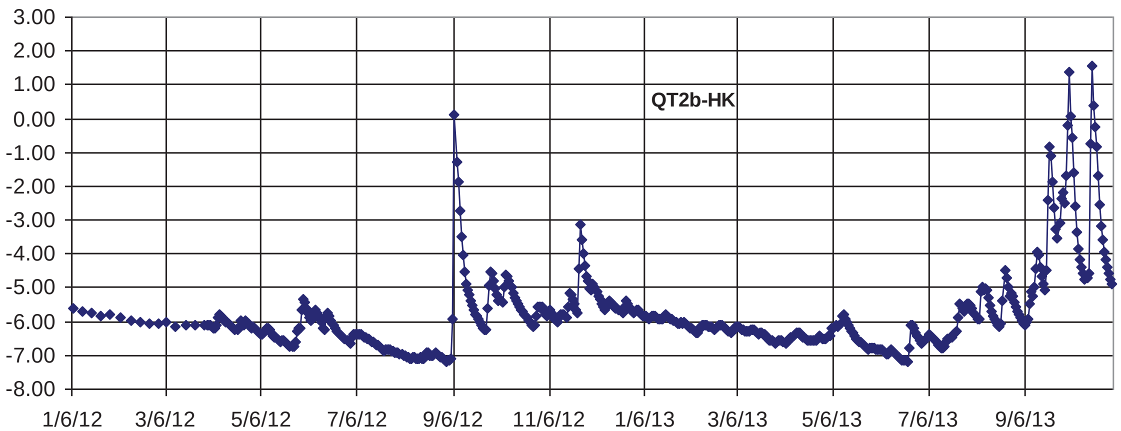


Fig. 8. Water level fluctuation in Huong Thuy, Huong Khe, Ha Tinh

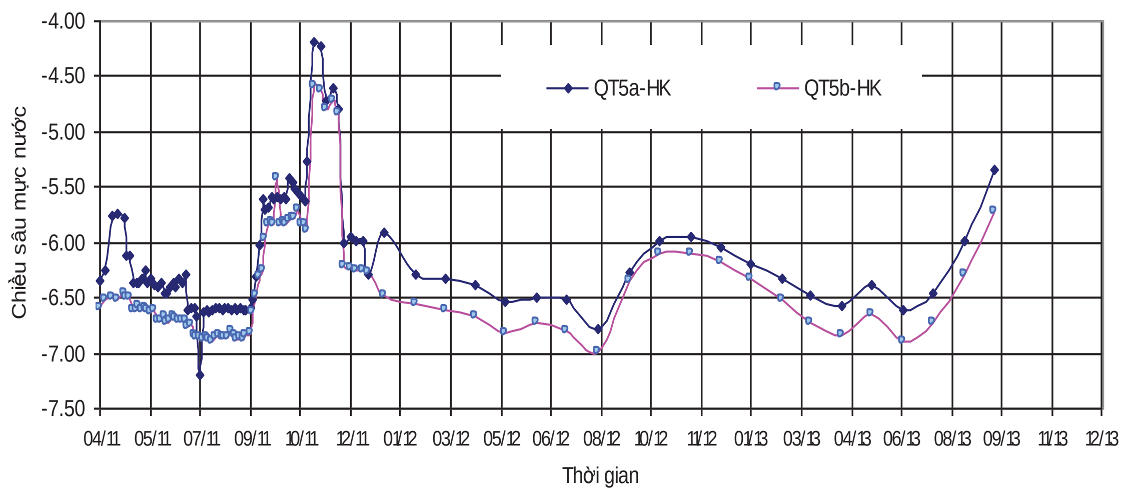


Fig. 9. Water level fluctuation in aquifers qp and t_2 in Huong Khe

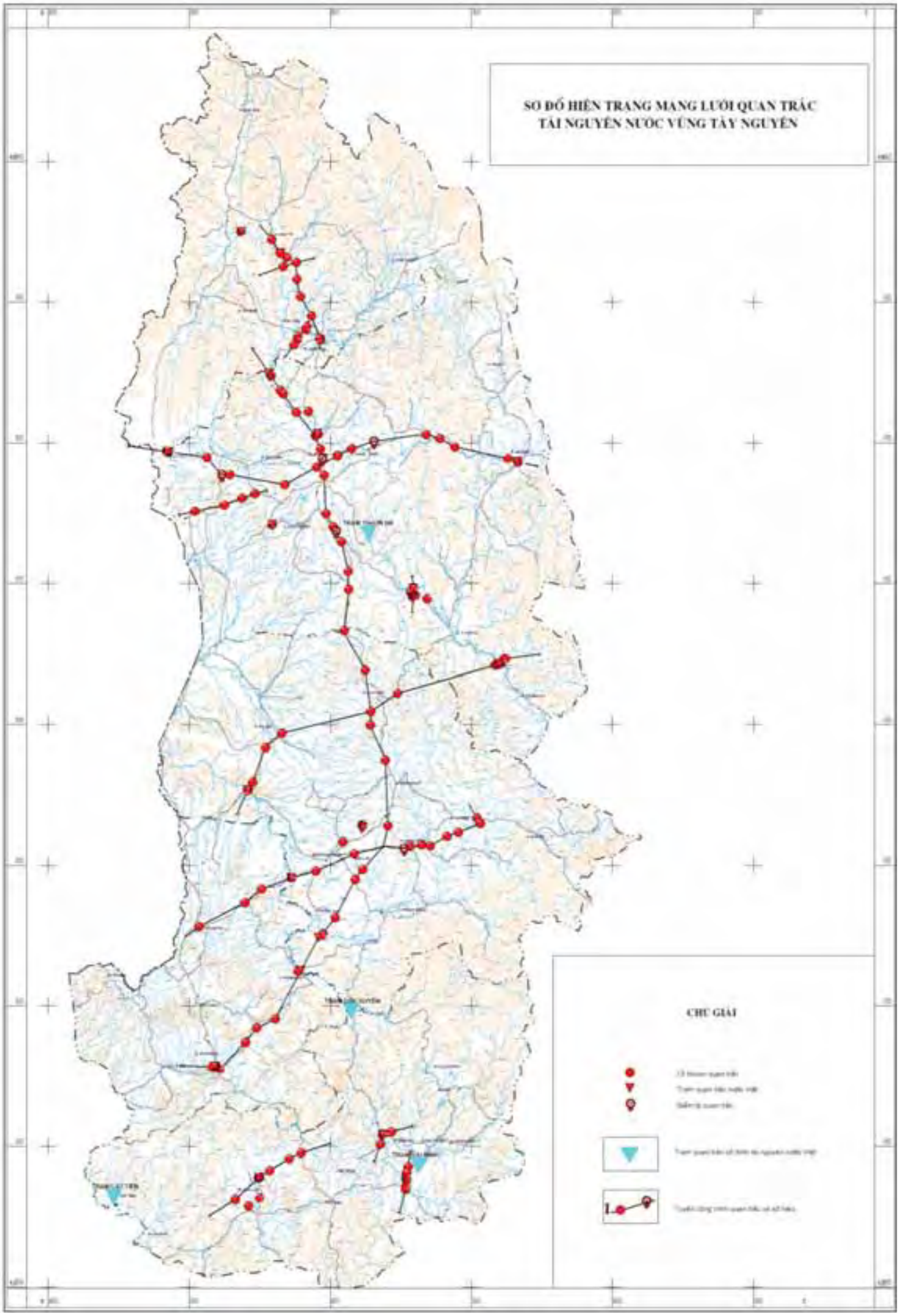


Fig. 10. Monitoring network in Highlands

2.2.3. Assessment of groundwater quality change in North Central Plain

The analytical results of water samples in 2013 show that all paramters analyzed are within the permissible limitation. However, there are still some parameters comprising As, Mn, NH4 + exceeded QCVN 09:2008/BTNMT standard, concentrating mainly in Thanh Hoa, Ha Tinh and small part of Huong Khe.

2.3. Central Highlands

2.3.1. Current situation of the network

Total number of groundwater monitoring stations in the Central Highlands is 212 stations in 123 monitoring sites with 4 balance yard, a lizimet tunnel and 4 surface water monitoring stations, allocated in territory of 05 Highlands Provinces (Kon Tum, Gia Lai, Dak Lak, Dak Nong and Lam Dong) (**Fig. 10**).

Groundwater monitoring network works towards to monitoring and controlling ground water resources throughout the Central Highlands area; as the results, the wells are set into 12 alignments, 8 independent works, works system, 04 balancing yards and hydraulic relation alignment.

2.3.2. Assessment of groundwater change in Highlands

Ground water change throughout the Central Highlands follows below variable trends:

- *Seasonal water level fluctuation*

Annually, water level fluctuation has a maximum value (on August - November) and a minimum value (on June – July). Water level may fluctuate in co-phase or "slow phase" with rainfall in 1-2 months period, depending on the allocation depth and permeability characteristics of the water-bearing rock in aeration zone (**Fig. 11**).

This is a typical trend for the regions less affected by man-made activities such as water mining, irrigation, deforestation, etc.

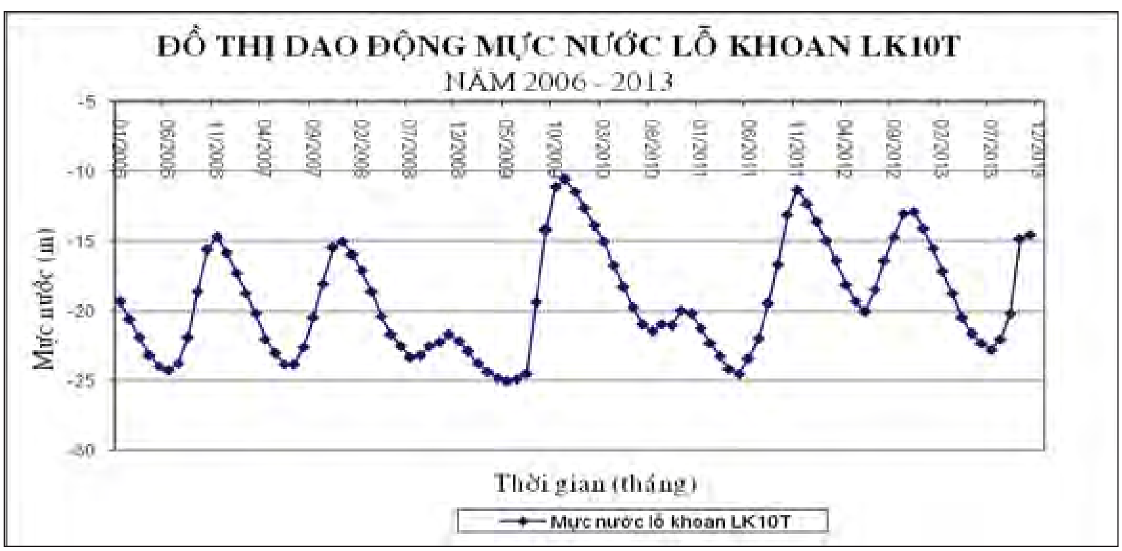


Fig. 11. Đồ thị mực nước theo mùa tầng chứa nước phun trào bazan Pleiku

- *Complex fluctuation*

This trend is discovered in wells allocated in area influenced by man-made factors such as irrigation in Ayun Pa field, the distribution of Quaternary deposits in the valleys (Kon Tum, Ea Sup, Phu Thien), riparian areas and streams where water is related to the hydraulic system of surface water (**Fig. 12**).

- *Water level drop*

This trend is discovered in wells distributed in a number of large water extraction areas such as eastern area of Buon Ma Thuot, Bao Loc area. Graph of water level in recent years show the declining trend (**Fig. 13**).

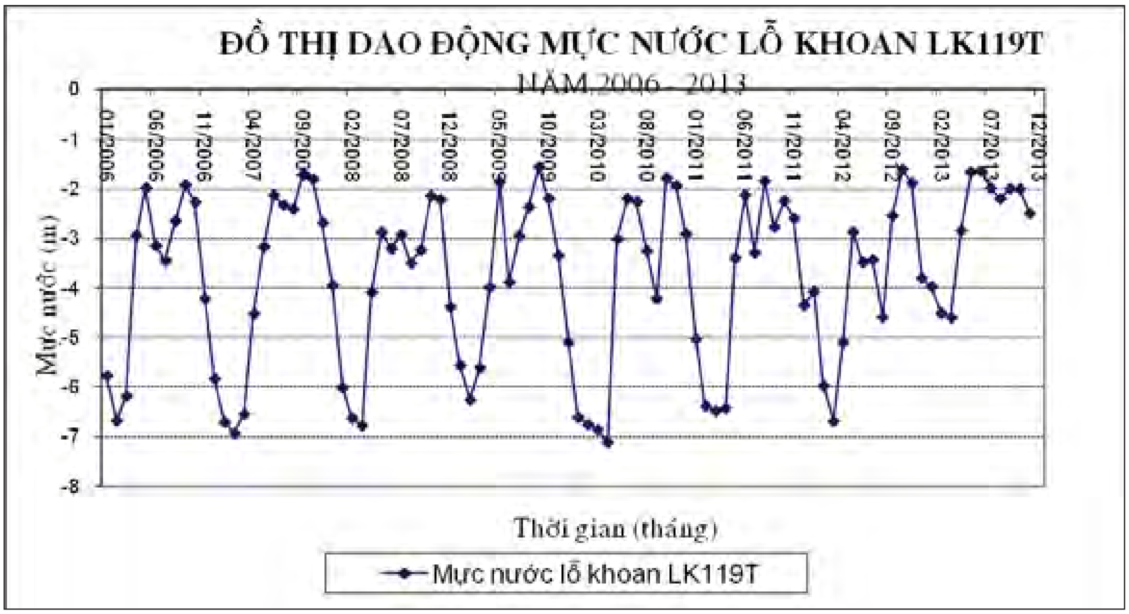


Fig. 12. Water level fluctuation in Da Dung riparian area

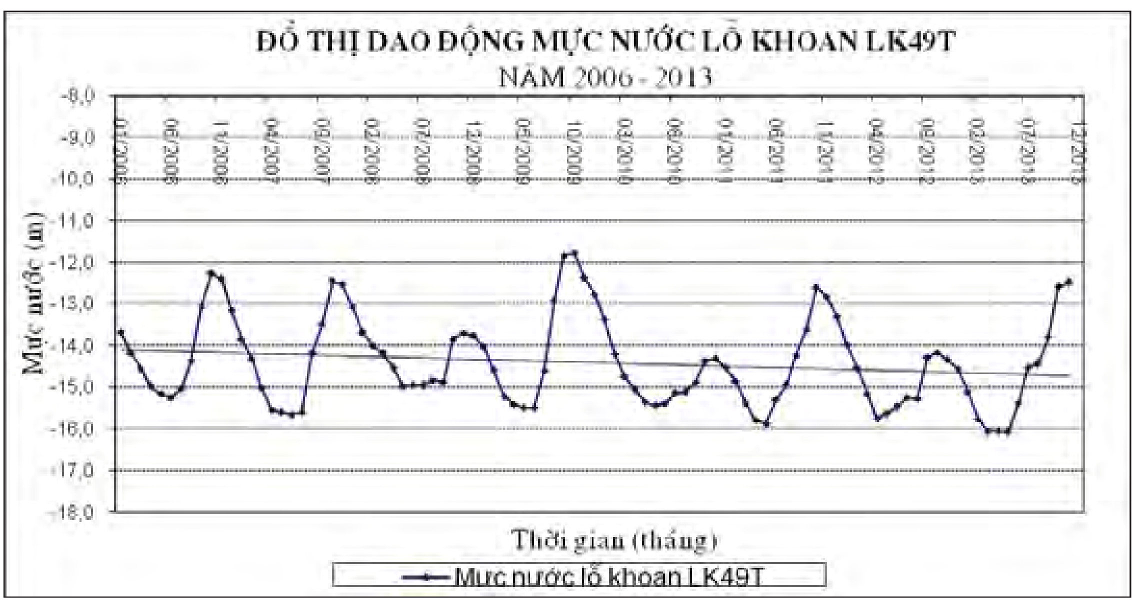


Fig. 13. Water level fluctuation in Hoa Thang – Buon Ma Thuot

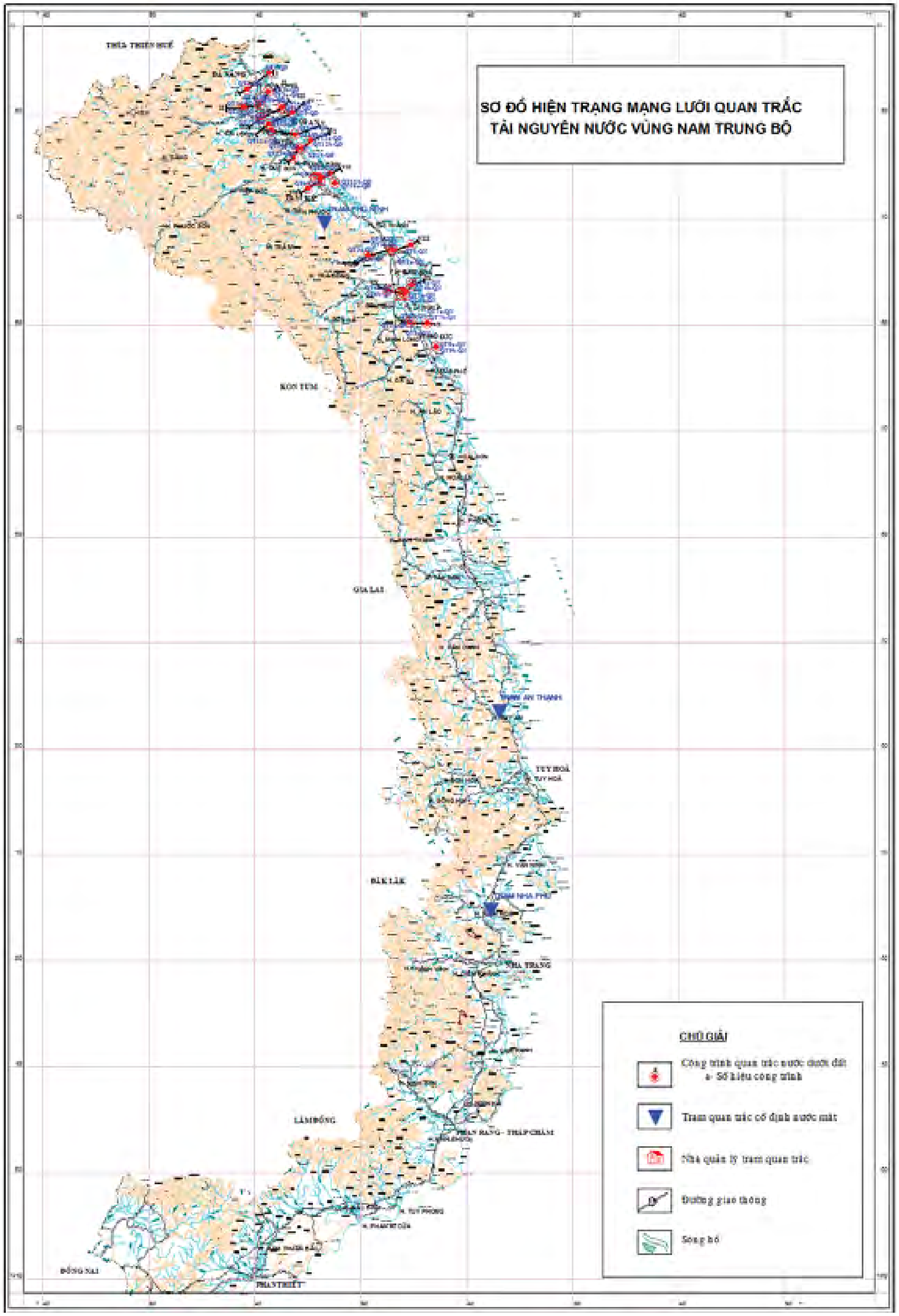


Fig. 14. Water resources monitoring network in South Central Coast

2.3.3. Assessment of groundwater quality in Central Highlands

- *Criteria of Multi-substance samples*: Monitoring results show that the values are lower than QCVN 09:2008 except Iron. There are 4 cases exceeded the standard comprising LK11T in Mang Yang, Ayun Pa - Gia Lai; Krong Pac, Dak Lak; Bao Lam, Lam Dong.

- *Criteria of Nitrogen compounds*: Monitoring results show that most of the works are being exceeded this criteria, except DL10, DL11, LK165T and LK160T.

- *Criteria of Micro substance*: Monitoring results show that most of the criteria have lower content than standard, excepting works of C11am1 (Le Loi Ward, Kon Tum District, Kon Tum) with Mn slightly exceeding standard (0.713 mg/l compared with standard-based 0.5 mg/l).

2.4. South Central Coast

2.4.1. Current situation of the network

Total number of groundwater monitoring stations in South Central Coast regions is 46, set in two area comprising Quang Nam - Da Nang and Quang Ngai, all the stations are installed automatic measurements (**Fig. 14**).

The entire monitoring stations in the South Central Coast region is allocated in 10 alignments perpendicular to the shore line, each has 2 to 4 monitoring points allocated in 2 plains consisting of Quang Nam (7 alignments, from I to VII) and Quang Ngai (3 alignments, from VIII to X). For locations having narrow horizontal plain, single point is set.

2.4.2. Assessment of groundwater change in South Central Coast

General trend of water level fluctuation in Quang Nam - Da Nang is seasonal variation, having a minimum value around August, and peak around November. Due to shallow groundwater level are (usually about 0.5 ÷ 6m compared with ground level), water level is fairly sensitive to the rain water supply. The water fluctuation shown in the graph (**Fig. 15**) is moderately complex; the line representative for water rise is steeper than the decline (due to flat terrain, groundwater drainage process is slower).

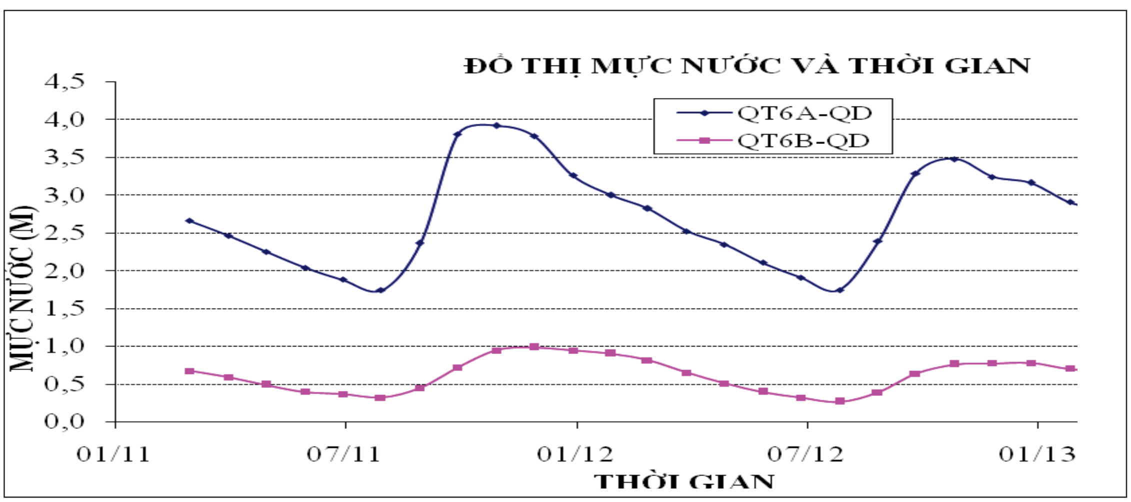


Fig. 15. Seasonal water level fluctuation in Dien Duong, Dien Ban, Quang Nam

General trend of water level fluctuation in Quang Ngai area is seasonal variation, obtaining a minimum value around June and peak around November. Due to shallow groundwater level (usually around 0.5 ÷ 6 m compared with the ground), water level is moderately sensitive to rain water supply, and water fluctuation shown in graph is fairly complex, especially in the rainy season (**Fig. 16**).

Margin of water level fluctuation is about 1 ÷ 3 m, depending on gradually declining topography from the sea inwards.

2.4.3. Assessment of groundwater quality change in South Central Coast

(1) Holocen qh aquifer

- Criteria of Multi-substance samples: 22 stations are monitored each season; monitoring results show that the majority of these samples are within the allowable limitation (QCVN09).

- Criteria of Nitrogen compounds: 22 stations are monitored each season; monitoring results show that the majority of these samples are within the allowable standard, excepting cases: QT6a-QD, QT11a-QD, QT4a-QN, QT9a-QN (dry season); QT8a-QD (rainy season).

- Criteria of Micro substance: 22 stations are monitored each season; monitoring results show that the majority of these samples are within the allowable threshold, excepting only 1 case exceeding Mn standard in dry season is QT11a-QD (0.656 mg/l compared with standard-based value 0.5000 mg/l).

(2) Holocen qp quifer

- Criteria of Multi-substance samples: 15 stations are monitored each season; the majority of these samples are within standard.

- Criteria of Nitrogen compounds: 15 stations are monitored each season; the majority of these samples are within standard.

- Criteria of Micro substance: 15 stations are monitored each season; the majority of these

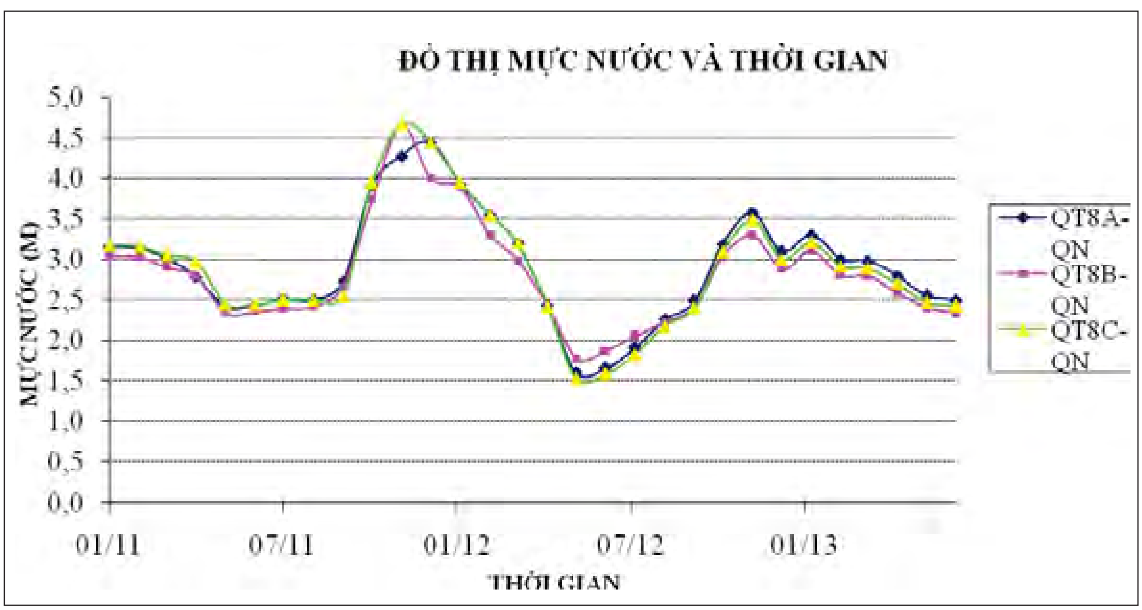


Fig. 16. Water level in Dien Duong, Dien Ban, Quang Nam

samples are within standard, excepting only 1 case exceeding Mn standard in dry season is QT6b-QN (0.898 mg/l compared with standard-based value 0,5000 mg/l).

(3) Fractures aquifer, aged Neogene (n), origined wetland and lake's sediments

- Criteria of Multi-substance samples: 5 stations are monitored each season; only QT6b-QD has Cl^- criterion exceeding standard in both seasons.

- Criteria of Nitrogen compounds: 5 stations are monitored each season; 2/5 stations having exceeding criteria are QT7b-QD with NO_3^- beyond standard in both seasons and QT6b-QD with NO_2^- beyond standard in rainy season.

- Criteria of Micro substance: 5 stations are monitored each season; all the stations have criteria within allowable QCVN 09:2008 standard.

2.5. Southern region

2.5.1. Current situation of the network

Existing water resources monitoring network in Southern region comprises mainly groundwater monitoring stations with 220 works of 86 stations allocated in 17/19 Southern cities and provinces (except Tien Giang and Ba Ria - Vung Tau). The monitoring points are designed to create 5 alignments perpendicular and 4 alignments parallel to main surface water route (Mekong River, Dong Nai River) to control most of the Southern region. The alignments particularly deal with hydraulic relationship between surface water and groundwater in the area between Dau Tieng reservoir and Vam Co Dong River, between Tri An reservoir with Ret stream, N25 Bridge at Kinh Dong and 1 balance yard studying on groundwater recharge avalabilility from rain water for Pleistocene aquifer (**Fig. 17**).

Q099 balance yard located in Pham Van Coi Commune, Cu Chi, Ho Chi Minh City study on groundwater recharge availability from rain water for the Pleistocene aquifer (qp3) in the Northwestern area of HCMC. Stations of Q099 and CT 00R QT monitor rainfall, the five remaining are set in the form of an envelope (02C in the middle, 4CT 02A, 02B, 02C and 02d at 4 corners) with a distance of approximately 2km.

2.5.2. Assessment of groundwater change in Southern region

Based on monitoring data from November 2012 to November 2013:

Water level of aquifer fluctuates seasonally under direct or indirect influence of rainfall and surface water system. Typically, water level reached the lowest value in April and May, 2013 and peak in October, November.The monthly average water level of most aquifers is lower than sea level except stations allocated in high terrain of the Southeastern area.

Details of aquifers in Southern area are below:

(1) Water level change in Holocen aquifer (qh):

water level is seasonally fluctuated due to the direct influence of Southern meteorological factors and many others (lowland and coastal areas) are influenced by tidal impacts of the South China Sea, West Sea. Average monthly water level of the aquifer is -3.11 m (Southeastern region) and -1.82 m (Southwestern region). Water level has the rising trend in Soc Trang, Binh Minh (Vinh Long) and Can Gio (HCM City); downward trend in Binh Chanh (HCMC), Thanh Hoa (Long An), Tan Chau (An Giang). The growth of groundwater level can result of harvesting water from rainfall or surface water recharge. The reduction of

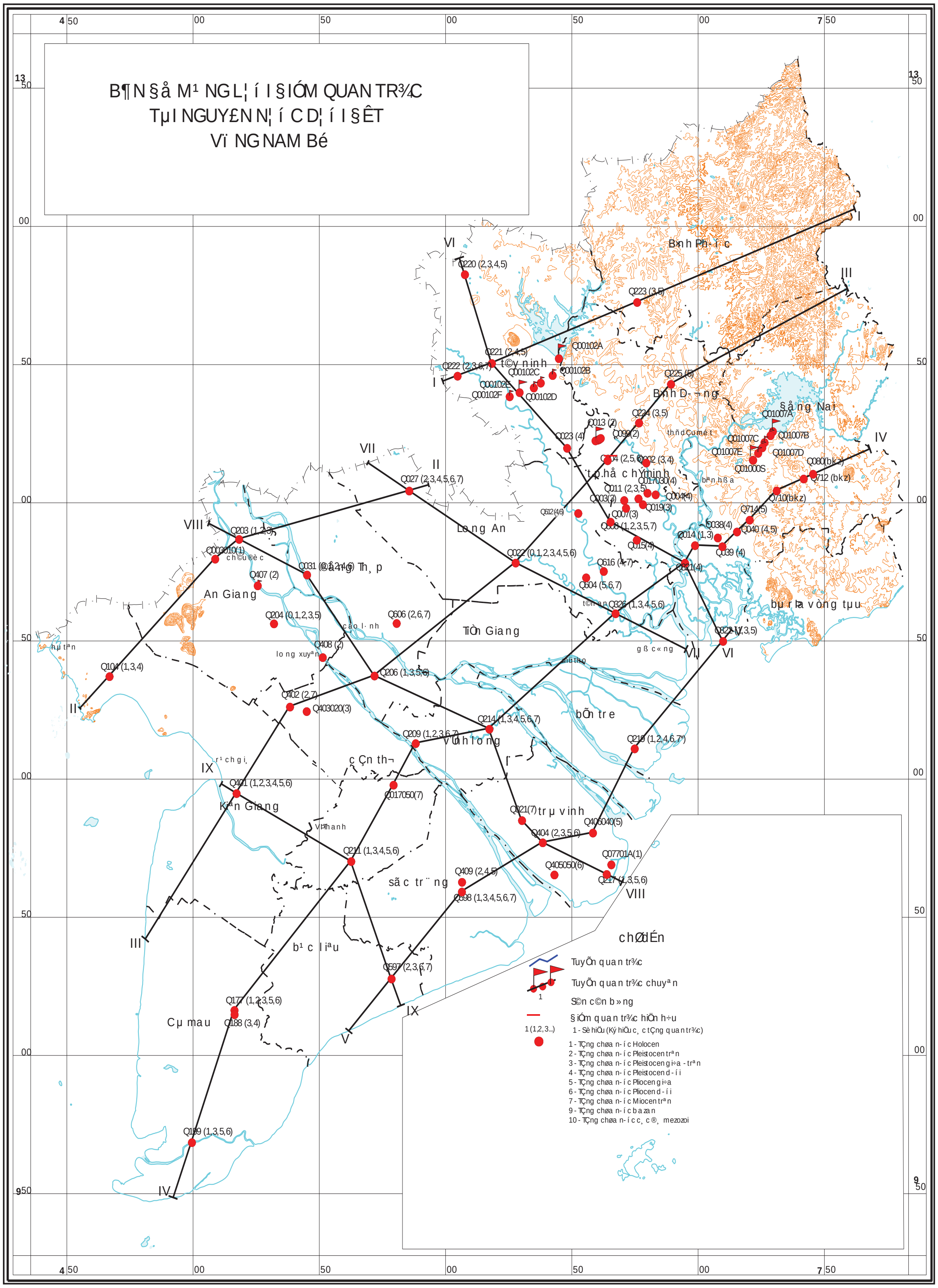
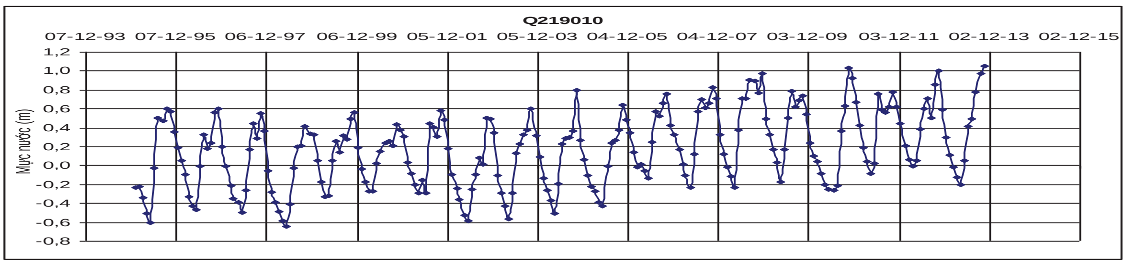


Fig. 17. Groundwater monitoring network in Southern region

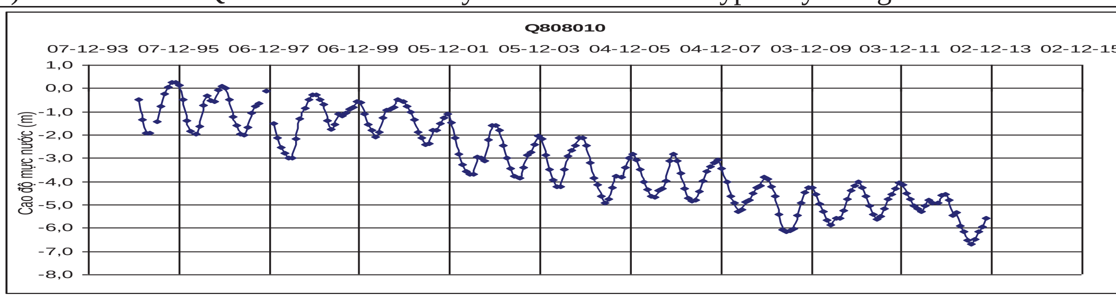
water level can be influenced directly or indirectly by extraction of groundwater. It is essential to gain attention on the decline of water level in Le Minh Xuan, Binh Chanh, HCMC; the decrease is 0.65m in 2013, significantly increased when compared with 0.27/year (annually) (**Fig. 18**).

(2) Water level change in Pleistocen aquifer - upper (qp_3):

Water level is seasonally fluctuated under direct influence of meteorological factors; in Southwestern region, water level also fluctuates due to direct or indirect influence of the tide. Average monthly water level of the aquifer is -3.88 m in the Southeast and -4.70 in the Southwest.



a) Water level in Q219010 is seasonally fluctuated and has typically rising trend



b) Water level in Q808010 is seasonally fluctuated and has typically decline trend

Fig. 18. Water level change with typical rise / decline of qh aquifer

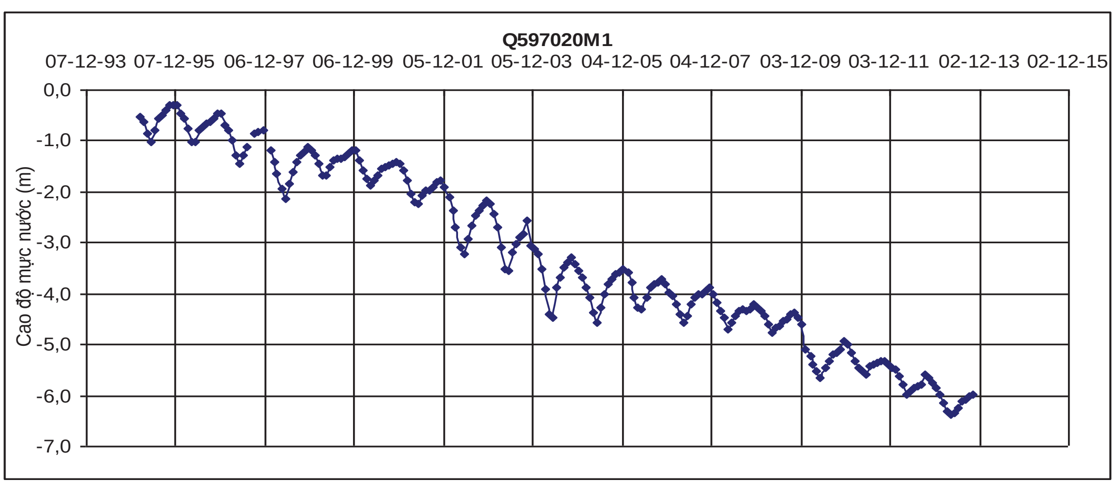
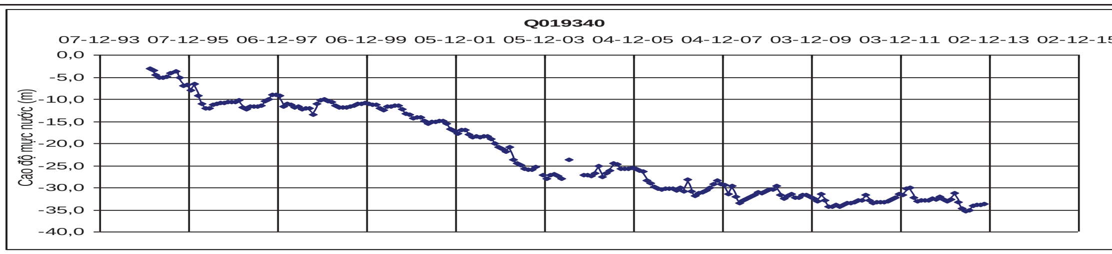


Fig. 19. Decline trend of typical water level in Q597020M1, qp_3 aquifer

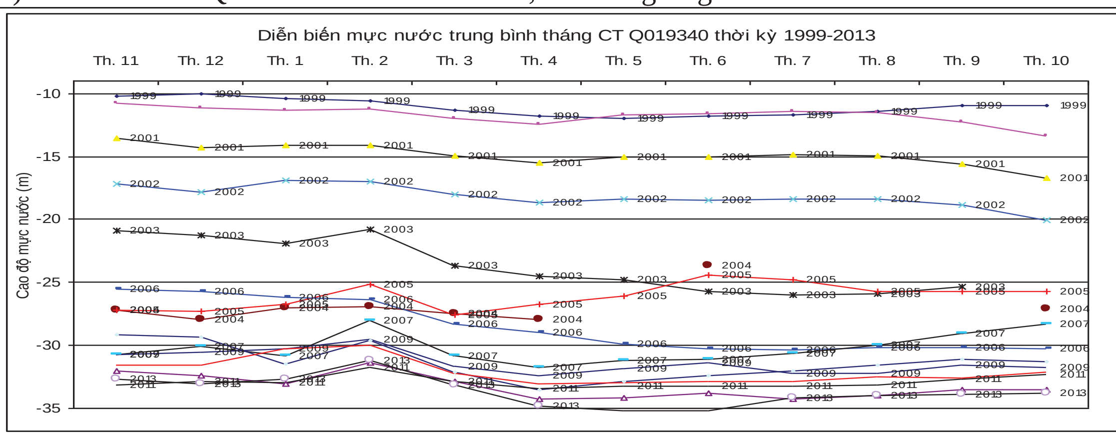
Difference between water level monitored in 4/2013 and the same period last year is from 0.33 to -2.99 m (at SE) and from 1.30 to -0.65 m (at SW). Decline trend occurs mainly in the Southwest; the typicalness is continuous decrease in Bac Lieu City (**Fig. 19**) and Vinh Thanh (Can Tho) due to groundwater overexploitation at the locals of these areas. Decline speed of 10 year average in the Southwest is 0.18 m/year; the largest value is 0.40 m/year (Q402040 in Thanh Vinh, Can Tho).

(3) Water level change in Pleistocen aquifer - middle, upper ($qp_{2\text{-}3}$):

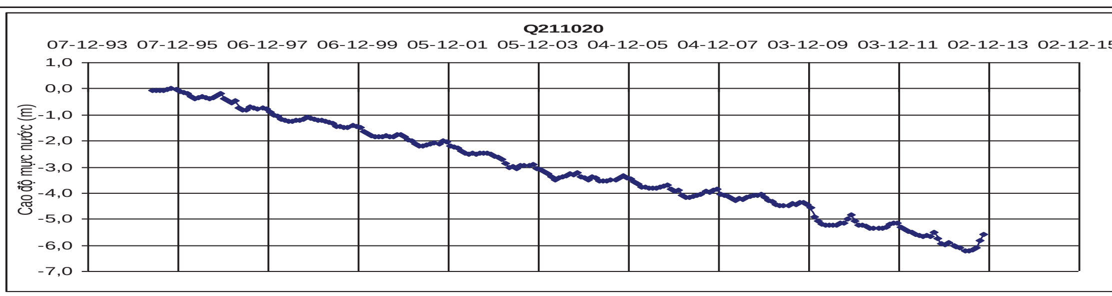
In the Southeast and high terrain regions, water level is seasonally fluctuated under the direct influence of meteorological factors; in the Southwest and lowland region, water level is fluctualed due to tide and season with smaller amplitude under indirect effects of meteorological factors. Average monthly water level is -9.42 m (at SE) and -7.37 m (at SW).



a) Water level in Q019340 has decline trend, but being stagnated since 2007



b) Annual average monthly water level in period of 1999-2013 in Q019340 shows a significant decrease of annual water level difference since 2007, compared with period of 1999-2003



c) Water level in Q211020 is seasonally fluctuated and has typically decline trend

Fig. 20. Decline trend of typical water level in $qp_{2\text{-}3}$ aquifer

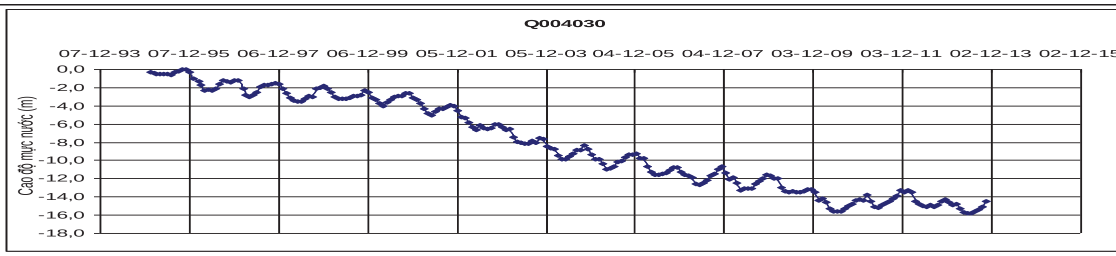
Difference between water level monitored in April and the same period last year is insignificant but some places reach to -1.98m (at SE) and -0.65m (at SW). Downward trend is commonly occuring in the aquifer (**Fig. 20**).

(4) Water level change in Pleistocen aquifer - lower (qp_1):

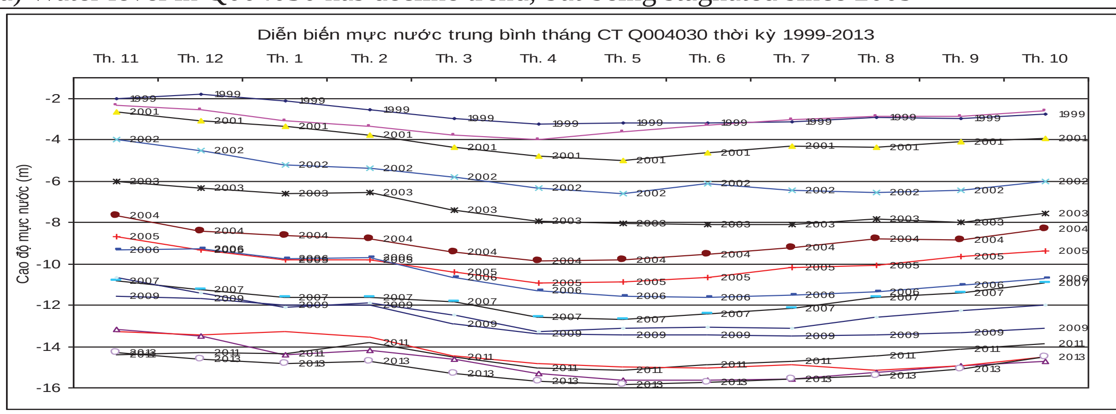
Average monthly water level in 2013 is -10.20 m in the aquifer (in the SE) and -6.41 m (at the SW). Water level in April compared with the same period last year at the SE show 23/24 stations having lower water level, 0.47 m in average. Water level decline is common trend of the aquifer; typically found in Hoc Mon (HCMC), Duc Hoa (Long An) and continuously with increasing decline trend found in Soc Trang City (Soc Trang) (**Fig. 21**).

(5) Water level change in Pleiocen aquifer - middle (n_2^2):

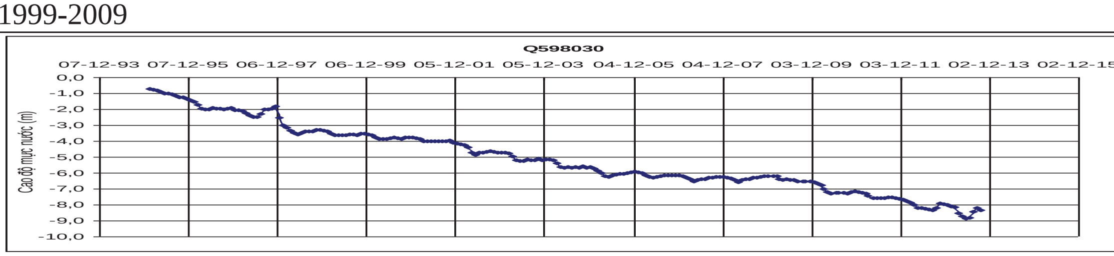
Average monthly water level in 2013 is -9.22 m (at the SE) and -8.91m (at the SW). Water level in April compared with the same period last year in the SE is not significant but some regions are lower than -2.24 m; in the SE, some areas are higher than 0.47, and others are lower than -1.52 m (**Fig. 22**).



a) Water level in Q004030 has decline trend, but being stagnated since 2009



b) Annual average monthly water level in period of 1999-2013 in Q004030 shows a significant decrease of annual water level difference since 2009, compared with period of 1999-2009

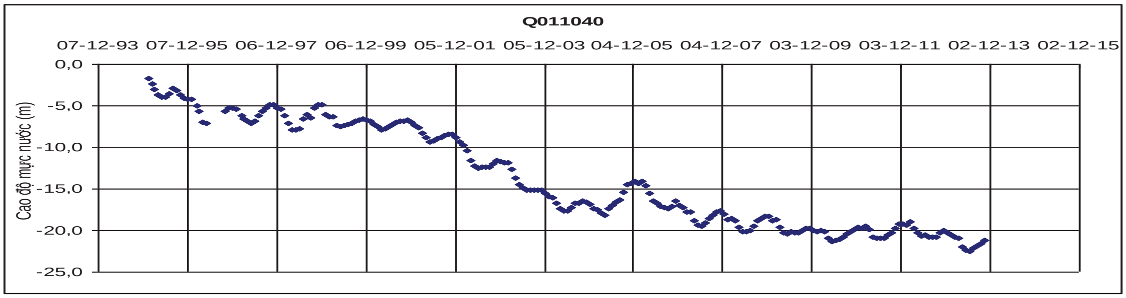


c) Water level in Q598030 has decline trend, and becomes more serious since 2009

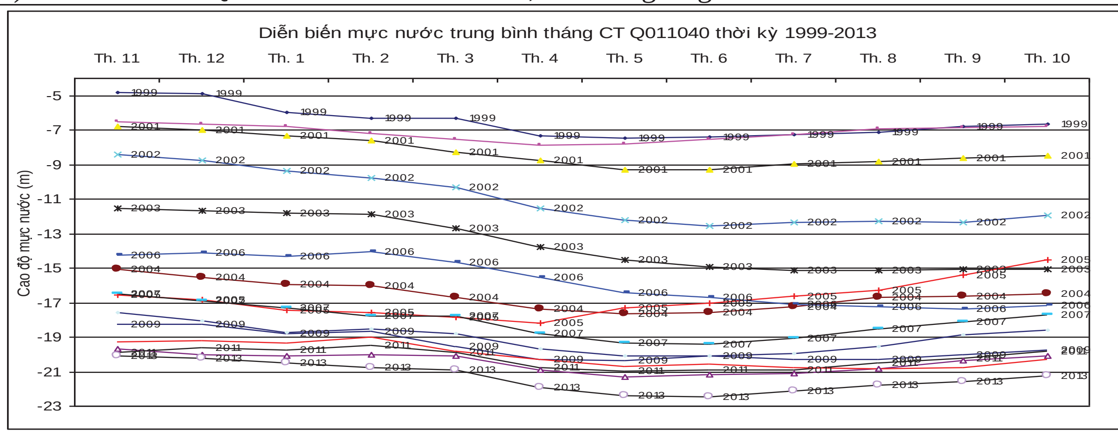
Fig. 21. Decline trend of typical water level in qp_1 aquifer

(6) Water level change in Pleiocen aquifer - lower (n_2^1):

Monthly water level in 2013 of the aquifer is -10,50m (in the SE) and -8,39m (in the SW). Water level monitored in April of both regions is lower than the same period last year; average difference in the SW is -0,42m, and in the SW is -0,62m (**Fig. 23**).



a) Water level in Q011040 has decline trend, but being stagnated since 2009



b) Annual average monthly water level in period of 1999-2013 in Q011040 shows a significant decrease of annual water level difference since 2009, compared with period of 1999-2009

Fig. 22. Decline trend of typical water level in n_2^2 aquifer

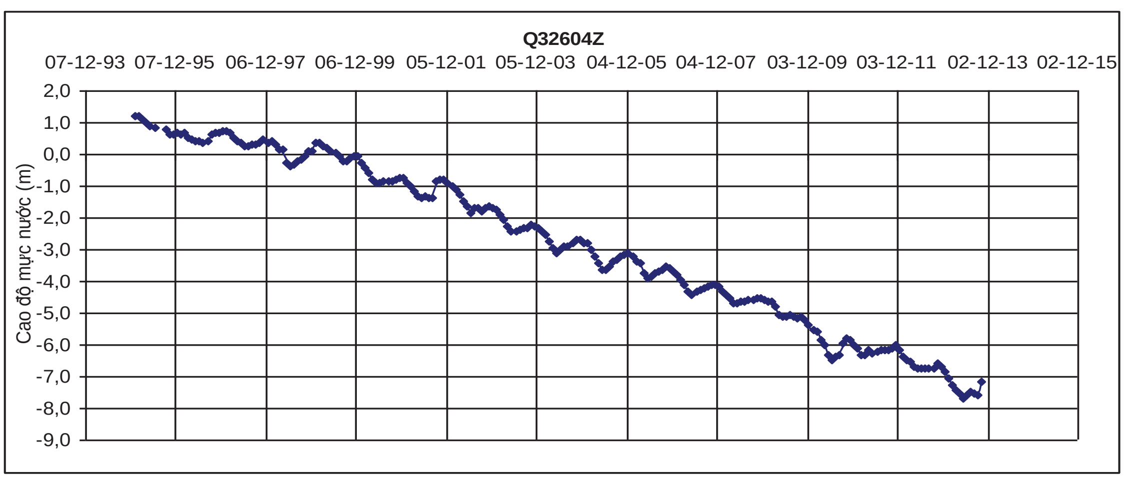


Fig. 23. Decline trend of typical water level in n_2^1 aquifer

(7) Water level change in Pleistocen aquifer (n_1^3):

Monthly water level in 2013 of the aquifer is -13,86m (in the SE) and -9,27m (in the SW). Water level monitored in April of both regions is lower than the same period last year; average difference in the SW is -2,06m, and in the SW is -0,65m (**Fig. 24**).

(8) Water level change in fractures aquifer of Mesozoi rock

A comparison carried out between average water level monitored in April, 2013 and the same period last year shows that water level in stations of Q225060 and Q223060 is lower than last period; difference in Q225060 is1.25 m, and in Q223060 is 0.71 m. Water level at the end of the rainy season has recovered sharply higher than last period. This is a fairly rare phenomenon at monitoring stations in the Southern region (**Fig. 25**).

(9) Water level change in fractures - pore aquifer in Kanozoi bazan

There are 9 stations, average monthly water level is from -21,51m (in Q71207ZM1) to -2,87m (in Q710070); absolute elevation of monthly water level is from 53,39m (in Q01007E) to 182,72m (in Q71207T). Maximum water level occurs mainly in October 2013, minimum water level occurs in April, June 2013 (**Fig. 26**).

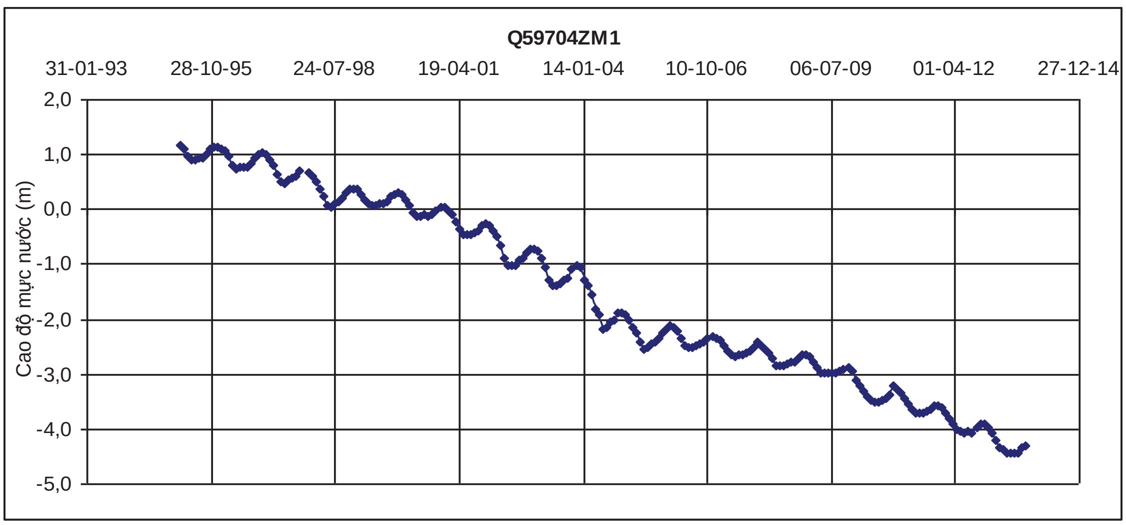


Fig. 24. Decline trend of typical water level in n_1^3 aquifer

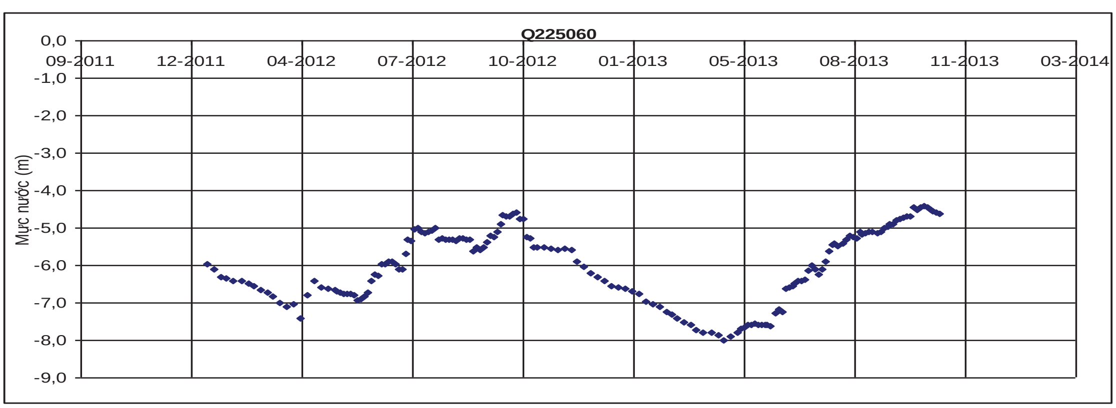


Fig. 25. Water level change from Jan 2012 to Oct 2013 in Q225060

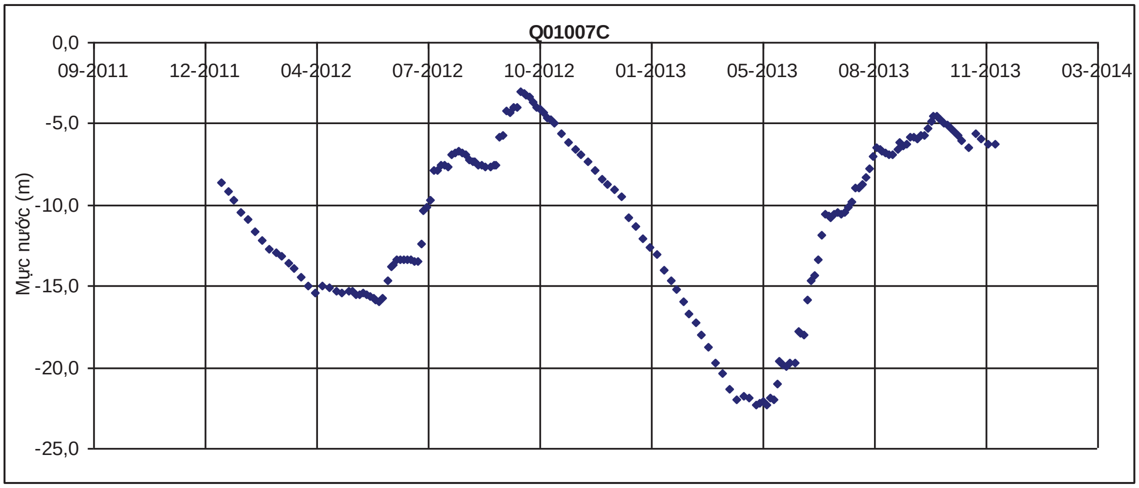


Fig. 26. Water level change from Jan 2012 to Oct 2013 in Q01007C

2.5.3. Assessment of groundwater quality change in Southern region

The current situation of water quality in 7 main aquifers in the Southern regions is evaluated under a comparative basis with QCVN 09:2008 as following:

- Criteria of multi-substance samples comprising 7 indicators: pH, total hardness, total solid, COD , Cl , SO4 , total Fe are exceeded limitation threshold with varying degrees; causes comes from the salty, insipid characteristics of aquifer.

- Criteria of nitrogen compounds are also often exceeded limitation with varying degrees; in which NH4-N, NO2-N in Holocene aquifer has the greatest exceeding gradation. The exceeded level is descending in deeper aquifers. The cause leading to large excess beyond limitation of aquifers distributed near the ground surface is the pollution pending from sources as domestic wastewater, etc.

- Criteria of micro substance comprise 10 indicators: in which 3 most exceeded criteria beyond the limitation are Mn, phenol and F^-; in addition, there is a case of As in Q20302T in qh aquifer positioned in Le Chanh, Tan Chau, An Giang.

3. Conclusion

(1) National Water Resources Monitoring (WRM) network is under management and operation of National Center for Water Resources Planning and Investigation (NAWAPI), allocated in five regions comprising Northern Delta, North Central Plain, Central Highlands, South Central Coast and Southern Region. The network dealing with both surface water resources and groundwater consists of of 710 groundwater stations and 07 surface water stations

(2) Under cooperative framework of Vietnam in the CCOP, Vietnam is always towards the overall objective of the program. In the 3 phases cooperative program, Vietnam is very interested in issues regarding salinization in coastal aquifers; land subsidence due to groundwater exploitation in the cities and provinces of the country as well as capacity building for staffs working in the field of water resources with the above problems.

(3) Regarding to the groundwater resources monitoring in Vietnam, we are looking forward to opening up the cooperation to develop monitoring network into the fresh regions and

implement the modernization of monitoring network to respond data requirements for forecasting, warning of underground water resources.