Reference:
TA-6498 REG: Knowledge and Innovation Support for ADB's Water Finance Program (42384-012)
ADB & Thai DGR/MNRE

Pilot project

"Subsurface Water Storage",

"Harvesting the floods, studied at Nakhon Phanom Province", (SWS)

Applied research
Songkhram and Un river watersheds
Nakhon Phanom Province, Thailand

January 2016

CKI UNESCO-IHE Institute for Water Education Deltares ARCADIS Aveco de Bondt

EXECUTIVE SUMMARY

Introduction

Almost every year Thailand suffers from floods as well as from droughts. As a low-lying coastal region, it is particularly susceptible to floods due to climate change. Many years the floods are followed by periods of serious droughts. The Great Flood of 2011 was in many ways a disaster for the country. Moreover, the well-being of its society and economic prosperity were seriously at stake. Therefore, it became obvious that a sustainable approach would be required, really resulting in reduced risk and occurrence of both floods and droughts. Once sufficiently aware of the relation between floods and droughts, or about the relation between land and water, extra attention should be paid to keep a part of the monsoon water (as main cause of superfluous water volumes that require run-off to lakes and seas) where it precipitates for availability, supply and use in the following periods, particularly the hot and dry periods. Based on this insight of keeping the water instead of wasting it, water storage came to the fore, particularly storing water in the subsurface, in shallow and deep aquifers. Simultaneously, this subsurface water storage may incline the groundwater table. In some parts of Thailand, a land subsidence is due to a rapidly declining groundwater table. For the same reason, farmers are extracting groundwater from deeper and deeper aquifers, which is economically and environmentally undesirable.

To investigate opportunities for a sustainable subsurface water storage, a pilot research project was studied at the province of Nakhon Phanom, particularly to two catchment areas of the watershed of the combined Un and Songkhram rivers in the north of that Thai province as well as adjacent Sakon Nakhon province. The attention paid to in this SWS pilot project includes both hydro-geological, geographical, land use planning, and institutional applied research. While many preparations of this project dated back to December 2011, directly after the Great Flood, the fieldwork research has been executed in the course of September and in December 2015.

Major reasons to select Nakhon Phanom Province for application of this SWS pilot project concern amongst others: (a) the availability of new, 2014 published, geologic and hydrogeological maps and data, (b) the Province is located adjacent to the Khong River, (c) probably comparable circumstances at other side of the Khong River in Lao PDR, and therewith relevant to the workings of the Khong River Committee, (d) Nakhon Phanom has faced both floods and droughts several years, (e) the Province was seen as suitable for a SWS model approach, and (f) the Province is becoming part of an Economic Zone in future.

Findings

Within the possible extent of this pilot project, main attention has been paid to two sections of the two catchment areas belonging to the Un/Songkhram watershed system. In principle, the attention paid concerned primarily the Nakhon Phanom province. However, the section studied in the Un river catchment is situated in Sakon Nakhon province, adjacent to Nakhon Phanom, and seen its hydrogeological stratification and subsurface (aquifers) and surface (available sites) characteristics particularly relevant to Nakhon Phanom province.

In case of the Songkhram river section studied, subsurface characteristics observed may strongly contribute to the pilot project main objectives. In the subsurface of the adjacent areas aquifers are available that have adequate porosity, permeability, transmissivity, and conductivity to function effectively for subsurface water storage and inclining the overall groundwater table.

The study also disclosed serious shortcomings regarding the quality of a rather large part of available data and databases of boreholes. Although the number of boreholes is rather large, lithology stratification and soil quality information is absent in majority, partly databases include mistakes making them not useful for refined hydrogeological and technical decision making for SWS.

During the study in Nakhon Phanom province, simultaneously extensive attention has been paid to the integrative land & water development workings. This concerns cooperation between soil qualities, land use and land use planning on the one hand, and on the other hand, surface and subsurface (ground-) water resources management. This particular study part underlines a difficult problem which relates mainly to the limited quality and effectiveness of land use plans in order to support water resources management as well as to provide necessary directions and protections.

Outcomes

The Songkhram river section offers a useful drainage potential in the shallow aquifer. However, a serious constraint requires attention. For all, the shallow aquifer(s) are vulnerable. They may certainly have a potential for pollution and/or contamination.

In contrast, the Un river offers deep aquifers suitable for drainage and transmissivity. They offer probably, seen the stratification and layer materials, a better development option.

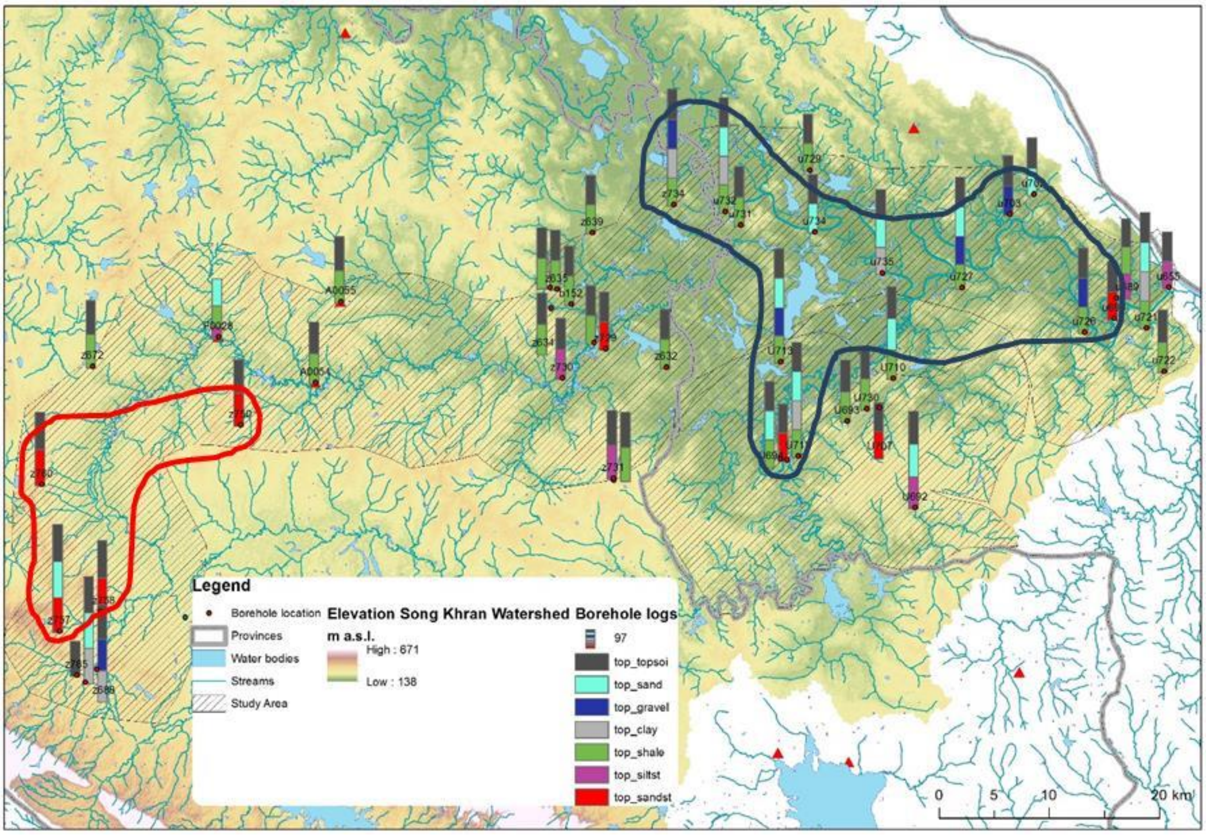

Figure 1.1 (repeat of 5.11.): The borehole logs are here shown as bar stack of different colours according to the lithology. The Gravels (blue) and Sandstones (red) are the most porous media found in these logs and therefore are the most suitable for artificial recharge. The thick Blue line identifies the downstream potential areas, while the Red thick line identifies the upstream potential areas.

Nevertheless, in both cases, further analysis in practice is required first, to extra justify these findings, and to see if the aquifers indeed suit for SWS.

Further study and according findings in conclusion necessitate protection and directions in land use and land use limitations, through and fixed in suitable and for that purpose adequate land use plans. Plans that allow effective control, monitoring when and where needed enforcement to reach its targets not violated. It is obvious from the explained and reasoned limitations and even weaknesses of applied land use plans, that a long way is to go. Long way or not, land use planning improvements are a prerequisite, particularly for a final outcome towards a multi-level integrated land & water (resources planning and management, in favour of flood and drought risk reduction.
An obviously observed need concerns strengthening of data and database management capacity, through tailor-made training programmes. This training should preferably also pay attention to related project management issues.

Results
The main result of this SWS pilot study project is the support it delivers to the ideas fixed in the project's objectives. That is, aquifers are available in the study area. The identified aquifers are (probably) suitable for gravitational drainage, aquifer recharge and have sufficient transmissivity and velocity to move and to spread aquifer stored groundwater. Those aquifers relate to land surface sites suitable to allocate and to apply as gravitation water storage bodies.
In this context, suitability refers to adequate and effective SWS qualities (porosity, permeability and conductivity, transmissivity), while availability refers to land property (ownership) and existing and/or planned land uses, as well as constraints they cause.

Recommendations

(a) In general for subsurface water storage approach
Creation of various drainage water storage (retention) bodies along the rivers and their tributaries at sites that may, after excavation of the (clay) top layer support gravitation of stored water into the subsurface aquifers which have sufficient porosity, permeability and conductivity. The most suitable sites are indicated in the concerned map images. It is obvious that this system of superfluous water delivery through precipitation and rivers into drainage water storage bodies for drainage/percolation requires spatial preparations by land use development and planning. Resulting land use plans need to allocate, express and fix these land usages, preferably with regulations that offer opportunities to control, monitor and enforce.

(b) In particular for subsurface water storage approach
For the sake of further comparable subsurface water storage applied research, the compilation and production of a manual for application of such work is desirable, particularly for the overall preparations to guarantee the availability of all required information as well as the involvement and cooperation of all necessary (governmental) departments and sections.

For a (more) suitable availability of required hydrogeological, geographical, land use planning and institutional data, a strengthened and more integrated database management would benefit and improve the outcome of applied SWS research in the future. It may also reduce the currently faced fragmentation of data sources and database systems.

Aware of the crucial role of borehole data in hydrogeological research for SWS, a drastic improvement of the database management approach of borehole data is needed. This concerns extension of stored data items, the recognisable quality and sources of boreholes, the areal spread and density of the drilling points, and an elaborated government directive on data delivering to DMR Department of Mineral Resources) and/or DGR (Department of Groundwater Resources) for each subsurface penetration.

In line with the compilation of such a handbook for applied SWS research and the improvement of connected hydrogeological, database management, tailor-made training of DGR staff members for the sake of capacity strengthening and capacity building in the DGR organisation is desirable. It would provide a useful basis for further SWS applied research in other areas within the Kingdom of Thailand, where floods and droughts should also be sustainably reduced.

(c) Specifics for SWS based on currently and possibly in future applied approach and strategy

The pilot SWS project brought a variety of rather detailed recommendations justified to be mentioned in this report. They are included in this report in section Recommendations. They can be seen as specifications and elaborations of the above in general and in particular stated recommendations.

Relevance

The study, although a stand-alone activity, obviously contributes indirectly to Thailand's ongoing Integrated Water and Flood Management. Moreover, it is also obvious that the results of this SWS research provide added value to ADB's overall water sector work with a sound opportunity to scale up the approach and to apply it to various locations in Thailand as well as in other Asian countries.

Cooperation

This applied SWS pilot project in the Songkhram and Un river watersheds, in the Nakhon Phanom Province in Thailand, concerns a tight cooperation between (staff of) the Thai Department of Groundwater Resources (DGR) and the Nakhon Phanom Provincial office of Public Works and Town & Country Planning on the one hand, and, on the other hand, the Dutch team of experts and their organisations, embracing *knowledge institutes*, notably: Compuplan Knowledge Institute of Applied geo-Informatics (CKI, in Cuijk), UNESCO-IHE Institute of Water Education (in Delft) and DELTARES (in Delft), as well as *engineering companies*, notably: ARCADIS (in Amsterdam) and Aveco De Bondt (in Amersfoort).

The execution of this SWS project has mainly been financed by a grant of the Asian Development Bank (ADB), within its framework of **TA-6498 REG: Knowledge and Innovation Support for ADB's Water Finance Program (42384-012)**.

ACKNOWLEDGEMENT

This report and research on SWS subsurface water storage in Nakhon Phanom province would not have been realised if not so much support delivered by many people from a manifold of Thai national and international organisations. It is for their help and input that the Dutch expert team wants to thank and acknowledge here, in alphabetic sequence:

ADB	Mr. Yasushi Negishi, Mr. Pavit Ramachandran, and Dr. Luxmon Attapich
DGR	Mr. Sumrit Chusanatas, former deputy Director-general
	Dr. Aranya Fuangswasdi, current Deputy Director-general and staff members:
	Mr. Mahippong Worakul, Dr. Alin Chintraruck,
	Ms. Punyawee Intaraksa, Dr. Warangkana Larbkich,
	Ms. Jurarud Yanawongsa, Mr. Patsakorn Assiri,
	Mr. Narong Wannam, Mr. Sombon Puangkasorn,
	Ms. Natchanok Ounping, Ms. Pornusa Udomsilpa,
DWR	for the intiative (SWS) seminars (Dec 2011, Jan 2012)
	Ms. Sukontha Aekaraj, former director of Foreign Affairs Bureau ,
	Ms. Kobkul Rungsiaroy, Policy and Planning Expert,
	Mr. Saravuth Cheevaprasert, director of Policy and Planning Division
DPT	Mr. Mahesuan Pakdeekong, Deputy Director-general
	Dr. Thongchai Roachanakanan, Acting Expert on Architectural Planning Comprehensive and Specific Planning Bureau
Dutch Embassy	Mr. Joan Boer, previous ambassador
	Mr. Karel Hartogh, current ambassador and Ms. Peggy Vissers, former head of Economic Affairs
KPI	Secretary-general Assoc. prof. Woothisarn Tanchai
MNRE	Mr. Chode Trachu, former Permanent-secretary
Nakhon Phanom	CPO:
	Mr. Wijit Ngamchuen, Mr. Tanakorn Wanna and also for the during fieldwork offered hospitality of CPO
	DLD branch in Nakhon Phanom: for soil data delivering,
	Mr. Kriengkrai Imsumpoch, and Mr. Chaiyuck U-thapaset
	DDPM branch in Nakhon Phanom: for explanation about floods in the province
Si Songkhram	Ms. Nawarat Lijuan, Municipal Clerk of Si Songkhram sub-district,

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   Hydrogeological and geological investigation
6. Research activity B. LAND USE PLANNING, PLAN "NING" FOR EFFECTIVE (GROUND-) WATER MANAGEMENT.
   Spatial extents of droughts and floods in the context of land use planning
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   Institutional issues, conference, workshops; the research report and to address special related topics
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PART 2: SWS REPORT ANNEXES

Annexes

Topographic names

In this report topographic names have been standardized according to two maps of DGR, notably:

1. Topographic map BAN KHA sheet 5844III
2. Topographic map AMPHOE SI SONGKHRAM sheet 5844II

These concerns: Nakhon Phanom, Amphoe Si Songkhram, Sakon Nakhon, Maenam Khong or Khong River, Un River, and Songkhram River.

PART 1: SWS REPORT

1. INTRODUCTION

The Asian Development Bank (ADB) as a development oriented and financial support organisation is through its regional **Knowledge and Innovation Support for ADB's Water Finance Program** involved in on-going endeavours of various Asian countries in their fights against disastrous flood and drought events, and in pro-active initiatives to tackle these problems now and in future in particular.

In line with this ADB involvement, the Thai Department of Groundwater Resources (DGR) took responsibility in initiating project ideas and consequent compilation of a project proposal, the subsurface storage of a substantial part of monsoon water in order to reduce flood risks for urban areas along major rivers due to the voluminous runoff of river water. Subsurface water storage embraces incline of the groundwater table as well as delivering of (percolating, gravitational drainage) water into deep aquifer layers. As such, two targets have to be achieved, that is (a) reduction of flood water, harvested so to say, and (b) a possible reduction of drought risks because the water is not wasted (not totally discharged to the sea) and therewith available once needed.

Challenges include managing the water discharge during floods, retaining sufficient water to cover water demands, expanding access to appropriate infiltration techniques and identifying appropriate locations. Research and pilots are needed to further explore potential applications.

The overall objective of the current "Subsurface Water Storage, harvesting the floods" (SWS) study is to contribute to a sustainable and safe water system in Thailand, notably prevention and mitigation of water related disasters in Thailand caused by both droughts and floods. Specific objectives are:

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- **Hydrogeology**: to provide alternative way for balancing groundwater level;
- **Land use Planning**: to provide guidance to spatial developments for mitigating flood and drought risks.

Together these specific objectives underline the overall need of a Multi-level Integrated Land & Water Resources Planning and Management, a framework to integrate land use and surface and subsurface (ground-) water, to cooperate through the responsible organisations, and to defragment mandates of different governmental departments working in (sections of) Land & Water Management.

The pilot project site is the province of Nakhon Phanom and the Un/Songkhram watershed adjacent to the Maenam Khong (Basin). The focus of this project concerns three units of research activities, notably:

1. Research activity A. HYDROGEOLOGICAL CHARACTERISTICS OF THE NAKHON PHANOM PROVINCE AND SURROUNDINGS
   Hydrogeological and geological investigation
2. Research activity B. LAND USE PLANNING, PLAN "NING" FOR EFFECTIVE (GROUND-) WATER MANAGEMENT.
   Spatial extents of droughts and floods in the context of land use planning
3. Research activity C. INSTITUTIONAL
   Institutional issues, conference , workshops; the research report and to address special related topics

As part of research activity C, this project report considers some social and economic implications for the target area. Moreover, during the workshops, extra attention is paid to institutional framework implications of the various proposed SWS solutions possibly to be applied in Nakhon Phanom.

Major reasons to select Nakhon Phanom Province for application of this SWS pilot project concern amongst others: (a) the availability of new, 2014 published, geologic and hydrogeological maps and data, (b) the Province is located adjacent the Khong River, (c) probably comparable circumstances at other side of the Khong River in Lao PDR, and therewith relevant to the workings of the Khong River Committee, (d) Nakhon Phanom has faced both floods and droughts several years, (e) the Province was seen as suitable for a SWS model approach, and (f) the Province is becoming part of an Economic Zone in future.

The project is executed in tight cooperation between DGR, DPT, Nakhon Phanom stakeholders, and various Dutch land use planning, geography, water and (hydro-) geology experts.

2. KEEP THE WATER, DON'T WASTE IT

In 2011, Thailand faced its great flood, a deluge inundating 2/3 of northern part of the country, with an ultimate risk of total inundation of the capital city Bangkok.

In 2011/12, together with the Department of Water Resources (DWR), CKI initiated two seminars. Although the topic of the seminars was flood reduction, the proposed approach was a bit different compared to the overall publicly and professionally uttered solution to reduce flood risk through by-passes, high speed channels and Room for the river, all of them to discharge fast and safe the voluminous run-off of Thailand's main rivers, especially during the monsoon periods. In general the slogan was "Keep the water, do not waste it", in particular special attention was requested to pay to storage of a part of the voluminous monsoon water, at precipitation locations, into the subsurface deeper situated aquifers. Later-on, aware of the rapid decline of the groundwater table in extensive areas (Arlai et al., 2010; DGR 2011, 2012), a reduction of drought risk had been added to the topic, simultaneously taking into account the water demand of farmers in the dry period following the wet season. The two seminars were attended amongst others by the DGR, Department of Groundwater Resources.

In 2013, representatives of UNESCO-IHE, Arcadis, Deltares, Aveco De Bondt and CKI discussed this topic and approach, aware that subsurface water storage, into aquifers, is not a simple issue, requiring serious study and fieldwork.

In April 2014, with the aid of the Dutch Embassy staff, venue the Embassy, a next meeting was organized to discuss that proposal with the Thai involved departments. This meeting was attended by Embassy staff, Department of Groundwater Resources (DGR), Department of Public Works and Town & Country Planning (DPT), Nakhon Phanom Provincial (Changwat) Planning Office (CPO), King Prajadhipok's Institute (KPI), International Union for the Conservation of Nature, Bangkok branch (IUCN), Asian Development Bank, Bangkok branch (ADB), and CKI. Outcome of the meeting, after presentations, explanations and discussion, a decision of DGR to submit a proposal to the ADB, and therewith to take the lead of the project at the Thai side.

3. CONTRIBUTION TO REDUCE FLOOD AND DROUGHT RISKS

In September 2014, ADB accepted the proposal and approved it with some slight adaptations. In February 2015, the project start could be fixed, that is preparations in Nakhon Phanom in July and research and fieldwork in the selected catchment areas of the northern watershed of the Un and Songkhram rivers in the course of September 20th – 26th, 2015.

This report of the research with findings, results and recommendations has been compiled (in draft) as an outcome of the September fieldwork activities (see Figure 3.1. during sightseeing). After the rounding of the project during conference, brainstorm session and information workshops (26 - 27 November 2015), the report has been completed, taking into account remarks of DGR staff after reading the draft.

Figure 3.1.: Water collect tower of DGR at a groundwater extraction well site

The draft report became basic information for the extended Thai and Dutch team executing fieldwork in the Nakhon Phanom Province in the course of November. While, from the Dutch side, the September workings were done by CKI and UNESCO-IHE. On 22nd – 25th November 2015, the Dutch team became extended with experts coming from DELTARES, ARCADIS and Aveco De Bondt.

All fieldwork visits were cooperative activities between DGR and the Dutch experts. During each visit, DGR added a substantial staff representation, guaranteeing that both required information would be as much as possible available and accessible, and, any language barrier problem would be avoided through the aid of well English speaking Thai staff members.

The draft project report and the extra findings during the November fieldwork study were presented at Centara Grand and Bangkok Convention Centre, CentralWorld in Bangkok, on 26th November 2015 (see Figure 3.2). During the conference extensive presentations had been delivered about the SWS topic and backgrounds, approach and fieldwork results, as well as about opportunities to continue the project for sustainability purposes.

Figure 3.2.: Participants of the SWS conference gathered for a joint photo, at the balcony of Central World, 23rd floor, in Bangkok, on 26th November 2015

Finally, during the day after the conference, on the 27th November 2015, a small series of workshops were provided by the Dutch team on a selection of project relevant topics.

4. MAINLINES APPLIED SUBSURFACE WATER STORAGE RESEARCH IN NAKHON PHANOM PROVINCE

The applied research on subsurface water storage embraces the following three main research sections, notably:

A. hydrogeological and geological investigation
B. spatial extents of drought and floods in the context of land use planning
C. institutional issues, conference and workshops to present the research report and to address special related topics.

In the submitted proposal these sections have been described as follows:

Research activities A
This activity focuses on the geological, hydrological, geo-hydrological and geochemical aspects of the study area and will answer questions related to:

- Presence of aquifers, and, of subsurface cavities (karst);
- Stratification and subsurface composition;
- Presence of contamination.

The outputs of research activity A are:

- data and maps characterising water bodies system in the selected watershed area;
- data on geological and hydrogeological characteristics of the subsurface;
- data on subsurface layers qualities, available aquifers, groundwater table in historical perspective.

Research activity B
This activity analyses the causes and spatial extent of flood and drought impacts, through the following specific activities:

- Analyses the yearly flood and dry/drought cycles;
- Characterise the water demands for agriculture, industry;
- Compile land & water integrated balanced specifications for spatial planning;
- Map the affected areas, in terms of land uses and occupations.

The outputs of the activity B are:

- Data and maps on topography, land uses and occupancies;
- Information on directions of land & water integration in spatial plan development and regulations;
- Data on yearly flood and dry/drought periods;
- Water demands charts for agriculture, industry, and other uses.

Research Activity C
This activity focuses on the institutional framework, participatory planning and knowledge transfer, through the following activities:

- Baseline assessment of institutional framework, social and economical aspects and stakeholders;
- Identification of technological solutions for subsurface infiltration, and key areas for pilots together with local experts and stakeholders.

The outputs of activity C are:

- Joint organisation and execution of a comprehensive seminar with connected training sessions with focus upon water retention for sustainable drought and flood management
- Presentation of results to all stakeholders
- Preparation to establish agreement on possible application projects in future

The study is carried out following an ‘action research’ methodology, meaning active involvement of local experts and stakeholders during all activities (DGR, DPT, Nakhon Phanom Provincial Authority), in co-operation with invited foreign experts.

Each above mentioned section is addressed in the next three chapters.

5. Research activity A. HYDROGEOLOGICAL CHARACTERISTICS OF THE NAKHOM PHANOM PROVINCE AND SURROUNDINGS

Hydrogeological and geological investigation

In this chapter we zoom in from the large North-East region to the Nakhon Phanom Province and surrounding territories. This approach helps the reader to put the Nakhon Phanom morphology and hydrogeology in a regional framework, as the main characteristics of the two areas are complementary. We start with the description of the Methodology used, and then we describe the Physiography and Geology of the North-East region of Thailand. We address the Physiography of the Un River Basin and Songkhram River Basin (Nakhon Phanom Province and surrounding territories), then we provide an overview of the Hydrogeology of the Nakhon Phanom (Songkhram River basin) and we conclude with our preliminary findings. The study area was part of the Songkhram river basin as show in Figure 5.1.

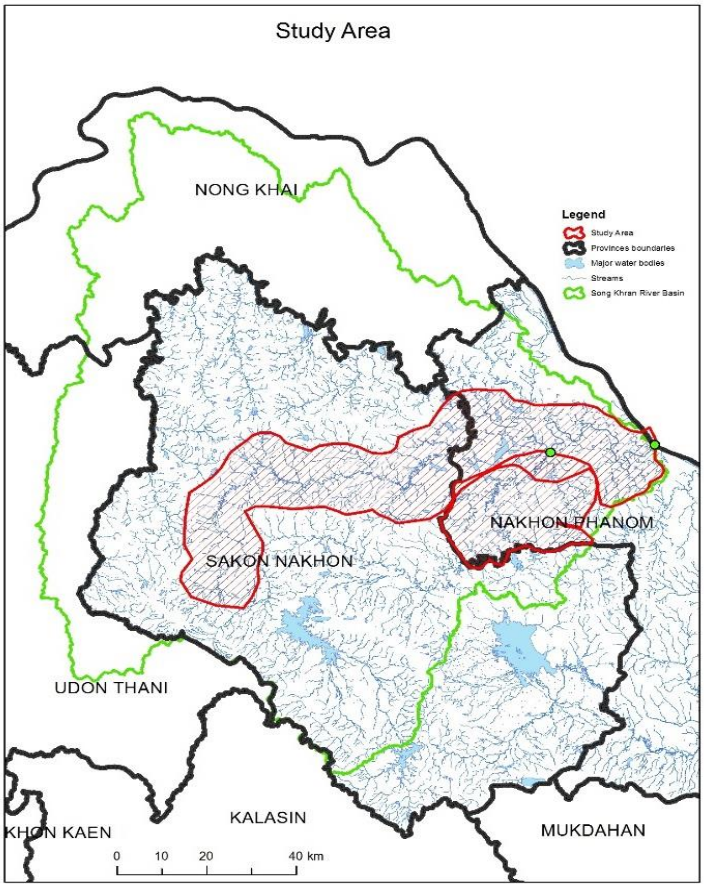


Figure 5.1.: Hydrography and boundaries of the study area. In green colour the whole Songkhram River basin boundaries that extend much further than the Nakhon Phanom and Sakon Nakhon Provinces. The area with the diagonal black lines is the study area. This is represented by the Un River from the border of the Nakhon Phanom Province up to the junction with the Songkhram River and a branch of the Songkhram River itself. The main Songkhram River channel runs along the border between the Sakon Nakhon, the Nong Khai and the Udon Thani Provinces.

1. Methodology

During the development of this project we were able to access the newly released Hydrogeological Map and Groundwater Map of the North-East region of Thailand at the scale of 1:50,000 that constitute a very comprehensive synthesis of the knowledge of the hydrogeology of this region. The mapping has been done by the two private companies GMT Corporation Ltd. and Metrix Associates Co., Ltd on behalf of the Department of Groundwater Resources. The maps consulted for this study were the ones shown in Figure 5.2.

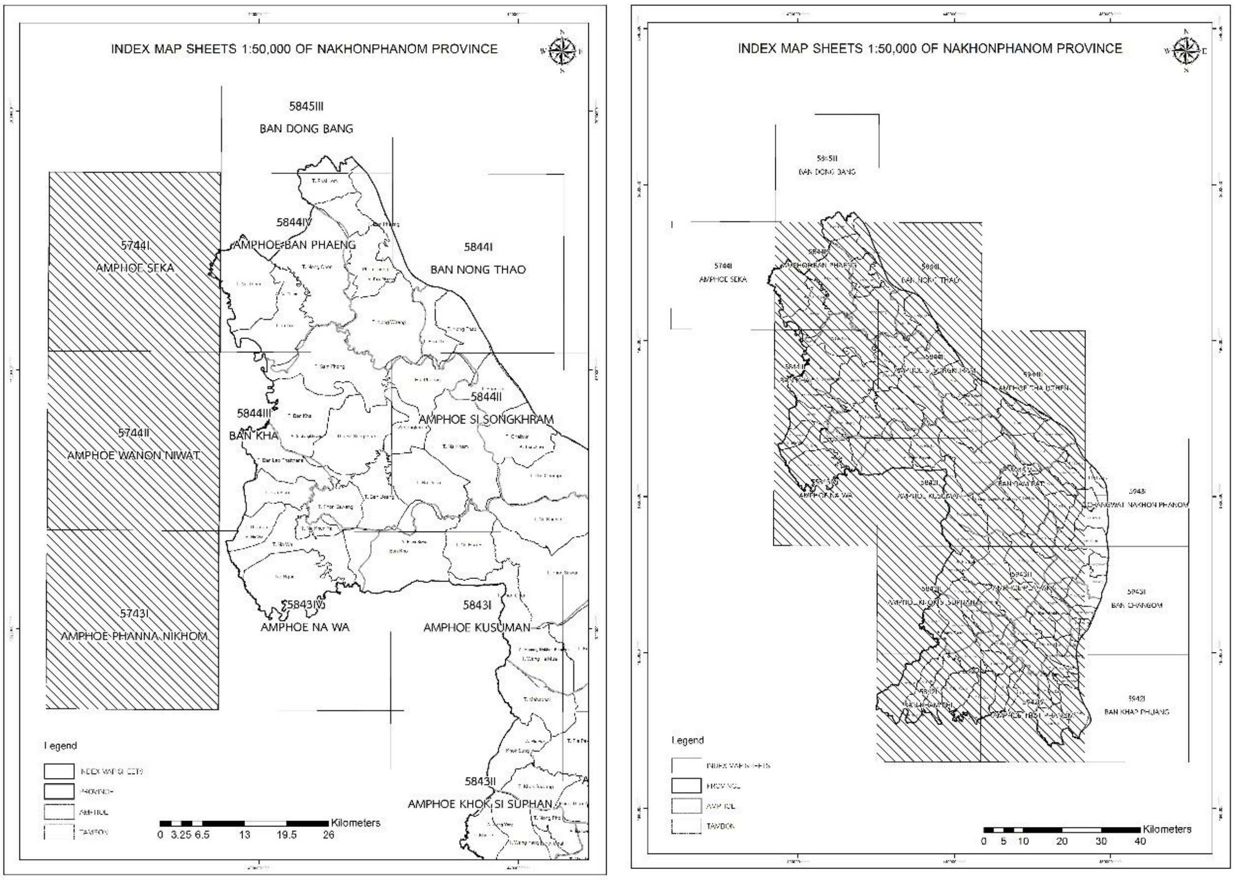


Figure 5.2.: Index map of the Hydrogeological and Groundwater maps used within this study, for the Nakhon Phanom Province (right hand side) and for the Sakon Nakhon Province (left hand side)

We first analysed the freely available terrain data (SRTM at 30 m of pixel size) in order to derive an accurate Digital elevation Model (DEM) and drainage network for the whole region, presented in Figure 5.3.

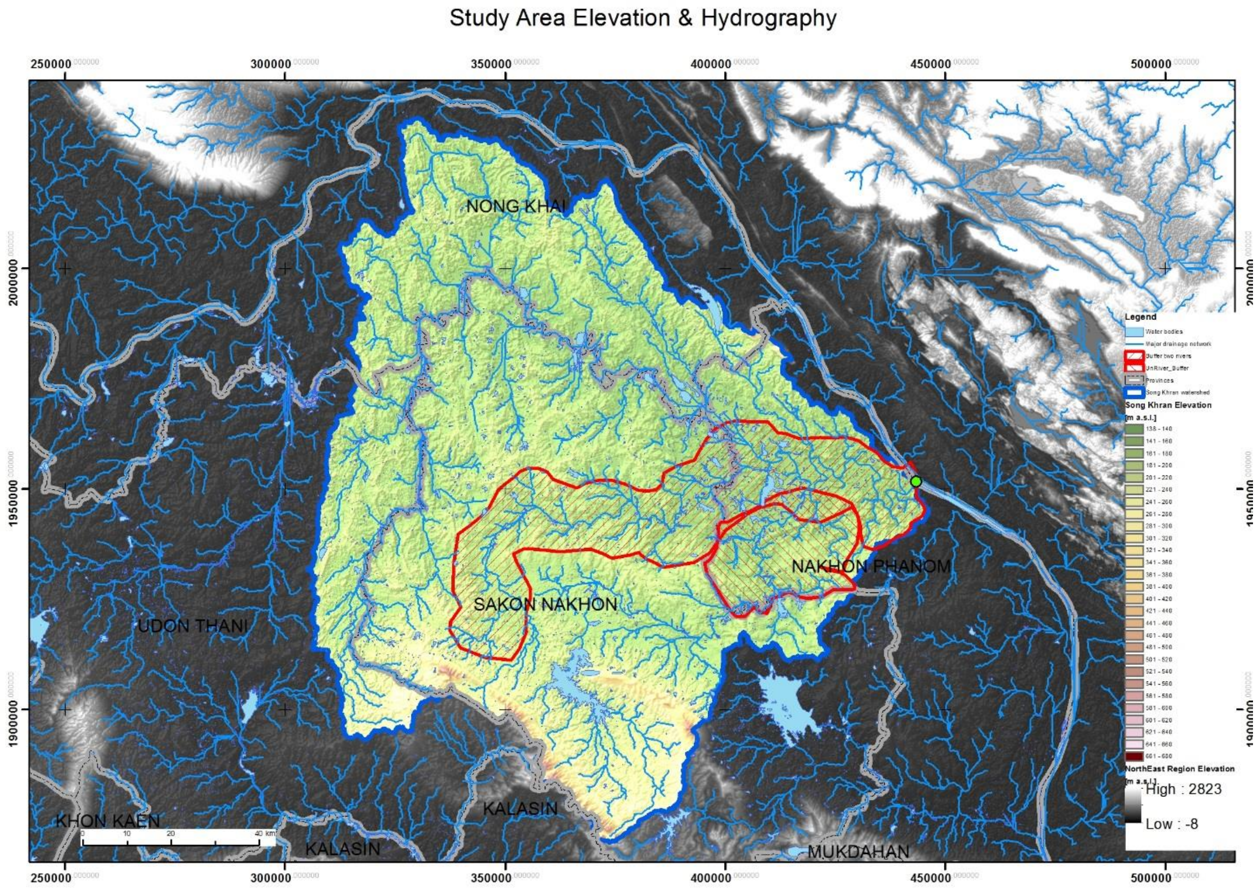


Figure 5.3.: Elevation and Hydrography of the study area derived from the freely available Digital elevation Model at 90 m resolution (NASA SRTM90m): the elevation of the whole region is shown in black and white, and the elevation of the Study Area is shown with colours. The here delineated drainage network may differ slightly from the one derived from Aerial Photography and depicted on the topographic maps. Lakes and other extended water bodies are the ones available in the topographic maps.

In particular the information on location and type of aquifers were very useful, especially when combined by our own analysis of borehole and well datasets. In Figure 5.4., we present the location of existing boreholes for which the location is known. Based on this data availability we focused on the study area shown in the various figures.

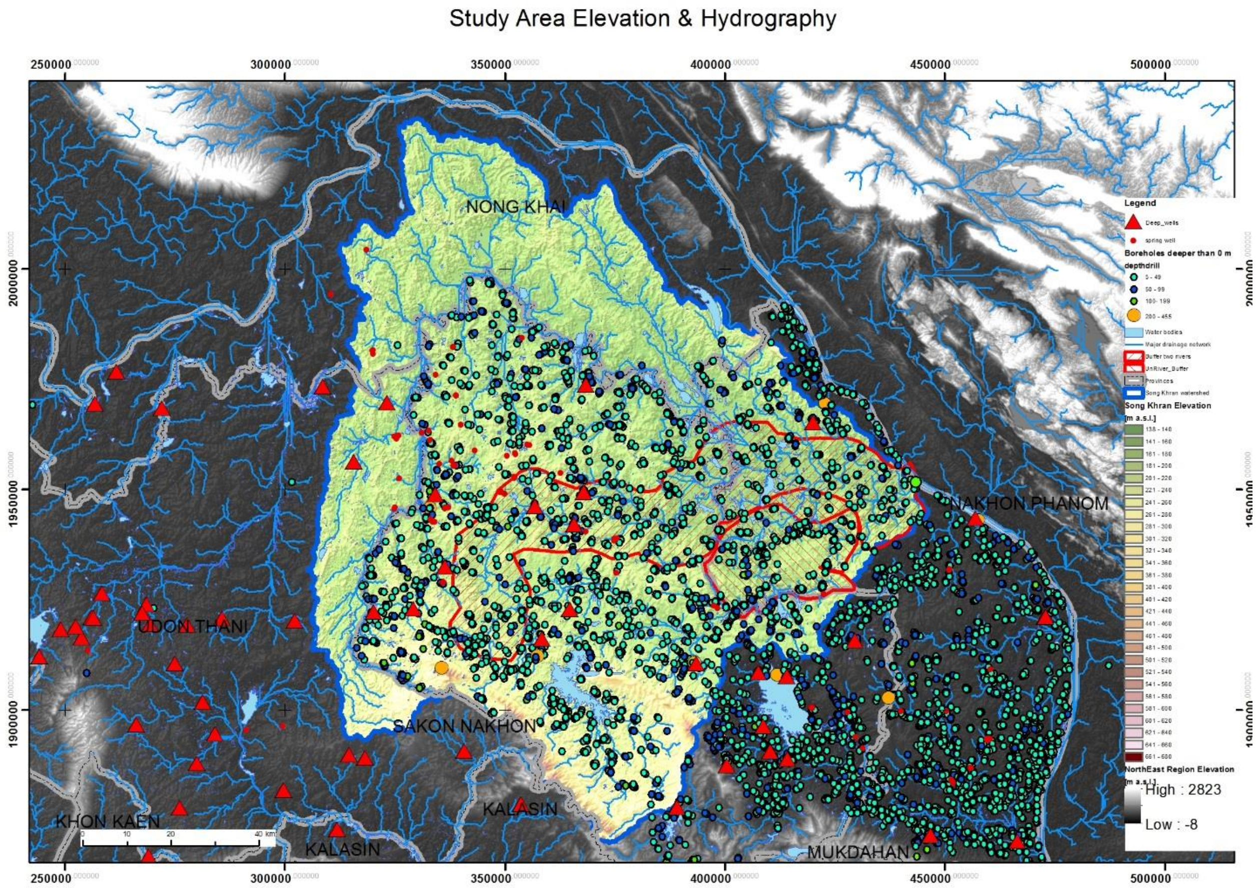


Figure 5.4 .: Location of known Boreholes for the two Provinces of Nakhon Phanom and Sakon Nakhon, and location of the Deep Wells and Spring Wells for the region.

Then, we conducted an in depth analyses of the existing hydrogeological and groundwater maps and reports together with the analysis of the borehole logs available. The total number of boreholes with some information for the two provinces of Nakhon Phanom Province and Sakon Nakhon is of 7,163 (with 3,258 for Nakhon Phanom and 3,905 for Sakon Nakhon).

The intersection of these boreholes with our study area let us with a total of 898 boreholes containing at least these information: Borehole Depth (BD), Static Water Level (SWL), Yield (Y) and Screen Depth (SD). In addition, in our study area there are also 3 Deep Wells and 11 so called Spring Wells.

Unfortunately out of this great amount of data, only 47 boreholes had a description of the stratigraphy that is the different geological layers found during the drilling. Only with this crucial information it is possible to reconstruct the subsurface geology that is the first step towards the identification of potential SWS for surface water.

Using GIS analyses, we created several interpolated surfaces and specifically the thickness and its variability in space of:

- top clay (TC) and top sand (TS) deposits
- underlying sand (US) and clay (UC) deposits

- gravel (G) deposits
- shale (S) rocks
- siltstone (St) rocks
- sandstone (Sd) rocks

2. Physiography and Geology of the North-East region of Thailand

The morphology and drainage system of the NW region are mainly described from LaMoreaux et al (1954)

The North-East region of Thailand lies almost entirely in the Khorat Plateau with a surface of about 170,000 square kilometres, constituting one of the main physiographic regions of Thailand. The Khorat Plateau has a skewed bowl shape with two boundaries better defined to the South (Phanom Dang Raek escarpment) and West (Thiu Khao Phetchabun Mountains) and gently sloping towards the Mekong River in the North and East boundary. The average elevation in the large plains of the centre of the plateau is about 150 metres above average sea level (ASL), while the southern and western margins are constituted by ranges of mountains reaching up to 700 metres ASL in the South and about 200 m ASL in the West. The topography can be appreciated drawing some topographic profiles oriented West to East and South to North (Figure 5.5).

The plateau is divided by the Phu Phan Range into two depositional basins, the large Khorat basin in the south and the Sakon Nakhon in the north. The dominant landforms are low hills and ridges with broad crests and gentle straight slopes of 20 to 30 metres relief separated by broad valleys (Löffler et al, 1984).

In the Khorat plateau the dominant type of rocks are sedimentary with some basaltic intrusions in the south only. The sedimentary sequence reflects the geological evolution of this area in the far geological past when a rifting process was happening in the Carboniferous to Triassic age (termed "post-Indosinian"), giving rise to erosion and deposition of initially coarse and then finer deposits. These deposits have then been eroded by what is known as the Indosinian Unconformity. On top of this unconformity are Quaternary deposits (see Figure 5.6.). Interbedded with the sedimentary strata, especially in the west area of the plateau, are several salty deposits that influence also the quality of groundwater.

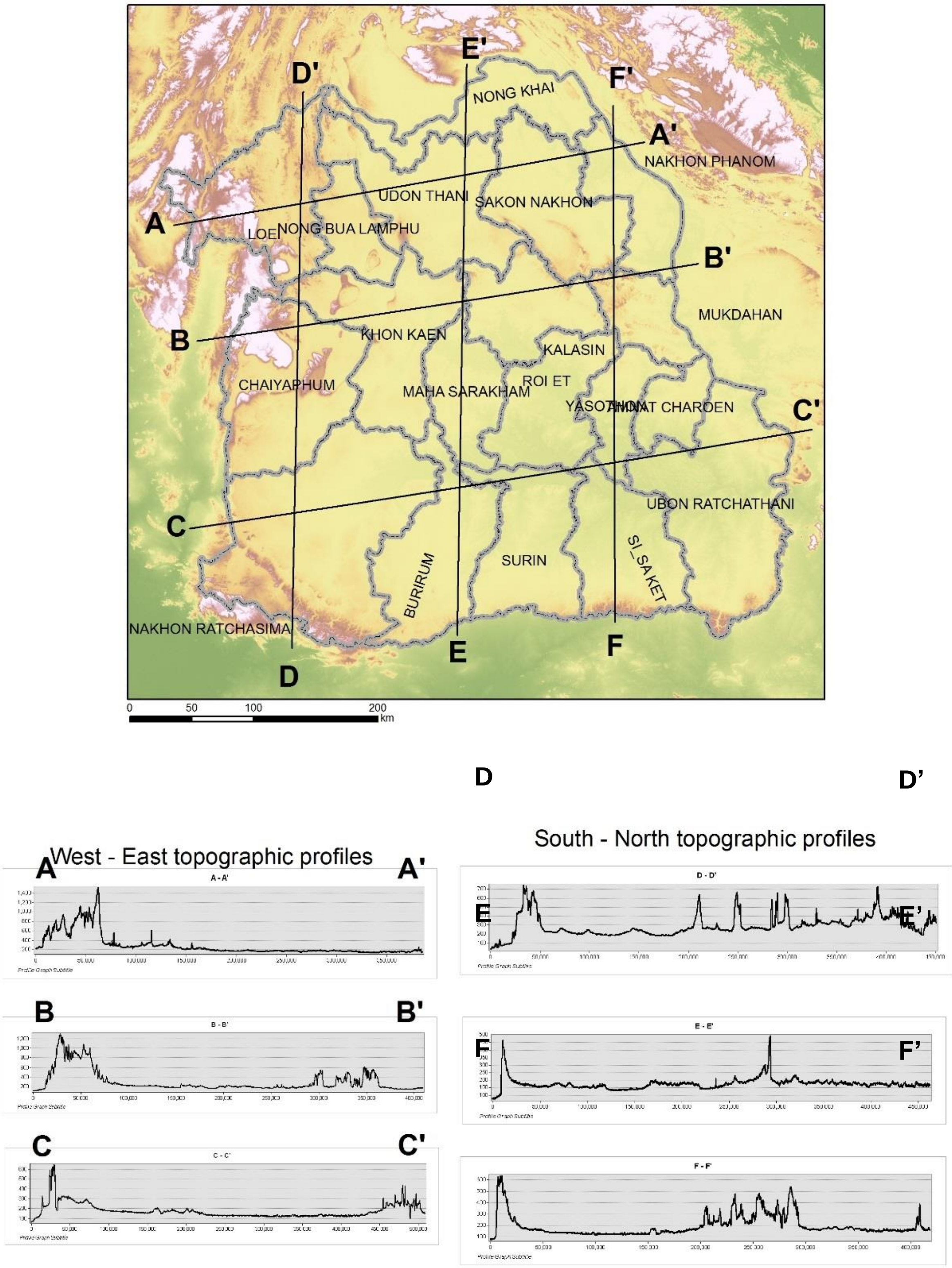


Figure 5.5.: Multiple topographic cross sections across the Northeast region showing the major topographic features, described in the text.

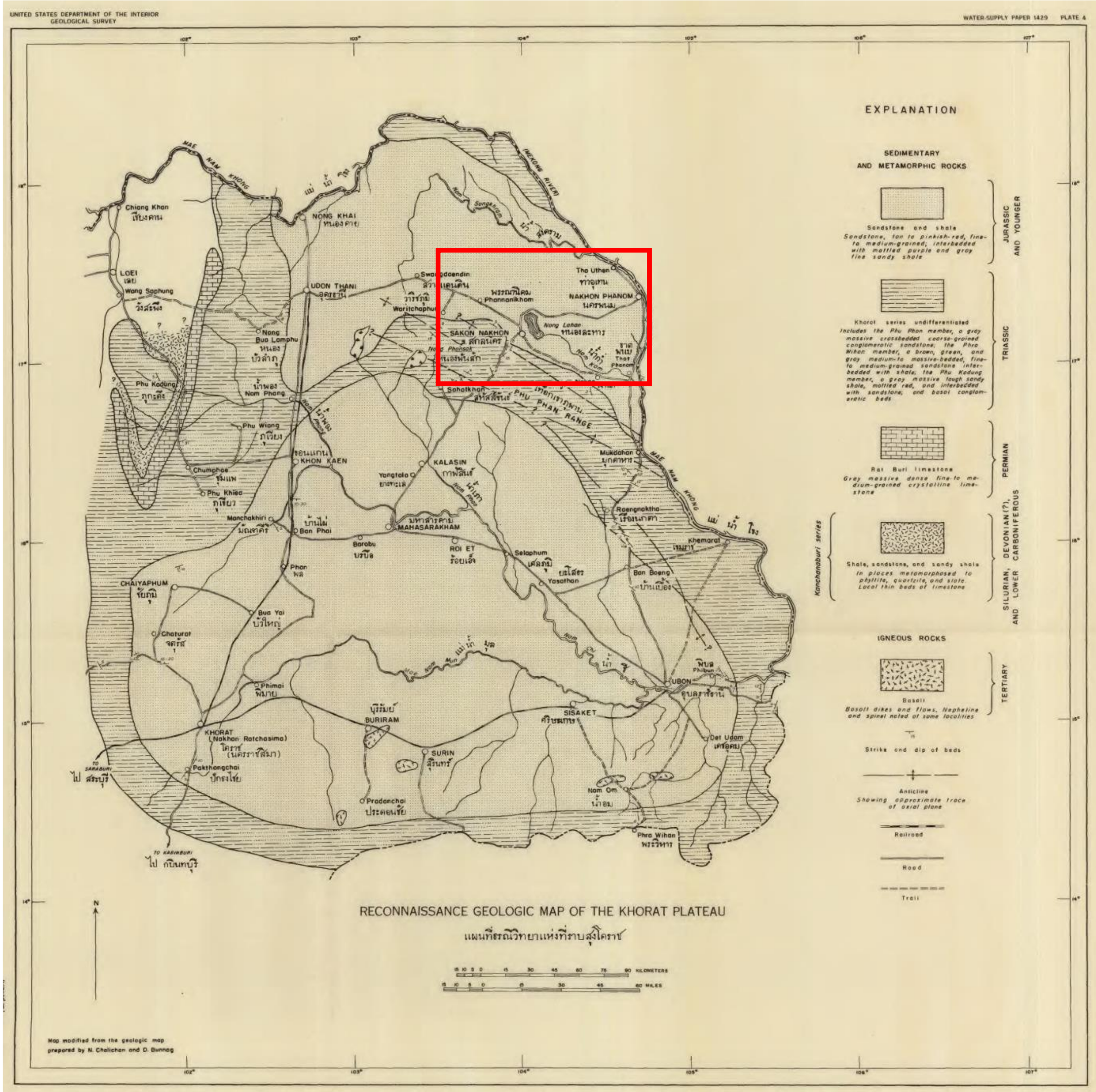


Figure 5.6.: Reconnaissance Geological Map of the Khorat Plateau (LaMoreaux et al., 1958) highlighting its syncline structure and the Triassic Khorat undifferentiated geological formation that creates a belt around the Northeast region, and that is composed by: a coarse-grained conglomeratic sandstones (the Phu Phon member), a brown, green, and grey, medium to massive bedded fine to medium grained sandstone interbedded with shales (the Phro Wihon member), and a grey, massive sandy shale, interbedded with sandstones and basal conglomerates (the Phu Kodung member). In red is the approximate location of this study area.

The Meso-Cenozoic geology of the Plateau is not too complicated by tectonic structure although it is older, Paleozoic, geological history has witnessed several orogenesis whose folds and faults form now the basement of the sedimentary sequence (what is called the Pre-Permian basement, Chantong, 2005) as shown in Figure 5.7.

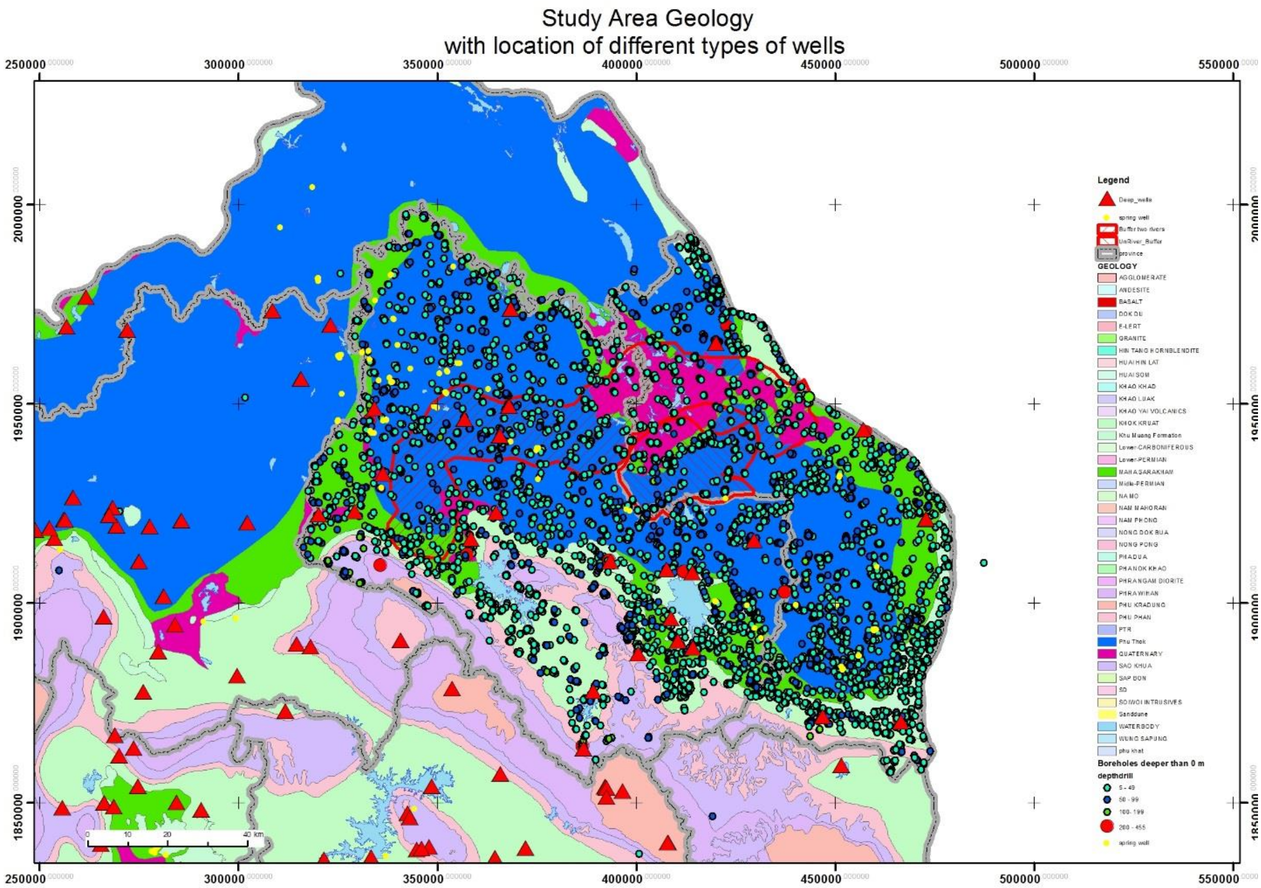


Figure 5.7.: Modern Geological map of the Northeast region (DGR, 2015)

From an hydrogeological point of view there are three main types of aquifers described here from top to bottom: (1) the top alluvium deposits, made of loose clays, silt, sands, and gravels, generally few meters to tens of meter thick, very permeable; (2) the Phu Thok formation (Upper, Middle and Lower), deposited during the post-Indosinian period, constituted mainly of sandstone and siltstone (Upper and Middle part) with variable thickness from few tens to some hundreds of metres, and mudstone and claystone in the Lower part of the Phu Thok formation; (3) underneath the Phu Thok is the Maha Sarakham unit which is bearing salty deposit.

The aquifers of the Phu Thok formation are classified as fissured aquifer, bearing water mainly thanks to secondary porosity (along fissure and fractures), and only relatively primary porosity (intergranular).

As described by LaMoreaux et al (1958) *"The rocks forming the Khorat Plateau consist chiefly of alternating beds of shale, sandy shale, and sandstone. The shale is relatively impermeable and the sandstone beds are believed to be permeable. These beds normally dip 10° or less toward the centre of the plateau. The more permeable sandstone beds are water-bearers. Rainfall on the area in which the beds crop out seeps downward by force of gravity into these permeable beds of sandstone and becomes confined between the relatively impermeable beds of shale."* and shown in Figure 5.8.

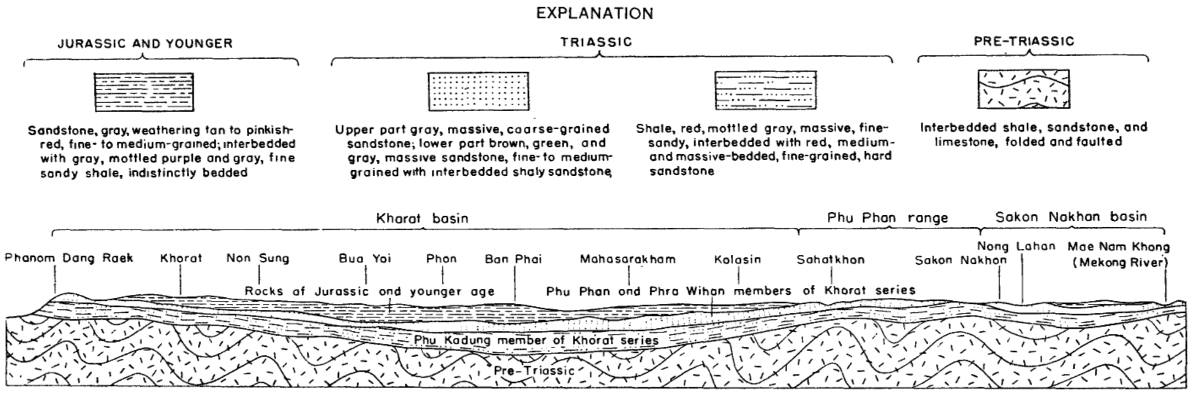


Figure 5.8.: Schematic geological cross section in Khorat Plateau, from Phanom Dang escarpment through Khorat and Nakhon Phanom (from LaMoreaux et al., 1958)

The Plateau is occupied for its largest part (almost 120,000 km^2) by the drainage basin of the Mun River including its largest tributary, the Chi River (almost 50,000 km^2). The Songkhram River in the north is the second largest basin with about 13,000 km^2. The superficial waters system is characterised by innumerable small artificial water bodies, most of which are anthropic by means of building earth dam at the outlet. These are functional for the rice cultivation that is widespread in the plateau. The presence of all these water bodies is also reflecting the kind of clayey top soils that are the vast majority in this area. The same proxy indicator for highly impermeable top soils is given by the dendritic layout of the drainage network in most of the plateau.

As reported by LaMoreaux et al (1958) *"Large areas of the interior of the plateau are flooded during the wet season as a result of poor drainage; however, during the dry season, the lack of rainfall and high evaporation cause the area to be classed as semi-arid during part of the year".*

The Plateau is entirely part of the transboundary Khong River Basin and is thus of regional relevance for its hydrology and hydrogeology.

The general hydrogeological setting of the plateau has been described very well by LaMoreaux et al. (1958) and even if successive studies did complement this seminal work, so far there is no other comprehensive report in English of the hydrogeological conditions of the entire plateau. The majority of the plateau hydrogeology is belonging to artesian conditions. The recharge areas are of two kinds: (1) located at the western and southern margins of the plateau where the strata are almost vertically dipping, (2) along the rivers and streams in the middle of the plateau where seepage from stream can cross more permeable surface layers and thus infiltrate more deep downwards. LaMoreaux et al. (1958) already noted "*Recharge from streams can be sizable, and in parts of the plateau, geologic and hydrologic conditions are believed to be favorable for inducing recharge through development of wells of large capacity in areas underlain by alluvium*"

It is important to underline the presence of salt diapirism in the western and southern part of the Khorat Plateau as highlighted during oil exploration of the plateau and shown in Figure 5.9. (Sattayarak and Polachan, 1990)

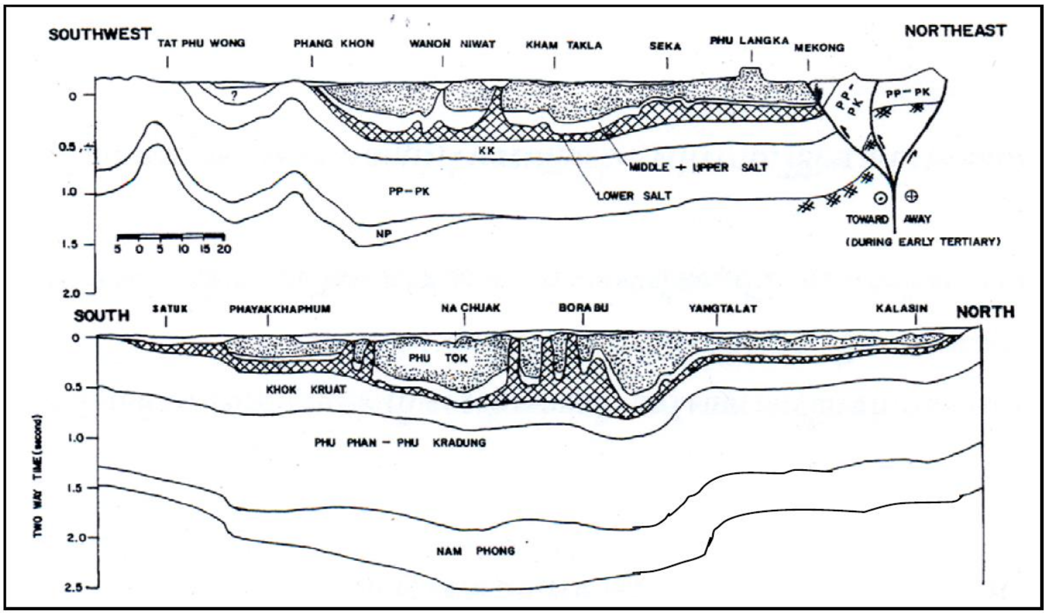


Figure 5.9.: Cross section from seismic exploration showing subsurface geology o fthe Khorat Plateau. Many salt diapirs (with the hatched pattern) intrude through the Phu Thok formation, the main aquifer of the plateau. These sections are western and southern from the study area of this report (from Sattayarak and Polachan, 1990)

3. Physiography of the Un River Basin and Songkhram River Basin (Nakhon Phanom Province and surrounding territories)

The Nakhon Phanom Province is about 5,450 km^2 in surface and is the easternmost province of Thailand bordered by the Khong River to the East. We focused on two sub-watersheds in this study: the Un River basin, with a surface of slightly more than 100 km^2, in the Nakhon Phanom Province, and the Lam Nam Yam River, with a surface of about 2,000 km^2. Both are tributaries to the larger Songkhram River basin with an area of about 13,000 km^2 developing for about 1,880 km^2 in the Nakhon Phanom Province and the rest in its neighbouring provinces. The Songkhram River spans from 137 to 671 metres ASL while the Lam Nam River spans from 580 to 140 m ASL the Un River is also a tributary of the Songkhram River and they join at the town of Ban Pak Un, frequently subject to flooding by the Un and Songkhram rivers. The elevations of the Un River basin are relatively low and constant throughout the basin with an elevation difference between the highest and lowest point of only about 50 metres.

4. Hydrogeology of the Nakhon Phanom (Songkhram River basin)

The hydrogeology of the Nakhon Phanom and surrounding areas is dominated by the Phu Thok Aquifer in particular by the Middle and Lower parts of this formation as described well in the last Hydrogeological Report by DGR (2015).

The upper part of the subsurface is made of unconsolidated rock namely **Quaternary Alluvial Aquifer** (Qa). These are gravel, sand, well rounded, well sorted, intercalated with sandy clay or lateritic soils. Groundwater accumulated in voids between the sediments. The thickness is 20-25 metres, with good yields ranging in between 2 and 10 m^3/hr.

Below the quaternary formations are consolidated rocks, starting from the **Kam Ta Kla Aquifer** (Middle Phu Thok) that consists of fine grained sandstone to siltstone, silty mudstone brick red in colour, with calcite nodules and thin calcite layers. Here groundwater accumulates in fractures, bedding planes and weathered zones. This thickness of the beds is 3-12 metres with yields ranging from 2 to 10 m^3/hr.

Below this aquifer is the **Na Wa Aquifer** (Lower Phu Thok) that is made up of reddish-brown mudstone interbedded with thin anhydrite layers, also calcareous and mostly saturated with salty water. Groundwater here accumulates in fractures, bedding planes and weathered zones. This thickness of the beds is 6-9 metres with yields of about 2m^3/hr.

The lowermost aquifer is the **Maha Sarakham Aquifer** made up of yellowish grey and brownish grey mudstone intercalated with thin gypsum layers at the lower part, and underlain by rock salt causing the waters to be salty. Also, here groundwater accumulates in fractures bedding planes and weathered zones. This aquifer has yields of less than 2 m^3/hr.

Where existing, below the Maha Sarakham Aquifer there can be two other deeper aquifers, and specifically the **Khok Kruat Aquifer** that is formed by reddish-brown to reddish-purple sandstone, siltstone interbedded with shale containing organic material and thin layers of gypsm and anhydrite intercalated. Groundwater accumulates in fractures bedding planes and weathered zones. The thickness of the beds is 3-6 metres and a yield range of 2-10 m^3/hr. Below this aquifer can be found the **Phu Phan Aquifer** that is made up of sandstone, conglomeratic sandstone, conglomerate, coarse grained with clay matrix. The groundwater accumulates in fractures bedding planes and weathered zones. The thickness of the beds is 3-6 metres and the yield is low with less than 2 m^3/hr.

5. Field visits in the Study Area and findings

During the visit to Nakhon Phanom and Bangkok DGR offices we were able to collect and organise several data and information related to the present and past hydrogeological setting.

In particular we collected the:

- Topographic maps covering the watershed of the Songkhram and Un rivers (both printed maps and scanned);
- new Hydrogeologically maps set of the North-East region, scale 1:50,000 (both printed maps and scanned);
- new Groundwater maps set of the North-East region, scale 1:50,000 (both printed maps and scanned);
- Geological maps scales 1:50,000 and 1:250,000 of the study area in Nakhon Phanom
- Administrative boundaries and locations of cities, villages and other major features, in shapefiles
- Geological units of the North-East region in shapefiles
- Electrical logs of 69 boreholes
- Lithological logs of more than 100 boreholes in the Sakon Nakhon and Nakhon Phanom administrative provinces, of which 36 were falling within the watershed of our interest
- Flooded areas extent of the north eastern region from 2005 to 2015, in shapefiles

The boreholes preliminarily selected in the Lam Nam Yom River were 627 for most of which we had data on:

- Depth drilled
- Depth of development
- Static Water Level
- Draw Down
- Yield
- Screen interval

Out of 627, only 35 had a stratigraphic log and where then used to reconstruct the underground geology. We used the preliminary assessment of boreholes already in the field to visit the locations of selected boreholes in order to assess the landforms surrounding them (as shown in Figure 5.10.)

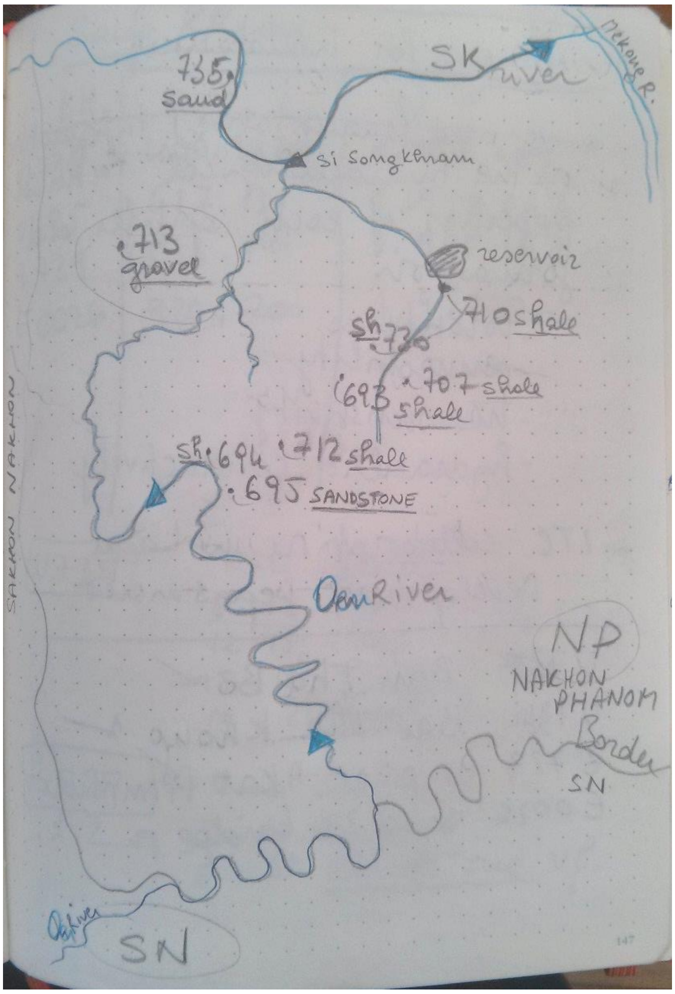


Figure 5.10.: Hand sketch of the Un and Songkhram rivers and the locations of visited boreholes during the September 2015 field mission, showing the main covered lithology under the clay/sand blanket.

After processing the same data in a GIS environment, we were able to display the same data in a more comprehensible way, in the form of graphs shown in Figure 5.11. We complemented the data of these 35 boreholes with data from 3 deep wells that are within the low land of the Lam Nam Yom River.

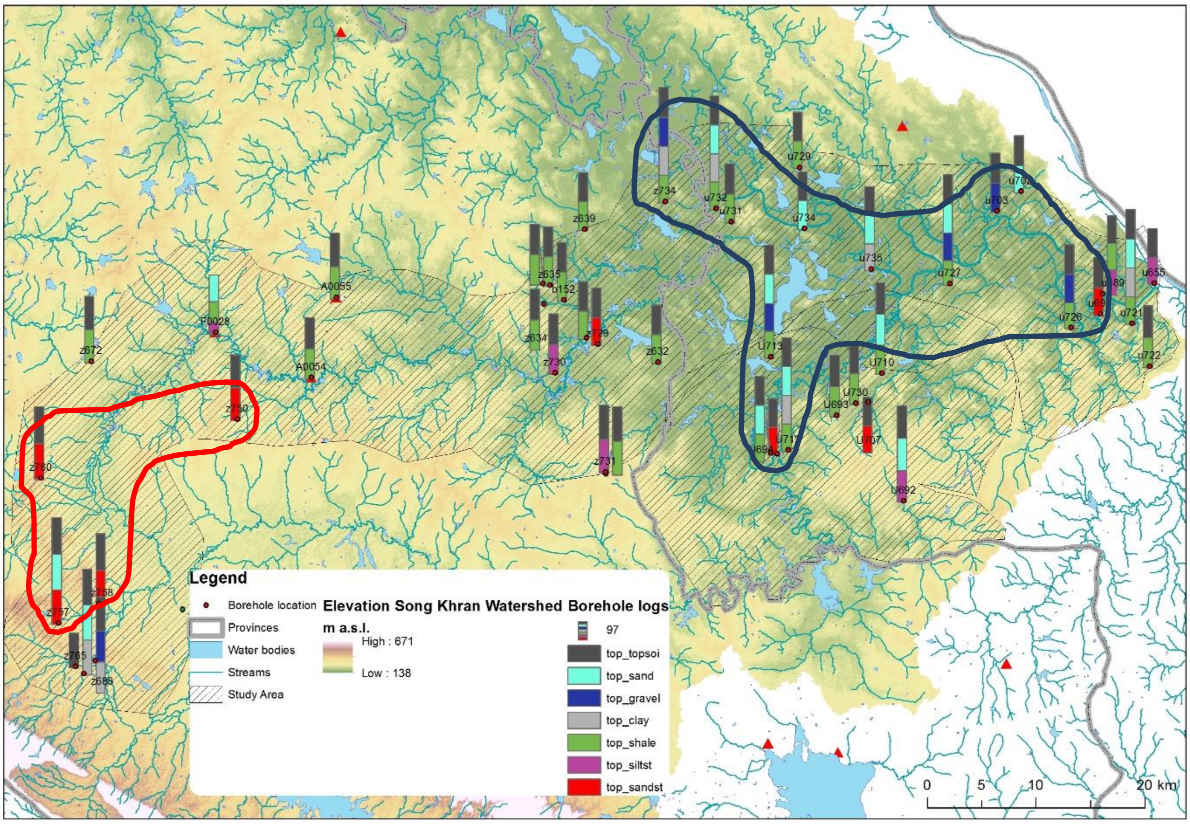


Figure 5.11.: The borehole logs are here shown as bar stack of different colours according to the lithology. The Gravels (blue) and Sandstones (red) are the most porous media found in these logs and therefore are the most suitable for artificial recharge. The thick Blue line identifies the downstream potential areas, while the Red thick line identifies the upstream potential areas.

In creating the bar stacks we homogenized all the logs to the following stratigraphy from top of the borehole to the deeper rock types:

Lithology	***Description***	***Colour (Figure 5. 11)***
Top Soil	Mainly clay or sandy clay soil, present in great majority of logs	
Sand	Loose sand interval, rarely present	
Gravel	Gravel or loose Conglomerate	
Clay	A clay layer that sits below the gravel	
Shale	This seems similar to the top part of the Maha Sarakham Aquifer	
Siltstone	This could corresponds to lower part of Maha Sarakham Aquifer	
Sandstone	This could be reconduced to the Khok Kruat Aquifer	

From Figure 5.11., it is quite clear where the locations of the most porous lithologies (gravel and sandstones) are, and whether they have a topsoil plug or not. The DEM in the background shows also the elevation where these boreholes are located in relation to the drainage network and water bodies. It turns out the boreholes in the lowland with most Gravels (dark blue colour) are located near the junction between the Un and Songkhram rivers, or downstream. Similarly, the ones with a Sand layer are also located more or less in similar locations as the ones with Gravel, while the ones with Sandstones (red colour) are almost all concentrated more upstream.

Again it has to be underlined that the quality of the metadata of these boreholes did not allow for a proper 3D modelling because in some cases the depth of drilling was not clear. So in principle there may be two areas potentially relevant for SWS: the upstream boreholes with a Sandstone layer and the downstream ones with Gravel & Sand layers on top. The Sandstones are always lower than all the other lithologies, while the Sand and Gravel are always shallow (a matter of few meters below ground).

6. Preliminary results

We analysed, critically reviewed and combined in a GIS environment all the available data collected during the September, 2015 mission and we present here the preliminary results regarding the general stratigraphic sequence and the characterisation of the main aquifers in the region of interest. Most boreholes analysed where not deep that is up to a maximum of few tens of metres (30 to 50 on average). Only a very limited number of boreholes were drilled up to or more than 100 metres deep.

The description that follows presents the general stratigraphy from top to bottom.

- Generally the whole area is covered, like with a blanket, with clay soils that can be from one to 8-10 meters deep. The clays can have a variable percentage of sand fraction and in places are forming a frequent alternation of clays and sands with each layer only few meters thick. In places there is Laterite as topsoil instead of the clay layer.

- Below the clays the most frequent lithology are shales with depths below surface variable in between few meters to ten or so meters below ground surface and thickness of several tens of meters.

- In few locations we can find Sandstone directly below the clay top layer. The sandstones are very fine to fine in grain size and several tens of metres thick. And in even fewer locations there are Gravels below the Clay/Sands with a thickness of 1-3 metres.

- There are no tectonic elements in the study area such as faults or folds, apart from a fault that runs parallel to the main Khong River, north-east of the study area.

- The floodplains are quite wide especially at the junction between two rivers and they often host paddy rice cultivation thanks to the presence of the impermeable clays on the top.

- In the area, there are also some plateau used for paddy rice. Almost all the lakes in the study area are artificial, being created with earth dams or other hydraulic structure and regulated by gates (more or less functioning, more or less new). Some new large scale structures have been recently built in the area and are creating larger reservoirs.

- The general topography is flat, typical of these lowlands.

- The land is not intensely occupied by urban or rural settlements but it is intensely cultivated.

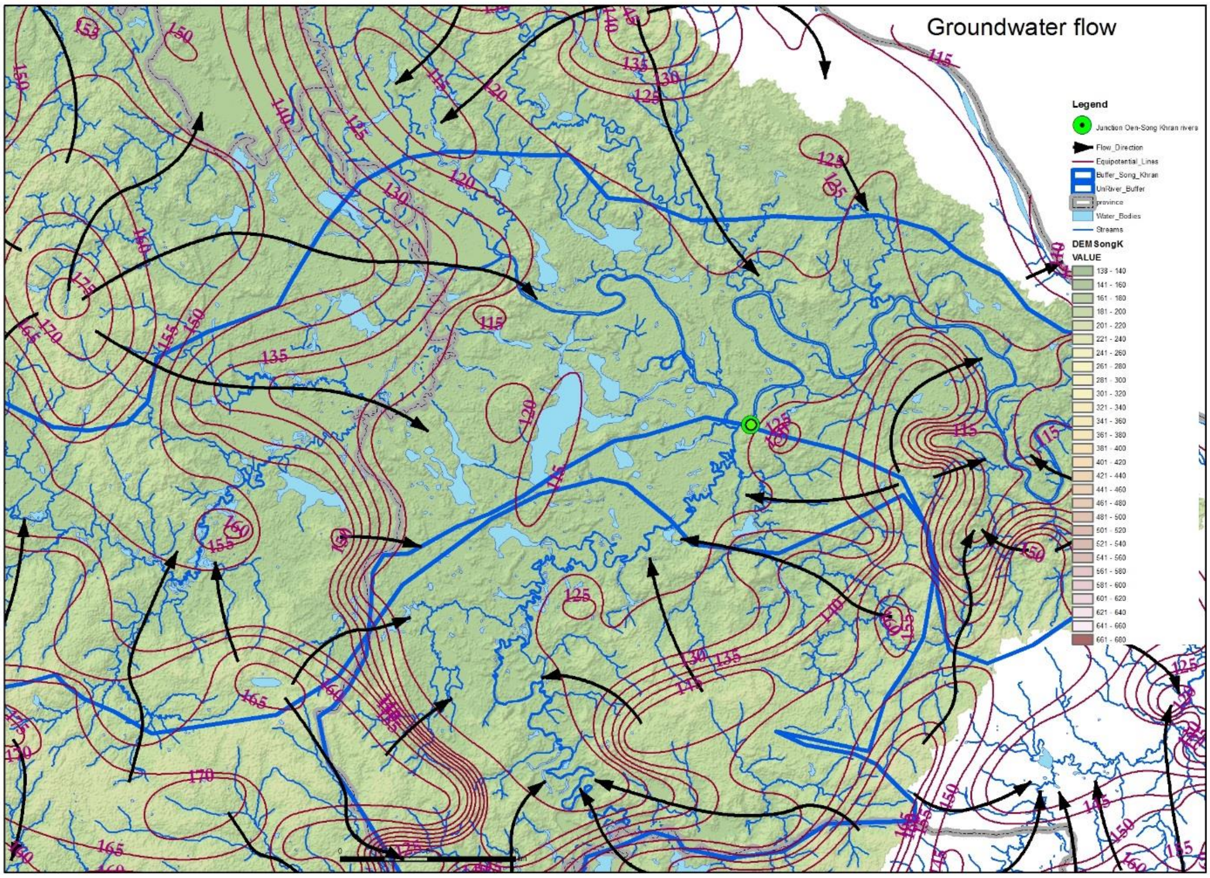


Figure 5.12.: Equipotential lines and groundwater flow directions with regards to the superficial hydrology and topography.

7. Groundwater flow and properties

From the analysis of the hydrogeological and groundwater published maps (DGR, 2015), it is clear that mainly the Un River acts as a depocenter area for the groundwater flow. The equipotential lines establish a relative minimum just west of the junction of the Un and Songkhram rivers, in proximity of a lake, as shown in Figure 5.12. There the depth of the groundwater table is about 35 m below ground level. It is important to notice though that from the existing data there is no monitoring of the groundwater fluctuations and therefore it is not possible to know how the water table moves up and down as a function of rainfall and recharge. The Songkhram River has a less clear role in the groundwater flow direction and therefore with the limited data available it is difficult to establish its relationship with the water table.

To proceed with the understanding of the relationships between river and aquifers it is imperative to have some monitoring boreholes where the flow and elevation of the table is monitored in close relation with the river discharge and rainfall. It is also important to establish which the natural recharge areas are.

Matching the equipotential lines with the borehole logs gives an indication of where the natural flows are matching or not with the most porous layers underground, as shown in Figure 5.13. There seems to be no apparent correlation between the principal groundwater flow directions and the logs.

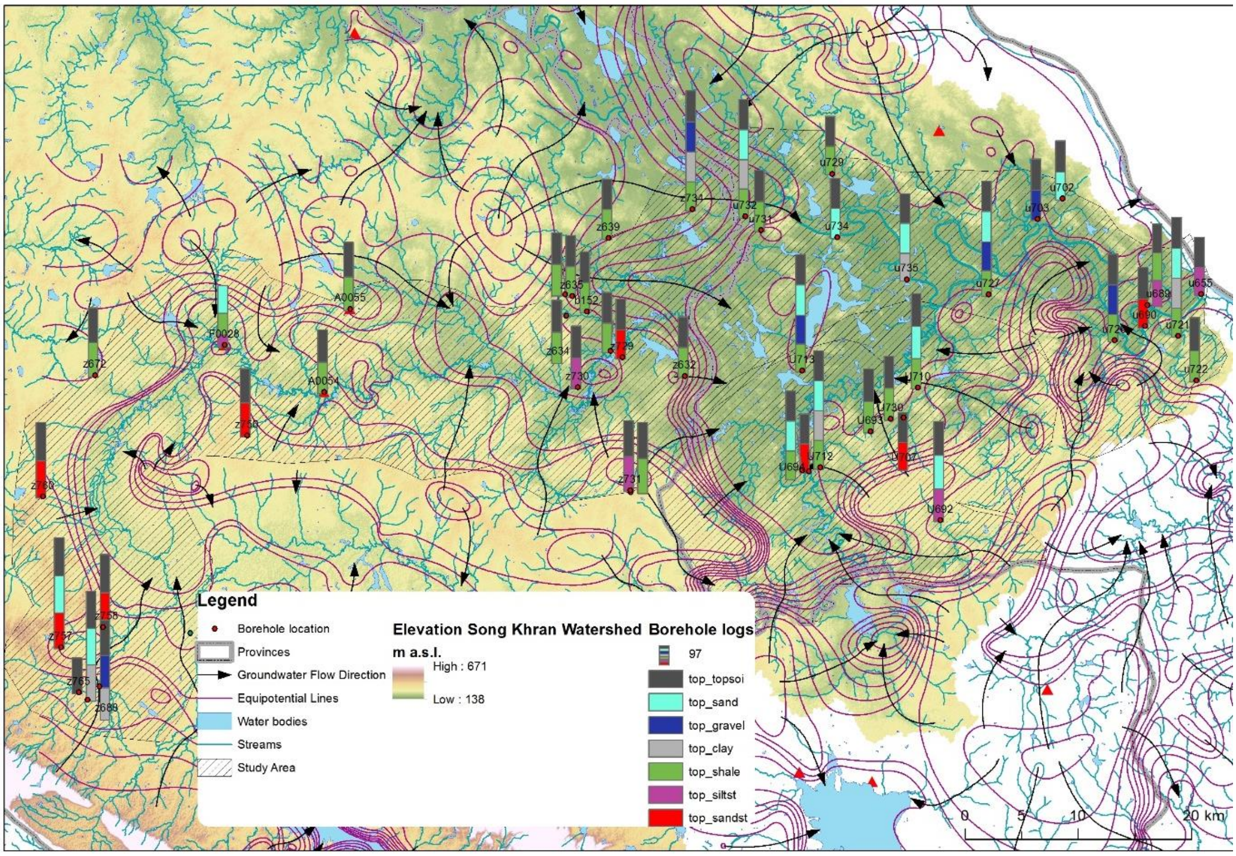


Figure 5.13.: Elevation map of the Songkhram area

Identification of SWS potential from a hydrogeological point of view

Combining all the information described above in a comprehensive GIS system we were then able to identify the areas with the highest hydrogeological potential for SWS. This preliminary analysis does not consider some limitations like land ownerships, distance from the main river, cost analysis. Instead it considers only the physical properties of the underground geology. It is clear that to have a proper picture of the underground we should have had the borehole logs of ALL the boreholes existing in the study area. In reality, we were able to source only less than 10% of those boreholes. For the others only depth, depth of screens and a yield were available. For the yield, we do not know under which pump test this yield has been assessed and using which method. It seemed to us that also DGR may have encountered the same problem in the preparation of the new Hydrogeological Model from the GeoScene3D software. This is deducted from the cross sections that appear in the Hydrogeological Maps and in the few figures of the Geoscene 3D that are present in the Report, showing only the deep boreholes for which logs are available.

From this point of view, the areas that have the highest potential are the ones with a thick clay cover that protect an underlying coarse grained aquifer: in this case Gravels and Sandstones. As already highlighted in Figure 5.11, these potential areas are in the lower part of the Songkhram River, for what concerns the shallow Gravels, and in the upper part of the basin.

Considering the landforms it seems more ideal to address the downstream portion of the basin, where retention basins are more likely to be constructed and from where the infiltration could happen more easily.

Research activity B. LAND USE PLANNING, PLAN "NING" FOR EFFECTIVE (GROUND-) WATER MANAGEMENT

Spatial extents of drought and floods in the context of land use planning

Introduction

Subsurface water storage

It is often stated that adequate groundwater management can only become really successful if this mainly subsurface oriented activity is strongly accompanied by other water related activities at the surface level. One of them concerns surface water resources, another refers to irrigation. Both store and deliver, in response to demand and supply. Their and others connected activities are, and should, be related to and dependent of adequate land use planning. Land use planning is responsible for the best perfect spatial organisation of cities, provincial, rural and countryside, and nation as a whole.

In particular this regards to water, water management, flood and drought risk reduction and prevention, groundwater contamination, specific water supply shortages, urban flooding, landslides, land subsidence, etc. In general, it is land use planning that should undertake PRO-ACTIVE INTERVENTIONS WHERE REQUIRED. Finally it will deliver 'resilience', preferably durable.

Therefore, in a context of land use (see map image Nakhon Phanom province) and land use planning (see map image Provincial Plan Nakhon Phanom), before paying attention to subsurface water (storage, quality, extraction, contamination, etc.), it is necessary to consider land surface and surface water. This is logic because most of the subsurface water is generated through precipitation from surface and surface water bodies (rivers, lakes, and retention reservoirs).

Societies facing flood and drought risks undertake serious efforts to integrate land & water in their spatial organisation. Such societies expect that land use planners (or town & country planners) are the particular discipline and professionals to take the lead and work intensively together with various other water relevant agencies and professionals.

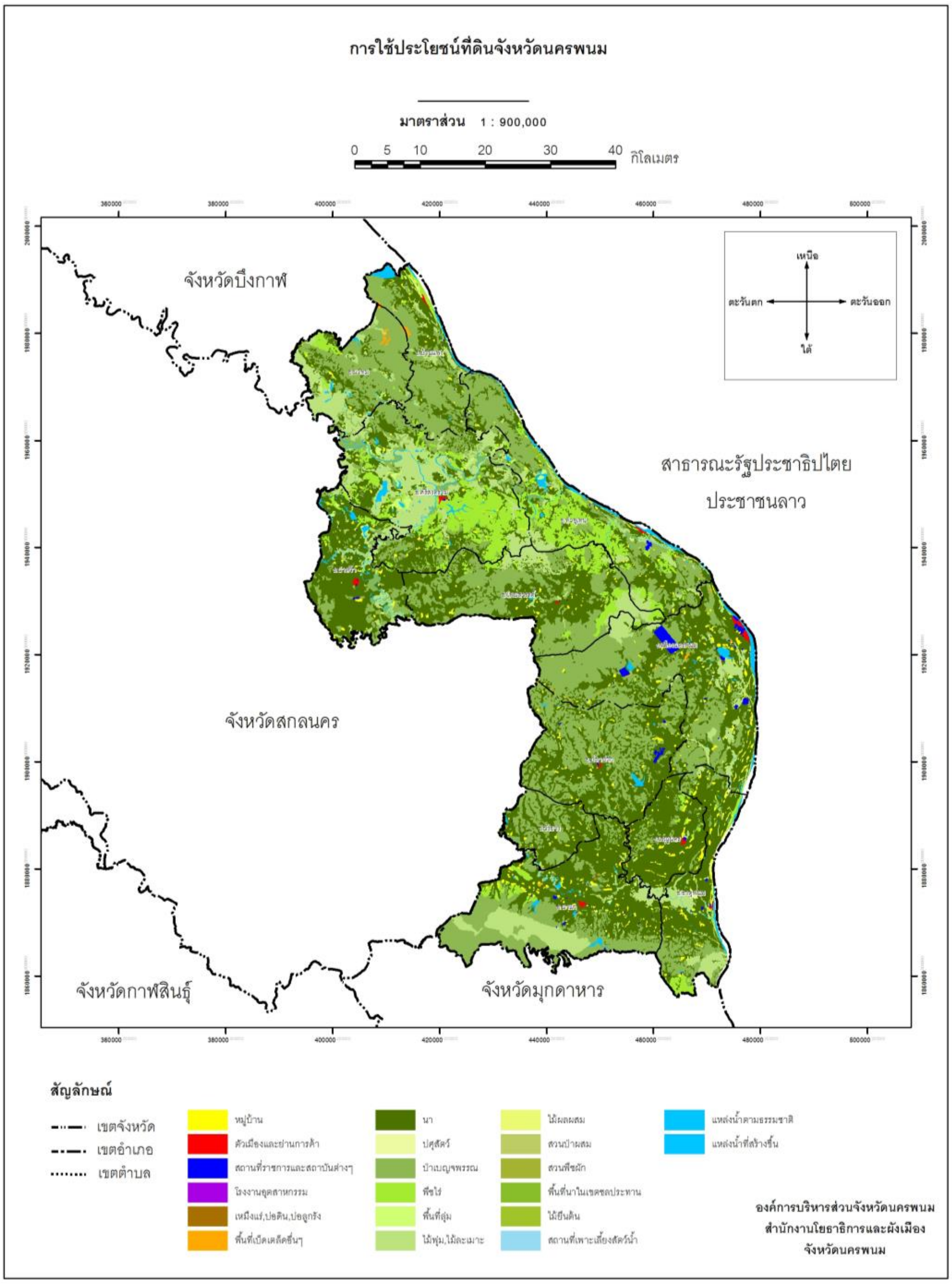


Figure 6.1.: Land use map of Nakhon Phanom Province (source DLD, CPO Nakhon Phanom)

Map legend in English:

Provincial boundary			
District boundary			
Sub-district boundary			
Village	paddy field	mixed fruit	natural water resources
Town	livestock	mixed tree farm	manmade water resources
Government building	mixed forest	vegetable garden	
Industrial	field crops	paddy field in irrigation zone	
Mine, puddle	marsh	tree	
	shrub	aquaculture area	

Consequently, and for other related reasons, the connecting link between land use planning and surface and subsurface water are elaborated in the following, with prime focus upon Nakhon Phanom Province and its human settlements in the catchment of the Un and Songkhram river watershed.

In that sense, nowadays, increasingly this comes to the fore where is spoken about 'multi-level integrated land & water resources planning and management'. In Thailand, a comparable insight is indicated as IWRM (see chapter 3 Cabinet Memo 2015), or 'integrated water resources management', although:

(1) It is not explained in that Memo what is meant with it, and certainly it is not seen as an overall involvement of all parties that preferably are involved (to mention: DPT, DWR, DGR, RID, DLD, DDPM), and,
(2) this integrative approach is not or weakly recognisable in the various standard Thai land use plans, such as the provincially produced Province Plan, and the for urban areas produced Comprehensive Plans.

The decades long absence of a strong leading land use planning as well as absence of a sound integrated land & water planning and management are certainly indirectly main causes of frequent flood and drought disasters in Thailand. Without any doubt, 2011 was an extreme, known as Great Flood. Another in the meantime extreme concerns the serious droughts and related conflicts ("Water wars", Bangkok Post July 2015) in the course of 2015, seen as due to the effects of the El Nino weather conditions in the region.

Domino effects
Multi-level integration is important to avoid domino effects. In case 'brother'/ 'sister' decision relevant colleague departments within the government as a whole are not working closely together, their choices could become counterproductive, and, instead of reducing problems increase them. Examples are available:

(1) Separate highway decision making resulted in construction works with concrete walls in Chonburi province. Consequence was serious floods in July 2015, due to locked natural drainage corridors;

(2) Floods with serious traffic consequences due to extensive concrete pavements in cities (e.g. Bangkok, June 2015), making downward gravitation into the subsurface impossible. The traffic problems are particularly a burden for the commuters, living outside and employed in the urban domains;

(3) The yearly flooded communities along rivers because set back policies are not applied for centuries. Currently, the Bangkok Metropolitan Authority (BMA) considers pedestrian and bicycle lanes, a promenade, the 'New Landmark of Thailand', at two sides along the Chao Phraya River which requires now extensive land readjustments efforts.

(4) Reduced river capacity caused by encroachment of eroded soil sediment in the countryside where the rivers meanders. The same applies to houses and entrepreneurial building constructions at the embankments of the rivers in the cities;

(5) Deforestation is cause of landslides and reduced rainwater storage capacity of soils.

Land use and water resources plan making

What applies to Thailand as a country, as a whole, is true for its provinces and to the (urban) human settlements too. This is, hereafter, elaborated for the Province area Nakhon Phanom, with the explicit focus upon the northern part. It will be underlined that without integrated land and water resources planning and management at the land surface, flood & drought risk reduction is not effective. It is argued that subsurface groundwater resources management may be helpful in reducing (a part of) those flood and drought risks and problems. This help applies to groundwater and aquifer recharge, sometimes referred to as MAR, managed aquifer recharge, as well as to rainwater harvesting (RWH) (Pavelic et al., 2012).

Provincial level

This absence of a strongly integrated land and water approach in the Province Plan which applies to the SWS study area Nakhon Phanom must be recognised as a serious problem. Due to the absent integration, the provincial land use plan shows a few rather vague, insufficiently elaborated land use plan categories. Nor it highlights specifications to provide effective starting points for adequate control and enforcement. Consequently the Provincial Plan does not contribute to a spatial policy of flood and drought risk (prevention and mitigation) management.

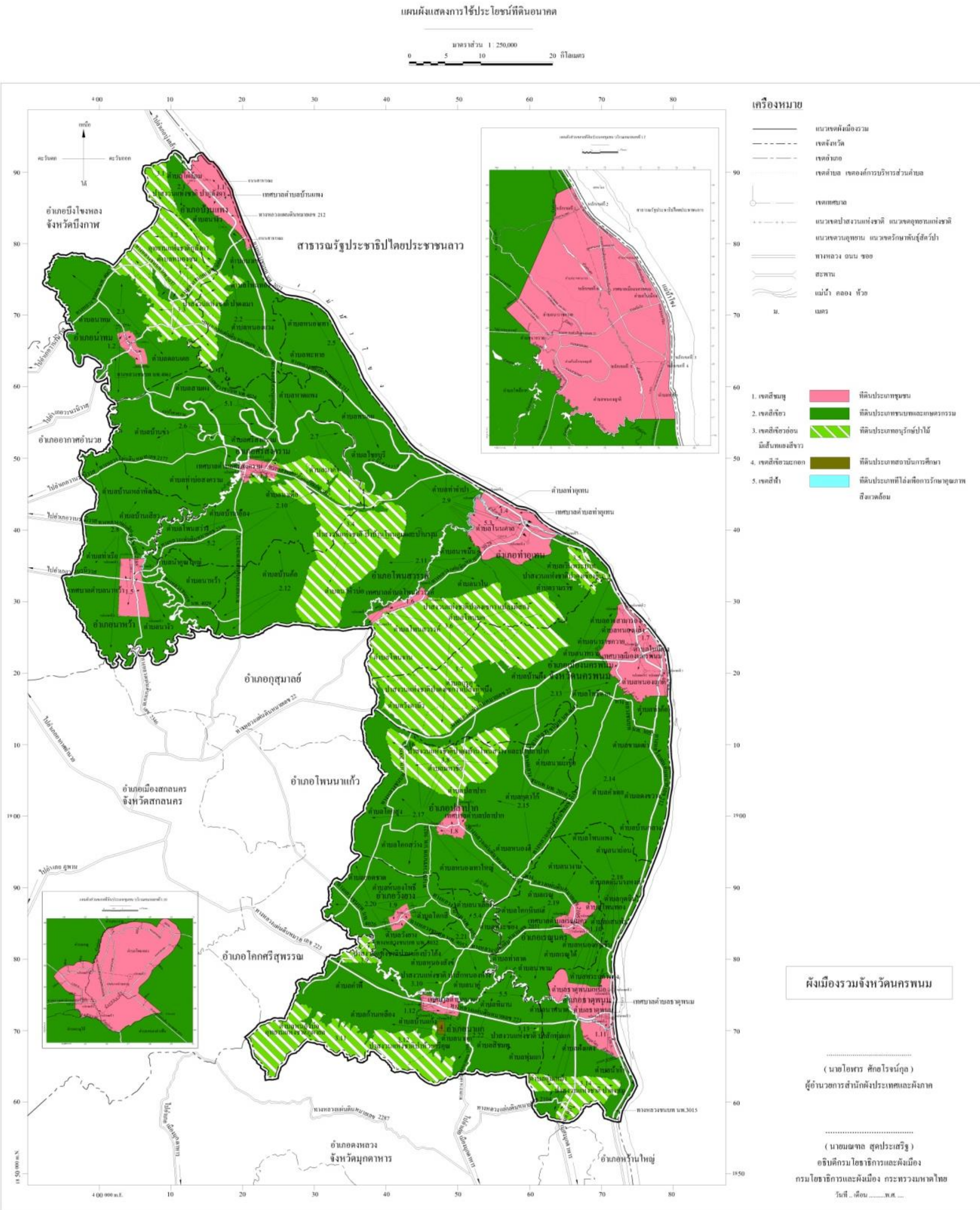


Figure 6.2.: Current approved Province Plan Nakhorn Phanom

Moreover, consequently, the provincial plan is not helpful to avoid floods and droughts in the future (although the Province plan is an essential expression of the Province's spatial future, and even although it is a document of law responsible for the well-being of the people, their possessions and activities assigned to the plan area).

That vagueness can be explained as follows. At provincial level land use planners produce Provincial Plans. The following image concerns the provincial plan for Nakhon Phanom´s future. Nakhon Phanom is a province facing frequent floods and droughts. However, studying this provincial plan, it gives no clue that such flood and drought water problems have been taken into account in plan development and design.

Asking the involved land use planners about this, they confirmed that the floods and droughts have not been leading issues. But, even if they were, it would not have a real effect on the plan product.

From figure 6.2, the plan image uses (besides some lines for area units' demarcation and various symbols) 5 colours explained as:

- Pink : (urban) human settlement zone
- Dark green : rural and agriculture zone
- Green with hatch of white lines : protected forest zone
- Dark brown : education purposes
- Light blue : open space for environment protection

The large watershed of Un and Songkhram rivers is lightly visible, it does not show any prevention, for example, set back zoning along those rivers. There are no indications for elevated zones that would protect the lands adjacent to rivers and the build-up behind the set back zones. There are also no (surface or subsurface ground-) water storage allocations or such indicators (in the map visible) included. The same is true for groundwater protection zoning which is absent.

The consequence of this rather vague plan content is outlined through remarks made by local representatives during data and information collection for the SWS pilot project application in Nakhon Phanom province. Remarks noted are:

- Substantial as well as illegal groundwater is extracted from the subsurface under the forest area, in the plan indicated as 'protected';
- No real attention is paid to proposals of the Watershed Committee in order to reduce flood and drought risks;
- The Province plan does not take care of water problems; water was not an aspect to deal with during plan development.

During the previous years the districts in this province faced floods frequently. An overall flood image is fixed in the map of Figure 6.3. The image is limited to the northern part of Nakhon Phanom province. Of course a substantial part of the flooding is directly connected with the alluvial deposited areas along the rivers.

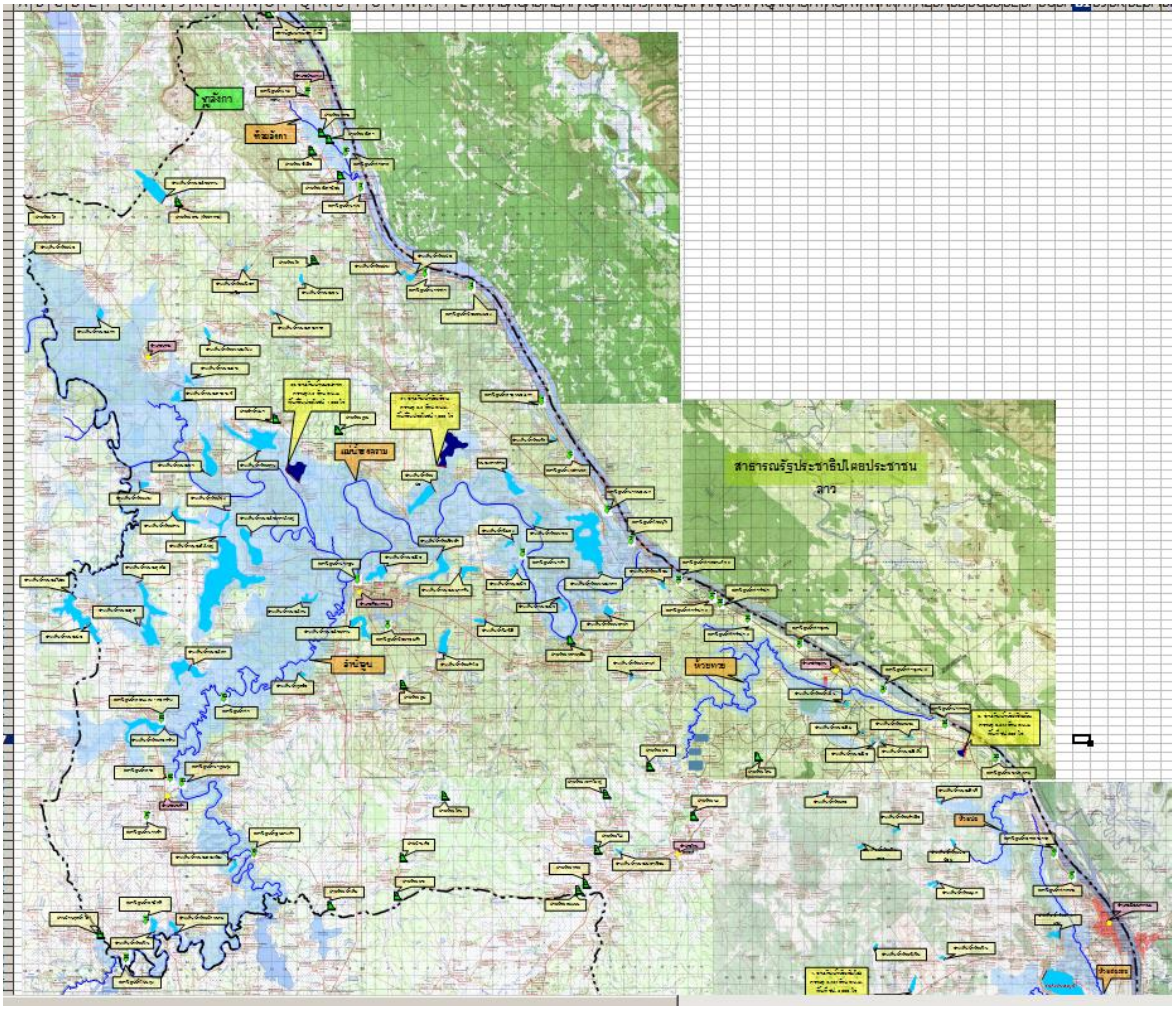


Figure 6.3.: Map image of experienced flooding in the previous years in the northern part of Nakhon Phanom Province (source data set Nakhon Province Planning Office (CPO)); studying this topographic map it refers to the 'Indian 1975' coordinate system (while all other maps are produced with reference to a newer coordinate system 'WGS84')

Local level

To protect the urban areas in regard to problems of flood risks, additionally to the land and water planning and management efforts through plan development at provincial level, production of local land use plans is required. They should prepare, spatially related, opportunities to improve and reduce such risks at the local human settlements level.

However, out of the 12 (urbanised) human settlements only one local comprehensive plan has currently been fully approved. This concerns Nakhon Phanom city (tesaban muang), Figure 6.4.

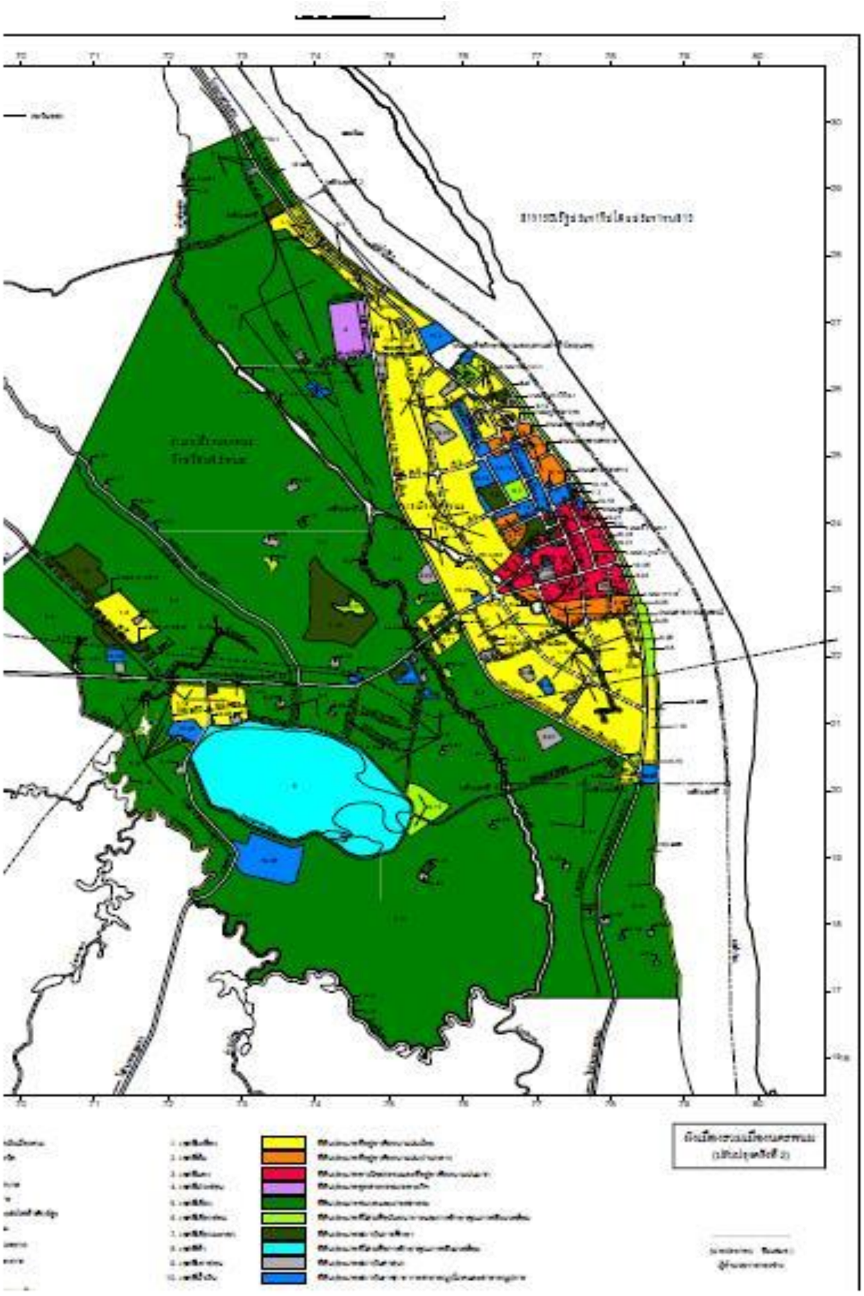


Figure 6.4.: Example of a comprehensive plan, as a plan model for urban areas, Nakhon Phanom city

What is true for the Provincial Plan development is even more serious for the plan design(s) in the urbanised areas, with instead of 5 colours a set of 10 colours.

Yellow	low housing density; sparsely populated
Orange	medium housing density
Red	high housing density; 'crowded area'
Purple	industry
Green	agriculture
Light green	open space for activities
Dark green	education

Light blue	preserved area for environment
Grey	religious area
Blue	government offices

Also these 10 colours comprehensive plan provides no clue for an integration of land and water management issues. Nor it provides intervention options to reduce flood and drought problems. This means that the plan does not consider flood and drought reduction and prevention. The Nakhon Phanom land use planners confirmed this, but even if they had such taken into account, the resulting standard map image does not support opportunities to steer, control or enforce accordingly.

The comprehensive plan is the standardly applied land use plan type in Thailand. These plans apply to urbanised areas and their surroundings. The comprehensive plan has no tools to become supportive to disaster protection. The indicated zones in the comprehensive plan avoid any subarea allocation in favour of flood and drought protection. Even an indication of set backs along roads and rivers are not part of this plan type. Instead, setbacks come from other directives. What is here applicable to the river embankment zones is also relevant to the concrete urban surface. Urban flooding after rainstorms is particularly due to the concrete surface, both on roads and on yards around houses and buildings. This makes infiltration in the subsoil and subsurface completely impossible. Rainstorm sewerage systems have insufficient capacity to react fast and effectively enough, consequently streets are seriously and for some time flooded. These problems could recently be observed in Bangkok, in June as well as in October 2015 ("Anupong on mission to target floods. Commuter routes under dept spotlight", Bangkok Post, 7 October 2015).

Beyond heavy local rain downpours, human settlements near/along rivers face the consequences of high water levels. The used example for a comprehensive plan Nakhon Phanom city is located outside the study area, the northern part of the province. Nevertheless, the Nakhon Phanom city comprehensive plan approach will follow the same way and procedure to use for plan development and design in other Nakhon Phanom settlements.

NAKORNPANOM WATER DATA SUMMARY

District	Reservoir Million CUM	Irrigation Area (rai)	Rain2011 (mm)	Flood Area (rai) (Aug 2011)	Flood Area (rai) (Sep 2011)
อำเภอท่าอุเทน (ม.สงคราม) (ห้วยบ่อ) (ห้วยทวย)	0,98 1,88 0,19	950 2.250 1.100	0,00	4.426,00	10.001
อำเภอศรีสงคราม	5,19	5.160	1.943,80	68.663,00	169.857
อำเภอนาทม	5,45	1.450	2.726,80	5.852,00	31.243
อำเภอนาแก	1,94	4.555	1.735,90	4.470,00	
อำเภอนาหว้า	1,54	3.750	2.056,40	4.162,00	29.621
อำเภอเมือง (ห้วยบังกอ) (ห้วยบังฮวก) (ห้วยบ่อ)	0,45 3,06 -	840 4.065 -	2.719,60	1.216,00	
อ.บ้านแพง			2.905	26	
อ.วังยาง			2.417,70	592	
อ.เรณูนคร			2.255,80	517	
อ.ธาตุพนม			1.790,30	2.033	

Table 6.1.: Nakhon Phanom water data summary, storage, irrigation, rain and floods in August 2011 and September 2011 (source: CPO Nakhon Phanom)

Figure 6.5.: Photo of a street in Si Songkhram city, flooded, after one monsoon rain day, July 2015

Floods therefore will repeatedly trouble these settlements, because:

- During the plan development and design, water is not really an aspect of consideration. Flood and drought prevention and mitigation are not addressed in the comprehensive plan and not in its plan map (for the future).
- Moreover, a comprehensive plan in the way Thailand produces this plan type, would anyway not really help, missing the required planning tools, for effectively achieving an adequate control and enforcement in order to reduce flood and drought risks.
- In general, comprehensive plans as well as provincial plans, as Thailand's major types of land use planning, do not provide clues for assignments of land for groundwater extraction or the limitation or even prohibition of extraction. The same is true for water recharge into the subsurface.
- The absence of clues in land use plans is simultaneously true for groundwater quality protection needed for drinking water, which is particularly relevant in industrial and agricultural areas (referring to the use of chemicals such as solvents, pesticides, fertilisers).

Figure 6.6.: Photo amphoe Ban Tha Bo flood memory, house poles, 1 m' high inundation, August 2015

Consequences of not integrating land and water planning for flood and drought risk reduction for amphoe and settlement Si Songkhram were well visible.

In July 2015 after a twenty-four hours of monsoon rain, one of the neighbourhoods adjacent the river flooded (see Figure 6.5). A month later another neighbourhood, in the amphoe Ban Tha Bo, was seriously inundated, a full meter high (see Figure 6.6).

Besides flood risks (see Figure 6.7, and recorded for the Songkhram area in August and September 2011, see table 6.1), it is obvious that Nakhon Phanom Province suffers droughts (see Figure 6.8.) too.

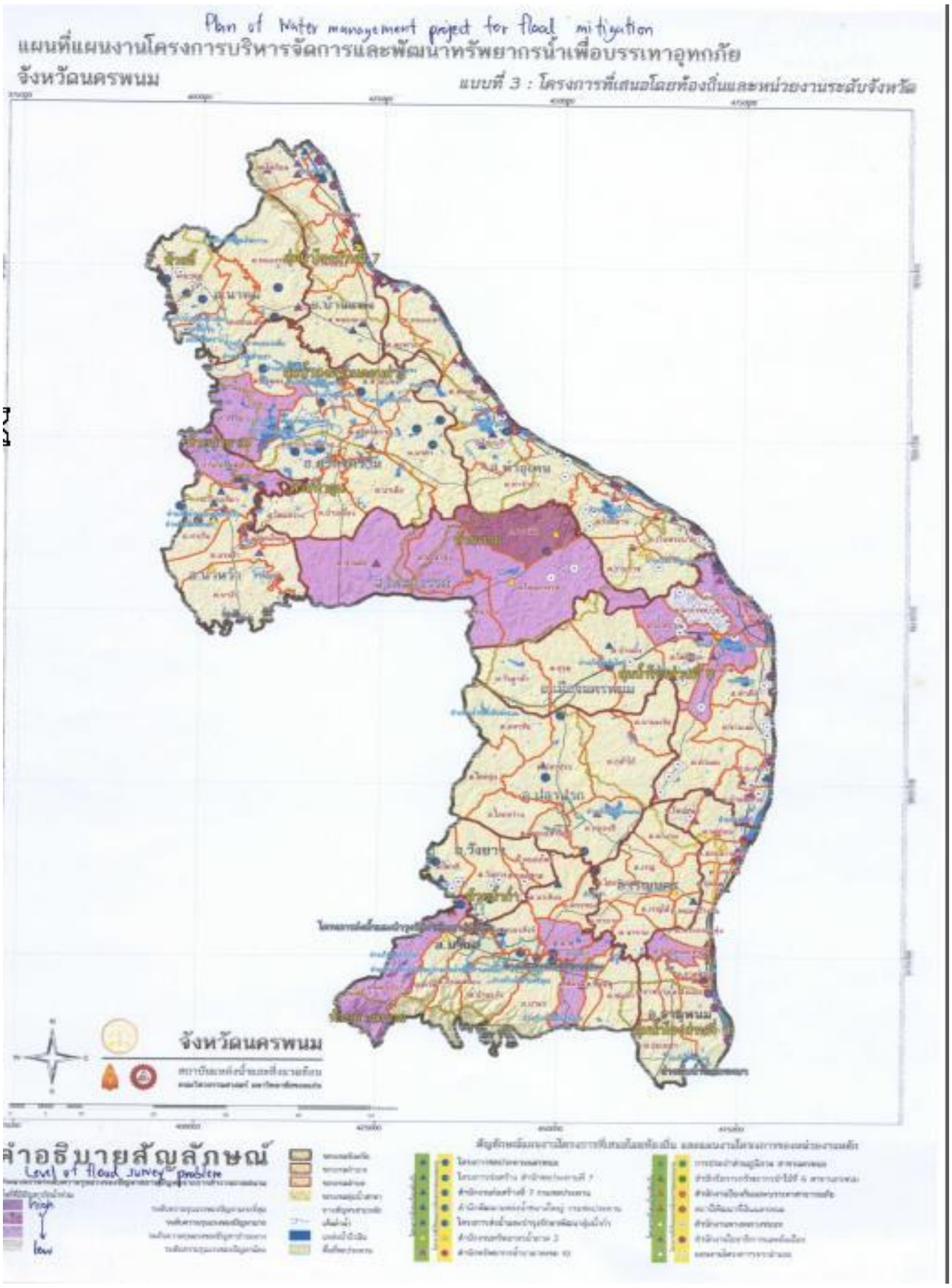


Figure 6.7.: Map image of flood areas in Nakhon Phanom province

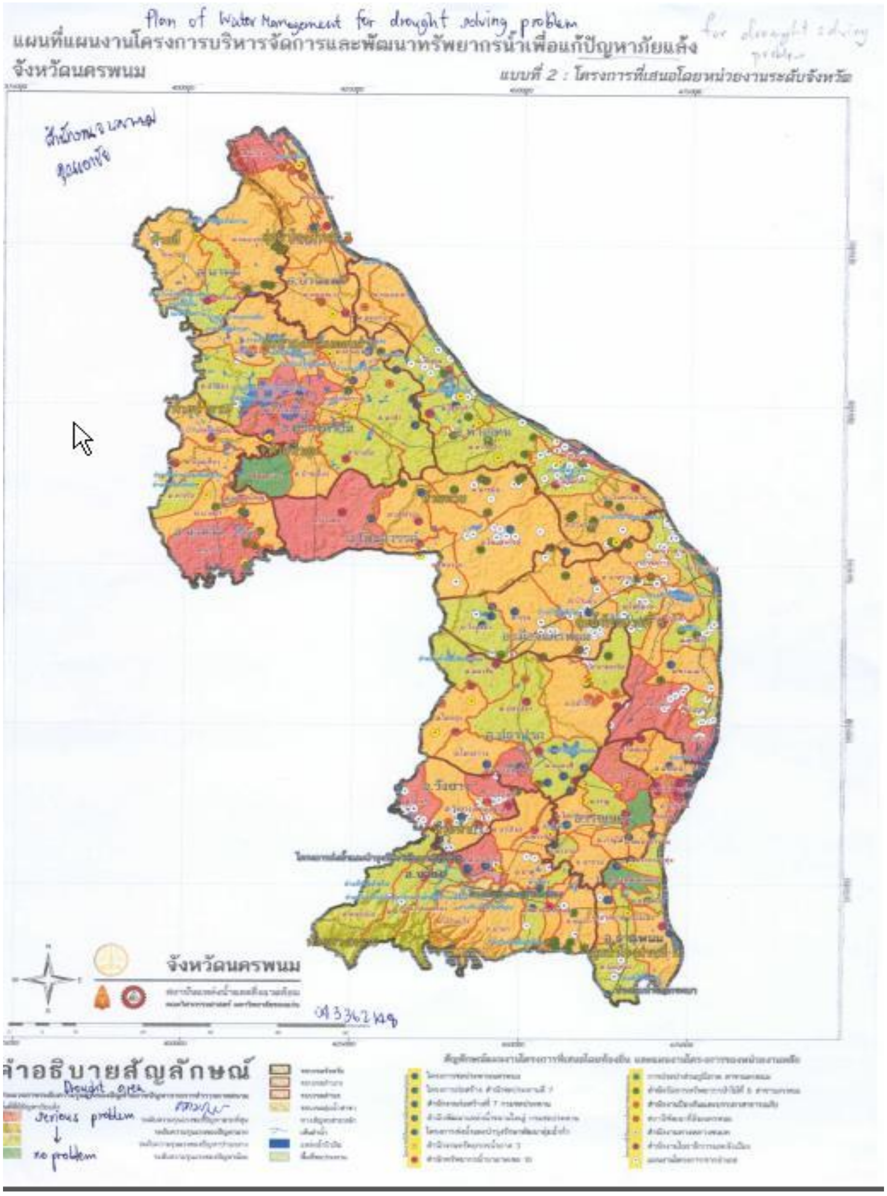


Figure 6.8.: Map image of drought areas in Nakhon Phanom province

This is evidenced in at least two ways:

(1) one concerns the map image showing drought (risk) areas in the province
(2) the other comes from press announcements in the course of 2015 in which the Thai Cabinet indicated several drought risk provinces, one of them was Nakhon Phanom (Bangkok Post, "PM puts face in kaem lings", 17th September 2015). Moreover, weather forecasting announced already that Thailand will face serious droughts in 2016 again ("Govt speeds up drought-busting plan", Bangkok Post, 7th October 2015).

This expectation for 2016 and ahead ("Chao Phraya drought will last till 2017", Bangkok Post 2 October 2015) justifies urgent attention to these water problems through integrated land and water planning, and to support flood and drought reduction effectively. Land use plans are crucial vehicles to achieve that goal, provided that control of planned and in spatial plans fixed specifics are controlled. Possible violations should be avoided, if necessary it requires enforcement.

Plan นิ่ง 'ning' or neglected flood & drought 'action & dynamics'

Usually planning activities are preparations for future developments, preferably approved by society and fixed in plans, directives and/or laws. Planning is embedded in many sectors, most of them are spatially linked to each other. That is a major reason why integration is so important and why it is repeatedly emphasised. Moreover, if in one sector a disastrous event originates, it may certainly trigger a domino effect in other sectors.

Improvements to reduce inundation risks should be prepared by various land use planning actions. They should be fixed and specified in adequate and effective land use plans. This applies both to countryside and local (urban) human settlements. In general, in a plan they concern:

1. Setbacks which are also in plan map images visible zones
2. Surface water balance
3. Drainage opportunities through non-concreted reserved and non-used land
4. Improved up to date rainstorm sewage system and capacity
5. Sufficient subsurface water storage opportunities
6. Linked to land parcels and registered ownership

Several (flood and drought) policies are indeed workable through land use planning. Through land use planning, risk reduction is connected with surface water bodies, particularly where they are situated near rivers and their tributaries. As such the content of the plan can become subject to protective measures, such as:

(a) In the rural areas and countryside:

1. Taking away encroachments with clear setback zones along river bodies
2. Waste cleansing of water bodies, frequently executed and monitored
3. Cleaning the river sides/embankments from bushes etc., and from erosion deposits, providing again Room for the River, and therewith more capacity for water storage and the keeping of precipitated rain water temporarily and locally
4. Widening surface water bodies, and creation of new retention lakes, preferably as drainage water storage bodies
5. Deepening river beds in order to create more storage capacity subsurface from river water
6. Creating dikes, elevated lining, along rivers and canals
7. Extending the use of weirs, both tempering river run-off volume speed, and, simultaneously, increasing time for drainage gravitationally of river water into the subsurface inclining the groundwater table in water extraction areas

8. Connecting retention units, particularly those that can work as gravity water drain storage bodies, with nearby river and irrigation systems.

Figure 6.9.: River requiring Room for the River actions, as providing more water storage capacity body

Figure 6.10.: example of a natural elevation usable weir for retention in a drainage water storage

(b) In the (urban) human settlements and surrounding areas additionally:

1. Cleaning the canals (e.g. Bangkok)
2. Enhancing the capacity of water bodies under adjacent to main roads (example Thung Song in Nakhon Si Thammarat Province)
3. Building storage caissons under the roads (Khon Kaen)
4. Promoting rain water storage from the roofs of houses
5. Buildings equipped with gutters combined with water storage bins for temporary storage of collected roof water placed on land surface (storage bins of at least 1 m3)
6. Introducing opportunities of urban agriculture and forestry, particularly raising awareness about the positive flood and drought reduction effects
7. Implementing a variety of urban wetlands, spread across the settlements territories
8. Reducing the (100 % complete) use of concrete for infrastructure works
9. Enhancing the use of pavements that work as water through-passing land surface, allowing percolation downward
10. Reducing the use of (concrete and other kinds of impermeable) pavement of house yards. Simultaneously increasing the yard proportion filled-up with earth, that is soil for gardens, which will enhance weathering opportunities (this could be an interesting issue to be specified and fixed in land use plan and architectural design)

Surface water is linked up with water storage in the subsoil and subsurface aquifers. Now after elaborating the overall land use planning problems and opportunities, in the following, special attention is paid to the problem solving idea as embodied in the SWS pilot project, (managed) subsurface water storage, applied to Nakhon Phanom.

Subsurface water storage

เพชรในตม **"Phet nai tom"** (a solving wonder: a diamond in the mud)

Concerning the watershed in the provincial, countryside, and urbanized areas, a substantial part of the superfluous precipitation during monsoon periods precipitated should be kept in the area of precipitation. It combines surface water bodies with groundwater and subsurface aquifers.

An aquifer is a subsurface (hydro-) geological soil/rock/sediment layer, saturated with groundwater, capable to store and transmit water by (significant) hydraulic conductivity (permeability). Confined aquifers are boundered by less permeable layers. The aquifer becomes useful in case transmission of water regards economic relevant quantities, and/or is such permeable that transmission velocity (hydraulic head) is sufficient to support flood and drought risks reduction at the land surface through infiltration or recharge. Therewith such aquifers can often provide capacity for and function as groundwater storage units. It may balance the groundwater table during the subsequent (wet and dry) seasons of the year. Moreover, they can offer water supply to consumers, agriculture, cattle breeding, industry, etc. during dry periods, if required.

The surface water bodies are seen as intermediate, suitable and applicable, as gravitational water bodies with preferably 'spontaneous' drainage in the aquifers, and/or where required, drained artificially into the managed aquifer recharge (MAR). Drainage from water storage bodies at land surface into the subsurface occurs primarily in a horizontal direction, reason why preferably the drainage water storage bodies are long and not wide. Such bodies may, therefore, be created parallel along rivers and tributaries, comparable with lagoons.

To become aware of suitable aquifers, geological and hydrogeological investigation is needed. In that sense, within the current pilot project, it is applied to Nakhon Phanom province in the course of September 2015. The outcomes of the study are described in this Nakhon Phanom SWS report. And in line with the previously formulated objectives for the SWS pilot project, the results show and evidence opportunities for the SWS approach, although some constraints are identified too.

Linking surface water with subsurface groundwater by (natural) gravitation or artificial support. Through the aid of drainage water storage body a link is created. This link is connected with a source, such as monsoon rain, river, lake, etc. The links are connections at a bit higher level than the average highest water level in the river (under normal conditions, comparable with weirs, an alternative could contain a closing device). Once the water level is higher the water can flow through the linkage towards the drainage water body, and once the drainage water body achieves a stage of possible overflow the water will flow stream-downwards back into the river. The water once in the drainage water storage body will percolate into the subsurface, with an inclined water table as result, moreover filling deeper aquifers (see Figure 6.11.).

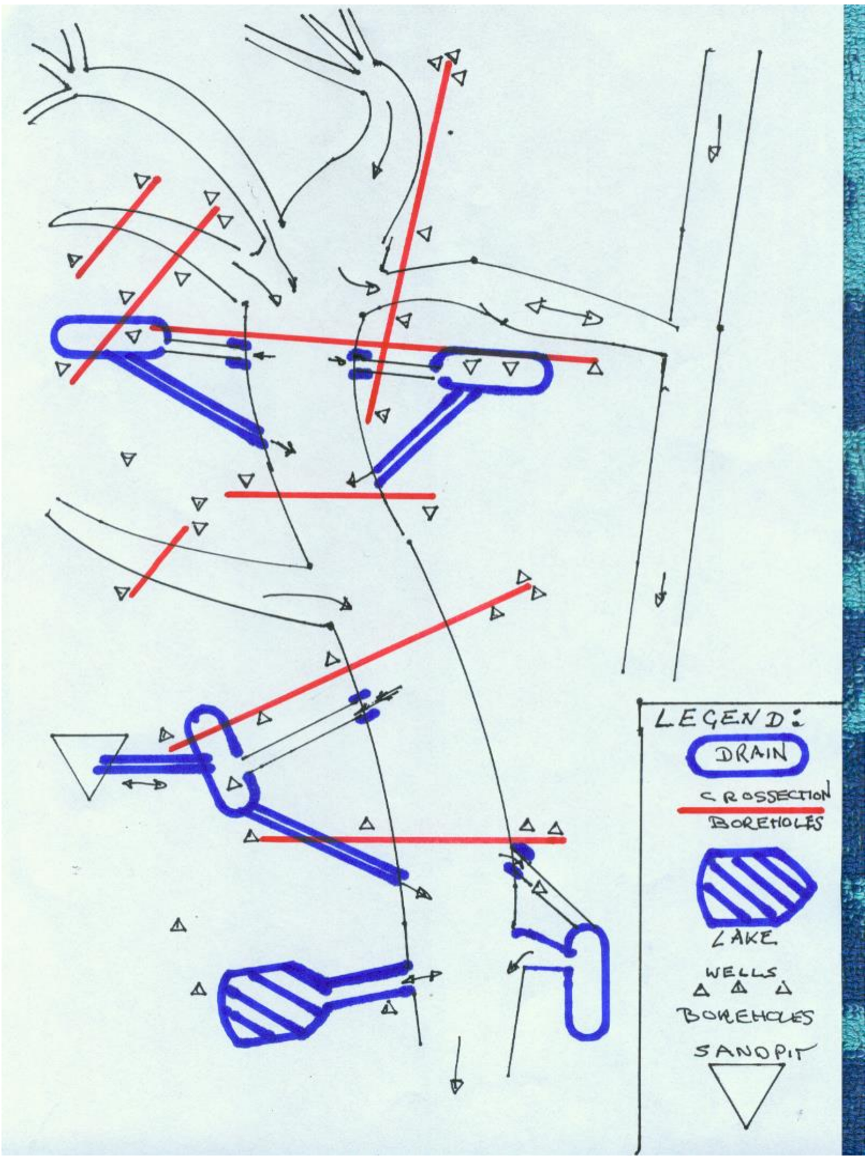


Figure 6.11.: Sketch, simplified, combining drainage water storage bodies along rivers in a watershed basin at (hydro-) geologically investigated sites with aid of boreholes/well information, and subsurface water storage in (shallow and deep) aquifers

As such the results of the study are in accordance with preliminary ideas as presented during the two DWR seminars in late 2011 and early 2012. The results are also in line with the indicated assumptions in articles on the topic. (Van der Meulen, 2012; Pavelic et al., 2012). Recently in Bangladesh, comparable opportunities (for a deltaic region) are mentioned (Partners for Water 2015).

Integration and defragmentation are necessary improvements for planning, decision making, and management if land and water go hand in hand to reduce water related risks such as floods and droughts. Subsurface water storage inclusively MAR and RWH as well as the extraction of stored water from the subsurface require groundwater management in cooperation with land use planning.

It would be advisable, through the land use plan, both provincially and locally, to assign areas or zones as specific land, such as drinking water protection area, limited use of land for housing and industry, retention and/or drainage water storage bodies, prohibition of building and construction works in natural drainage and wetland areas.

An interesting example is the dune zone along the Dutch North Sea coast. The dunes, built-up with sand, are used for (Rhine) river water infiltration. The dunes are used as a drainage subsurface water storage body. While the water percolates downward to and in suitable aquifers, the river water is purified. That in aquifer stored groundwater is the source of drinking water for cities as Amsterdam.

To be sure and to guarantee the quality and volumes of aquifer purified groundwater, (almost) all dune territory is specific assigned as Water Protection Zone, fixed in specific land use plans. The indicated zone(s) are fixed in connection with the legal, or cadastral (in Land Office registered) land parcels based on registered ownerships. As a whole the SWS approach can be summarised in the previous sketch.

Figure 6.11 shows a river, run-off, which is linked to drainage water storage bodies at surface level, which is made ready for effective percolation and MAR (managed aquifer recharge). The sketch is relevant to integrated land & water planning and management. Plan development and design for the rural area(s) in a Provincial Plan preferably link land uses such as agriculture with an allocation of 'groundwater storage' (drainage water storage bodies) or 'groundwater extraction' (regulation, prohibition). Therefore, it would be advisable to add in the concerned spatial land use plan a doubling of land use, therewith creating an assign option for specifics as well as an option for site/area protection.

In the (urban) human settlement through local or comprehensive plan, land use zones would preferably be handled comparably. In 'low/medium housing zones' a doubling could be used in order to reduce the proportion or ratio of concreted land coverage. This extra specific would contribute to a workable drainage/percolation into subsurface soil layers.

Subsurface water storage needs a final remark in case soil layers are salty or one or more layers in the subsurface stratification are salt (or other chemical materials containing) layers.

Saline awareness

Some parts in the watershed area include salted or salt layers. In that case a certain risk of washing out may occur. Saline soils and subsurface soils are often a risk and less attractive for agriculture, particularly in case of fresh water nourishing crops.

Although this is true, a few notes should be added:

(1) In case of declining groundwater table, water drainage has a vertical upward salt raising effect;
(2) In case of a salt layer in the subsurface stratification, pass that layer, artificially, should be considered for water extraction and/or recharge;
(3) Increasing use of adapted crops in salted soils in aride areas is more and more common across

the world. Nowadays they adapt because of sea level rising and salt water intrusion in coastal zones. An interesting (western) adaptation concerns potatoes that are recently harvested well while the soil is indeed salty (Water International, September 2015).

7. Research activity C. INSTITUTIONAL

Institutional issues, conference, workshops; the research report and to address special related topics

Introduction

Multi-level integration of the SWS approach, as a pilot research project, includes attention to pay to the organizational aspects and to connected data as a source and information delivery. Simultaneously, it includes a mean to explain the research in the project to a wider interested and professionally involved audience. Therefore, this section considers five topics:

1. Socio-economic data
2. Government initiatives
3. Organizational issue
4. Database management
5. Conference, brainstorming and information delivering workshops.

1. Socio-eonomic data

To mention a few socio-economic data of Nakhon Phanom province:

- (2014) Nakhon Phanom counted a total population: 713,341 people
  Male: 356,106 Female: 357,235 Household: 207,331
- (2014) Si Songkhram district (SKK) counted population: 63,798 people
  Male: 31,850 Female: 31,948 Household: 17,371
- Average income per population in SKK 36,562 baht/ person/ year

2. Government initiatives

Several reports produced by the Thai government are important. The reports are initiatives in order to solve water problems. The reports in fact are invitations to the professional world to tender and to deliver proposals. One of them is the 2012 announced '300b Baht' invitation to tender, and in January 2015 the current government launched, accompanied with an extensive and comprehensive report, a '900b Baht' opportunity for water flood and drought problems improvement. The objectives of this early 2015 initiative of the Cabinet are threefold:

1. To solve water resource problems that cause severe socio-economic impacts and must be urgently undertaken (2015-2026)
2. To integrate water management, so as to create happiness to people and provide opportunity of water accessibility to every single user in an appropriate way
3. To balance the development and the utilisation of water resources in accordance with the basin potential, in response to economic development and sustainably environmental conservations.

Although 2015 was not free of flood problems, main attention in that year went to the droughts. That is indeed understandable, in the course drought warnings have been announced already ("Drought warnings prompt crisis meeting", Bangkok Post, 15 November 2014). The awareness only increased because such droughts are also expected in 2016 (Bangkok Post, August 2015), and even also in 2017 (Snidvongs statement, Bangkok Post October 2015). To tackle flood and drought problems the current government announced various other interventions, together with financial budgets.

Regretfully, non-integrated approaches are still cause of damage due to fragmentation of executive and decision making agencies. Chonburi is a recent example. In this case, traffic authorities work separately from land and water responsible agencies, with serious floods in Chonburi and Rayong Provinces as consequence. The drainage problems created there may be an interesting subject to subsurface water storage in combination with drainage water storage bodies redirecting water streams that cannot longer use their original water drainage zone.

Another consideration of relevance institutionally concerns voluntary cooperations between involved (decentral) organisations. That is (amongst others) cooperatives of land user into 'voluntary water boards' (compare example Trang watershed, initiated through Thung Song municipality (tesaban muang), a TEI/CKI advised initiative 2011-2014) could be very helpful and decisive in preparing and maintaining rain water and flood water harvesting, at land surface as well as drainage into the subsurface. Close partnerships between the involved stakeholders, embracing inputs from government and land users, is promising to tackle flood and drought risks.

Also, to value as an interesting example concerns the land readjustment approach in the Dutch Room for the River Policy. Although a prime target of that policy is smooth, fast and safe run-off of water, it implements also solutions in an integrated land and water framework. An example concerns the arrangement with farmers in the embankment zone of certain rivers. The government proposed the farmers to accept shifting the farm buildings from the lower land towards the higher, elevated land, sometimes on dikes or mounds, while the low-lying agricultural land remains their farmland and property of those farmers. The readjustment intervention is handled by the government. As a result the two parties involved were 'happy' and each achieved its goals (safer river, improved run-off, continued agricultural land use and property consolidation).

3. Organisational features

In the following, three institutional aspects are distinct of and relevant for the SWS project application. The three aspects require separate attention, notably: project involved staff, organization internals, and organization externals.

3.1.STAFF involvement

The project has been executed in tight cooperation between DGR management, DGR staff, and the Dutch experts. During the several phases of the SWS project, the workings could rely upon a adequate support of DGR's managing directors and upon various staff members of DGR. Indeed all time, they showed great involvement and enthusiasm, helpful, while particularly the field work periods were rather exhausting, with long travel time, and intensive hydrogeological sightseeing sessions. A word of thanks is here correct in place (see appendix with photos of the visiting teams during three field visits in Nakhon Phanom).

Comparable wonderful support was also provided by the Province Planning Organisation in Nakhon Phanom Province, both for work accommodation, map plotting support. The same applies to the really useful explanatory information about its plan making efforts and about the provincial facings of floods and droughts.

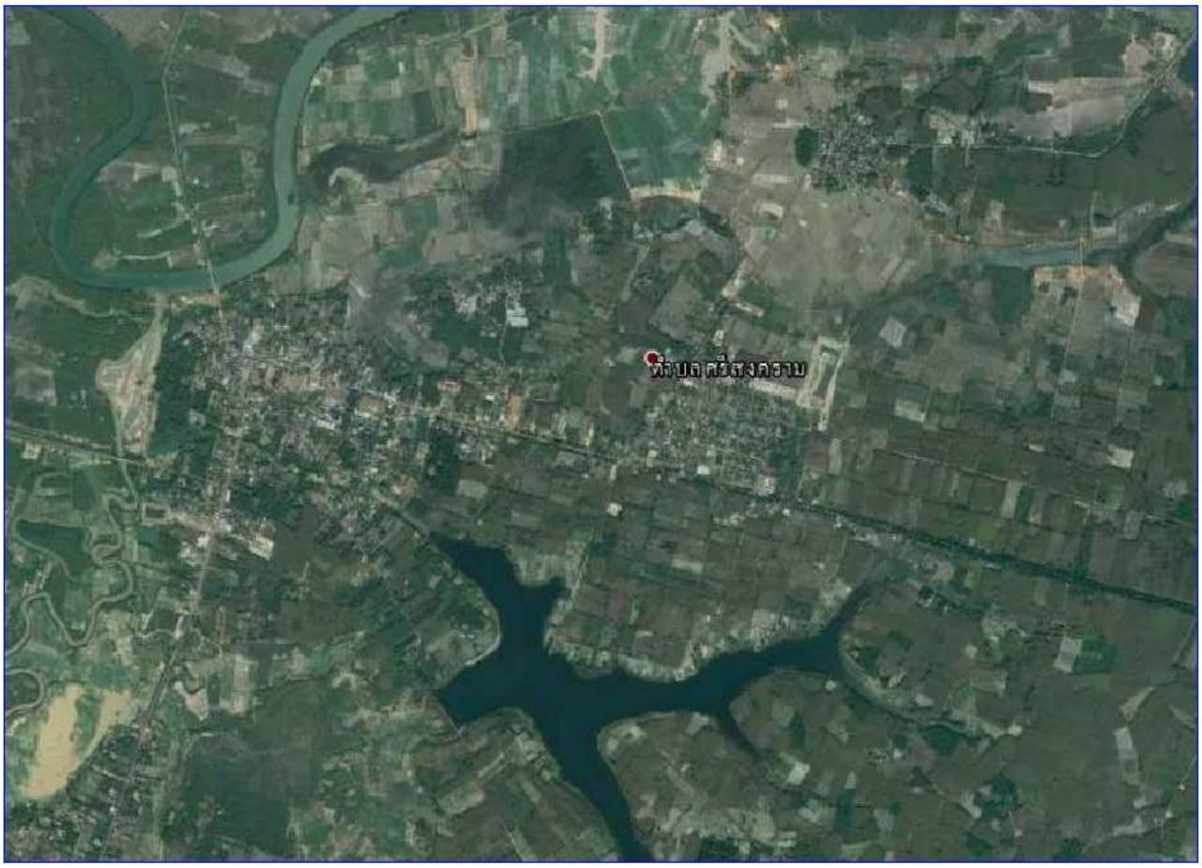


Figure 7.1.: Airphoto of Si Songkhram municipality, highlighting earthen protection dikes along the Songkhram river (source: Si Songkhram municipality)

What is true for the support at Province level has been experienced at local level too. This regards particularly to the support of the city clerk explaining Si Songkhram's flood and drought circumstances. The city clerk guided sightseeing to its major problem areas and protection works under construction (see Figure 7.1), with additional explanation.

3.2.INTERNAL aspects

During project application, an organisation faces features of smooth and effective progress as well as problems which possibly reduce the velocity and quality of the project's execution. In the case of this SWS pilot project, after the required preparation phase (December 2011 - June 2015), the project's progress went straightforward. Consequent steps have been realized since July 2015, with

(1) an acquaintance visit to Nakhon Phanom study area in the August 2015; based on this visit, mainly for feasibility reasons, a project decision has limited the further study activities to the northern part of the province, i.c. (a part of) the watershed of Un and Songkhram rivers;
(2) an extensive field work was carried out for (hydro-) geologic and related land use plan study in the northern part of Nakhon Phanom province in September 2015;
(3) compilation of the (draft) study report, with explanations of the study and results;
(4) the draft SWS report has been subject of reflection both in the Netherlands by the Dutch expert team and (next) in Thailand by the staff of DGR;
(5) In preparation of the conference, brainstorming and workshops in Bangkok (26 and 27 November), a third visit took place (22-25 November). In this case, the full expert team visited the Nakhon Phanom area and deliberated and discussed the study outcomes with Province and local stakeholders.

After that last (3rd) visit to the Nakhon Phanom study area, as said, a 2-days meeting followed, in Bangkok, for conference, brainstorm session, and workshops. With the rounding of the workshops, the SWS pilot project is completed. Consequently, a few days later the SWS study report is finalized and presented to DGR and ADB. During the project study, some features came to the fore which relate to the internal institution's circumstances. In this case:

(a) One of the very (hydro-geologic) knowledgeable staff members of DGR with also a long time of experience in Northeast Thailand, was regretfully on mission abroad;
(b) The absence of this DGR specialist caused also some delay in the data delivery during the start of the preparations
(c) A certain scattering of internal data sources came to the fore. This caused time consuming consequences, both previous and during the field work study phase;
(d) Another observed problem was a problem that relates to a high workload (too busy, forgot);
(e) Data problems have been encountered (see hereafter under Database management).

The remarks mentioned here are relevant because as in each other project, this project is rather vulnerable too. The consequence could be influential on working results and therewith on quality of study results and recommendations

3.3. EXTERNAL aspects

Water management is a comprehensive and complex field of workings and involvements. It is obviously a multi-disciplinary field of study. It is also a multi-dimensional phenomenon, reason why nowadays it is seen as multi-level integrated land and water resources relevant, requiring planning and management. As such it is understandable that in case of this SWS pilot study project, groundwater is a major issue of concern. Simultaneously, many other water relations are addressed. However, here problems of serious fragmentation are encountered. This is not new, for all, it was already identified by the Dutch Identification Mission Team in February 2011, previous to the Great Flood. The team identified circumstances which 'probably' would cause serious inundation of Bangkok City and beyond, in the near future.

It is also worth to note that during the preparations of this SWS pilot project, certain water related institutions did not really feel being involved. Addressing groundwater and subsurface water storage, specialisation and mandates in decision making cause extra fragmentation. So a staff member of the Department of Water Resources (DWR) mentioned that groundwater was not their issue, instead the department is dealing with and responsible for surface water. This attitude is regretful because surface water is anyway the resource for groundwater. It is also regretful because a substantial part of the drought and flood problems could be solved through a tight cooperation between the two water occurrences, and the two departments.

Another example of ignorance of institutional relevance for groundwater, floods and droughts comes to the fore in the workings of the Department of Public Work and Town & Country Planning (DPT). This regards both its standpoint and attitude (it is neither our main concern nor responsibility as public works agency), as well as its way of working in land use planning inclusively its major plan design and developments.

Although often making statements of doing integrated water resources management (IWRM), the recognised reality is different. Multi-disciplinary integrating work (based upon and connected with relevant organizations for data input) is limited or even absent.

Living alone together, that is, (each) organisation stands on its own and for its own (the explained land use case in one of previous sections may just serve an obvious evidence). Data comes from various institutions, although all are Thai government departments, it showed sometimes to be cumbersome to retrieve such data although the institutions work in related fields. Notwithstanding some difficulties regarding data retrieval, the project encountered excellent support and data delivery in general. This applies certainly to (hydro-) geological information and maps.

The availability of the recently produced maps on geology and hydrogeology for the Northeast of Thailand is a welcome and very useful up to date feature of DGR's and others endeavours. It provides new insights and knowledge about the subsurface, geology, lithology, and groundwater related information.

4. Database management

One of often experienced problems in projects was data: data quality, correctness, and completeness. This applied particularly to geo-connected projects. It regarded to digital and non-digital (paper recorded) analogue information. Such information may come late and sometimes too late. It might be delivered in a scattered way, even retrieved by surprise, possibly collected from a large number of (governmental) sources, and only available in a variety of data storage formats.

The performance in this project is not free of such problems either. Some problems were easy to overcome, others rather difficult. In case of difficult problems, they simultaneously and regretfully influenced the project's research efforts. Adequate delivery of data, maps and information had direct effect on outcomes, findings and results of study. Moreover, it influenced the overall project running time, which is per definition limited due to human and financial resources.

The project's concern of relatively late data availability is a matter of project management which can be avoided in comparable follow-up. The project's concern with scattered and via different formats stored data is a database management issue. The scatter issue is (1) partly a consequence of the high level of involvement of a variety of water management related departments, and (2) partly it is a matter of inadequate building up databases, which preferably should be done as relational databases. Scattering can be avoided if data organisation is sufficiently foreseen (1) through the relationship between databases, (2) preferably well-connected at the level of its data objects, and (3) through a data storage approach using a comparable and up-to-date storage format approach.

Data fragmentation has consequences for project outcomes. Outcomes may become incomplete, and may trigger mistakes during interpretation. Incorrect and incomplete data causes GIGO outcomes (GIGO refers to 'garbage in, garbage out', an indication used in Informatics Science to warn for not visual mistakes and typing errors in digital files which are basic to outcomes from the so-called black box).

{……..
Notice:
Beware, the following remarks apply to the borehole data that the project team received at the beginning of the fieldwork activities. After the fieldwork, various kinds of borehole data on paper sheets were handed to the team. Also after the fieldwork a summary explanatory report regarding the geologic and hydrogeological investigations and mapping has been provided. This Executive Summary (DGR/MNRE 2015) mentions about boreholes used during that geologic mapping works. At this moment, it is not clear if these boreholes are included in the through DGR to the expert team provided borehole data.
……}

Another project relevant problem relates to observations in digital databases. Regretfully, to understand that out of the mentioned total number of wells only a rather small amount of wells, boreholes and monitor wells have been registered with reasonable data sets. That relatively low proportion opts to very careful statements about the subsurface stratifications.

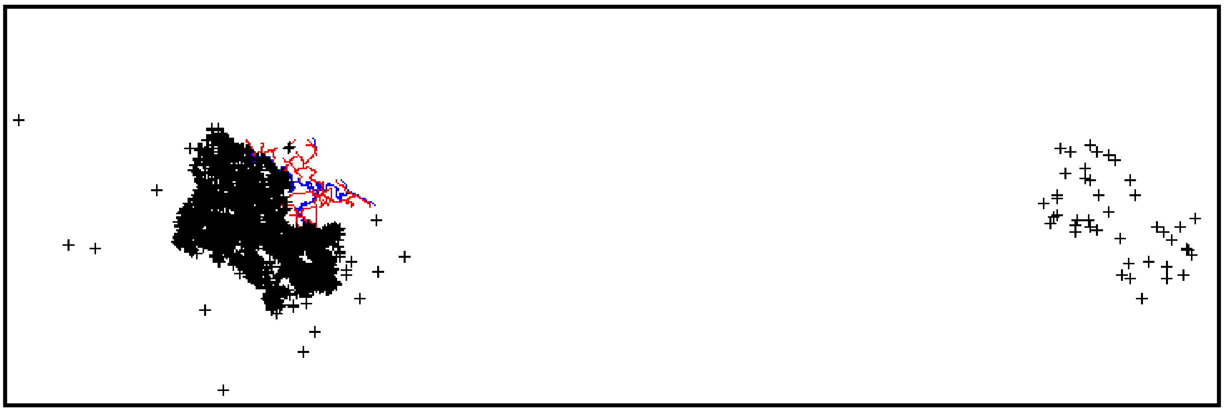


Figure 7.2.: Map image of borehole sites in the Nakhon Phanom and beyond area. A part of the boreholes is situated in Lao PDR and Viet Nam territory, a few even in the Chinese sea

Moreover, from the observations inside the digital databases, even a part of the boreholes digitally stored data is incomplete, in some cases the coordinates to allocate the drilling through X, Y or northern and eastern coordinates is absent. In other cases they are incorrect (see Figure 7.2).

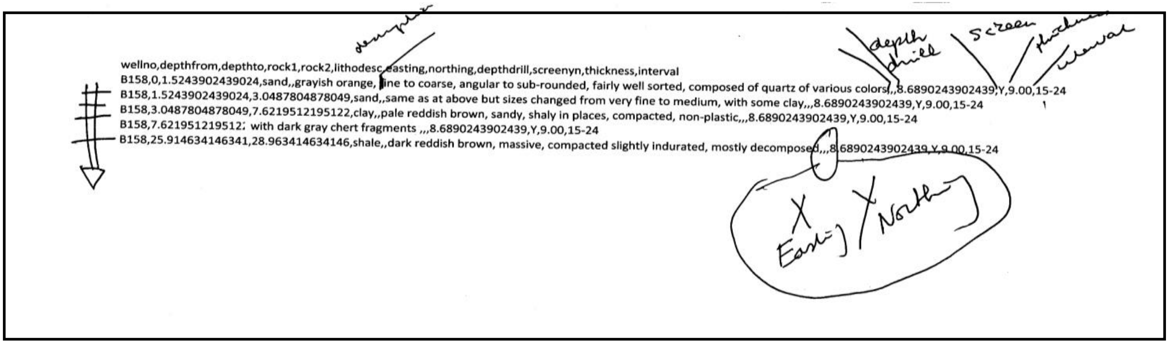


Figure 7.3.: Data records of a borehole, absent (X eastern,Y northern) coordinates

Although for the Northeast of Thailand DEM and (height) contour line are available and could be used for land surface height specification, these estimations could not adequately replace exact ASL height data of boreholes. In majority of the boreholes that data is absent. In other cases, they are not correct regarding the land surface height level (see Figure 7.4). Height estimations could easily cause interpretation mistakes in (hydro-) geologic cross-sections in the study area.

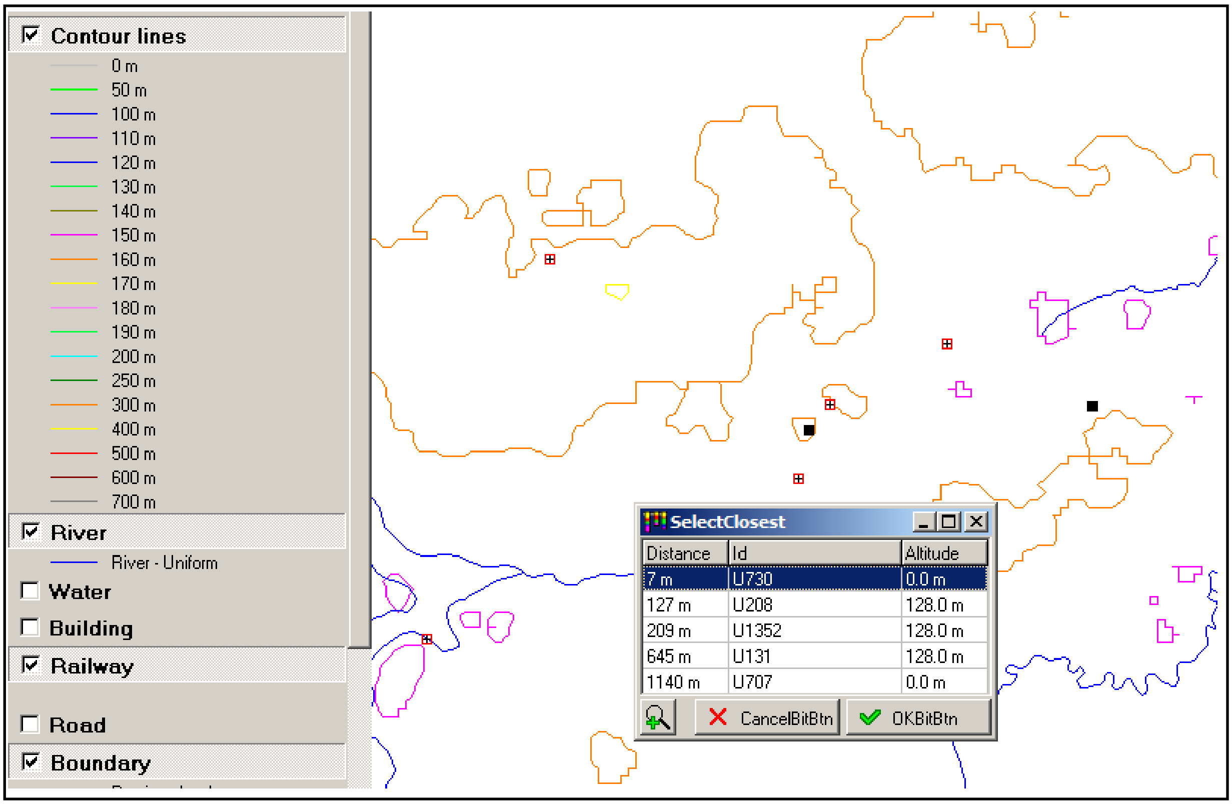


Figure 7.4.: Map image showing two wrongly input height data. The internal window shows '0' values which refers to two boreholes with nill height values; the other three boreholes show height values that do not fit between the two contour lines around them (image produced by CKI's software programme "ShiMoDes")

Furthermore, to get a more complete picture of the boreholes, various data sets had to be combined. This; however, was not in all cases straightforward to do, partly the sources were old and compiled through different formats in paper records available.

From the retrieved information, it is clear that an adequate data storage procedure and handbook are not at hand, but most desirable to develop in near future.

Considering the boreholes, a few words more are relevant for subsurface (hydro-) geological and the research. Aware of:

(1) the various ways this data is available,
(2) the awareness of the observed absence of data for the majority of wells, particularly the manifold of private drillings for consumption water supply, it is obvious that a suitable data system is needed.
(3) Several registrations within the borehole stratification are confusing (see Figure 7.5 with borehole depth differences for U727 the indicated drill depth is 8.23 m', while the bottom of the showed borehole is much deeper)

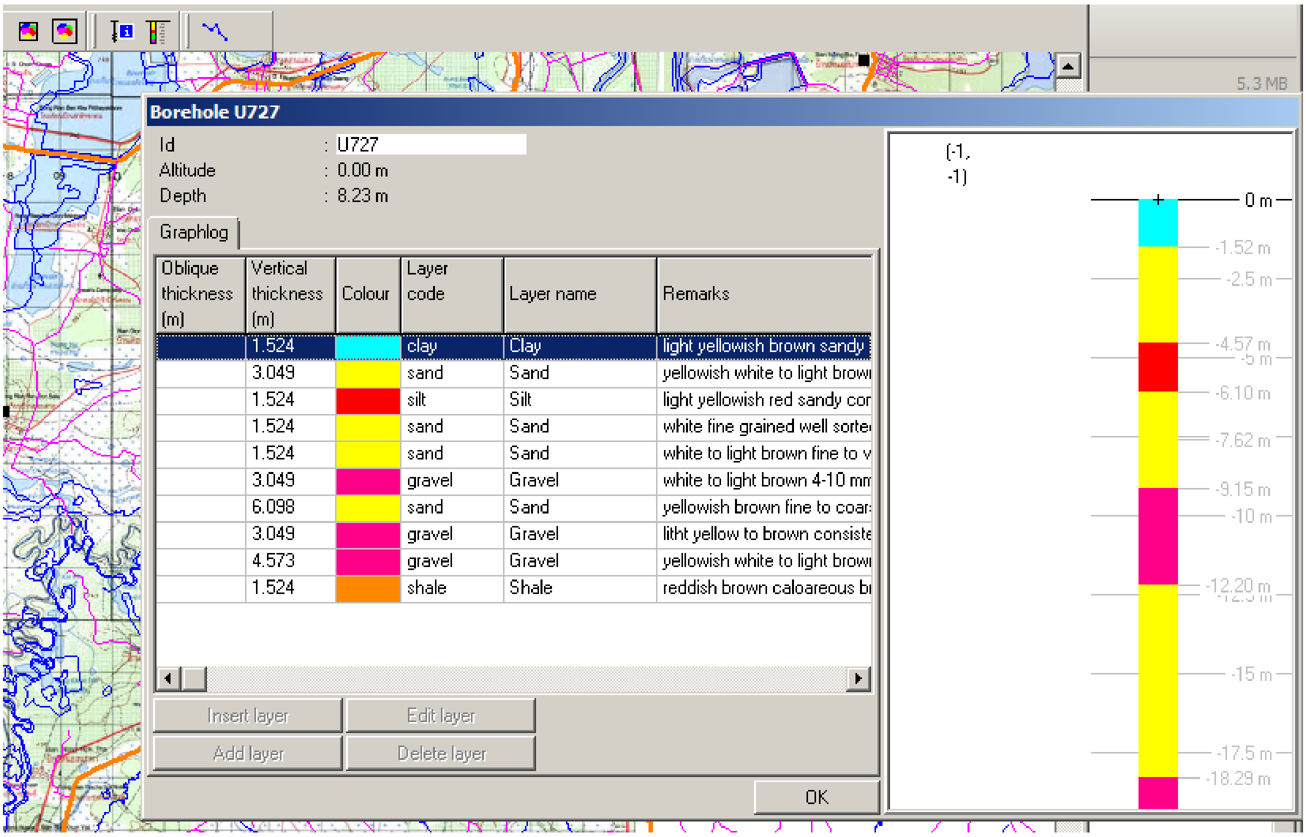


Figure 7.5.: Borehole U727 indicates different drill depth compared to the borehole size from top to bottom (source: image produced by CKI's software programme "ShiMoDes")

That is a consistent registration of wells and drillings according to a fixed way and registration protocol. Preferably, it includes material stratification and lithological description. As such it would provide a very useful support to research. This would be useful for (this) SWS research too. Such consistency relates to the digital storage and to the applied formats.

As a final general remark it should be said that data and database improvement us necessary for adequate follow-up research and executing application works. Of course, it is important for data and database reliability too.

5. Conference, brainstorming and workshops

This section pays attention to information delivery with regard to the SWS project's outcomes, findings, results, and recommendations. It embraces three subparts, notably: (1) conference (the morning of 26 November 2015), (2) brainstorm session (afternoon of the 26 November 2015), and (3) several short workshops to highlight information management gained during project execution, and to present experiences of the Dutch team's experts gained during years internationally, with a focus upon hydrogeological state-of-the-art and implemented solutions.

Conference

The conference would particularly put to the fore the SWS research pilot project. The focus was upon the project's outcomes, findings, and results. Based upon them, various recommendations were mentioned in order to be helpful for further SWS activities in future. The structure of the conference is built up as follows, in short:

(1) a few general words of welcome and overall information;
(2) a presentation of the Director of DGR's Groundwater Assessment Division about the groundwater resources matters in Thailand;
(3) Opening Ceremony Speech of the Deputy Director-general of DGR;
(4) a contribution of the Asian Development Bank, highlighting ADB's regional involvement in water resilience;
(5) an address of the Ambassador of the Netherlands in Bangkok explaining Dutch general international involvement in water management supporting projects;
(6) two presentations that relate directly to the SWS project activities and to the learned from the research activities in line with the objectives of the SWS project.

An overview of the conference is included in the appendices. Concerning the presentations, one of the appendices provides summaries of the presentations. Moreover, a memory stick is attached containing the PowerPoint presentations. The conference is ended through a rounding closing session.

Brainstorming session

After the conference, during the afternoon session, representatives of DGR, DPT and the Dutch expert team met to consider a possible future of the SWS approach, and opportunities for continuation. The session is subdivided as follows:

(1) as a start, an introduction underlining and explaining its goals;
(2) introductions of the Dutch experts and explanations of experiences of their organisations gained in projects and subsurface storage of water;
(3) a Thai-Dutch joint discussion about SWS follow-ups and opportunities in future;
(4) formulation of some conclusions of the brainstorming to complete the session.

The conclusions are fixed in an appendix to this SWS report.

Workshops

The Dutch expert team provided a number of SWS connected presentations. They presented in the form of information workshops. The presentations expressed experiences and matters of state-of-the-art in geology, hydrogeology and water issues in general. The workshop presentations lasted about an hour each. Only the first workshop lasted two hours. That workshop related directly to the experiences during the SWS application in August and September 2015. An overview of the workshops with summaries is presented in an appendix added to this SWS report.

8. RESULTS, RELEVANCE

Introduction

In the SWS submitted proposal, the project deliverables have been indicated through the following research results.

- A contribution to overall and specific reduction of flood water disasters, with the aid of a relatively fast storage of large monsoon rainwater volumes in water drainage bodies (dedicated retention reservoirs) and consequent gravitational as well as artificial infiltration of water into the shallow and deep aquifers.
- A contribution to overall and specific reduction of water shortages and the effects of droughts, through balanced ground water supply with an adequate height of the groundwater table and therewith increased accessible water to meet demands of agriculture, industry and others.
- A contribution to an optimised working relation between the various organisations responsible for (ground-) water in the overall water sector at land surface and in the subsurface, emphasising the crucial role of land use planning and plan development opportunities for land use allocation, protection and connected zoning, in a framework of multi-level integrated land and water resources planning and management.
- Nakhon Phanom watershed case study underlines relevance to up-scale this SWS approach towards other areas in Thailand. Other potential areas are preliminary identified.

Findings

Studying geological and hydrogeological data and maps, in combination with observations made in the field, along the two sections of Un and Songkhram rivers, sufficient information became at hand for the identification of aquifers. In connection with the identified aquifers, suitable sites at land surface for the implementation and use as drainage water storage bodies are (probably) available nearby too. That is, suitable at land surface to function as such, mostly after excavation of top layers (generally clay). Considering the studied sections of those two rivers in the watershed basin in the northern part of Nakhon Phanom province (and adjacent provinces), there is sufficient proof and reason to expect that the two sections are useful for SWS.

The study also disclosed serious shortcomings regarding the quality of a rather large part of available data and databases of boreholes. Although the number of boreholes is rather large, lithology stratification and soil quality information are absent in majority, partly databases include mistakes making them not useful for refined hydrogeological and technical decision making for SWS.

During the study in Nakhon Phanom Province, simultaneously extensive attention had been paid to the integrative land and water development workings. This concerns cooperation between soil qualities, land use and land use planning on the one hand, and on the other hand surface and subsurface (ground-) water resources management. This particular study part underlines a difficult problem which relates mainly to the limited quality and effectiveness of land use plans in order to support water resources management as well as to provide necessary directions and protections.

Outcomes
The Songkhram river section offers a useful drainage potential in the shallow aquifer. However, a serious constraint requires attention. For all, the shallow aquifer(s) are vulnerable. They may certainly have a potential for pollution and/or contamination. In contrast, the Un River offers deep aquifers suitable for drainage and transmissivity. They offer probably, seen the stratification and layer materials, a better development option. Nevertheless, in both cases, further analysis in practice is required first, to extra justify these findings, and to see if the aquifers indeed suit for SWS.

Further study and according findings in conclusion necessitate protection and directions in land use and land use limitations, through and fixed in suitable and for that purpose adequate land use plans. Plans that allow effective control and monitoring when and where needed enforcement to reach its targets not violated. It is obvious from the explained and reasoned limitations and even weaknesses of applied land use plans that a long way is to go. Long way or not, land use planning improvements are a prerequisite, particularly for a final outcome towards a multi-level integrated land and water (resources planning and management, in favour of flood and drought risk reduction. An obviously observed need concerns strengthen data and database management capacity, through tailor-made training programme(s). This training should preferably also pay attention to related project management issues.

Results
The main result of this SWS pilot study project is the support it delivers to the ideas fixed in the project's objectives. That is, aquifers are available in the study area. The identified aquifers are (probably) suitable for gravitational drainage, aquifer recharge and have sufficient transmissivity and velocity to move and to spread stored aquifer groundwater. Those aquifers relate to land surface sites suitable to allocate and to apply as gravitation water storage bodies. In this context suitability refers to adequate and effective SWS qualities (porosity, permeability and conductivity, transmissivity), while availability refers to land property (ownership) and existing and/or planned land uses, as well as constraints they cause.

Relevance
The study, although a stand-alone activity, obviously contributes indirectly to Thailand's ongoing Integrated Water and Flood Management. Moreover, it is also obvious that the results of this SWS research provide added value to ADB's overall water sector work with a sound opportunity to scale up the approach and to apply it to various locations in Thailand as well as in other Asian countries.

Indeed, SWS is more and more relevant. So is El Nino a phenomenon since 1950, fixed in record keeping. Quoting Mr. Trenberth of US National Centre for Atmospheric Research, Sullivan (2015) mentions opportunities to manage water availability, and to be prepared: "Planning could help agricultural economies weather the event better than the El Ninos in 1982-83 and 1997-98, perhaps leading to more water being captured for future use. The general thing about these things is, if you are prepared, it doesn't have to be a negative". In other words, SWS may become a pro-active approach and policy.

9. RECOMMENDATIONS

The field of multi-level integrated land and water resources planning and management is comprehensive. Consequently, a study as executed in the context of this SWS pilot project is certainly a starting-point for recommendations.

From section A and B, additionally enhanced from activities and views explained in section C, the following recommendations can be put to the fore in the conviction that they contribute to further and continued endeavours of “SWS harvesting the floods, keeping the water, and don’t waste it”, as well as contributes to an increased well and safe living of people in the Thai society.

1. *Institutional conditions*

- Facing problems of floods and droughts necessitates a government to consider national legislation, provincial and local directives. In general, to consider **effectiveness of laws**, particularly laws that relate to water, water at the land surface, and water under the land surface in subsurface soil layers, aquifers in particular.
- Enhance decentralized participation and **involvement of stakeholders** in order to strengthen their position in decision making for reduced flood and drought risks, therewith providing institutional effectiveness.
- Strengthen effectiveness of water resources management by **reducing fragmentation** of involved organizations, data sources, and decision making based upon overlapping mandates.
- Enhance the role of **watershed committees**. The committees have information and deliberation efforts sufficiently, regretfully their output is primarily paper work, reports that land on the shelf only. They feel wing cut, fragmented in the water decision making process.

2. *Integrated land and water resources planning and management*

- Adapt **land use plans**, provincial as well as local and urban, in such a way that the planned and mapped deliver clues in order to reduce flood and drought risks, simultaneously offer incentives for control, monitoring and enforcement.
- Underline institutionally the connection between surface and subsurface (ground-) water. Consequently, DWR, RID, and DGR should preferably emphasise joint water resources management efforts, in cooperation with land use planning, as **integrated land and water** planning and management.
- **Integrate and defragment** water management mandates and activities in watershed areas. It should preferably reduce too many departments that are involved at this moment. It would improve land use control and regulation which are currently not functional, partly locally not understood (as explained by insiders in Town & Country Planning agency).

3. *(hydro-) geological features / groundwater resources*

- Allocate surface **drainage water storage bodies**, to function as temporary retention of rainstorm/monsoon water, for subsequent percolation or managed recharge into shallow and deep subsurface aquifers.
- **Repeat the allocation** of drainage water storage bodies at land surface along rivers and tributaries sufficient times, capturing adequate water volumes out of these river bodies in order to reduce flood risks in run-off locations.

4. ***Follow-up of SWS study and application***
   - Elaborate the SWS approach through **further study and implementation** application in the Nakhon Phanom Un and Songkhram rivers watershed section(s) as recognised suitable in this study and report for aquifer subsurface water storage.
   - Extend the SWS approach and activities towards **other catchment areas** with serious flood and/or drought problems, such as Trang watershed (Nakhon Si Thammarat Province and Trang Province), and Chonburi and Rayong Provinces.

5. ***Capacity building***
   - Extensive and comprehensive **training** for DGR staff is recommended particularly paying attention to (hydro-) geologic database management, related project application management.

6. ***Other general issues***
   - Build up a digital and comprehensive **registration system** for borehole data, simultaneously providing a structure for complete data input of all subsurface penetrations, including all relevant (hydro-) geologic data.

10. OPTIONS FOR FURTHER SUBSURFACE WATER STORAGE RESEARCH

From the research done in sections of the Nakhon Phanom watershed of the Un and Songkhram rivers, it is rather clear that continued research in that watershed would be useful. Moreover, extending the research in other Un and Songkhram river parts situated in Sakon Nakhon as well as two or three adjacent provinces in Thailand will contribute to the already recognised relevance of the SWS research findings.

That conviction elaborates also the path towards other locations inside the Kingdom of Thailand, particularly there where the harvesting of flood waters and the risk of droughts ask for and require crucial interventions of the Thai government. At the same time, it is necessary not to see subsurface water storage as a stand-alone exercise. Sustainability can only be reached once a multi-level integrated land and water planning and management approach is undertaken, otherwise the effect of intervention will quickly vanish away, with continued appearance of flood and drought events.

Figure 10.1.: Waterfall in national park territory in Thung Song amphoe, being the start of the superfluous flood water through the Trang River during monsoon rain periods

Anyway, with this in mind, another option for further research and application work could be the Trang Watershed. The voluminous run-off of water from the mountainous area of Thung Song in Nakhon Si Thammarat Province and the consequent serious flood circumstances on its way down towards the Andaman Sea justifies a SWS project, in order to reduce the run-off substantially and sustainably. Also in this case, it concerns an integration of and cooperation between the various relevant fields: land use planning, surface water resources management, groundwater resources management, and irrigation management.

Aware of the more recent floods in Chonburi and Rayong, particularly visible on and near the motor way, the SWS approach may offer a useful solution to avoid such flood risks. Also, as mentioned and proposed by representatives of DPT, and also advised by the audience during the Brainstorm session, a plea is noted to extend the SWS approach to Sukhothai Province.

These examples are indeed just examples. Many more watersheds in Thailand can be addressed, in some cases primarily to reduce drought risks, in other areas for flood risk reduction.

Another issue of SWS activities, as follow-up of the workings in this Nakhon Phanom SWS pilot project, concerns technical interventions. The current SWS study and results show the relevance. A next relevant step is execution of technical works in order to (the testing of) actual subsurface water storage with the aid of drainage relevant surface water bodies on suitable sites along the involved river sections. That implies excavation of top layers to reach effective aquifer layers and to contribute to groundwater table inclination.

Figure 10.2.: Example of an artificial lake, a retention reservoir for possible SWS, located in the Songkhram watershed area

During the conference and workshops extensive attention has been paid to possible solutions and interventions, that is alternatives how to subsurface drain and infiltrate. Some of the alternatives suit well to the land surface circumstances. A part of the solutions have also been subjected to debating institutional justification.

11. CONCLUSIONS

To round this report, the following mentions the most relevant conclusions of this SWS pilot study project applied to Nakhon Phanom's Un and Songkhram Rivers, applied in the course of 2015:

- Subsurface water storage in the northern part of Nakhon Phanom province is possible, shallow aquifer in Songkhram River, and deep aquifers in Un river adjacent land zones. These land zones provide opportunities to combine infiltration with various sites where drainage water storage bodies can be realised.

- Beyond the gravitational drainage quality of the drainage water storage bodies, it is important that these bodies are included and allocated in land use plans together with regulations capable to protect the areas against pollution and contamination. This is particular a constraint relevant to the shallow aquifers of the Songkhram river.

- To achieve an adequate result of multi level integrated land and water resources planning and management, a strengthened work relation is demanded between the hydrogeologists and groundwater experts of DGR (MNRE), DWE (MNRE) and RID on the one hand, and, on the other hand the land use planners in Town & Country Planning (DPT). For sure, ultimately, the establishment of one integrated new Ministry including those land and water management responsible departments would really help to mitigate and handle flood and drought risk problems in Thailand in future.

- In line with the afore mentioned conclusions it is desirable for a possible continuation of the SWS approach, to commence an implementation project. That project preferably combines an executional and technical SWS application with land use plan development, in order to identify suitable locations and to allocate and produce effective drainage water storage bodies. The allocated sites require protection through land use plan regulations too.

- Regarding the characteristics of the identified aquifers, project continuation should preferably focus upon technical issues. This regards to analyses, modelling and calculation procedures regarding porosity, permeability, transmissivity, and hydraulic heads of the various aquifers considered. The outcomes are important in order to estimate their economic relevance and their contribution to an effective flood and drought risk reduction.

- Seen the observed data and database management problems particularly in connection with well and borehole data, it is obvious that improvements of data quality should be achieved. To realise these improvements an extensive and dedicated tailor-made training programme is a prerequisite.

Conclusions in short,

A. Continuation and testing of the SWS project in Nakhon Phanom is seen as necessary and justified;

B. Identification and allocation of drainage water storage bodies on for SWS suitable sites requires a leading role by land use planning and plan development in order to tune with regulations for allocation and protection;

C. Observed (e.g. borehole) data and database management problems necessitate improvement, which preferably are supported by extensive staff capacity strengthening endeavours. Data quality results may effectively be improved through organisational defragmentation and reduced scatter of data sources too,

-o-o-o-o-o-

Bangkok, December 2015

REFERENCES

- Arlai, P. (2010), M. Koch, M. Yongprawat, S. Pirom and T. Kitpaisalsakul: "Numerical Investigation of Combined Flood Mintigation and Groundwater Recharge in the Chao Phraya River Basin", in: IAHR-APD2010 Conference Proceedings.

- DGR. (2012): "Groundwater recharge for solving flood and drought problem", Department of Groundwater Resources, Ministry of Natural Resources and Environment (MNRE)

- DGR. (2011): "Pilot study and experiment on managed aquifer recharge using ponding system in the Lower North Region River Basin, Phitsanulok, Sukhothai, and Pichit provinces", Final report, Executive Summary Report, prepared by Khon Kaen University / Groundwater Research Center, March 2011.

- DGR. (2015): "Groundwater Investigation and Detailed Mapping, 1:50,000 in Scale (The Upper Northeastern Part of Thailand). Area 3: Nakhon Phanom and some parts of Bueng Kan, Sakon Nakhon, Kalasin and Mukdahan Provinces. Executive Summary Report".

- Foster, S. (2008): "Thailand: strengthening capacity in groundwater resources management", in: Sustainable Groundwater Management, Lessons from Practice, The World Bank, pp. 1-6.

- Kangrang A., et. al. (2008): "An observation of groundwater in rapid urbanization area", in: Journal of Applied Sciences, pp. 3995-3998.

- LaMoreaux, P. E., Charaljavanaphet, J., Jalichan, N., Phong Phan Na Chiengmai, Din Bunnag , Adul Thavisri, and Chumphon Rakprathum. (1958): "Reconnaissance of the Geology and Ground Water of the Khorat Plateau, Thailand", U.S. GEOLOGICAL SURVEY, Water-Supply Paper .

- Meulen, G. van der. (2011): "Lopburi Water Storage for run-off reduction & local usage. An integrated land and water concept for flood disaster risk prevention", Department of Water Resources, pwp document, Bangkok, December 2011.

- Meulen, G. van der. (2012): "Innovative storage of flash flood water in Thailand's subsurface. An integrated and comprehensive way to tackle floods and droughts", in English (internet accessible).

- Monjai, D. (2004): "Subsurface geology in Sakon Nakhon Basin", Proceeding of Annual Meeting, Department of Mineral Resources, Bangkok, Thailand, 51-63, (in Thai).

- Monjai, D. (2006): "Facies Genesis Analysis of the Phu Thok Formation and the Upper Clastic Cap Rock of the Maha Sarakham Formation", [M.Sc thesis in Geotechnology], Khon Kaen University, Khon Kaen, Thailand, 142 pp. (in Thai).

- Pavelic, P., K. Srisuk, P. Saraphirom, S. Nadee, K. Pholkern, S. Chusanathas, S. Munyou, T. Tangsutthinon, T. Intarasut, V. (2012): "Balancing-out floods and droughts: Opportunities to utilize floodwater harvesting and groundwater storage for agricultural development in Thailand".

- Sakchai, G. (2010): "Petroleum potential assessment of the Chonnabot prospect in Northeastern region of Thailand", Unpublished Thesis at the School of Geotechnology Institute of Engineering Suranaree University of Technology, Thailand. Retrieved from : http://sutir.sut.ac.th:8080/sutir/handle/123456789/3710

- Satarugsa P., Youngmee, and S. Meesawat (2005): "New Regional Boundary of Maha Sarakham Formation in the Northeastern Thailand: Results from 2D Seismic Mapping", Proceeding of the International

Conference on Geology, Geotechnology and Mineral Resources of INDOCHINA, Khon Kaen, Thailand, p.212-220.

- Sattayarak, N., and S. Polachan. (1990): “Rocksalt underneath the Khorat Plateau”, Proceeding of Annual Meeting, Department of Mineral Resources, Bangkok, Thailand, p. 1-14, (in Thai).

- Shamsudduha, M., et. al. (2009): “Recent trends in groundwater levels in a highly seasonal hydrological system; the Ganges-Brahmaputra-Meghna Delta”, in: Hydrological Earth Systems Sciences, 13, pp. 2373-2385.

- Suwanich, P. (1986): “Potash and rock salt in Thailand”, Appendix A, Department of Mineral Resources, Bangkok, Thailand: 252 pp.

- Sullivan, B. K. (2015): “El Nino spreads its mayhem all over the world. From the price of coffee to the fate of fish, winds are changing”, in: Sunday Forum session in Bangkok Post of 25 October.

- Thunthithum, W. (2013) : limited translation in Thai, in: Journal of the Department of Public Works and Town & Country Planning, Ministry of Interior, Thailand, Bangkok, February/March, 2013

The following related handbooks are references because they are available as academic copies for SE Asia (Chula Bookshop):

- Fetter, C.W. (2014): “Applied hydrogeology”, Pearson Education Lt., Edinburgh, pp. 612.
- Linsley, R.K., et.al. (1992): “Water resources engineering”, McGraw-Hill, Inc., New York, Singapore, pp. 843.

Reference:

TA-6498 REG: Knowledge and Innovation Support for ADB's Water Finance Program (42384-012)

ADB & Thai DGR/MNRE

P A R T 2 : SWS REPORT A N N E X E S

Pilot project

"Subsurface Water Storage",

"Harvesting the floods, studied at Nakhon Phanom Province", (SWS)

Applied research
Songkhram and Un river watersheds
Nakhon Phanom Province, Thailand

January 2016

CKI UNESCO-IHE Institute for Water Education Deltares ARCADIS Aveco de Bondt

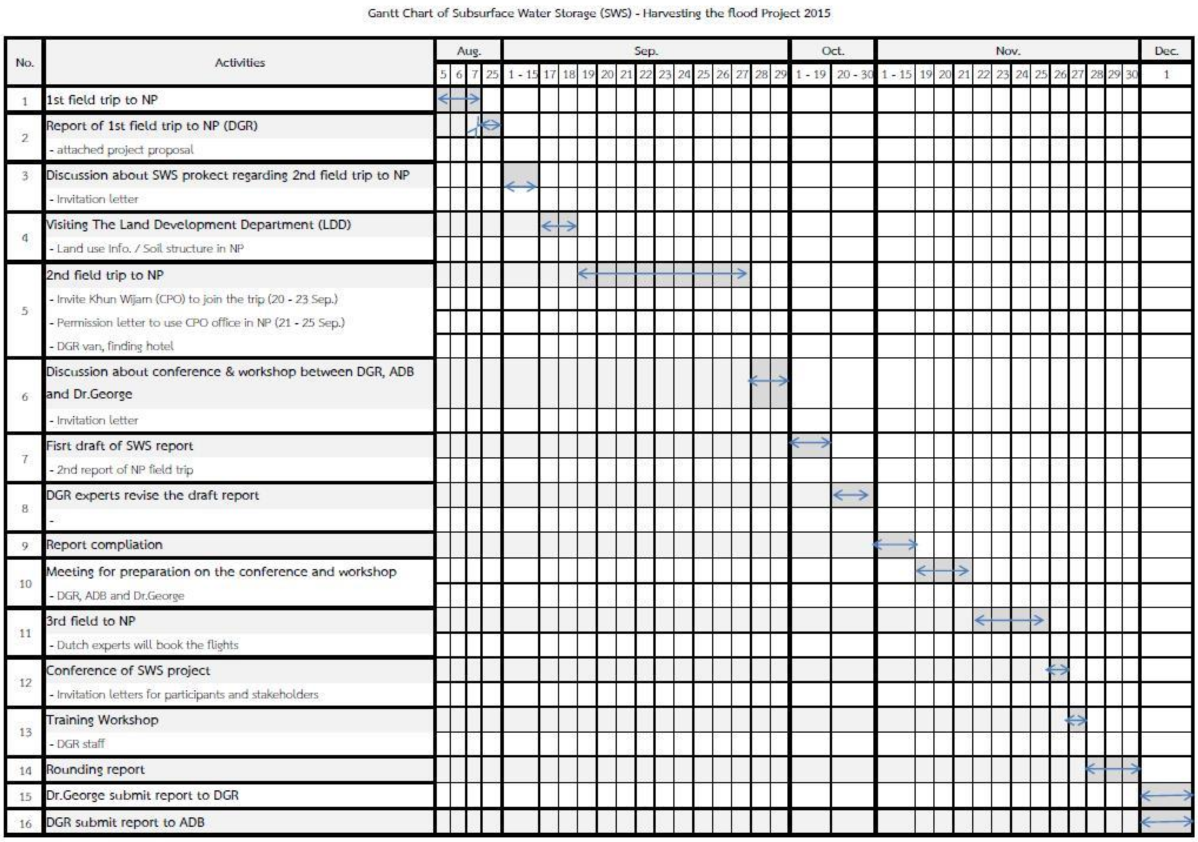
P A R T 2 : SWS REPORT A N N E X E S

ANNEXES

Overview appendices:

a. **Gantt chart of project activities and progress**
b. **Acronyms**
c. **Collected maps, boreholes, data, and other information**
d. **Socio-economic detail data Nakhon Phanom Province**
e. **Conference presentations (Thursday 26th November 2015)**
f. **Participants list**
g. **Brainstorm session SWS approach & activities in future: research and execution applications**
h. **Workshops (Friday 27th November 2015)**
i. **Summary workshops**
j. **Team composition**
k. **Thai-Dutch SWS project team photos**
l. **The conference and workshop gallery**
m. **Other involved and contacted persons**

a. Giant chart of project activities and progress



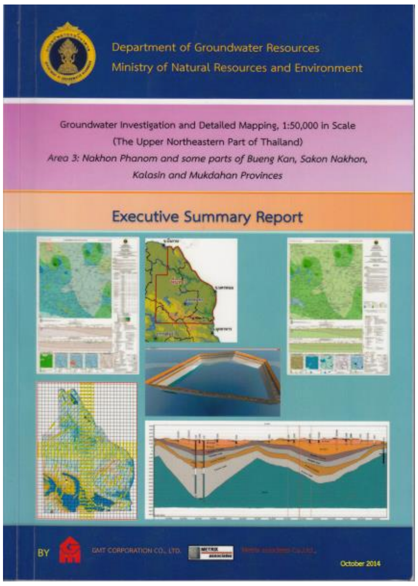
(Source: DGR, 2015)

b. Acronyms

ADB	Asian Development Bank
ASL	average or mean sea level
CKI	Compuplan Knowledge Institute of Applied geo-Informatics (Cuijk-NL)
CPO	Changwat Provincial Office (DPT)
DDPM	Department of Disaster Prevention and Mitigation (MoI)
DGR	Department of Groundwater Resources (MNRE)
DL	Department of Lands (MoAC)
DWR	Department of Water Resources (MNRE)
DPT	Department of Public Works and Town & Country Planning (MoI)
DLD	Department of Lands Development (MoA)
MAR	Managed Aquifer Recharge
MoAC	Ministry of Agriculture and Cooperatives, Thailand
MoF	Ministry of Finance, Thailand
MoI	Ministry of Interior, Thailand
MNRE	Ministry of Natural Resources and Environment, Thailand
NE	North-East
NP	Nakhon Phanom Province and Provincial capital city
RID	Royal Irrigation Department (MoAC)
RWH	(urban) rain water harvesting
SN	Sakon Nakhon Province
SKK	Si Songkhram district, Nakhon Phanom Province
SSKT	Si Songkhram municipality (tesaban tambon)
SWS	Subsurface Water Storage
UNESCO -IHE	UNESCO-IHE Water Education Institute (Delft-NL)

c. Collected maps, boreholes, data, and other information

- Maps (in general, both images and shape files):
    I. Topographic maps NP (Province)
    II. Topographic maps Sakon Nakhon
    III. Geologic maps NE Thailand
    IV. Hydrogeological maps NE Thailand
    V. Provincial Plan NP (Province)
    VI. Province Land Use Plan NP (Province)
    VII. Overview flood areas in NP (Province)
    VIII. Overview drought areas in NP (Province)
    IX. Comprehensive Plans urban areas in Nakhon Phanon (ready/approved NP city)
    X. Tesaban area of Si Songkhram municipality
- Boreholes:
    I. Nakhon Phanom Province area
    II. Electrical logs NP (Province)
    III. Lithological description logs NP (Province)
    IV. Sakon Nakhon Province area
    V. Electrical logs SN Province
    VI. Lithological description SN Province
    VII. Northeast Thailand deep drilled boreholes
- Data:
    I. Groundwater table data, monitored for a well near SSKT, 25 years overview
- Other information:
    I. Areal photo SSKT
    II. Handbook explanation geological maps NE Thailand, in Thai
    III. Handbook explanation geological maps NE Thailand, Executive Summary in English



d. Socio-economic detail data Nakhon Phanom province

Population in Industrail Section 2014 in NP

ตาราง 5 จำนวนและร้อยละของผู้มีงานทำ จำแนกตามอุตสาหกรรมและเพศ 2557

อุตสาหกรรม Industrial type	รวม Total	ชาย Male	หญิง Female
		จำนวน	
ยอดรวม	309,176	166,883	142,293
1. เกษตรกรรม การล่าสัตว์และการป่าไม้ Agriculture/forestry	176,831	93,441	83,390
2. การทำเหมืองแร่ และเหมืองหิน Mining	1,674	1,077	597
3. การผลิต Production	22,996	9,222	13,774
4. การไฟฟ้า ก๊าซ และไอน้ำ Electricity / Gas	377	252	125
5. การจัดหาน้ำบำบัดน้ำเสีย Waste water treatment	261	175	86
6. การก่อสร้าง Building	21,601	19,965	1,636
7. การขายส่ง การขายปลีก Trade	34,060	16,096	17,964
8. การขนส่ง สถานที่เก็บสินค้า Transportation	2,993	2,879	115
9. กิจกรรมการโรงแรม และอาหาร Hotel / Food	10,710	2,434	8,276
10. ข้อมูลข่าวสารและการสื่อสาร Communication	490	473	18
11. กิจการทางการเงินและการประกันภัย Finance	1,807	532	1,274
12. กิจกรรมอสังหาริมทรัพย์ Real Estate	55	23	32
13. กิจกรรมทางวิชาชีพและเทคนิค Technician	555	210	345
14. การบริหารและการสนับสนุน Administration	957	427	530
15. การบริหารราชการและป้องกันประเทศ Government service	15,080	12,228	2,851
16. การศึกษา Education	9,862	4,497	5,364
17. สุขภาพและสังคมสงเคราะห์ Health service	5,185	1,105	4,080
18. ศิลปะความบันเทิงนันทนาการ Entertainment	603	245	358
19. กิจกรรมบริการด้านอื่น ๆ Others	1,973	856	1,117
20. ลูกจ้างในครัวเรือนส่วนบุคคล Labour	1,108	745	363
21. องค์การระหว่างประเทศ International organization	-	-	-
22. ไม่ทราบ	-	-	-
		ร้อยละ Percentage	
ยอดรวม	100.0 %	100.0 %	100.0 %
1. เกษตรกรรม การล่าสัตว์และการป่าไม้	57.2	56.0	58.6
2. การทำเหมืองแร่ และเหมืองหิน	0.5	0.6	0.4
3. การผลิต	7.4	5.5	9.7
4. การไฟฟ้า ก๊าซ และไอน้ำ	0.1	0.2	0.1
5. การจัดหาน้ำบำบัดน้ำเสีย	0.1	0.1	0.1
6. การก่อสร้าง	7.0	12.0	1.1
7. การขายส่ง การขายปลีก	11.0	9.6	12.6
8. การขนส่ง สถานที่เก็บสินค้า	1.0	1.7	0.1
9. กิจกรรมการโรงแรม และอาหาร	3.5	1.5	5.8
10. ข้อมูลข่าวสารและการสื่อสาร	0.2	0.3	–
11. กิจการทางการเงินและการประกันภัย	0.6	0.3	0.9
12. กิจกรรมอสังหาริมทรัพย์	–	–	–
13. กิจกรรมทางวิชาชีพและเทคนิค	0.2	0.1	0.2
14. การบริหารและการสนับสนุน	0.3	0.3	0.4
15. การบริหารราชการและป้องกันประเทศ	4.9	7.3	2.0
16. การศึกษา	3.2	2.7	3.8
17. สุขภาพและสังคมสงเคราะห์	1.7	0.7	2.9
18. ศิลปะความบันเทิงนันทนาการ	0.2	0.1	0.3
19. กิจกรรมบริการด้านอื่น ๆ	0.6	0.5	0.8
20. ลูกจ้างในครัวเรือนส่วนบุคคล	0.4	0.4	0.3
21. องค์การระหว่างประเทศ	-	-	-
22. ไม่ทราบ	-	-	-

– มีข้อมูลเพียงเล็กน้อย

Population Occupation Survey 2014 in Nakhomphanom

ตาราง 4 จำนวนและร้อยละของผู้มีงานทำ จำแนกตามอาชีพและเพศ 2557

อาชีพ Occupation	รวม Total	ชาย Male	หญิง Femal
		จำนวน Total number	
ยอดรวม	309,176	166,883	142,293
1. ผู้บัญญัติกฎหมาย ข้าราชการระดับอาวุโส และผู้จัดการ Politician / Government officer / Manager	8,995	8,104	890
2. ผู้ประกอบวิชาชีพด้านต่างๆ various jobs	11,457	3,951	7,506
3. ผู้ประกอบวิชาชีพด้านเทคนิคสาขาต่างๆ และอาชีพที่เกี่ยวข้อง IT staff	3,137	1,968	1,169
4. เสมียน Clerk	5,569	1,879	3,691
5. พนักงานบริการและพนักงานในร้านค้า และตลาด Service / market	42,372	15,643	26,729
6. ผู้ปฏิบัติงานที่มีฝีมือในด้านการเกษตร และการประมง Agriculture / Fisheries	173,943	92,028	81,915
7. ผู้ปฏิบัติงานด้านความสามารถทางฝีมือ และธุรกิจอื่นๆ ที่ Craft	32,665	19,839	12,826
8. ผู้ปฏิบัติการโรงงานและเครื่องจักร และผู้ปฏิบัติงานด้านการ Industry	9,750	8,644	1,106
9. อาชีพขั้นพื้นฐานต่างๆ ในด้านการขาย และการให้บริการ Seller	21,287	14,827	6,460
10. คนงานซึ่งมิได้จำแนกไว้ในหมวดอื่น Others			
		ร้อยละ Percentage	
ยอดรวม	100.0 %	100.0 %	100.0 %
1. ผู้บัญญัติกฎหมาย ข้าราชการระดับอาวุโส และผู้จัดการ	2.9	4.9	0.6
2. ผู้ประกอบวิชาชีพด้านต่างๆ	3.7	2.4	5.3
3. ผู้ประกอบวิชาชีพด้านเทคนิคสาขาต่างๆ และอาชีพที่เกี่ยวข้อง	1.0	1.2	0.8
4. เสมียน	1.8	1.1	2.6
5. พนักงานบริการและพนักงานในร้านค้า และตลาด	13.7	9.4	18.8
6. ผู้ปฏิบัติงานที่มีฝีมือในด้านการเกษตร และการประมง	56.3	55.1	57.6
7. ผู้ปฏิบัติงานด้านความสามารถทางฝีมือ และธุรกิจอื่นๆที่	10.6	11.9	9.0
8. ผู้ปฏิบัติการโรงงานและเครื่องจักร และผู้ปฏิบัติงานด้านการ	3.2	5.2	0.8
9. อาชีพขั้นพื้นฐานต่างๆ ในด้านการขาย และการให้บริการ	6.9	8.9	4.5
10. คนงานซึ่งมิได้จำแนกไว้ในหมวดอื่น	-	-	-

-- มีข้อมูลเพียงเล็กน้อย

e. Conference presentations (Thursday 26 November 2015)

ข่าวกรมทรัพยากรน้ำบาดาล
กระทรวงทรัพยากรธรรมชาติและสิ่งแวดล้อม
26/83 ซ.ท่านผู้หญิงพหล (ซอยงามวงศ์วาน 54) ลาดยาว จตุจักร กรุงเทพฯ 10900
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3 พันธมิตร...กรมทรัพยากรน้ำบาดาล ธนาคารพัฒนาเอเชีย และสถาบัน Compuplan Knowledge Institute of Applied geo-Informatics ร่วมกันศึกษาวิจัยแก้ปัญหาน้ำท่วม น้ำแล้ง ในพื้นที่อำเภอศรีสงคราม จังหวัดนครพนม

วันพฤหัสบดีที่ 26 พฤศจิกายน 2558 เวลา 09.20 น. ณ โรงแรมเซ็นทาราแกรนด์และบางกอก คอนเวนชั่นเซ็นเตอร์ เซ็นทรัลเวิลด์ กรุงเทพมหานคร ดร.อรัญญา เฟื่องสวัสดิ์ รองอธิบดีกรมทรัพยากรน้ำบาดาลเป็นประธานกล่าวเปิดการประชุมสัมมนาเชิงวิชาการและประชุมเชิงปฏิบัติการภายใต้โครงการ Subsurface Water Storage (SWS) – Harvesting the Floods Project (โครงการกักเก็บน้ำท่วมลงสู่ใต้ดินเพื่อแก้ปัญหา น้ำท่วมและเพิ่มศักยภาพน้ำบาดาล) ร่วมด้วย Mr. Pavit Ramachandran ผู้เชี่ยวชาญด้านสิ่งแวดล้อมอาวุโส ธนาคารพัฒนาเอเชีย (ADB) โดยมี ดร.อรนุช หล่อเพ็ญศรี ผู้อำนวยการสำนักสำรวจและประเมินศักยภาพน้ำบาดาล เป็นผู้กล่าวรายงานรายละเอียดโครงการดังกล่าว สืบเนื่องจากกรมทรัพยากรน้ำบาดาลได้ร่วมกับ ธนาคารพัฒนาเอเชีย (Asian Development Bank, ADB) และสถาบัน Compuplan Knowledge Institute of Applied geo-Informatics จัดการประชุมสัมมนาฯ ระหว่างวันที่ 26 – 27 พฤศจิกายน 2558 เพื่อรายงานผลการศึกษาวิจัยหาแนวทางในการแก้ปัญหาน้ำท่วมและน้ำแล้งในอำเภอศรีสงคราม จังหวัดนครพนม รวมทั้งแลกเปลี่ยนความรู้และประสบการณ์ด้านการบริหารจัดการทรัพยากรน้ำบาดาลกับผู้เชี่ยวชาญด้านผังเมือง และการบริหารจัดการน้ำจากประเทศเนเธอร์แลนด์

โครงการ Subsurface Water Storage (SWS) –Harvesting the Floods Project เป็นการศึกษาแนวทางลดปัญหาน้ำท่วมและน้ำแล้งในพื้นที่นำร่อง ณ อำเภอศรีสงคราม จังหวัดนครพนม เนื่องจากเป็นพื้นที่รองรับน้ำจากแม่น้ำสงคราม และแม่น้ำอูนซึ่งเป็นแม่น้ำสายหลักที่ไหลมาจากเทือกเขาภูพานลงสู่แม่น้ำโขง เมื่อเข้าสู่ช่วงฤดูฝนจะมีปริมาณน้ำหนุนจากแม่น้ำโขงและน้ำซับปริมาณมากทำให้พื้นที่อำเภอศรีสงคราม จังหวัดนครพนม ต้องเผชิญกับปัญหาน้ำท่วมหนักกว่าบริเวณอื่นเป็นประจำทุกปี ดังนั้น เพื่อเป็นการศึกษาแนวทางแก้ปัญหาน้ำท่วมและน้ำแล้งในพื้นที่ดังกล่าว กรมทรัพยากรน้ำบาดาลจะเป็นหน่วยงานหลักในการให้ข้อมูลสนับสนุนการวิจัยและประสานงานกับหน่วยงานต่างๆ เพื่อลดปัญหาขาดแคลนน้ำและผลกระทบจากปัญหาน้ำแล้ง โดยทำให้ปริมาณน้ำในชั้นน้ำใต้ดินอยู่ในสภาพสมดุล มีปริมาณน้ำเพียงพอต่อการเกษตร อุตสาหกรรม และการอุปโภคบริโภคในช่วงหน้าแล้ง รวมถึงลดปัญหาน้ำท่วมโดยกักเก็บน้ำส่วนเกินในช่วงฤดูน้ำหลากไว้ในพื้นที่ และการใช้เทคโนโลยีการเติมน้ำสู่ชั้นน้ำใต้ดิน ซึ่งผลจากการศึกษาวิจัยครั้งนี้จะนำมาพัฒนาเพื่อแก้ไขปัญหาน้ำท่วมและน้ำแล้งบริเวณลุ่มน้ำอื่นๆ ในประเทศไทยต่อไป

การประชุมสัมมนาดังกล่าวจะจัดขึ้นที่โรงแรมเซ็นทาราแกรนด์และบางกอกคอนเวนชั่นเซ็นเตอร์ เซ็นทรัลเวิลด์ กรุงเทพมหานคร โดยแบ่งเป็น 2 วัน ดังนี้

1) วันพฤหัสบดีที่ 26 พฤศจิกายน 2558 เป็นการประชุมสัมมนาเชิงวิชาการ เพื่อรายงานผลการศึกษาวิจัยโครงการ Subsurface Water Storage (SWS) – Harvesting the Floods Project (โครงการกักเก็บน้ำท่วมลงสู่ใต้ดินเพื่อแก้ปัญหาน้ำท่วมและเพิ่มศักยภาพน้ำบาดาล) และวางแผนการดำเนินโครงการต่อไปในอนาคต พร้อมด้วยการบรรยายพิเศษจาก H.E. Mr. Karel Hartogh เอกอัครราชทูตเนเธอร์แลนด์ ประจำประเทศไทย

2) วันศุกร์ที่ 27 พฤศจิกายน 2558 เป็นการประชุมเชิงปฏิบัติการเพื่อรับฟังการบรรยายหัวข้อ "Hydrogeological, State of the arts/researches" "Hydrogeological experiences" "Institutional framework for water management" และ "River basin management" พร้อมแลกเปลี่ยนความรู้และประสบการณ์ด้านการบริหารจัดการทรัพยากรน้ำบาดาลกับผู้เชี่ยวชาญด้านผังเมืองและการบริหารจัดการน้ำจากสถาบัน Compuplan Knowledge Institution of Applied geo-Information (CKI) และผู้เชี่ยวชาญด้านการบริหารจัดการน้ำจากสถาบันต่างๆ เช่น UNESCO-IHE และ Deltares จากประเทศเนเธอร์แลนด์

สำหรับผู้เข้าร่วมประชุมสัมมนาประกอบด้วย ผู้แทนจากกรมทรัพยากรน้ำบาดาล ผู้แทนจากสถาบันการศึกษา ได้แก่ สถาบันเทคโนโลยีพระจอมเกล้าเจ้าคุณทหารลาดกระบัง จุฬาลงกรณ์มหาวิทยาลัย สถาบันพระปกเกล้า มหาวิทยาลัยเกษตรศาสตร์ มหาวิทยาลัยนครพนม มหาวิทยาลัยขอนแก่น และมหาวิทยาลัยราชภัฏสกลนครและมหาสารคาม รวมถึงผู้แทนจากหน่วยงานภาครัฐ อาทิ กรมชลประทาน สถาบันสิ่งแวดล้อมไทย สถาบันสารสนเทศทรัพยากรน้ำและการเกษตร (องค์การมหาชน) กรมป้องกันและบรรเทาสาธารณภัยและกรมทรัพยากรน้ำ

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ส่วนประชาสัมพันธ์และเผยแพร่ กรมทรัพยากรน้ำบาดาล

- **Programme:**

กำหนดการจัดประชุมสัมมนาเชิงวิชาการโครงการ Subsurface Water Storage (SWS)–Harvesting the Floods Project
วันที่ ๒๖ พฤศจิกายน ๒๕๕๘
ณ โรงแรมเซ็นทาราแกรนด์และบางกอกคอนเวนชั่นเซ็นเตอร์เซ็นทรัลเวิลด์กรุงเทพมหานคร

เวลา	กิจกรรม	วิทยากร
๘.๓๐ – ๙.๐๐ น.	ลงทะเบียน	-
๙.๐๐ – ๙.๑๕ น.	รายงานผลการดำเนินงานโครงการ Subsurface Water Storage (SWS) – Harvesting the Floods Project	ดร. อรนุช หล่อเพ็ญศรี ผู้อำนวยการสำนักสำรวจและประเมินศักยภาพน้ำบาดาล กรมทรัพยากรน้ำบาดาล
๙.๑๕ – ๙.๔๕ น.	พิธีเปิด	- ดร. อรัญญา เฟื่องสวัสดิ์ รองอธิบดีกรมทรัพยากรน้ำบาดาล - Mr. Pavit Ramachandran ผู้เชี่ยวชาญด้านสิ่งแวดล้อมอาวุโส ธนาคารพัฒนาเอเชีย (ADB)
๙.๔๕– ๑๐.๑๕น.	บรรยายพิเศษ	H.E. Mr. Karel Hartogh เอกอัครราชทูตเนเธอร์แลนด์ ประจำประเทศไทย
๑๐.๑๕ – ๑๐.๓๐ น.	รับประทานอาหารว่าง	
๑๐.๓๐ –๑๒.๐๐ น.	รายงานผลการวิจัยโครงการ Subsurface Water Storage (SWS)–Harvesting the Floods Project	Dr. George Van Der Meulen (CKI) Dr. Paolo Paron (UNESCO-IHE)
๑๒.๐๐ – ๑๓.๐๐ น.	รับประทานอาหารกลางวัน	
๑๓.๐๐ – ๑๕.๐๐ น.	บรรยายพิเศษเรื่อง “การแลกเปลี่ยนประสบการณ์ด้านการบริหารจัดการน้ำบาดาล”	Dr. George Van Der Meulen (CKI) Dr. Paolo Paron (UNESCO-IHE) Dr. Roelof Stuurman (Deltares) Mr. Robbert van Montfoort (ARCADIS) Mr. Gerhard Winters (Avecodebondt)
๑๕.๐๐ – ๑๕.๑๕ น.	รับประทานอาหารว่าง	
๑๕.๑๕ – ๑๖.๓๐ น.	หารือการดำเนินโครงการ SWS สู่การปฏิบัติและวางแผนการดำเนินโครงการในอนาคต	กรมทรัพยากรน้ำบาดาล และผู้เชี่ยวชาญ

กำหนดการจัดประชุมเชิงปฏิบัติการโครงการ Subsurface Water Storage (SWS)–Harvesting the Floods Project
วันที่ ๒๗ พฤศจิกายน ๒๕๕๘
ณ โรงแรมเซ็นทาราแกรนด์และบางกอกคอนเวนชั่นเซ็นเตอร์เซ็นทรัลเวิลด์กรุงเทพมหานคร

เวลา	กิจกรรม	วิทยากร
๘.๓๐ – ๙.๐๐ น.	ลงทะเบียน	-
๙.๐๐ – ๑๐.๓๐ น.	บรรยายหัวข้อ SWS working strategies: step by step	Dr. George Van Der Meulen (CKI) Dr. Paolo Paron (UNESCO-IHE)
๑๐.๓๐ – ๑๐.๔๕ น.	รับประทานอาหารว่าง	
๑๐.๔๕ – ๑๒.๐๐ น.	บรรยายหัวข้อ "Hydrogeological, State of the arts/researches"	Dr. Roelof Stuurman (Deltares)
๑๒.๐๐ – ๑๓.๐๐ น.	รับประทานอาหารกลางวัน	
๑๓.๐๐ – ๑๔.๐๐ น.	บรรยายหัวข้อ "Hydrogeological experiences"	Mr. Robbert van Montfoort (ARCADIS)
๑๔.๐๐ – ๑๕.๐๐ น.	บรรยายหัวข้อ "Institutional framework for water management"	Mr. Gerhard Winters (Avecodebondt)
๑๕.๐๐ – ๑๕.๑๕ น.	รับประทานอาหารว่าง	
๑๕.๑๕ – ๑๕.๔๕ น.	บรรยายหัวข้อ "River basin management"	นายสราวุธ ชีวะประเสริฐ ผู้อำนวยการส่วนนโยบายและแผน สำนักนโยบายและแผน กรมทรัพยากรน้ำ
๑๕.๔๕ – ๑๖.๓๐ น.	แลกเปลี่ยนความคิดเห็น/ปิดการประชุม	-

The Conference of Subsurface Water Storage (SWS) – Harvesting the Floods Project
26th November, 2015
At Centara Grand and Bangkok Convention Centre, CentralWorld, Bangkok

Time	Activities	Responsibility
8.30 – 9.00	Registration	-
9.00 – 9.15	Report of SWS project	Bureau of Groundwater Potential Assessment
9.15 – 9.45	Opening Ceremony	- Dr. Aranya Fuangswasdi, Deputy Director General of DGR - Mr. Pavit Ramachandran, Senior Environment Specialist of ADB
9.45 – 10.15	Special Note	H.E. Mr. Karel Hartogh, Ambassador of the Kingdom of the Netherlands, Thailand
10.15 – 10.30	Coffee break	
10.30 – 12.00	Presentations -Subsurface Water Storage and Q&A - Approach/Application in Nakhon Phanom province and watershed and Q&A	Dr. George Van Der Meulen (CKI) Dr. Roelof Stuurman (DELTARES)
12.00 – 13.00	Lunch	
13.00 – 15.00	Aquifer experiences and studies presentations from 5 organizations	Dr. George Van Der Meulen (CKI) Dr. Roelof Stuurman (Deltares) Mr. Robbert van Montfoort (ARCADIS) Mr. Gerhard Winters (Avecodebondt)
15.00 – 15.15	Coffee break	
15.15 – 16.30	Deliberation of discussion about the future applications in Thailand	DGR representatives and Experts

- **Presentations:**
  - I. Director of Bureau of Groundwater Assessment and Potential of DGR, Dr. Oranuj Lorphensri
  - II. Representative of Asian Development Bank (ADB), Mr. Pavit Ramachandran
  - III. Ambassador of the Kingdom of the Netherlands, Mr. Karel Hartogh
  - IV. Deputy Director-general of DGR, Dr. Aranya Fuangswasdi
  - V. Dr. George van der Meulen (CKI)
  - VI. Dr. Roelof Stuurman (DELTARES) & Ir. Robbert van Montfoort (ARCADIS)

- **Speeches text / Summaries:**
  I. Director of Bureau of Groundwater Potential Assessment of DGR

Report

On the Conference of Subsurface Water Storage (SWS) – Harvesting the Floods Project

26th November, 2015

At Centara Grand and Bangkok Convention Centre, Central World, Bangkok

By

Dr. Oranuj Lorphensri, the Director of Bureau of Groundwater Potential Assessment

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Your Excellency Mr. Supot Jermsawatdipong, General Director of Department of Groundwater Resources

I'm Oranuj Lorphensri, the Director of Bureau of Groundwater Potential Assessment. On behalf of the conference and workshop organizer of Subsurface Water Storage (SWS) - Harvesting the Floods Project and all distinguish participants, we would like to thank you for being the guest of honor for this event.

The Bureau of Groundwater Potential Assessment and the Planning Division with the cooperation of Dr. George Van der Meulen (the leader and consultant of this project) and his hydrogeological expert team from the Netherlands have been conducting SWS project since July 2015.

The purpose of this project is to investigate opportunities for sustainable subsurface water storage in Amphoe Si Songkhram, Nakhon Phanom province where it is the two catchment areas belong to the Un and the Songkhram watersheds. The Un and Songkhram rivers both originate in the Phu Phan mountain range in Sakon Nakhon province later converging, before flowing into the Mekhong River. This project will conclude on the 1st December 2015 and would not have been possible without the full support from the Asia Development Bank who generously provided 150,000 USD.

We recently completed three field trips to Nakhon Phanom for collecting data and observing the area. We would like to extend our thanks to the Public Works and Town& Country Planning Office, Disaster Prevention and Mitigation Office, Natural Resources and Environment Office, Land and Development Office in Nakhon Phanom, and the Municipal Clerk of Amphoe Si Songkhram for providing us with relevant data, office space and helpful staff. This all contributed to making our time there productive and informative.

The result of this research showed that subsurface water storage in the north part of Nakhon Phanom is possible. The Songkhram River offers a useful drainage potential in the shallow aquifer. However, shallow aquifers are vulnerable and have a potential for pollution and contamination. In contrast, the Un River offers deep aquifers suitable in both drainage and transmissivity.

Today's conference aims to share the project outcome and to exchange opinions and knowledge of subsurface water storage systems. Tomorrow is the training workshop which focuses on knowledge transfer on water retention for sustainable drought and flood management.

On behalf of the project organizer, we would like to sincerely thank everyone again. And now it's time to welcome the director of Department of Groundwater Resources to deliver his opening speech.

II. Ambassador of Kingdom of the Netherlands, Mr. Karel Hartogh

Good morning ladies and gentlemen, expert team, members of the cooperation between the Thai Department of Groundwater Resources and the Dutch SWS-team,
For me as the new Ambassador of the Netherlands in Bangkok, it is a great pleasure to be here, this morning, at this impressive venue, called Central World.

Today is a special day, for me and for the relations between the Kingdom of Thailand and the Kingdom of the Netherlands, which is why my speech today is shorter than originally planned: today I am invited by your Crown Prince H.R.H. Vajiralongkorn to a ceremony to offer my Credentials to the Royal Thai government.
But fortunately I can at least attend and participate in part of today's conference. Today's event will focus on a number of very important topics. But central to the conference is the plea that will be made not to waste the water by rapid run-off to the sea, as the same water is so hardly needed a few months later during the dry season, in which the water demand is high and often exceeds availability.
As the Ambassador of the Netherlands please allow me to say the following, without the intention to push 'our' Dutch solutions as the only and best solutions.
Of course there are many possible solutions to mitigate water problems and water disasters and every country chooses the solutions, which most fit their specific problems, and their policy making system and culture.
In any case, what honours me is that the Netherlands and Thailand have had a long history of cooperation in the water management field. The Thai authorities have reached out to the Netherlands in the past and vice versa, to cooperate on finding solutions to prevent and mitigate future floodings in Thailand.
Please allow me to recall in this connection the outcomes of the Dutch Identification Mission Team in February 2011. It studied flood risks and solutions in Thailand, on the request of the former Thai Minister of Science & Technology.

The team -lead by Mr van der Meulen, your so-to-say Dr George, present here today - studied the future flooding risks in Thailand. It came to the conclusion inter alia that indeed serious floods could reoccur in the future. Moreover the team came up with recommendations to reduce risks. The members of that mission are present with us here today.

Unfortunately four months after the team presented its conclusions, in July 2011 and later that year, a substantial part of the country was dramatically flooded, for several months.

The Great Flood in Thailand was massive. It *inter alia* damaged crops in many parts of the country and caused immense socio-economic damage. To prevent and mitigate similar disasters in the future many preparations and activities are currently being undertaken by the Thai authorities.
Nevertheless in the Netherlands we learned that effective flood and drought management requires an as-much-as-possible integrated approach, based on a long-term and holistic vision on the country's spatial organisation.

The Dutch vision of becoming the best protected delta in the world might be definitely useful in the Thai context and might serve as an inspiration for the Thai vision on future flood prevention and mitigation in the future. Our 'best Delta practice' has a national and an international dimension to it. Nationally the Netherlands has to ensure continuously that our systems and procedures for flood prevention and mitigations are nearly flawless. As some parts of my country are as much as 6 meters below sea level, floods would have devastating consequences for the country.

Internationally the Netherlands supports and cooperates with several countries to inter alia improve their delta water and living circumstances, for example in Indonesia, Bangladesh, and Vietnam.
In this regard also Thailand should be mentioned. Already long before 2011 we had a water management advisory relation with Thailand. Please allow me to recall that the first Director General of the current RID, the Royal Irrigation Department, was a Dutch irrigation engineer. This was Yehoman van der Heijden. In 1902, appointed by your King Rama V Chulalongkorn, he started working in the Department of Canals Development (since the decision to rename it by King Rama VII Prapaklao in 1927 it became RID, royal irrigation department).

Anyway that Dutch engineer Van de Heijden was at that time responsible for a water department which is nowadays one of Thailand's key stakeholders in the Thai water management policy arena.
More recently and partly on request of KPI – the King Prajadhipok's Institute – 50 -100 Thai civil servants visited the Netherlands to get more familiar with the Dutch efforts and successes in the field of water management.

Ladies and gentlemen, slowly coming to the end of my address, I want to mention the important role of groundwater for water control management at land surface level:
SWS focuses particularly on the storage of surface captured water. In the Netherlands we have several examples of how this can be done in practice, one of which concerns the Dune-zone along the North Sea coast. This area consists mainly of sand and rain water is automatically absorbed into deeper aquifers. This natural phenomenon is linked to the man-made urban water supply system of the city of Amsterdam, which enables the water to be used as drinking water in Amsterdam city.
About the the Dutch water sector in general: the Dutch private sector possesses a substantial part of the water expertise and know-how of the Netherlands. We have a large number of high quality consultancy firms working all across the world, knowledge institutes as well as engineering companies.

Today you see only a few of them, Knowledge institutes such as CKI, UNESCO-IHE and DELTARES.
Engineering companies such as ARCADIS and AvecoDeBondt.
Most of these companies are united in the largest Dutch association of water companies and organisations, called the Netherlands Water Partnership (NWP). NWP has a large network of international contacts all over the world.

Last but not least I would like to mention the wonderful current cooperation between the Dutch expert team, present here today, and Thai authorities, such as the Department of Groundwater Resources (DGR) and the Department of Public Works and Town & Country Planning (DPT).

The project is a good example of regional attention for water problems, fitting in the ADB's regional overall water program for technical support. The Asia Development Bank kindly provided the necessary financial support to make this project possible.

For the project and its continuation in the future, I want to express my best wishes to all the involved organisations and persons. Hopefully all your work results in a holistic approach, effective and sustainable in the future.

Thank you for your kind attention.
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III. Deputy Director-general of DGR Dr Aranya Fuangswasdi

Opening Remark
On the Conference of Subsurface Water Storage (SWS) – Harvesting the Floods Project
26th November, 2015
At Centara Grand and Bangkok Convention Centre, Central World, Bangkok
By
Dr. Aranya Fuangswasdi, Deputy Director General, DGR

Excellency Mr. Karel Hartogh, the Ambassador of the kingdom of the Netherlands to Thailand
Mr. Pavit Ramachandran, Senior Environment Specialist of the Asian Development Bank,
Expert team,
Distinguished guests, ladies and gentlemen.

It gives me a great pleasure today to inaugurate the Conference and Workshop of Subsurface Water Storage (SWS) – Harvesting the Floods project on behalf of the Director General and pass on his warmest greeting.

The paradigm in water resources management has shifted towards more integration and sustainability. SWS project has arrived in time to recover Thailand from existing flood and drought with its scheme to include land use planning.

Excellencies,
Ladies and gentlemen.
In Thailand, more than three hundred villages face high flood risk each year, droughts which occur annually can cause great damage to agriculture and industry. Nearly one third of the country's land area is classified as medium or high drought risk. Of particular concern is water scarcity, which occurs against the backdrop of low water availability, high pollution, and increases per capita consumption.

As mentioned, SWS project was undertaken with an integration approach, including a multi-level of land and water planning and management concept, both surface and subsurface water. The study aims to reduce flood and drought risks by storing rain water into the aquifer and offering a possibility to extract such water during the drought period to keep irrigation and other activities going.

This Conference is a gathering of specialists in water management, climate change, land use, civil societies, academic and development partners. It aims to give planners and policymakers an opportunity to exchange the recommendations speedily. Therefore, we are here today to exchange experience and knowledge that we had learnt from the project Subsurface Water Storage-Harvesting the floods" that applied to Nakhon Panom Province.

Before the conference begins, on behalf of the DGR, I would like to thank ADB for their support to make this project financially feasible. I also thank the Department of Public Works and Town & Country Planning and Sri Songkhram sub district municipality for their excellent hospitality during the field work studies. Also, thank to DGR staffs from Bureau of Groundwater Exploration and Assessment and the International Relations Unit for their dedication to make the project completed.

I wish you all a very successful Conference and Workshop. I now declare the Conference open.

IV. Dr. George van der Meulen (CKI)

MULTI-LEVEL INTEGRATED LAND & WATER RESOURCES PLANNING AND MANAGEMENT, APPLIED TO NAKHON PHANOM PROVINCE, NORTHERN PART, WATERSHED BASIN, REGARDING UN AND SONGKHRAM RIVERS
Beyond groundwater, a cooperation and integration of DPT Land use planning and DGR groundwater management

This contribution to the SWS conference puts emphasis upon the following mutually related topics:

1. A general introduction about some backgrounds and historic issues
2. Explanation about why a strong cooperation between DGR and DPT (as well as with several other departments) is necessary for ultimate success
3. An underlining why at land level land use planning should have and take a crucial and leading role to undertake in order to:
   a. Allocate adequately land use in a framework of spatial development and future organisation
   b. Allocate (ground-) water relevant sites suitable for subsurface drainage and percolation
   c. Reduced risks of floods and droughts through its (preferably drastic improved) land use plans which take care of socio-economic and environmental developments expected in future
   d. Produce such plans capable to control, monitor and enforce for the quality of percolated rain water into subsurface aquifers
   e. Relate its plans, environmentally sound, to specific land uses requiring large volumes of water (e.g., agriculture, livestock, industry), simultaneously protecting against possible contaminations caused by such land uses
4. A dedicated role for groundwater experts and managers at the subsurface level, taking into account:
   a. Opportunities provided by (hydro-) geologic circumstances (such as porosity, conductivity, transmissivity)
   b. Conceptual useful concepts (in the presentation provided as a working sketch)
   c. The main outcomes of the SWS project workings in Nakhon Phanom province
   d. Opportunities for SWS continuation (see hereafter section 8)
5. An overview of some experiences gained during the SWS pilot project application of SWS in Nakhon Phanom province, notably:
   a. In general
   b. With regard to data and relational database management problems encountered
6. An overview of recommendations made
7. As rounding and conclusion , considering a justification for a possible SWS continuation, and eventually mentioning other relevant application areas for SWS in Thailand

V. Dr. Roelof Stuurman (DELTARES)

Right to left: Gerhard Winters, Robbert van Mensfoort, Roelof Stuurman

This presentation gave primarily an overview of the encountered geologiocal and hydrogeological features in the Un and Songkhram watersheds during the November 2015 fieldwork activities. Moreover, about 10 solutions supporting a possible water drainage into the underground and subsurface aquifers. Suitable locations to apply Subsurface Water Storage have been identified, with awareness of a limited and solvable salination constraint.

Solutions mentioned in a nutshell:

1	Collect & infiltrate local rainfall from buildings, streets & rice paddy's	a. Dry wells, b. Recharge basins, c. Rice system
2	Improved rainfall harvesting ponds	a. improved design b. Adding infiltration wells
3	Water reservoir optimalization	a. Increasing water level b. Adding infiltration wells
4	Retain intermittent stream water	a. Adding small dams or weirs b. Divert into infiltration depressions c. Increase stream bottom elevation
5	Harvest monsoon river water	a. Divert into infiltration basins b. Add IT-drains
6	Reduce groundwater drainage	a. Increase bottom elevation b. Install vertical underground dams
7	Collect sandstone area drainage water & infiltrate in alluvium area	a. Divert water into infiltration basins along the sandstone – alluvium border
8	Reduce evaporation Infiltration areas	a. Improve land use (planning)
9	Infiltration by IT-drains	a. Rain water ⌛ b. Pond, Reservoir or River water
10	Re-use waste water	

f. Participants list

Participants' name list for Subsurface Water Storage (SWS) – Harvesting the Floods Project Conference, at Centara Grand at CentralWorld Hotel, 26 November 2015

No.	Name-Surname	Position	Organisation
๑	นางอรัญญา เฟื่องสวัสดิ์	รองอธิบดีกรมทรัพยากรน้ำบาดาล	DGR
๒	นางอรนุช หล่อเพ็ญศรี	ผู้อำนวยการสำนักสำรวจและประเมินศักยภาพน้ำบาดาล	DGR
๓	นางสาววิลาวัณย์ ไทยสงคราม	ผู้อำนวยการสำนักควบคุมกิจการน้ำบาดาล	DGR
๔	นางจินตนา เหลืองวิไลย์	ผู้อำนวยการสำนักบริหารกลาง	DGR
๕	นายจิตรกร สุวรรณเลิศ	ผู้อำนวยการสำนักอนุรักษ์และฟื้นฟูทรัพยากรน้ำบาดาล	DGR
๖	นางสาวทัศนีย์ เนตรทัศน์	นักธรณีวิทยาชำนาญการพิเศษ	DGR
๗	นายมหิปพงศ์ วรกุล	นักธรณีวิทยาชำนาญการพิเศษ	DGR
๘	นายประกอบ อยู่คง	นักธรณีวิทยาชำนาญการพิเศษ	DGR
๙	นายบรรจง พรมจันทร์	นักธรณีวิทยาชำนาญการพิเศษ	DGR
๑๐	นางสาวพรอุษา อุดมศิลป์	นักธรณีวิทยาชำนาญการ	DGR
๑๑	นางสาวอลิน ชินทรารักษ์	นักวิเคราะห์นโยบายและแผนชำนาญการ	DGR
๑๒	นางสาวนิสา กันธิยะ	นักธรณีวิทยาชำนาญการ	DGR
๑๓	นางสาวณัฐฑิณี รตานนท์	นักทรัพยากรบุคคลปฏิบัติการ	DGR
๑๔	นางสาวสุทาภา โพธิ์เก่า	นักประชาสัมพันธ์ปฏิบัติการ	DGR
๑๕	นางสาวนาถชนก อุ่นปิง	นักธรณีวิทยาปฏิบัติการ	DGR
๑๖	นางสาวละเอียด สังข์ทอง	นักธรณีวิทยาปฏิบัติการ	DGR
๑๗	นางสาววศินี อัศวมานะศักดิ์	วิศวกรปฏิบัติการ	DGR
๑๘	นางสาวปุณยวีร์ อินทรักษา	นักวิเคราะห์นโยบายและแผนปฏิบัติการ	DGR
๑๙	นางปุณฑริกา ศศิรุจิวัฒน์	นักธรณีวิทยา	DGR
๒๐	นางสาวกนกวรรณ ยะพรม	นักธรณีวิทยา	DGR
๒๑	นางสาวพลอยนพรัตน์ เพาะสูงเนิน	นักธรณีวิทยา	DGR
๒๒	นายสุพิทยา มัฐผา	นักวิชาการทรัพยากรน้ำบาดาล	DGR
๒๓	นายสิทธิศักดิ์ มั่นอยู่	นักธรณีวิทยาชำนาญการพิเศษ	DGR
๒๔	นางสาวสมจใจ จั่วนาน	นักจัดการงานทั่วไป	DGR
๒๕	นางสาวภคปภา ชาญแสงสวัส	นักจัดการงานทั่วไป	DGR
๒๖	นางอัญชลี พงษ์สถิตย์พัฒน์	นักธรณีวิทยาชำนาญการ	DGR

๒๗	นางสาวกันต์กนิษฐ์ ทุมประเสริญ	นักธรณีวิทยาชำนาญการ	DGR
๒๘	นางสาวสุพรรษา สุวรรณ์	นักธรณีวิทยาปฏิบัติการ	DGR
๒๙	นางสาวอาภากร วงศ์สิทธิ	นักธรณีวิทยาปฏิบัติการ	DGR
๓๐	นางสาวจรินยา ฉิมพาลี	นักธรณีวิทยาปฏิบัติการ	DGR
๓๑	นายไฉน รินแก้ว	นักธรณีวิทยาชำนาญการ	DGR
๓๒	นายบุณฑริก บริสุทธิ์	นักธรณีวิทยาปฏิบัติการ	DGR
๓๓	นายบุญสิทธิ คิ้วดวงตา	นักธรณีวิทยา	DGR
๓๔	วิศรุต เตชะสุวรรณวงศ์		DGR
๓๕	ประภาวดี โอตรววรรณะ	นักธรณีวิทยาชำนาญการ	DGR
๓๖	นางสาวชื่นชนก จันทนะลิขิต	ผู้ประสานงานโครงการ	ADB
๓๗	นางสาวชลิตตา เทพภักดี		King Mongkut's Institute of Technology Ladkrabang.
๓๘	พินิช ธนชัยโชคศิริกุล		King Mongkut's Institute of Technology Ladkrabang.
๓๙	หฤหัสก์ ห่อบาล		King Mongkut's Institute of Technology Ladkrabang.
๔๐	Dr. George Gerard van der Meulen	Consultant and Teamleader Project	CKI
๔๑	Dr. Roelof Stuurman	Groundwater hydrologist/hydro-geologist	Deltares
๔๒	Dr. Robbert van Montfoort	Specialist Hydrology	ARCADIS
๔๓	Dr. Gerhard Winters	Senior Consultant	Aveco de Bondt
๔๔	รศ.ดร.อุมา สีบุญเรือง	ผู้ช่วยคณบดีฝ่ายวิเทศสัมพันธ์	King Mongkut's Institute of Technology Ladkrabang.
๔๕	นายวิจารณ์ ต้นติธรรม	วิศวกรโยธาชำนาญการพิเศษ	Department of Public Works and Town & Country Planning)
๔๖	รศ.ดร.สมบัติ ชื่นชูกลิ่น	ผู้อำนวยการสถาบันวิจัย ฯ ด้านทรัพยากรน้ำ	Naresuan University Faculty of Engineering
๔๗	ดร.ภูริภัส สุนทรนนท์	อาจารย์ภาควิชาวิศวกรรมโยธา	Naresuan University Faculty of Engineering
๔๘	นางอณัญญา ราชิวงศ์	นักวิเคราะห์นโยบายและแผนชำนาญการ	สำนักงานทรัพยากรน้ำภาค ๓
๔๙	ดร.วินัย เชาวน์วิวัฒน์	นักวิจัย	สถาบันสารสนเทศทรัพยากรน้ำและการเกษตร (องค์การมหาชน)
๕๐	นายสมชาย เรืองชาติชัย	นายช่างโยธา	กองมาตรการ

g. Brainstorm session SWS approach & activities in future: research and execution applications

I. Explanation why brainstorm session
II. Aquifer experiences and studies (Dutch experts)
III. Groundwater demands in framework of floods and droughts (DGR, DWR, DPT)
IV. Deliberation & discussion future applications in Thailand
V. Future applications within ADB's regional water management programme

Brainstorm session in a nutshell

From the side of the Dutch experts, an overview of solutions for SWS has been presented. This concerned particularly experiences during the 3rd field work study as executed in November previous to the conference.

The participants in this brainstorm session showed not only their interest in the matter but moreover were active discussants.

Final conclusions underlined the ideas of the audience. First the SWS project is indeed continued in Nakhon Phanom. And later-on extend to some other areas, mentioned are (by audience: Sukhothai) and (by the team) Trang watershed in Nakhon Si Thammarat, and the Chonburi / Rayong 2015 flood area (drainage zone crossing motorway).

h. Workshops (Friday 27th November 2015)

The Workshop of Subsurface Water Storage (SWS) – Harvesting the Floods Project
27th November, 2015
At Centara Grand and Bangkok Convention Centre, CentralWorld, Bangkok

Time	Activities	Responsibility
8.30 – 9.00	Registration	-
9.00 – 10.30	Lecture of SWS working strategies: step by step	Dr. George Van Der Meulen (CKI)
10.30 – 10.45	Coffee break	
10.45 – 12.00	Lecture of Hydrogeologic, State of the arts/researches and Q&A	Dr. Roelof Stuurman (Deltares)
12.00 – 13.00	Lunch	
13.00 – 14.00	Lecture of Hydrogeological experiences	Mr. Robbert van Montfoort (ARCADIS)
14.00 – 15.00	Lecture of Institutional framework for water management	Mr. Gerhard Winters (Avecodebondt)
15.00 – 15.15	Coffee break	
15.15 – 15.45	Lecture of River basin management	Mr. Chanawat Arrunrata Plan and policy analyst, Department of Water Resources
15.45 – 16.30	Discussion / Closing	-

Team contributions:

I.	Dr. George van der Meulen	SWS working strategy re: database management
II.	Dr. Roelof Stuurman	Hydro-geology, state-of-the-art
III.	Mr. Robbert van Montfoort	Hydrogeological experiences Preliminary basis for design
IV.	Mr. Gerhard Winters	Institutional framework water management

DWR contributionL

V.	Mr. Chanawat Arrunrata	River Basin Management

i. Summary workshops

I. Dr. George van der Meulen: Data and relational database management

Data and relational database management regarding boreholes and related project management issues are major topics of attention in this workshop. The workshop focuses upon data quality regarding boreholes. Of concern are data input correctness, data registration, imaging, and mapping.

Problems encountered during the SWS pilot project workings are presented. Also, consequently improvements are indicated. Moreover, it is underlined that this nutshell workshop, offering information and some backgrounds of the problems encountered, require serious consideration by DGR to initiate tailor-made training, preferably in a framework as offered through the Dutch NUFFIC, organisation of Netherlands Universities Federation for International Cooperation.

II. Dr. Roelof Stuurman: Hydro-geology, state-of-the-art

This contribution counts three sections. That is, (1) a RECAP of hydrogeological solutions mentioned during the brainstorm (Ref. Research activity A. This is followed by George van der Meulen to address the Recap of sections Research activity B, and Research activity C.); (2) Demonstration of the Dinoloket TNO, which is an extensive software and database system for underground data and stratifications, available on website and freely retrievable; (3) a presentation about his experiences regarding Groundwater monitoring: case New Orleans.

III. Mr. Robbert van Montfoort: Hydrogeological experiences

Preliminary basis for design – tools and technique (modelling) using the best available knowledge and techniques for assessment of SWS feasibility

In order to determine the feasibility, conceptual design and cost of the surface water storage (SWS) and recovery needed to meet the specified requirements (quantity/quality and water rights), key figures for a preliminary design should be obtained. These key figures, input and output parameters for design purposes, can be obtained by field investigations, field/pilot tests, reference projects, the conceptual site model and preliminary (hydrogeological) calculations. The challenge lies in finding a good balance between the use of 'hard data' (extensive field investigations/monitoring) and 'soft data' (assumptions and derivatives) to obtain these key figures that are accurate enough for assessment of SWS feasibility. Data availability, time frame, risk, cost and return determine largely the budget for research. Modelling can be used as a cost effective tool to determine parameter bandwidths for a preliminary basis for design. Modelling tools can also be used as a validation of the conceptual site model and scenario calculations in support of decision making.
During the workshop the process and various tools and techniques are presented that can be used for a preliminary basis for design.

IV. Mr. Gerhard Winters: Institutional framework water management

Institutional aspects and analysis
A short journey through the natural properties of the physical water system and the human water demands

Introduction
The institutional issues of water management are subject of research activity C in this study. The definition of the institutes in water management is described thoroughly in literature. The whole framework of a natural water system used by humans for many different and sometimes conflicting purposes in quantity, time, place and water quality is the scope of Integrated Water Management. Worldwide numerous examples are available of success full and failing attempts to define or optimize the institutional part of water management. However the focus in this study is tightened to the analyse the actual institutional and organisational aspect of the Nakhon Phanom region within the Thai context.

Scope
The physical water system is assessed in research activity A, while research activity B depicts the presence of water in the river catchment and the impact on different stakeholders. The step towards research activity C lies in the way people cope with water. The final stage in coping with everyday needs of water, seasonal flooding and seasonal droughts and even long term changes due to climatic disturbances is what we call the "Institutional Framework". Institutions inherently bring order and structure and have stabilizing effects on the community as social system. Every water system is managed by a complex set of formal and informal rules. The formal rules are not blue printed for the subject of water management but evolve in time in the regional context from informal rules to more or less solified formal rules. And then executed in practical specialised organisation with budgets, staff, policy development and maintaining tasks.

Methodology
The complexity of the interaction between the physical properties of the catchment and the institutional aspect is not ease to unravel. Therefore, we use expansionary models and the guiding principles concerning water written in the **Dublin Statement on Water and Sustainable Development** (see textbox).

GUIDING PRINCIPLES

The Dublin Principles for Water as Reflected in a Comparative Assessment of Institutional and Legal Arrangements for Integrated Water Resources Management, Global Water Partnership Technical Advisory Committee (TAC), Stockholm, Sweden, 1999.

Concerted action is needed to reverse the present trends of overconsumption, pollution, and rising threats from drought and floods. The Conference Report sets out recommendations for action at local, national and international levels, based on four guiding principles.

Principle No. 1 - Fresh water is a finite and vulnerable resource, essential to sustain life, development and the environment

Since water sustains life, effective management of water resources demands a holistic approach, linking social and economic development with protection of natural ecosystems. Effective management links land and water uses across the whole of a catchment area or groundwater aquifer.

Principle No. 2 - Water development and management should be based on a participatory approach, involving users, planners and policy-makers at all levels

The participatory approach involves raising awareness of the importance of water among policy-makers and the general public. It means that decisions are taken at the lowest appropriate level, with full public consultation and involvement of users in the planning and implementation of water projects.

Principle No. 3 - Women play a central part in the provision, management and safeguarding of water

This pivotal role of women as providers and users of water and guardians of the living environment has seldom been reflected in institutional arrangements for the development and management of water resources. Acceptance and implementation of this principle requires positive policies to address women's specific needs and to equip and empower women to participate at all levels in water resources programmes, including decision-making and implementation, in ways defined by them.

Principle No. 4 - Water has an economic value in all its competing uses and should be recognized as an economic good

Within this principle, it is vital to recognize first the basic right of all human beings to have access to clean water and sanitation at an affordable price. Past failure to recognize the economic value of water has led to wasteful and environmentally damaging uses of the resource. Managing water as an economic good is an important way of achieving efficient and equitable use, and of encouraging conservation and protection of water resources.

In the workshop, we will fill out next bullets with the experiences of the attendees. The workshop is too short to obtain a complete overview, but the descriptive model is very helpful in finding the flaws and needs for innovation in the system as a whole.
Descriptive

- Physical properties watershed
- Social and economic aspects
- Policies (State, regional, local)

Institutes & organisations

- Water policies
- Resource management
- Day to day water management: service organisations, farmers, municipalities, etc.

Utilization

- Spatial and temporal planning and allocation
- Conflict management
- Cost and investment aspects

Implications for sustainable use

- Acceptance of present situation or improvements needed
- Compatibility between institutional framework and organizational structures and needs
- Filling gaps between needs and actual situation

Another descriptive model is the "policy cycle": This model is convenient for "institutions & organisations" part of the former model, but it will apply also on other sections.

V. Mr. Chanawat Arrunrata : River Basin Management

Strategic Plans for Water Management of Thailand

According to his summarizing conclusions, the strategic plans for water management of Thailand (2015-2026)

1. The strategic plan has changed of concepts of formulation processes by integration of economic, geo-social aspects, and limitation of areas

2. The strategic plan has been integrated with governmental policies, the National Economic and Social Development Plan, and other related water and natural resources strategic plans to be consistent with balance and sustainability of management approaches

3. The strategic plan was established under stakeholder participation concepts and implementation by linkage of national strategies and water management in river basins.

j. Team composition

- DGR:
  a. Dr. Aranya Fuangswasdi, Deputy Director-general
  b. Mr. Mahippong Worakul, director of Groundwater Potential Assessment section
  c. Dr. Alin Chintraruck, head of Bureau of International Relations
  d. Dr. Warangkana Larbkich, Plan and Policy Analyst, hydro-geologist
  e. Ms. Jurarud Yanawongsa, hydro-geologist
  f. Ms. Natchanok Ounping, geologic information
  g. Mr. Patsakron Assiri, hydro-geologist
  h. Mr. Somboon Puangkasorn, surveyor, technical borehole specialist
  i. Ms. Punyawee Intaraksa, Plan and Policy analyst, linguist support officer
  j. Ms. Pornusa Udomsilpa, Hydrogeologist
  k. Mr. Gomet Chinsiri, geologist Udon Thani DGR branch office (NE Thailand)
  l. Ms. Nisa Kantiya, (hydro-) geologist Udon Thani DGR branch office (NE Thailand)

- Province Authority Nakhon Phanom
  a. Mr. Paitoon Rukprated, vice governor
  b. Mr. Siripong na Songkla, chief irrigation
  c. Mr. Pairoad Kopon, chief DDPM branch Nakhon Phanom Province
  d. Mr. Somwang, Plan & Policy Analyst
  e. Mr. Wirasak Chaipet, Plan & Policy Analyst

- DPT:
  A. Department of Public Works and Town & Country Planning:
  a. Dr. Thongchai Roachananakan, senior architect (DPT Bangkok)
  b. Mr. Wijarn Tantitum, (Public Works section, Bangkok)

  B. Province Planning Office
  a. Mr. Wijit Ngamchuen, senior civil engineer of CPO, Nakhon Phanom
  b. Mr. Narong Wanna, senior technician of CPO, Nakhon Phanom

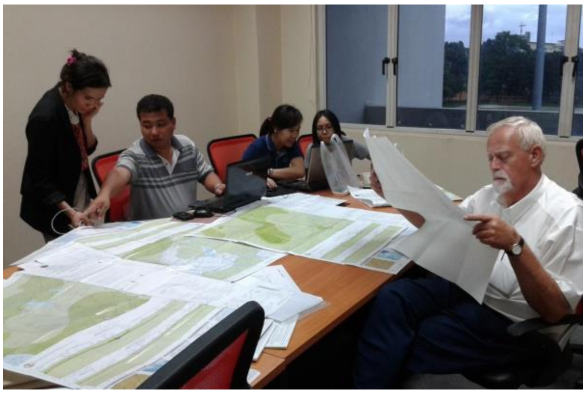
- ADB-SWS, Dutch team members:

a.	Team leader	Dr. George van der Meulen (CKI)
b.	Hydro-geologist	Dr. Paulo Paron (UNESCOF-IHE)
c.	Geologist	Dr. Roelof Stuurman (Deltares)
d.	Geo-hydrologist	Mr. Robbert van Montfoort (ARCADIS)
e.	Water specialist	Mr. Gerhard Winters (Aveco De Bondt)

k. **Thai-Dutch SWS project team (photos) 2015**

1st SWS Mission to Nakhon Phanom Province, August 2015

2nd SWS Mission to Nakhon Phanom Province, September 2015



Un and Songkhram River (left)
Songkhram bridge (right), see water level memories on poles

3rd SWS Mission to Nakhon Phanom Province, November 2015

(salt sections visible in groundwater in excavation)

I. The conference and workshop gallery

m. Other involved and contacted persons

- DLD: Nakhon Phanom
  a. Mr. Chaiyuk U-Thapaset
  b. Mr. Kriengkrai Imsompoch

- **Sri Songkhram municipality:**
  a. Ms. Nawarat Lijuan, palad tesaban

- **Songkhram District Land Office:**
  a. Mr. Kriengkrai Imsompoch
  b. Mr. Chaiyuck U-Thapasat