Viet MAR

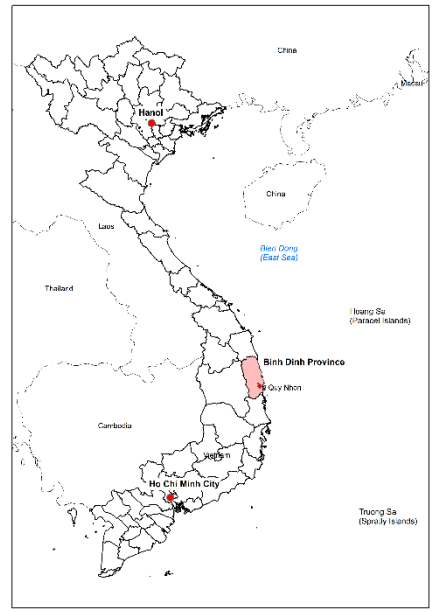
Feasibility Studies for Managed Aquifer Recharge

Preliminary results of the Finnish-Vietnamese Institutional Cooperation

Managed aquifer recharge to ensure sustainable groundwater availability and quality under ongoing climate change and fast economic development in Vietnam (Viet MAR), 2018 – 2023

Key activities:

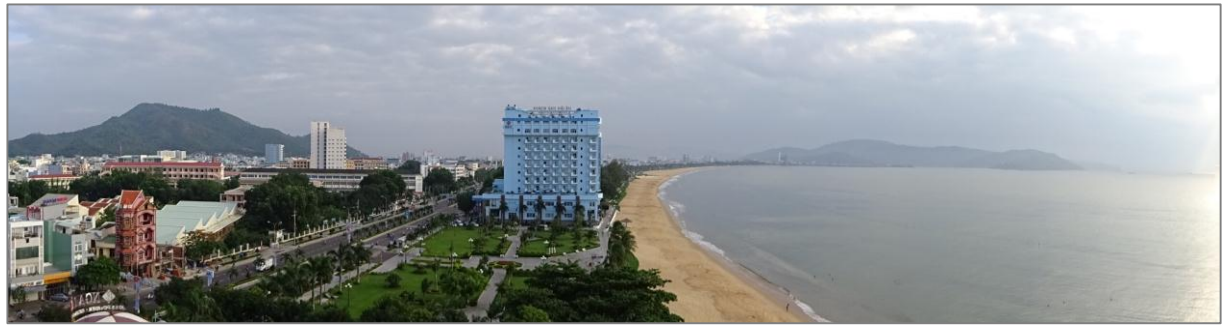
- Training of Vietnamese experts in background studies for a MAR site including geochemistry and sampling, analysing climate change and anthropogenic impacts, groundwater modelling and environmental impact assessment.
- Developing case specific guidelines for a feasible MAR implementation in the Phuong Mai peninsula, Quy Nhon city.
- Legislative background studies for MAR, assessment of risks and challenges, and providing tools for decision making.
- Dissemination to increase awareness of MAR potential in Vietnam.



Viet MAR – capacity building for MAR studies

The project enhances the Vietnamese experts' capability to conduct comprehensive background studies for a feasible MAR site planning. It supports Vietnam's preparedness for future water shortages due to high economic development and negative impacts of climate change. The project focuses on the following key issues:

- Improving the knowledge of local hydrogeological and environmental conditions.
- Studying the whole investigation chain needed for a feasible MAR approach.
- Applying good practices of environment and water management as well as MAR implementation from Finland to Vietnam.
- Developing general recommendations and guidelines for a MAR feasibility study.
- Enhancing decision makers' knowledge on sustainable water resource management and MAR.
- Theoretical and practical training of local experts and stakeholders.



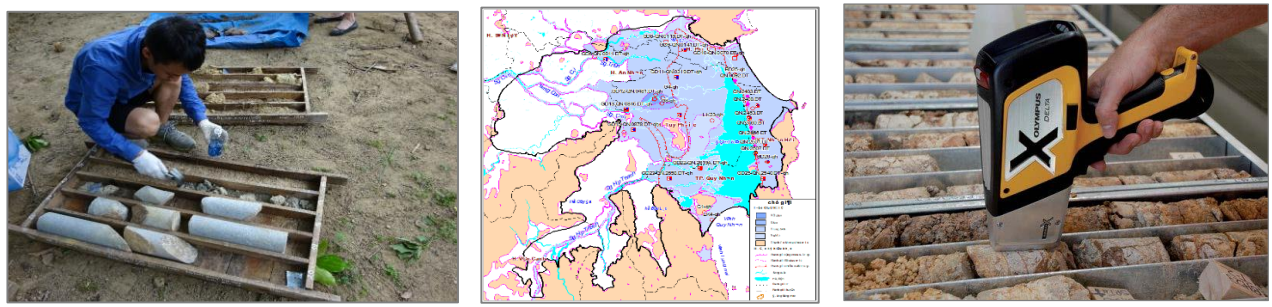
Case study in the Binh Dinh province – Quy Nhon city, Phuong Mai peninsula

- Quy Nhon city is located on the coast of South-Central Vietnam in the Binh Dinh province. The Phuong Mai peninsula locates in the eastern side of the city. Phuong Mai is currently under strong industrial and economic development.
- The population of Quy Nhon city is about 290 000 with total area of 286.1 km^2 (2018).
- Main economic fields of the Phuong Mai peninsula are industry, such as pharmaceutical, wind and solar power, animal food, concrete, and steel production along with tourism and related services.
- The lack of sufficient industrial and domestic waste treatment are potential threats to the environment and water quality. Water supply of Phuong Mai relies partly on groundwater and partly on surface water from river Ha Thanh led to the peninsula via a pipeline.
- Topographically the area is manifold with sand dunes rising to 100 m a.s.l. A mountain range delineates the peninsula from the ocean on the eastern side. The western side of the dune formation has several springs recharging to the Thi Nai lagoon.

The Phuong Mai peninsula (left); sand excavation (centre left); fishery village (centre right); aluminium roof factory (right).

Geological and hydrogeological studies

- Thorough geological and hydrogeological studies form the basis for the MAR feasibility study.
- Geological information was collected from existing monitoring well drill cores on the site.
    - Selected drill core samples were analysed for element composition using portable XRF analyser.
    - Mineralogical studies were made to analyse the buffer capacity of the local soil layers.
    - Local pumping test results and field observations were used to define hydraulic conductivity.
    - Confining layers and aquifer material were identified from the drill cores.
- Field studies were conducted to determine the general features of the case study area: bedrock outcrops, dune area extent, water bodies, elevations.
- Background information was collected from the previous projects in Quy Nhon, for example the Groundwater Protection in Big Urban Areas project (Quy Nhon Urban Area) by NAWAPI.



Analysing geological drill cores (left); hydrogeological maps of aquifer *qh* in Quy Nhon (centre); pXRF analysator (right).

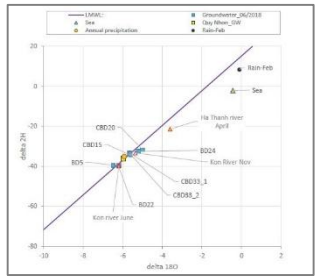
Groundwater studies - geochemistry

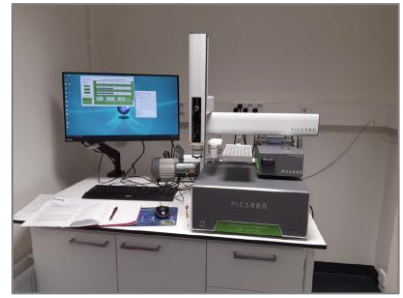
- Groundwater samples were collected from monitoring and private wells and springs.
- Concentrations of common cations and anions as well as trace elements were analysed at NAWAPI laboratory.
- In addition, bacteria (coliform bacteria) and some organic pollutants (dioxins and furans, cyanide) were analysed.
- Based on preliminary studies, only some of the analysed elements, such as Fe, Mn, Cd and Ni exceeded Vietnamese national technical regulation values for drinking water quality. Salinity makes the water unusable occasionally at some locations near the coast.

Filtering water samples on field (left); water sampling (centre left); installing pumping equipment in a monitoring well (centre right); groundwater monitoring well (right).

Groundwater studies - isotopes

- Groundwater and surface water samples were collected for isotopic analyses of oxygen and hydrogen isotopes O^{16}/O^{18} and H/H^2.
- Isotopes can be used:
  - to estimate the source of water (groundwater, surface water, rain)
  - to estimate the residence time of water in the ground
  - as a natural tracer for groundwater (no chemicals needed)
  - to identify interaction between a surface water body and an aquifer
  - to identify the source area of a contaminant in aquifer
- Isotope samples were analysed at GTK research laboratory in Espoo, Finland.
- Training for using isotopes in hydrological studies was organized in Hanoi, in Espoo and online.
- More frequent sampling is required for comprehensive understanding on groundwater – surface water interaction and dynamics on site.

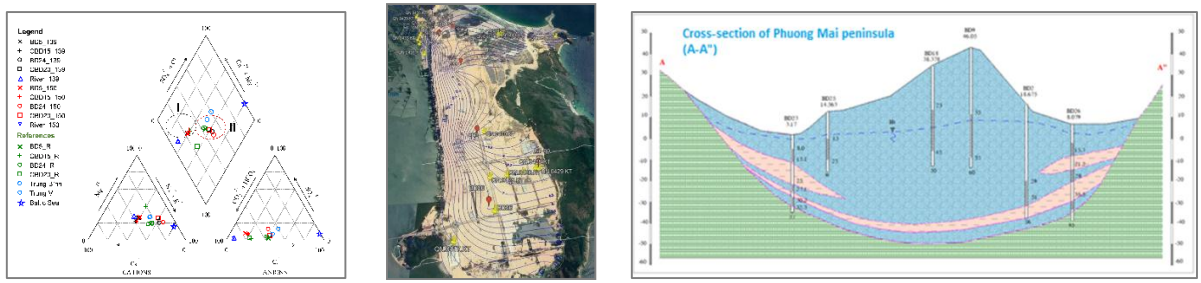


Isotopic analysis results of water samples (left); water sampling in Phuong Mai (centre); isotope analysis device Picarro (right).

Groundwater studies - modelling

- Groundwater flow modelling was conducted with FEFLOW software, model was calibrated with PEST.
- Climate variables (precipitation, evaporation rate) were included into the flow model.
- Two separate MAR piloting scenarios with estimated infiltration rates were modelled.
- Modelling results can be utilized to recommend a feasible option for the MAR site pilot:
    - Suitable location of infiltration, monitoring, and pumping wells
    - Amount of needed infiltration water for managed aquifer recharge
    - To estimate sustainable pumping rates.
- Next steps in groundwater modelling: steady state groundwater flow, saltwater intrusion modelling, future climate and pumping rate scenarios modelling.



Piper diagram on the geochemical groundwater analysis results (left); estimated groundwater level isolines (centre); cross section of the Phuong Mai soil layers (right).

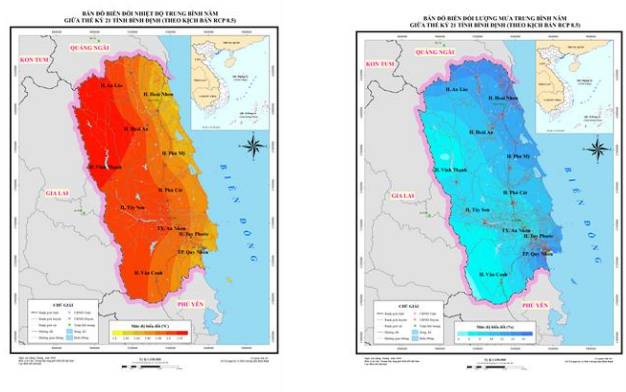
Surface water studies

- Surface water samples for chemical analyses were collected from natural springs and an artificial pond located in southern Phuong Mai peninsula.
- Several springs were studied for yield, electrical conductivity, and temperature in separate field campaigns during dry and rainy seasons.
- Representative sampling of surface water is challenging. Several sampling campaigns are required to indicate the seasonal and annual changes in water quality. Continuous monitoring devices are recommended.
- Concentrations of basic cations and anions as well as trace elements were analysed.
- In addition, bacteria (coliform bacteria) and some organic pollutants (dioxins and furans, cyanide) were analysed.
- Only some of the analysed elements (such as Fe, Mn and NO_3^-) exceeded Vietnamese guideline values for drinking water quality in the natural springs.
- There were no signs of pollution in surface water or sediment samples taken from the artificial pond, only elevated concentrations of arsenic were detected.

The pond sampling in Phuong Mai (left); spring mapping (centre); spring yield measurements with a weir (right).

Climate change scenarios

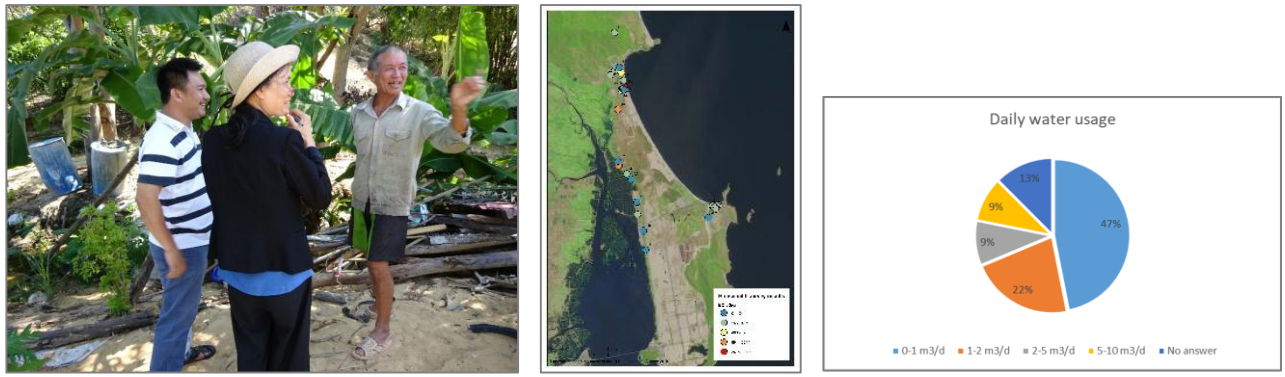
- SIHYMECC analysed climate change impacts on the case study area concerning temperatures and precipitation in 2016-2100. Analysed scenarios were RCPs 4.5 and 8.5.
- Water balance studies are carried out in cooperation with CEWAFO groundwater modelling: groundwater recharge and water demand in changing climate and socio-economic development.
- Enhancing the benefits of MAR: securing water supply for example during prolonged droughts.
- Groundwater protection plans: Hydrogeological studies on aquifers, vulnerability analysis, minimizing risk activities, land use restrictions to protect aquifer and water intakes, saving future water reserves.



Mid-century (2046 – 2065) average annual change in temperature in °C (left) and precipitation in % (right) in comparison to baseline period (1986 – 2005) according to climate change scenario RCP 8.5.

Anthropogenic impact and estimated water consumption

- A questionnaire survey to local residents was conducted to find out experienced challenges in water quantity and quality.
- Anthropogenic impacts on water resources were assessed using estimates on water demand of population and industries in the coming decades.
- Current and future contamination risk activities were estimated based on land use plans and field observations.
- Depending on the development scenario for the Phuong Mai peninsula, there will be a severe lack of water in the area by 2040. Estimates vary between 60 000 – 80 000 m^3/day.



Interviewing a local resident (left); measured EC values in interviewed households (centre); daily water usage among interviewed households (right).

Capacity building in Finland and Vietnam

- A two-week training period in Finland was organized in August-September 2019.
- Lectures on geochemistry and isotopes.
- Field visits to groundwater facilities using MAR: Turku, Kuopio and Porvoo waterworks.
- Visiting and sharing information with Finnish research institutions and other cooperation bodies: Finnish Environment Institute, Savonia University of Applied Sciences.
- Visiting Finnish companies with expertise in environmental monitoring and waste treatment sectors: Ekomo-Ämmässuo eco-industrial centre, Viikinmäki wastewater treatment plant.
- International share of information and capacity building via workshops in Vietnam in cooperation with KIGAM, VIGMAR, UNESCO, the Vietnam Water Supply and Sewerage Association (VWSA) and the Finnish Water Forum (FWF).

Lectures in the first workshop held in Hanoi (left); practical training on groundwater sampling in Finland (centre); learning how to use the ground penetrating radar (right).

Further steps – guidelines for application of MAR

- The methodologies, tools and results of the Viet MAR project will be applied in the future MAR feasibility studies in Vietnam.
- CEWAFO and SIHYMECC utilize acquired skills and experiences from Finland to estimate the MAR applicability in the Binh Dinh province and other areas in Vietnam.
- Guideline for application of MAR in coastal areas is prepared based on experiences from Quy Nhon.
- Acquired data and feasibility study will support local action plans and targeted guidelines as well as law making.
- Dissemination of results continues from local level stakeholder communication to policy makers.
- Rising awareness of MAR applicability supports overall sustainable water management in Vietnam.

Managed aquifer recharge site in Porvoo (left); tasting artificially infiltrated groundwater at Turku Region Water MAR site (centre); raw water intake from river for MAR (right).

Partnership

The Viet MAR project is funded by the Ministry for Foreign Affairs of Finland under the Institutional Cooperation Instrument (ICI). It is conducted by the Geological Survey of Finland (GTK), the Sub-Institute of HydroMeteorology and Climate Change (SIHYMECC) and the Centre for Water Resources Warning and Forecasting (CEWAFO).

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