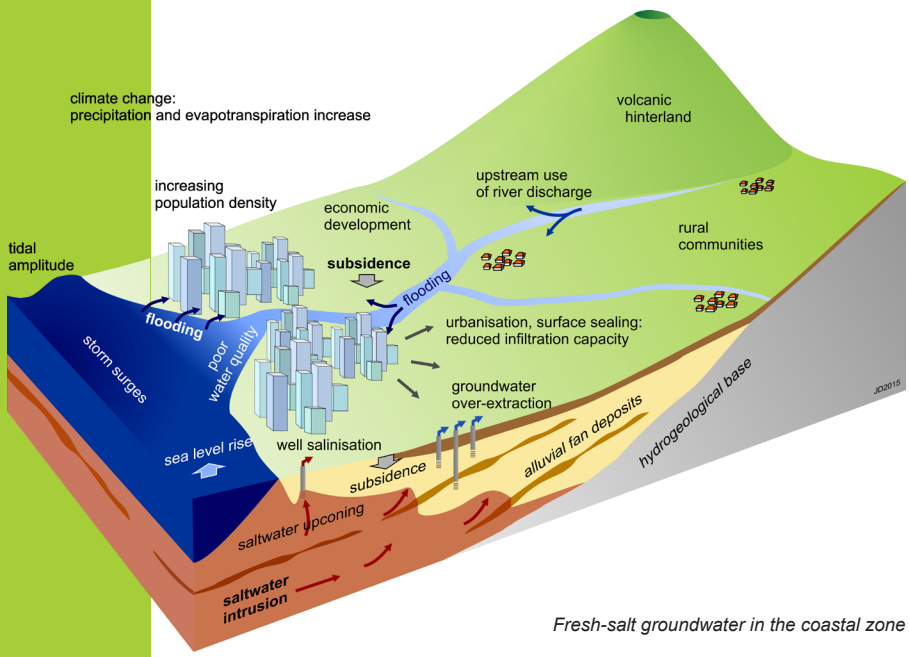
Deltares

Enabling Delta Life

On fresh-saline groundwater in coastal zones

The salinisation of fresh groundwater resources leads to serious problems for farmers, (drinking) water companies, industry and water managers in deltas and islands around the world. These problems, mostly related to the loss of crop yield, the forced abandonment of extraction wells, or the urgent need to (re) build infrastructure, may lead to considerable monetary consequences. Future climate and anthropogenic stresses represent an even greater threat to fresh groundwater in the coastal zone. Deltares advises clients about the sustainable management of this precious fresh groundwater. We have expertise on coastal groundwater processes, use the latest modelling techniques, incorporate innovative monitoring tools and survey techniques. On top we propose responses (managed aquifer recharge) and solutions in the context of adaptive strategies. All this allows us to better advise our clients in their quest for robust, climate-proof, fresh groundwater supplies in the coastal zone, now and in the future.



Fresh-salt groundwater in the coastal zone

Fresh groundwater in deltas and coastal areas is used for domestic, agricultural, and industrial purposes. Huge quantities of high-quality fresh groundwater are available, making it a popular resource. One third of the world's population now lives within a hundred kilometres of the coast, so the pressure is increased on fresh groundwater resources in many parts of the world. Increased salinities in surface water, upconing of saline groundwater under extraction wells and lateral intrusion of salt water are to be expected. This could eventually lead to severe salt damage to crops and the shutting down of extraction wells. Farmers and water supply companies can reduce the financial impact of salinisation of fresh water by acting on time and appropriately.

Increasing threat to fresh groundwater resources requires an integrated response

The use of fresh groundwater resources is likely to increase in the future due to population growth, increasing industrial and agricultural water demands, and the loss of high-quality surface water due to contamination. Sea-level rise and the associated changes in recharge and evaporation patterns will also intensify pressures on fresh groundwater resources. In combination with existing problems, such as serious land subsidence due to enormous groundwater extraction, it is clear that business-as-usual responses cannot solve the problems ahead. Additional mitigation and/or adaptation responses that integrate knowledge of the coastal groundwater system are needed to safeguard fresh groundwater supplies.

Keywords: *fresh-saline groundwater, salt water intrusion, climate change, water system analyses, variable-density modelling, monitoring and surveys, managed aquifer recharge, aquifer storage and recovery.*

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From problem analysis to tailor-made responses: the way we work

Deltares researchers analyse processes involving fresh and saline groundwater in coastal aquifers at different scales. Depending on the complexity of the problem, we combine modelling software, monitoring techniques, airborne surveys and rapid assessment tools. Stakeholder participation is often encouraged to design and implement solutions. We switch between national and local scales to respond to the problem in question. On the national to regional scale, we study the effects of climate change, changes in land and water use, and the combined effects of preventive measures on groundwater salinisation. We analyse how changes in surface water due to water infrastructure activities influence the quality of groundwater. We advise governments, non-governmental organisations and companies about safeguarding freshwater supplies. On the local scale, we give local stakeholders such as farmers more information about the presence and dynamics of fresh groundwater, which is used for irrigation during droughts. Research and consulting topics include preferential groundwater flow via sandy layers and boils that connect deep saline aquifers with shallow aquifers and with fresh surface waters. These preferential flow paths are major factors in the salinisation of low-lying areas such as in the Netherlands. Our knowledge is applied in similar deltas around the world, where we are engaged in the design of measures needed for salinisation prevention and adaptation.

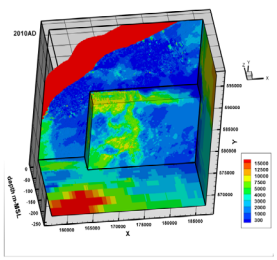
Monitoring tools for salinity

Deltares has knowledge and expertise in developing and applying measuring and monitoring tools and techniques such as resistivity, EM, and seismics. This includes existing techniques, but also our developments such as the in-house designed T-EC probe and EM-Slimflex. A new innovation is monitoring salinities with glass-fibre techniques such as Fibre Bragg Gratings. Similar as for the modelling studies, Deltares excels at providing the client information rather than (solely) data. Our wide expertise and extensive range of equipment allows us to choose the most appropriate measurement or monitoring technique for the problem at hand. The collected data is interpreted by different researchers of various disciplines. Modelling, measurements and monitoring are all therefore often strongly connected in projects at Deltares.

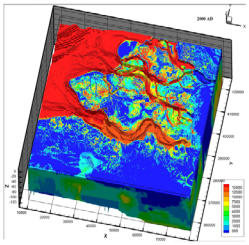
Numerical modeling tools for variable-density groundwater flow and coupled salt transport

For already twenty-years we use numerical computer codes (like iMOD-SEAWAT, SEAWAT using FloPy, Hydrus, MOCDENS3D) to simulate variable-density groundwater flow and coupled solute transport. A recent new software innovation is the parallelisation of iMOD-SEAWAT, significantly speeding up computation times. Modelling tools help us to better understand salinisation processes, to better manage fresh groundwater assets and to predict the effect of future stresses such as sea-level rise and climate change on coastal groundwater.

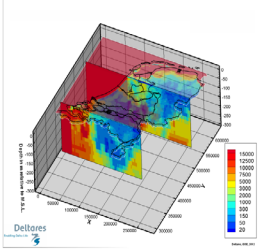
Friesland, the Netherlands



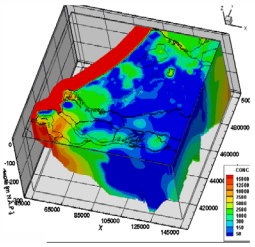
Zeeland, the Netherlands



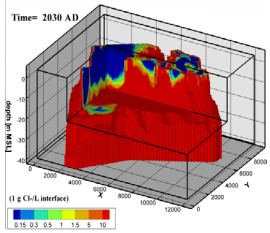
NHI, the Netherlands



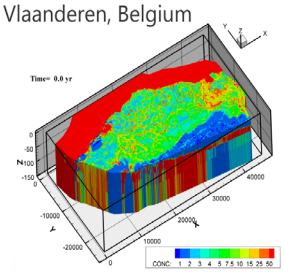
Zuid-Holland, the Netherlands



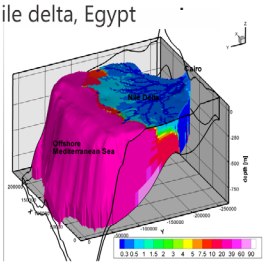
Jurong island, Singapore



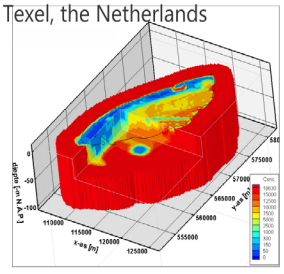
Vlaanderen, Belgium



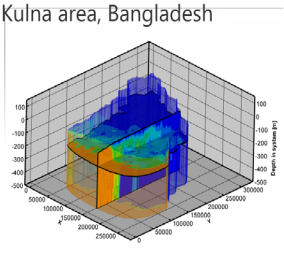
Nile delta, Egypt



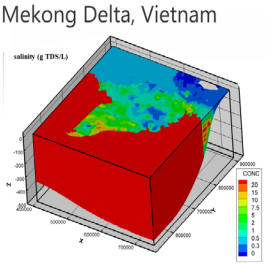
Texel, the Netherlands



Kulna area, Bangladesh



Mekong Delta, Vietnam



Examples of Deltares groundwater projects in the coastal zone

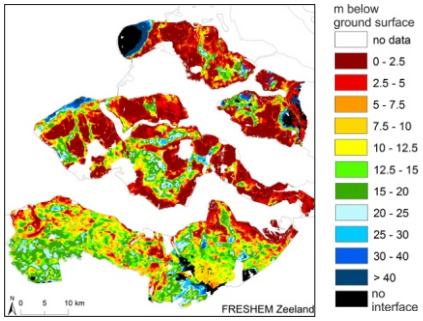
SWIBANLGA - Impacts of Salt Water Intrusion on coastal groundwater systems in Bangladesh

2013-2014 - Bangladesh

For: BRAC-WASH International Reference Centre for Community Water Supply

Partners: Deltares, UNESCO-IHE, Jahangirnagar University (Bangladesh)

The goal of the project was to investigate the impacts of salt water intrusion in Bangladesh, the main salinisation processes, possible mitigation strategies, and the tools needed to provide input for the Water Safety Plans (WSP). The main outcomes of the project were: key components relating to salinisation issues for Water Safety Plans, suitable mitigation strategies to mitigate the impacts of salt water intrusion, a regional 3D variable-density groundwater model, a water-quality monitoring kit, leaflets containing information about salinisation and workshops on modelling and monitoring.



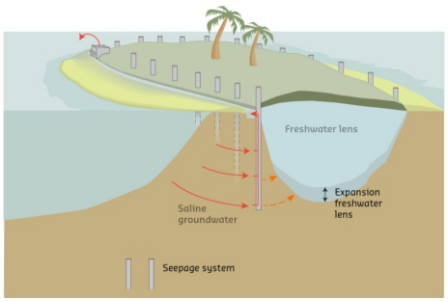
FRESHEM – Describing fresh-salt groundwater distribution using helicopter electromagnetic surveying in the Province of Zeeland

2014-2017 - Zeeland - Netherlands

For: Province of Zeeland, Scheldestromen Water Authority, VNSC, Delta Programme, Evides, RWS, ZLTO, municipalities

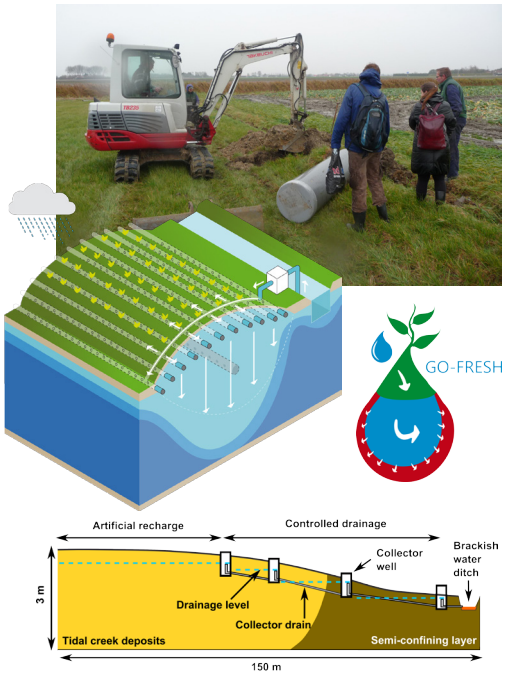
Partners: Deltares, TNO, BGR Germany (Bundesanstalt fur Geowissenschaften und Rohstoffe)

Fresh water supplies cannot be taken for granted in the Province of Zeeland in the Netherlands. The main surface waters are predominantly saline. A detailed picture of the current fresh-salt water distribution is essential to detect possible trends in the subsoil and to respond in time to these trends. This project developed an approach to determine the three-dimensional chloride distribution in the groundwater by using HEM surveys in combination with a priori data, advanced modelling techniques and information about the groundwater system and especially geology. The final result of FRESHEM Zeeland will be a 3D distribution of chloride concentrations in the groundwater in the Province of Zeeland.



Small Island Developing States (SIDS)

Most small islands in the Cariben or the Pacific, suffer from fresh water security wich affected their food production. Surface water resources are limited and they rely on small precious fresh groundwater lenses which are threatened by coastal erosion and over-exploitation. On top, these resources are extremely vulnerable to future sea-level rise, as most islands are situated no more than a few meters above the sea mean level. Deltares studies the dynamics of these fresh groundwater lenses using innovative monitoring techniques and the latest modelling tools. Once the fresh-saline groundwater processes are understood, responses are formulated to protect these lenses and the accompanying foodproduction. Two possible responses are the SeepCat (short for seepage catcher) to catch the excess saline groundwater that flows towards the freshwater lenses under sea-level rise conditions, and an Aquifer Storage and Recovery technique called the CARD (a controlled artificial recharge and drainage system) that efficiently stores access of fresh water from precipitation under the ground.



GO-FRESH Valorisation of promising measures for local freshwater supplies

2012-2017- Zeeland - Netherlands

For: Province of Zeeland, water authorities, farmers, municipalities

Partners: Deltares, Alterra, Acacia Water, KWR Watercycle Research Institute, HZ University of Applied Sciences Sciences, Southern Agriculture and Horticulture Organization (ZLTO), Deltafund.

The goal is to improve the use of existing fresh groundwater resources and create new freshwater reserves to increase regional self-sufficiency and reduce dependence on external freshwater supplies. The aims of the applied research project are: a. to investigate which measures actually 'work' in practice and b. to determine whether those measures are economically feasible. Three promising groundwater storage technologies are being developed and implemented to increase local or regional water supplies. Two showcases are being set up for aquifer storage and recovery (ASR) that focus on the potential of sandy creek ridges for water storage. The third showcase focuses on optimising the freshwater volume in shallow rainwater lenses in a saline seepage area on the island of Schouwen-Duiveland. The integration of new knowledge, stakeholder participation and opportunities for practical implementation in the region (including an analysis of economic feasibility) will also be considered.

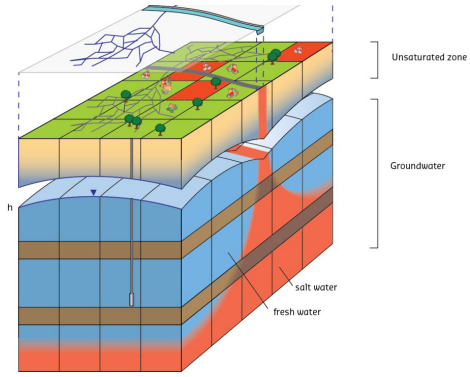
Rise and Fall: strategies to tackle increasing salt water intrusion in the context of subsidence and urbanisation in the Mekong Delta (Vietnam)

2014-2018 - Mekong delta - Vietnam

For: DWRPIS, Vietnam

Partners: Utrecht University, Deltares, TNO, Vitens

This project aims to empower individuals and organisations to develop sustainable strategies for dealing with groundwater extraction, land subsidence and salt water intrusion in the increasingly urbanised Mekong Delta (Vietnam). We will enlarge the knowledge base of stakeholders (including policymakers, water managers and scientists) and work with them to develop and implement innovative tools and technologies in practice and policy. A new delta model will be developed, linking surface water, groundwater and geo-mechanical models to analyse the interrelated character of groundwater extraction, subsidence levels and salt water intrusion. The model will be built and applied in collaboration with stakeholders to quantify the effects of water management strategies in the Mekong Delta. Stakeholders will analyse and develop adequate strategies by simulating and demonstrating the effects of development scenarios and policy recommendations as expressed in the Mekong Delta Plan.



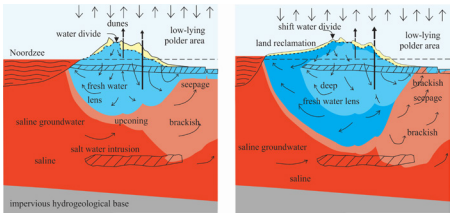
Netherlands Hydrological Modelling Instruments for integrated water management and policy analysis

2008-present - Netherlands

For: RWS Waterdienst, Provincial Authorities, Water Authorities, drinking water companies

Partners: Deltares, Alterra, KWR Watercycle Institute

National and regional water authorities develop long-term plans for sustainable water use and flood protection in changing climate conditions. Decisions about investments in adaptive measures are based on an analysis supported by the Netherlands Hydrological Instrument (NHI). It is based on the best available data and state-of-the-art modelling technology, and the development process involves collaboration between national research institutes. The NHI consists of various physical models on the appropriate temporal and spatial scales for all parts of the water system. Intelligent connectors couple model codes at a deep level in the software to allow transfers between different scales and fast computation. A workflow and version management system guarantees consistency in the data, software, computations and results. The NHI is freely available through an open web interface that allows the exchange of all data and tools.



Nature Coast: the hydrogeological impact of mega-suppletion on the Dutch coast: The Sand Motor

2012-2017 - South Holland - Netherlands

For: Rijkswaterstaat, Dunea

Partners: Utrecht University, Deltares

The Sand Motor pilot project has created a dynamic environment on the Dutch coast. We developed tools to understand and predict the effects of the Sand Motor and similar mega-nourishment operations on fresh groundwater availability and salt water intrusion processes in the Dutch dune-beach system and other mega-suppletion situations. We define three research subjects: a. on factors that determine the fresh-salt groundwater mixing zone, b. on the effect of tides and storm surges on the fresh-salt groundwater mixing zone, and c. on the possibility of enhancing coastal reserves of fresh groundwater

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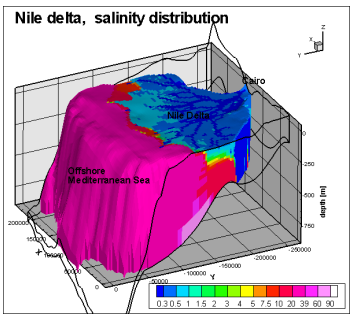


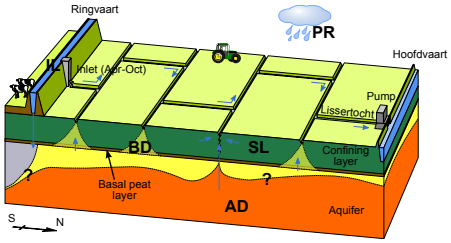
Understanding salinisation processes in the Nile Delta, Egypt, in a context of climate and global change, using a 3D fresh-saline groundwater model

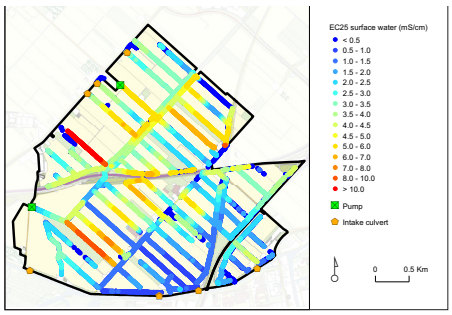
2013-2015 - Nile Delta - Egypt

For: Research Institute Groundwater (RIGW), Enhanced Water Resources Management Project

Partners: Deltares, RIGW, Mott MacDonald

The salinisation of the precious fresh groundwater resources in the Nile Delta due to salt water intrusion and extensive groundwater use is a major concern for Egyptian water users and managers. Groundwater is used for irrigation, industrial and drinking purposes. Sea-level rise and the ongoing increase in the use of groundwater and surface water are expected to have a further negative effect on the groundwater system. A new 3D regional model has been constructed for variable-density groundwater flow and coupled salt transport for the Nile Delta aquifer system using the latest data. The objective is to use the model as a water management tool for different climate and water management scenarios. More specifically, RIGW is interested in the impact on fresh-saline groundwater and the head distribution in the Nile Delta of: a. sea-level rise and b. changing the existing groundwater extraction rates.





Saline groundwater - surface water interaction in coastal lowlands

2010-present - low-lying polders - Netherlands

For: Dutch water authorities

Partners: Deltares, Universities (Utrecht University, Delft University of Technology, VU-University of Amsterdam)

Saline groundwater exfiltration is a common problem in the coastal zone of the Netherlands, but the hydrological processes and physiographic factors involved are not fully understood. Research is being conducted to identify the processes and physiographic factors controlling the spatial variability and temporal dynamics of the exfiltration of saline groundwater to surface water, and therefore the contribution of saline groundwater to surface water salinity. In addition, the operational management of regional salt-fresh water resources is being assessed using Model Predictive Control (MPC) for the real-time control of water quantity and quality in low-lying polders.

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Smart freshwater management

2015-2017 - Netherlands

For: Rijnland Water Authority, Delta Programme, RWS

Partners: Deltares, Rijnland Water Authority

Copious amounts of diverted river water are used to mitigate the surface water quality deterioration caused by saline groundwater exfiltration, and enable freshwater agriculture in the coastal region of the Netherlands. This practice of 'flushing' presents a large burden on already limited freshwater resources. Notwithstanding, no formal goals or guidelines existed to manage the use of freshwater for flushing. This practice was found to be inefficient in lowering surface water salt concentrations. Together with water users, transparent and achievable goals were derived, and freshwater management was formalised to achieve these goals. In addition, local measures were identified and put in place, including a novel cost-efficient approach for automation of small-scale flushing structures. A sound understanding of system functioning was vital to building trust among stakeholders and identifying system optimisation possibilities. Overall, freshwater demand could be decreased by 50% without compromising water quality goals.

Further information:

wiki

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