Dutch Groundwater

Fact sheets of expertise on groundwater

Netherlands Water Partnership

Importance of groundwater

Groundwater makes up about 96% of all unfrozen fresh water on earth. It is globally a primary source of water for drinking and irrigation. Groundwater is an exceptional resource because it can be found almost everywhere on earth. Groundwater provides security against droughts and fulfils a crucial role in the hydrological cycle, providing baseflow for rivers and maintaining fragile ecosystems. Due to growing global population and economic development the proper exploitation and management of groundwater resources becomes more and more important.

The Netherlands has developed significant experience in the field of groundwater. The Dutch Groundwater Sector is a frontrunner in many technical and managerial aspects of this precious resource. The Dutch Groundwater Sector, united under the Netherlands Water Partnership, has contributed worldwide to sustainable solutions in groundwater development and management and is pleased to present its broad, united expertise.

This brochure elaborates on how this expertise is used for a successful implementation of projects to achieve high quality groundwater management practices. We sincerely hope that this brochure will support the international groundwater sector activities and will serve to strengthen relations with the Netherlands.

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Chair Netherlands Water Partnership

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Wells

Groundwater systems globally provide more than 50% of the world's public drinking water and about 97% of the rural drinking water. The growing global population is stimulating the development of new groundwater resources. It is estimated that over 2 million new groundwater wells are being drilled every year and older wells are being regenerated. These vary from small scale groundwater wells for rural communities to highly sophisticated systems for the world's mega cities.

The Dutch Groundwater sector has gained valuable experience in providing solutions to cope with the increased global demand for groundwater wells Recent innovations in well technology have focused on aspects such as alternative drilling methods, the development of low cost well equipment and the provision of services focusing on the efficiency of well data interpretation and decision making.

- Horizontal drilling
- Dutch water wells
- Full service: from monitoring to interpretation

Horizontal drilling

Horizontal directional drilling (HDD) is used frequently for the laying of pipes underneath rivers, dikes, railroads and buildings. The HDD technology can also be used to construct long horizontal wells. Advantages of HDD wells are: long screens and thus high capacity per well. They are very suitable to exploit shallow and thin aquifers and can be applied under existing structures like buildings and roads. Small diameter HDD wells have been realized frequently for groundwater remediation. Large diameter HDD wells (> 150 mm) are still rare. However, large diameter HDD wells have significant advantages for drinking (ground) water production, industrial water supply and thermal energy storage (requiring high flow rates). With large capacity HDD wells only few well heads have to be protected and the total investment cost may be lower in comparison with numerous small capacity vertical wells.

The Dutch drinking water industry has developed a new method to create HDD wells. The method relies on a biodegradable drilling fluid, together with the removal of the filter cake along the bore hole with peroxides (patented method). It is one of the many examples of developments taking place in the field of HDD drilling in the Netherlands. Dutch drinking water industry, contractors, engineers and hydro geologists are cooperating to realize large diameter, large capacity HDD wells and are willing to assist with the realization of similar projects around the world.

QUICK FACTS

Large flow rate per well

Fewer wells necessary

Cost effective

New patented method to drill and develop the well

Under existing structures

Enabling the exploitation of shallow and thin aquifers

Dutch water wells

Two thirds of the drinking water in The Netherlands comes from groundwater. Most groundwater in The Netherlands is located in sandy to clayey aquifers, typical for groundwater occurrence in other deltaic areas in the world. Deltaic areas are densely populated and often face typical problems associated with groundwater exploitation, like land subsidence, salt water intrusion and salt water upconing. In The Netherlands, the construction of production wells has been perfected, delivering high quality groundwater under stringent constraints imposed by sustainable development.

The Dutch water sector developed the knowledge and technology that makes it possible to realize high quality wells at relatively low costs. This experience is now being made available on a worldwide basis by WellTech-NL, a consortium that consists of leading Dutch contractors, suppliers and consultants in the field of groundwater wells.

Dutch water wells are made with PVC screens and casings: PVC has proven to be a strong, non-corrosive, very economic material for this purpose. Additionally, the Dutch water sector has tackled the maintenance issues such as monitoring and clogging. Research has shown the way to effective and efficient clogging treatment and prevention technologies. Solutions for these issues have been worked out in guide-lines for prevention and control.

QUICK FACTS

Groundwater wells

High quality installations at reasonable cost

Long life time, low clogging rate

Sustainable yield

Sustainable groundwater quality

Prediction of subsidence and salinisation

Low maintenance

Low sand production

No leakage

Experts on efficient rehabilitation of clogged wells

Full services from monitoring to interpretation

Monitoring of groundwater is vital if groundwater exploitation is to be managed in a sustainable way. However, in many regions in the world, groundwater monitoring networks are underused and under equipped. The analysis and interpretation of data with the assistance of modern computer technologies, dedicated software and equipment helps to understand the behaviour of groundwater basins. There is an increased need for systematic data collection and interpretation by national or regional organizations responsible for groundwater management, so that adverse trends can be predicted and proper management measures can be taken.

Dutch groundwater research and training institutes, consultants and equipment suppliers are experienced in the execution of quick scans and initial assessments of groundwater basins (quality and quantity), the design and equipping of monitoring networks and the assessment of training needs (data collection/screening/quality check, database & GIS development as well as in field measurements) for governmental and private staff. The processing of all data enables the development of an in-depth understanding of the groundwater basin, leading toward improvement of monitoring schemes and the conceptualization and development of a groundwater numerical model to aid groundwater management.

Dutch experts have gained vast experience in guiding and training experts, designing and equipping monitoring networks, developing knowledge of groundwater basins from the initial field surveys and data appraisal to advanced

3-D groundwater modelling, prediction of future trends, scenario evaluation and communicating results with decision makers. Dutch equipment is used world wide in monitoring groundwater levels and groundwater quality.

Examples are the historical inputs of the Dutch Groundwater sector in the management of the aquifers in the Nile basin. Recently full services are a key concept in the cooperation between Chinese and Dutch parties. In the Netherlands Waterboards and Municipalities subcontract full services to specialized consortiums.

QUICK FACTS

Quick scans and initial assessment of groundwater basins, groundwater problem settings and training needs of staff to arrive at proper and effective monitoring

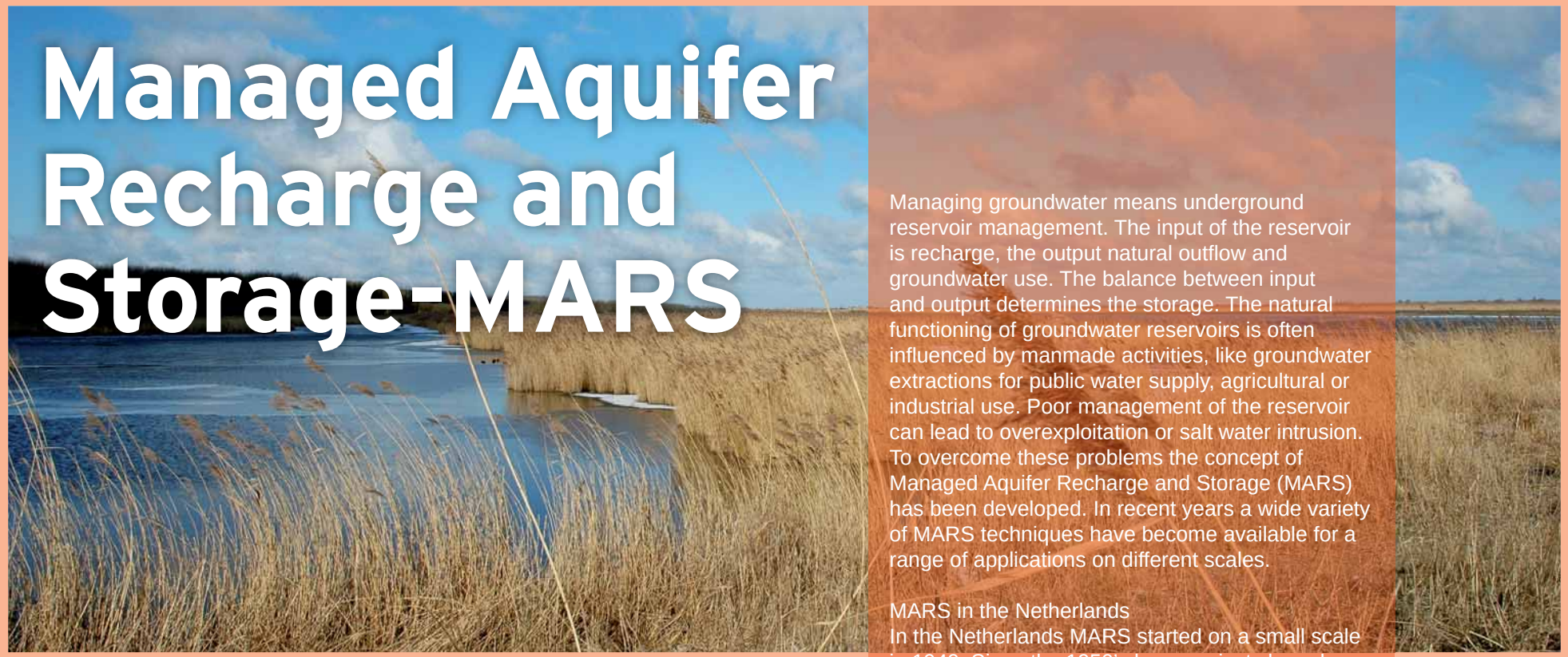
Design and supply of sensor equipment for monitoring networks

Experience in linking and explaining the results from monitoring networks and desktop studies of data sets to the real world situation in the field

Hands-on training in modern software packages

Training in the development of exploitation

Managed Aquifer Recharge and Storage-MARS



Managing groundwater means underground reservoir management. The input of the reservoir is recharge, the output natural outflow and groundwater use. The balance between input and output determines the storage. The natural functioning of groundwater reservoirs is often influenced by manmade activities, like groundwater extractions for public water supply, agricultural or industrial use. Poor management of the reservoir can lead to overexploitation or salt water intrusion. To overcome these problems the concept of Managed Aquifer Recharge and Storage (MARS) has been developed. In recent years a wide variety of MARS techniques have become available for a range of applications on different scales.

MARS in the Netherlands
In the Netherlands MARS started on a small scale in 1940. Since the 1950's large projects have been established to safeguard drinking water supply in the densely populated western parts of the country (along the North Sea coast). In these areas groundwater extraction is restricted due to salt water intrusion and a lowering ground water tables. The projects turned into fully integrated projects for nature conservation, recreation and water supply. The projects are a permanent source of innovation in groundwater technology and modelling.

- MARS for urban water supply
- MARS storage dams fot agricultural & rural water supply
- MARS for peak demand in tourism & industry sector

MARS for urban water supply

Urbanization and increasing water demands put a heavy burden on city water supply companies to provide sufficient water of good quality to its citizens. Managed aquifer recharge and storage (MARS) is a cost effective option to ensure water quality and create storage for daily and seasonal water demand fluctuations and emergency situations (strategic reserves). For coastal cities, the MARS technology may also prevent or mitigate intrusion of saline groundwater into the coastal aquifers.

Recharge of river water in dune infiltration ponds and in infiltration wells is practiced in the western part of the Netherlands over the last 50 years. It has become a key component in securing the safe drinking water supply to Amsterdam, The Hague and many other cities. The infiltration areas have also become important recreation areas in the highly urbanised western part of the country. The system is cost effective and can potentially be applied in other parts of the world. The combined Dutch expertise of water supply companies, research institutes and consultancy firms can offer all the services needed to apply this technique elsewhere. This includes feasibility studies, design and operation and maintenance of urban MARS systems

QUICK FACTS

making use of natural infiltration and storage capacity to improve water quality

providing storage for demand fluctuations

strategic reserve of good quality water for emergency situation

creating recreation and nature areas in highly populated regions

MARS storage dams for agricultural & rural water supply

MARS storage dams are a low cost, high benefit solution for reliable provision of good quality water to people living in arid rural regions.

Provision of sufficient storage capacity under growing water demand and increasing climate variability is one the main concerns for water managers in the coming decades. Controlled recharge and subsurface storage of water in aquifers, and recovery of this water in times when water is scarce, forms an alternative to surface water storage to maintain sufficient water supply in the future.
MARS dams infiltrate floodwater and overland flow during rainfall events in order to recharge local aquifers, thus impeding quick runoff. Water stored underground is not subjected to evaporation losses and bacteriological deterioration, and can serve household or production water supply during times when other water sources are not available. This is particularly important for people living in rural (semi-) arid regions characterized by erratic rainfall and prolonged periods of drought. In addition, MARS dams might reduce or mitigate soil erosion and the severe damage and loss of life caused by flash floods in some desert regions.
A participative approach in dam construction enhances technical efficiency, social acceptance and economic dam life-span. General community benefits include significant improvements in crop production and local income, as well as improvements in nutrition and hygiene conditions through a more secured supply of better quality water.
Practical examples of this approach are recently developed in Kenya with inputs from the Dutch Groundwater sector.

QUICK FACTS

improvement of water quality and quantity

sustainable use of water resources

participatory bottom-up approach

durable and low cost technology

drought resistance

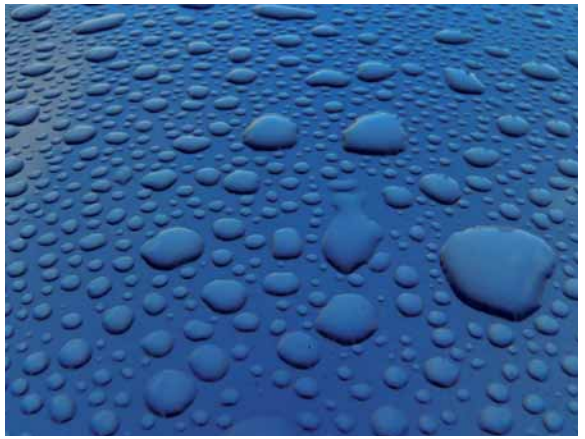
socio-economic benefits

MARS for peak demand in tourism & industry sectors

Individual water supply plants for tourism and industry sectors are generally designed and temporarily operated for peak demands. Where required water treatment is minimal to standard, the technical advantages of this concept weight more than the costs. Where water prices are a substantial part of the economy of a production unit, the use of underground storage of clean water is a viable additional option. This holds for example when mainly sea water or brackish groundwater is available as primary source. Although desalination costs are decreasing, MARS in desalination schemes can lead to 10 to 20% savings in costs at favourable locations. This can be reached by producing a small additional amount of fresh water during low demand periods and storing it properly underground.
Besides the economic advantages a MARS scheme provides generally higher volumes of strategic reserves than surface tanks and has no disadvantages as visibility and land occupation. Proper land use and groundwater monitoring can be integrated in the facility management.

Examples of this technique are already found in the Arab countries. A Dutch Groundwater sector consortium starts a pilot project in Egypt in 2007. A careful ranking of feasible sites is a first step.

At the output side of individual water supply schemes MARS is also a useful technique. Treated waste water, if properly controlled, can be stored underground. In many part of the water scarcity areas in the world, this water is reused for tree production or industrial processes. The Dutch Groundwater sector has worldwide experience in guiding this process properly.



QUICK FACTS

increase of economical efficiency of individual desalination plants

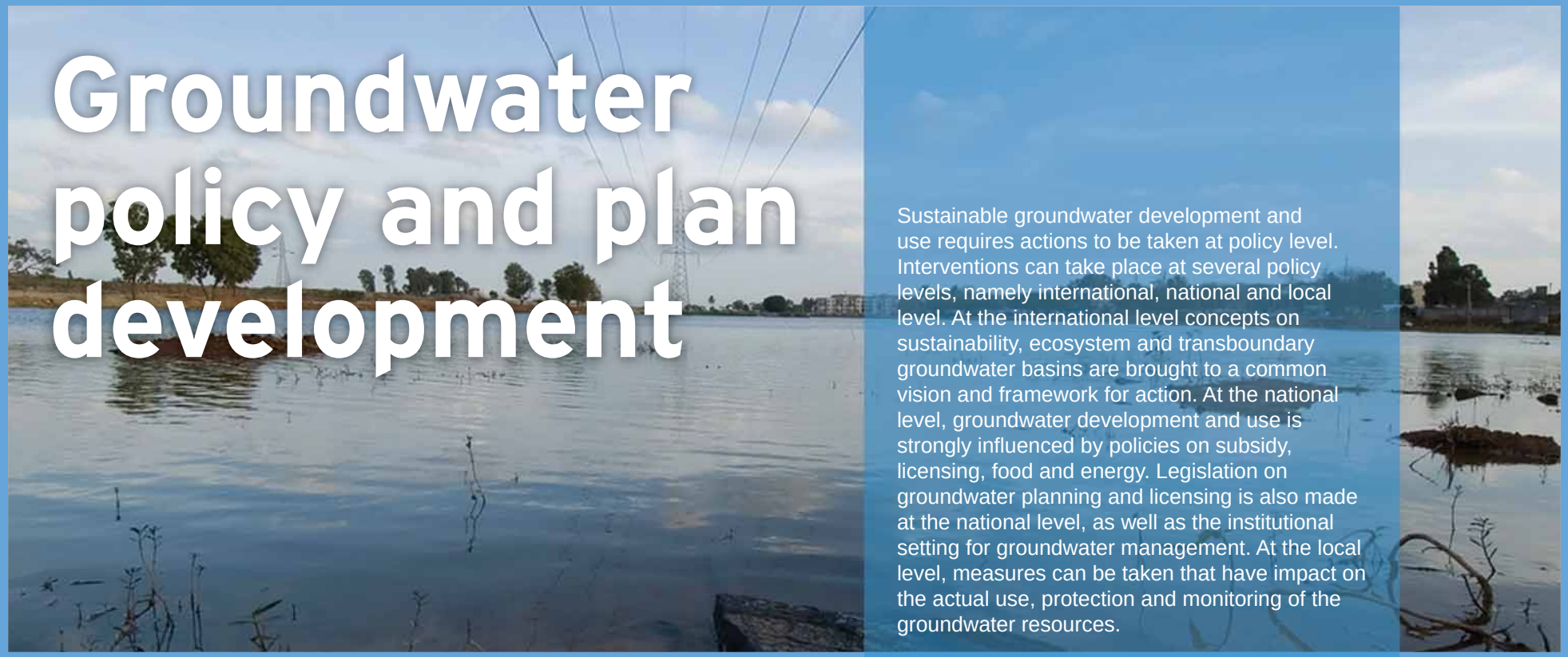
increase of strategic water reserves for long-term or emergency water supplies

increase in the amount of available groundwater

increased benefits of waste water reuse

optimal for small scale stand alone schemes

ecological benefits



Groundwater policy and plan development

Sustainable groundwater development and use requires actions to be taken at policy level. Interventions can take place at several policy levels, namely international, national and local level. At the international level concepts on sustainability, ecosystem and transboundary groundwater basins are brought to a common vision and framework for action. At the national level, groundwater development and use is strongly influenced by policies on subsidy, licensing, food and energy. Legislation on groundwater planning and licensing is also made at the national level, as well as the institutional setting for groundwater management. At the local level, measures can be taken that have impact on the actual use, protection and monitoring of the groundwater resources.

The importance of groundwater in the Dutch water supply and water management system is great. For example: 60% of the Dutch drinking water originates from groundwater and in the higher sandy areas of the Netherlands surplus irrigation in dry periods depends 100% on groundwater. The Dutch Groundwater sector has a long history of being part of an integrated water resources planning cycle. This experience is a Dutch product of international value.

- Information management for decision making
- Quick scan integrated groundwater management
- Groundwater body management

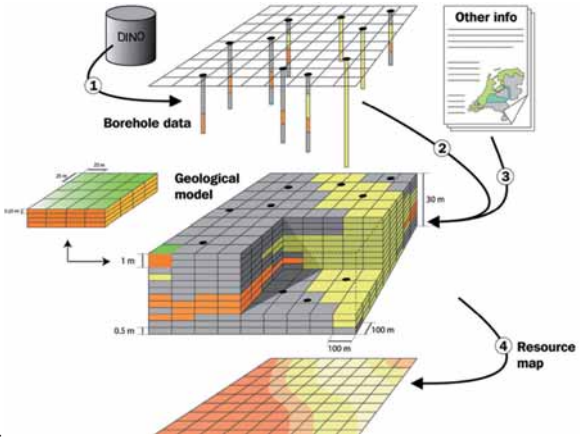
Information management for decision making

Groundwater makes up about 96% of all unfrozen fresh water on earth. Compared to surface water, very limited information is available about this invisible and often poorly understood resource. At the same time, the existing information on groundwater is often not accessible, inadequately stored or misplaced. This leads to loss of information, often acquired at considerable expense, and duplication of groundwater studies. Proper groundwater information management is necessary for adequate decision making on issues such as extreme droughts and other disasters, transboundary aquifer management, sustainable groundwater management, salinisation, groundwater and soil pollution, ecological degradation and land subsidence.

Contemporary decision making requires up-to-date, reliable and clearly presented information input. In order to ensure such input, information management needs to include systematic storage, transparent processing, clear visualization and simple dissemination of the spatially and temporally distributed groundwater information.

A vast majority of groundwater management decisions requires integration of information input, which can be provided either through stand-alone (local) hydrogeological information systems or web-based portals, both integrating information from different sources.

The Netherlands is frontrunner in the development and implementation of hydrogeological information systems, which range from the web-based and freely accessible National Groundwater Information System to dedicated regional stand-alone systems. Dutch groundwater specialists have implemented state-of-the-art information systems throughout the world, often in co-development, to respond to the precise needs of the client.



QUICK FACTS

Visualising groundwater helps understanding this valuable resource

Groundwater information has been made accessible by Dutch initiatives

Groundwater information management is indispensable for proper decision making

The Netherlands is frontrunner in hydrogeological information management systems and decision support systems (DSS)

Sustainable solutions are supported by high-quality information

Quick scan integrated groundwater

Water managers and water users are often confronted with questions and opportunities regarding water development and management in which the complex and invisible nature of groundwater plays a central role.
Quick scans provide the client with a quick analysis of a groundwater (or related) issue, within the broader context and deliver an expert advice on further steps to be taken. Quick scans can also clarify yet unknown opportunities for solutions on groundwater policy level.

Quick scans typically include the following actions:

- Consultation, definition of problem, TOR and assignment of contract
- Inventory of existing data and information
- Short visit to the project area for collection and verification of data through interviews with stakeholders and field measurements
- Reporting including an independent expert advice on next steps to be taken to arrive at solutions.

The quick scan is implemented for a fixed price and provides the client with a clear overview of the question in its context.

Examples
Specific problems such as water logging and flooding related to groundwater in deltaic areas can be subject to quick scans. Another example is that of small islands, having limited water resources, often relying on desalinated seawater for domestic and commercial use. A holiday resort may consider using groundwater and surface water in combination with renewable energy. A quick scan will provide an overview of the technically feasible solutions and a clear advice on further possible actions.

QUICK FACTS

Existing practices and local knowledge are useful inputs in project identification

Quick scans allow consideration of all possible options at an early stage of project development, and provide a sound basis for preparation of feasibility studies

Consulting users and stakeholders promotes awareness and support for further plan development

Quick scans ensure an end product against a fixed price

Groundwater body management

Due to the combination of multiple land use functions in a densely populated delta, the Netherlands has been a forerunner in managing and promoting the sustainable and integrated use of groundwater resources.

In the development of groundwater legislation, such as the European Water Framework Directive (WFD) and the Groundwater Directive (GWD), defining and achieving the good status of the groundwater bodies has become a crucial concept. This concept holds for transboundary as well as national groundwater bodies. The European directives require also that monitoring and measures have to be harmonized between different countries or different provinces within states at groundwater basin and catchments scale.

The system based approach for groundwater body management has proven to be very successful in the Netherlands and in international projects implemented by Dutch consortia. The introduction of groundwater body management represents a paradigm shift, from mainly protecting groundwater for drinking water supply towards safeguarding a quantitative and qualitative state that does not negatively affect surface water, ecology and economical functions like water supply for the public and private parties.

The knowledge and experience gained by the Dutch groundwater sector can be beneficial to other regions facing similar concerns. Some examples of Dutch international experience:

- involved in monitoring/data management aspects in Eastern Europe, assisting with meeting WFD targets
- linking the experiences in the Kempen area with other regions having historical diffuse pollution problem
- Linking harbour problems in the Netherlands with other experiences.

Examples
New member states of the EU can profit from the Dutch experience with groundwater body management. A quick scan visit to Romania because of a local groundwater problem has recently triggered further cooperation between the Romanian and Dutch groundwater sectors. Between future potential member states and the Netherlands these initiatives can be started in an early stage of the process (viz. Turkey, where the first steps have been launched already).

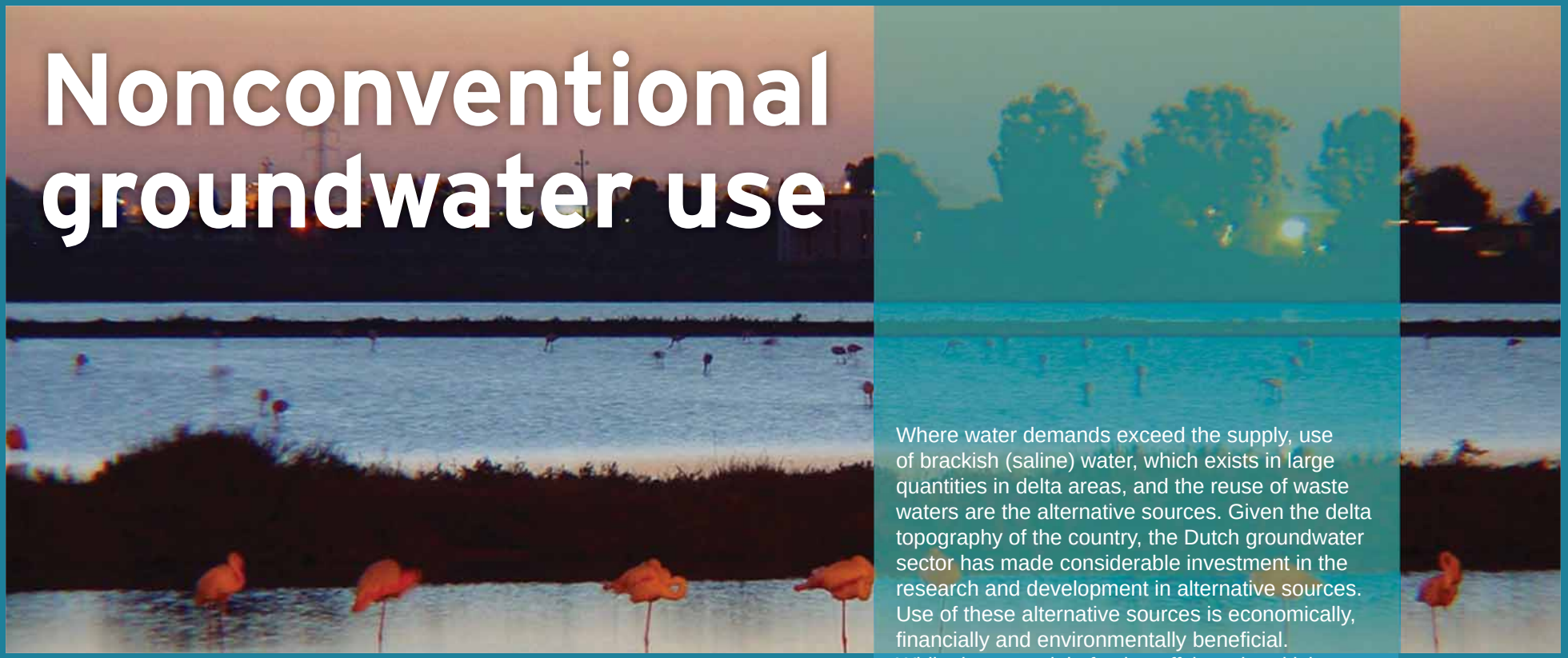
QUICK FACTS

integrated groundwater management following system based approach

experience and expertise of groundwater legislation (i.e. WFD/ GWD)

cooperation between new and future EU member states and the Netherlands

Nonconventional groundwater use



Where water demands exceed the supply, use of brackish (saline) water, which exists in large quantities in delta areas, and the reuse of waste waters are the alternative sources. Given the delta topography of the country, the Dutch groundwater sector has made considerable investment in the research and development in alternative sources. Use of these alternative sources is economically, financially and environmentally beneficial.
While the potential of using offshore brackish groundwater is still being investigated, Dutch companies and consortia have been in the top of (ultra filtration) membrane technology for the use of turbid groundwater.

- Off shore brackish groundwater development
- On shore brakish groundwater development
- Turbid groundwater treatment

Off shore brackish groundwater development

The development of offshore groundwater is a novel solution to water shortage problems. Unknown to many, confined aquifers below the seabed will often contain groundwater of surprising good quality and in huge volumes. It is an unconventional supply option available at numerous locations worldwide. The costs are considerable lower than seawater desalination but higher than traditional surface or groundwater development. Its advantages are numerous:

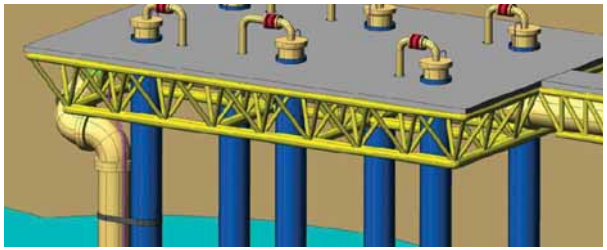
- **Financial benefits**
  - o Lower overall capital & operational cost
  - o Lower cost for increased capacity of existing desalination plants (mixing)

- **Operational benefits**
  - o Protected from surface pollution
  - o Little solute & organic load, constant temperature & chemistry

- **Environmental benefits**
  - o Less energy required
  - o Less brines disposed
  - o Less chemicals used

Depending on quality requirements, the groundwater may be used directly or after treatment and delivered at a cost possibly less than half that of RO-based seawater desalination.

The development of this groundwater is possible through innovative and partly proprietary exploration approaches and tools, in combination with proven offshore production and onshore water treatment technologies.



Development services include:
- Groundwater exploration and appraisal
- Concepts for development and treatment
- Project economics and execution planning

QUICK FACTS

Alternative to conventional solutions such as sea water desalination

Financial, operational and environmental benefits

Large quantity of off shore brackish groundwater available worldwide

On shore brackish groundwater development

The sustainable management of brackish groundwater and energy (conservation) can be achieved with small scale renewable wind powered groundwater desalination techniques to the large scale underground storage of CO2. Aquifer Thermal Energy Storage (ATES) systems for heating and cooling large buildings in the Netherlands are notable examples of alternative use of brackish groundwater, saving about 80% on primary energy.

Experience
Given the topography (delta land), climate and water use pattern (two-thirds of the drinking water in the Netherlands comes from the groundwater resources), the Netherlands (through public and private enterprises, teaching and research institutes, professionals, equipment manufactures and suppliers, hard and soft wares) has gained many years of experience and considerable expertise in the assessment and sustainable development of groundwater resources.

The use of brackish groundwater can be optimized by using MARS (Managed Aquifer Recharge and Storage) techniques in combination with (small) desalinization plants.

QUICK FACTS

Large amount of brackish water in delta areas

Use of on/offshore brackish and other non-conventional groundwater as cost effective alternative sources

MARS techniques combined with small desalinization plant can be used for optimal use of brackish groundwater

Turbid groundwater treatment

During heavy rainfall, water companies whose water treatment plants run mainly on groundwater water are vulnerable to increases in turbidity. One of the largest concerns is the cryptosporidium and guardian bacteria, since these micro-organisms are chlorine-resistant. A notorious example of cryptosporidium outbreak is the one in Milwaukee, USA (April 1993) where more than 400,000 people became ill and dozens died.

Since cryptosporidium and giardia are relatively large micro-organisms, an absolute filter will remove them from the water. Ultra filtration membranes provide this filter and form an efficient barrier for these bacteria. Dutch companies are historically front runners in water treatment by means of activated carbon and membrane technology. Dutch ultra filtration membrane technology is being applied in large scale installations worldwide. Examples to be mentioned are the waste water treatment plants in London (Clay Lane WTW) and Hull (Keldgate WTW) where groundwater is being purified into potable water by ultra filtration membranes.

Dutch companies, research institutes and water companies work actively together in groundwater treatment. Research and knowledge institutes have prominent international positions because dedicated research aims on constant optimization and innovation of conventional technologies.

QUICK FACTS

Highly effective filtration

Protection against bacteria

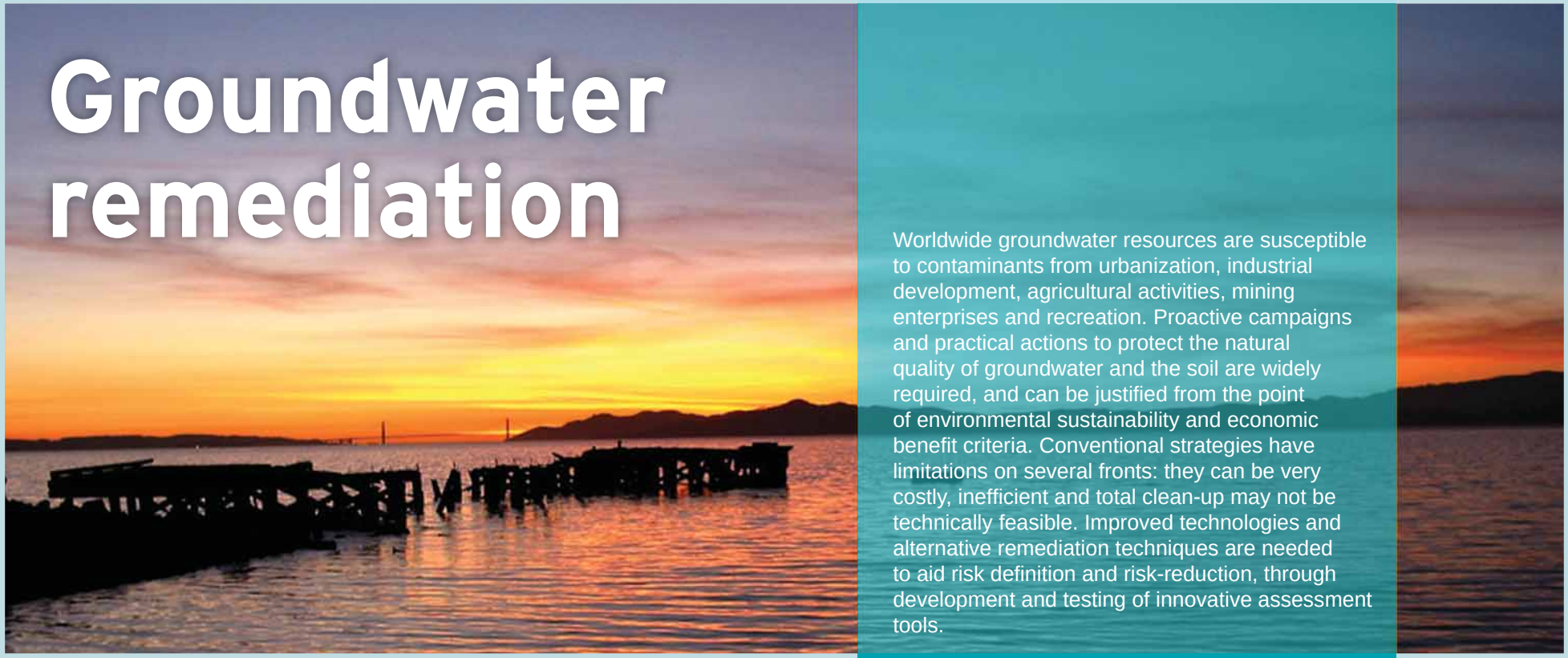
Renowned technology

Reliable drinking water

Dedicated research

Optimization of technology

Groundwater remediation



Worldwide groundwater resources are susceptible to contaminants from urbanization, industrial development, agricultural activities, mining enterprises and recreation. Proactive campaigns and practical actions to protect the natural quality of groundwater and the soil are widely required, and can be justified from the point of environmental sustainability and economic benefit criteria. Conventional strategies have limitations on several fronts: they can be very costly, inefficient and total clean-up may not be technically feasible. Improved technologies and alternative remediation techniques are needed to aid risk definition and risk-reduction, through development and testing of innovative assessment tools.

In the Netherlands, as in other countries, human interference has contaminated both the soil and the groundwater. Due to the tightly knit distribution of various user functions in close areas, remediation initiatives in the Netherlands has shown a most up-to-date and advanced approach.

- In situ groundwater remediation
- Risk based management mega sites
- In situ iron & arsenci removal

In situ groundwater remediation

Soil remediation technologies should not only be effective in mitigating damage to functional use of land and groundwater resources but also be low in energy and material demand, and in costs. In thirty years the Dutch developed their technology and policy from traditional non-sustainable (ex-situ and pump & treat technologies, and a policy based on strict quality standards) towards innovative and sustainable solutions (using natural attenuation and in-situ technologies where possible, and a policy supporting risk-based remediation end-points). The Ministry of Environment has now renewed the national remediation programme, maintaining a budget of 500 Million Euro per year: 60,000 sites creating a risk (15% of total contaminates sites) will be remediated at rate of 3,500 sites per year.

Special risk-based approaches have been developed for large contaminated area's (mega sites), such as the Port of Rotterdam. Policy and technology innovation have been accomplished by a sequence of R&D programmes, varying form research into basic soil processes, and in-situ and NA technology, to knowledge implementation and demonstration. The "Holland In situ demo" Programme (HIP) is currently running 24 in-situ demo projects with contractors, site owners, and local authorities. The number of international collaborations (i.e. Europe, Japan, Taiwan, China, Italy, Canada) with Dutch institutes, consultants and contractors has rapidly increased. The Dutch experience is especially useful for other heavily populated and industrialized delta and lowland regions world-wide.

QUICK FACTS

Technology development using natural attenuation and in-situ techniques

Remediation using a risk-based approach, risk mapping and risk modelling

Risk-based approach for industrial mega sites, such a harbours

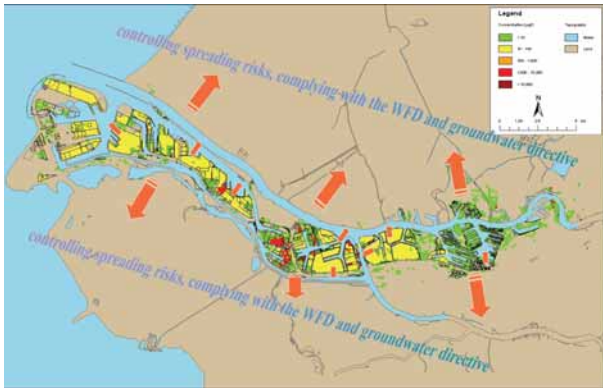
Holland In-Situ demonstration Programme (HIP): collaboration between contractors, site owners and local authorities in technology application

Cost and benefit analysis

Risk based management mega sites

Risk-based approach for contaminated land
In industrial and urban areas the long-term presence of various activities has resulted in considerable soil and groundwater contamination. This historical contamination is complex in nature and usually not limited to one particular site. A full cleanup is often technically and economically infeasible. In these cases it is better to develop an integral approach, in which risk management scenarios are combined with pollution characteristics where measures to be taken are prioritized and temporized on the basis of risks, leading to considerable cost reduction.

Dutch research, industry and government involved in developing Integrated Management Strategy
Future management of contaminated industrial and urban areas can only be cost-efficient when built on a risk-based approach at mega site level. This approach combines the impact of contamination on the various receptors, including the impact to groundwater and surface water systems, terrestrial and aquatic ecosystems and human health. The risks determined on the short-term and long-term impact on these receptors. This approach fits well with the guidelines issued by the EU in the Framework Directive for Water (WFD) and the Directive for Groundwater (GWD). An integrated management strategy (IMS) has been developed by Dutch research institutions and consultants in remediation planning projects and in European research efforts. In these activities full participation of industry and governmental agencies has been secured. The methodologies developed comply with the WFD/GWD standards.



Examples
The methodology has been successfully applied for industrial mega sites as the Port of Rotterdam, urban areas like the City of Apeldoorn and rural areas with historical soil and groundwater contamination like the Kempen area.

QUICK FACTS

Dutch expertise developed on the integral management of industrial mega sites

Evaluation of current and future impact of contaminants to different receptors, considering all possible exposure pathways (modelling and monitoring)

Identification of potential measures to reduce or eliminate the impact

Setting priorities with respect to timing and the allocation of financial resources, taking the financial situation of the local economy into account

Risk-based management in compliance with EU guidelines

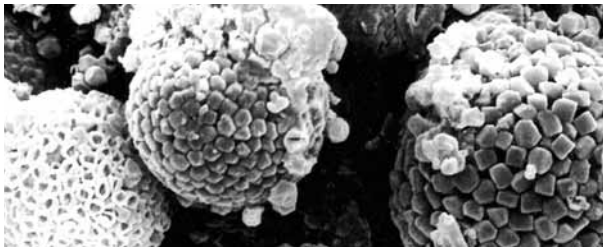
Risk-based management leads to considerable cost reduction

Risk approach leads to sustainable long-term management of mega sites

In situ iron & arsenic removal

Often the ‘above ground’ removal of natural dissolved iron and manganese from groundwater is difficult to achieve. This may be due to a lack of space, a shortage of well trained personnel or the relatively high costs of removal associated with small (rural) groundwater extraction systems.

Instead, the subsoil itself may be utilized for in-situ removal, using only air (natural oxygen) as chemical agent. Under favorable natural geochemical circumstances, concentrations are reduced to below drinking water standards, thus allowing continued local use of groundwater at low cost. This is a great opportunity for sustained use of safe groundwater in extended rural communities, and often also for regular pumping stations.



QUICK FACTS

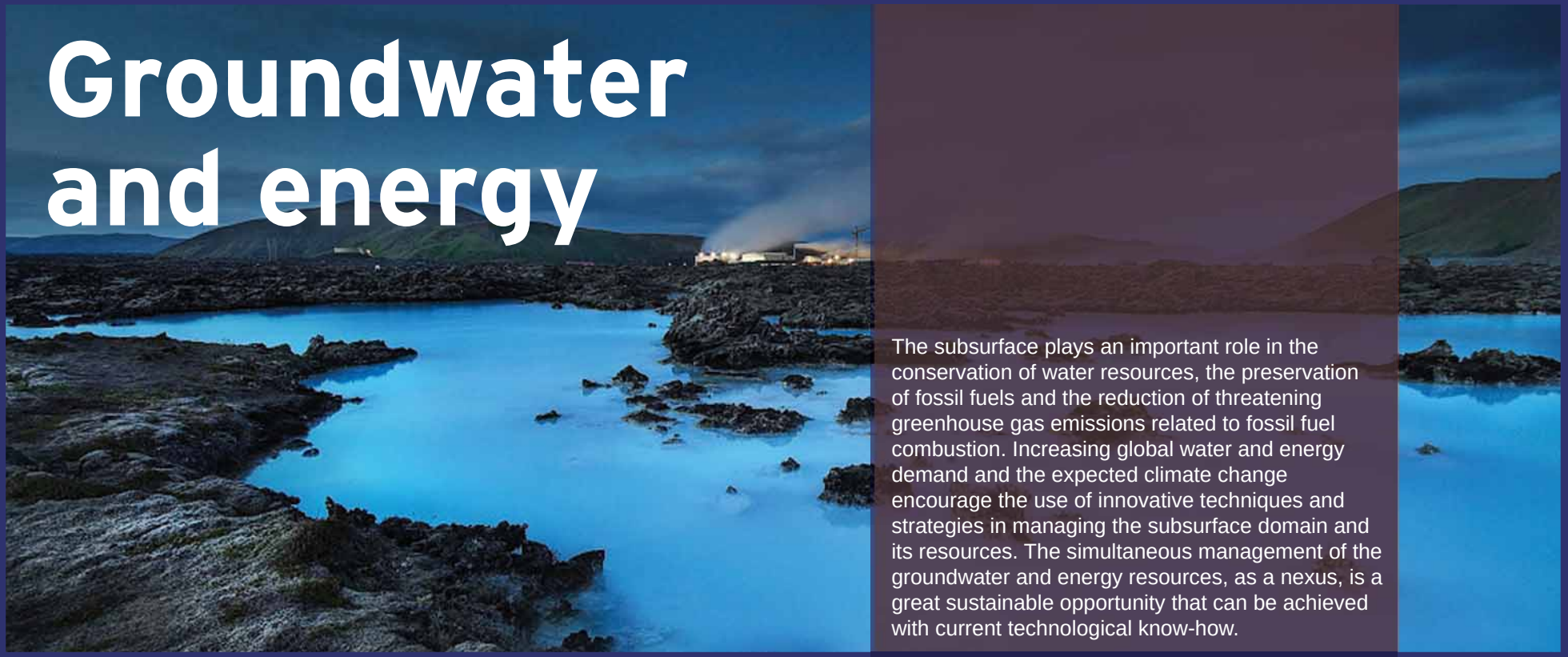
Dutch expertise developed within/with several drinking water companies

Practical experience with subsurface removal in cooperation with Egypt

Low cost removal of iron and manganese

Possibly also applicable to the removal of arsenic

Groundwater and energy



The subsurface plays an important role in the conservation of water resources, the preservation of fossil fuels and the reduction of threatening greenhouse gas emissions related to fossil fuel combustion. Increasing global water and energy demand and the expected climate change encourage the use of innovative techniques and strategies in managing the subsurface domain and its resources. The simultaneous management of the groundwater and energy resources, as a nexus, is a great sustainable opportunity that can be achieved with current technological know-how.

Solutions range from small scale renewable wind powered groundwater desalination techniques to the large scale underground storage of CO2. Techniques such as the storage of thermal energy in aquifers have been successfully tested and applied in numerous locations.

- Aquifer Thermal Energy Storage systems for heating & cooling (ATES)
- Renewable energy & water (renew)
- CO_2 storage

Aquifer Thermal Energy Storage systems for heating & cooling (ATES)

Aquifer Thermal Energy Storage (ATES)
The idea is simple: store cold or the heat when available and retrieve it for use when needed. During the summer, cool water from a “cold well” is pumped from the well to the building ventilation system for direct cooling. In the cooling process, the water picks up thermal energy and becomes warmer. This warm water is returned to a “hot well” at a different location. In the winter, the flow is reversed. Warm water is pumped from the hot well and sent through the heating system to pre-heat building intake air. In other cases, a heat pump may be added to provide heating at a higher temperature to the building. In transferring thermal energy to the building, water becomes cooler. This cooler water is returned to the cold well. The cycle then repeats itself the following year.

ATES in the Netherlands
In the Netherlands, the first ATES projects were realized more than 15 years ago. In the beginning of 2006, over 500 large scale ATES systems were operational in the Netherlands, more than in any other country. ATES has become a standard design option for heating and cooling systems for large buildings developments. In recent years, the application in the agricultural sector (mushroom nurseries, greenhouses) and in new housing developments is expected to further increase.

QUICK FACTS

Heating and cooling of buildings, offices, processes

Saves up to 80% on primary energy

Cooling without air conditioning

Using winter cold for cooling in summer

Using summer heat for heating in winter

Renewable energy & water (RENEW)

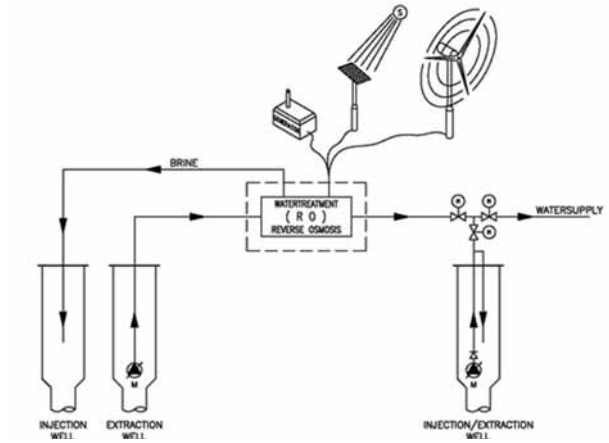
Growing water demands and the expected changes in climate ask for innovative techniques and strategies in developing natural resources.

This applies particularly to remote areas where only brackish groundwater is available or the availability of fresh water is seasonal. Providing a secure water supply in these vulnerable areas is often costly, limiting socio-economic development if no alternative solutions are introduced.
Sustainable stand-alone systems of intermediate scale, making use of local renewable energy and water sources can be a competitive alternative. These systems are based on the principle that the average availability of fresh or brackish water and renewable energy (solar radiation and wind) is sufficient to meet the daily water demand. As natural supply of water and energy and the demand for water vary strongly, storage capacity is critical in order to match supply and demand.

The stand-alone systems contain various technical components, like extraction and injection wells, a wind generator or solar panels, a backup fuel generator, a reverse osmosis unit and surface and subsurface storage reservoirs.

Depending on supply and demand variations, these systems have typical capacities in the order of 10 to 1,500 m3/day, serving communities of 500 to 10,000 people or 5 to 50 hectares of irrigated cash crops. Smaller systems are also an equally interesting option for remote holiday resorts, marinas or industries.

RENEW systems can compete in costs and reliability with more traditional approaches including seawater desalination.



QUICK FACTS

Stand alone water supply systems in remote areas

Alternative for vulnerable long distance water conveyance

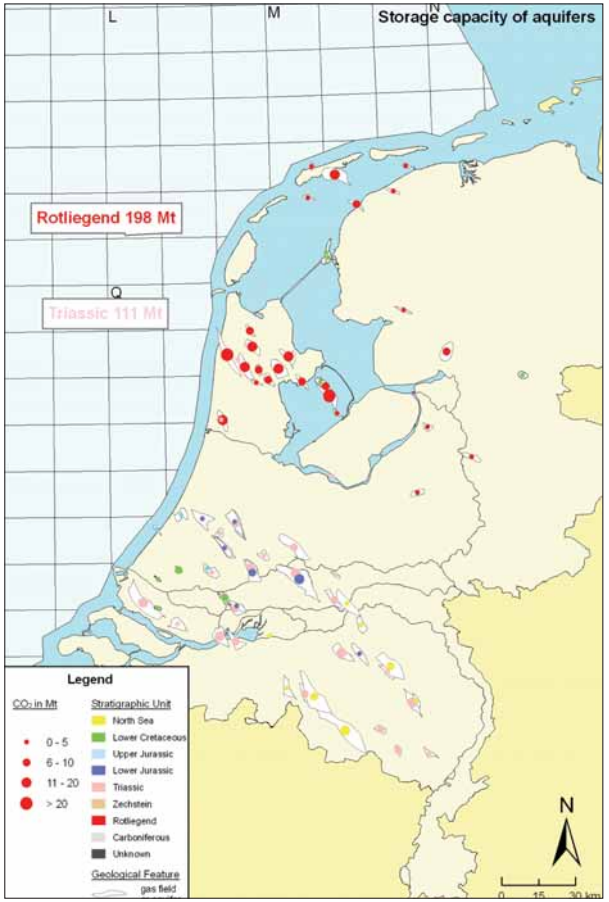
Making optimum use of renewable energy and local groundwater

Promotes eco-tourism

CO_2 storage

Nowadays, general scientific consensus exists about the relation between climate change and rising carbon dioxide (CO_2) concentrations in the atmosphere. Storage of CO_2 from point sources (e.g. power plants) is considered to be a feasible option to reduce the anthropogenic CO_2 emissions into the atmosphere. Storage in deep saline aquifers is considered to be one of the most promising subsurface solutions because of the potentially large storage capacity. Worldwide field demonstration sites are being developed (i.e. Sleipner field in Norway, one megaton of CO_2 stored annually since 1996). Nevertheless, it is clearly recognized that extrapolation of these promising results is difficult. The specific characteristics of each individual aquifer should be evaluated to assess the total storage potential and the long-term stability of the injected CO_2.

Other options for subsurface storage are (depleted) gas fields, enhanced oil recovery and Enhanced Coal Bed Methane (ECBM). Dutch research institutes and energy companies are leading initiatives in both the development of CO_2 storage and in ECBM technology development (CO_2 is injected in coal formations, substantially increasing the production of methane for energy production). The combination of a power generation plant located on top of a coal formation, producing energy and (re)injecting CO_2 is promising. A good example is the RECOPOL project in Poland. Further pilot demonstration projects and new initiatives are on the way.



QUICK FACTS

Storage of CO_2 emissions from point sources in the subsurface is feasible

Storage in deep saline aquifers most promising

Long-term stability by dissolution of CO_2 by mineral fixation and integer cap rocks

ECBM, the increased production of energy by CO_2 injection in coal formations is feasible

Reduction of CO_2 emissions into atmosphere is major benefit

ECBM promising development in the energy cycle

Institutional development and capacity building

The Netherlands has considerable experience and expertise in institutional development and capacity building for the groundwater sector. Since the early 60's, Dutch groundwater institutes and companies have been sharing their information and experience through consultancy, courses/training and various network platforms in groundwater-related issues at international level. Various products and services are offered by the sector ranging from short tailor made courses, to the involvement in the restructuring of a groundwater institution and the publishing of groundwater related tools and handbooks.

With several countries long lasting groundwater cooperation programmes with the Netherlands have proven to be effective and efficient, viz. Egypt, Mozambique and Yemen. These programmes are constantly subject to optimization.

- Cources - training
- Institutional empowerment
- International cooperation

Courses & Training

To understand and to consider the sustainable use of groundwater resources, a profound knowledge and understanding of all aspects is required. The most relevant groundwater aspects are included in the concept of integrated groundwater management (IGWM). Groundwater specialists should be equipped to apply hydrology in order to develop and use water in a sustainable manner. They should also be capable to assist in the mitigation of water-related disasters and to manage the resources effectively at all levels.

In the Netherlands, a number of institutions for higher education and universities offer courses in hydrogeology. The training offered by the universities focus on the resources and not so much on management of water resources and/or the socio-economic aspects. The institutions for higher education focus on the practicable purpose of the acquired knowledge and thereby concentrate on the demand management aspects of groundwater with reference to management of the resource. Besides universities and institutions for higher education, a number of specialist institutions and companies offer custom made courses in the field of groundwater.

The courses offered generally have an international focus and strongly encourage the development of an integrated approach, taking into account the multidisciplinary settings of hydrogeological issues, with the aim of achieving sustainable solutions. Special focus is put on local conditions that will invariably influence the processes of project planning and design.

QUICK FACTS

Integrated groundwater management (IGWM)

Hydrogeological theory and practical applications

Custom made courses/ training

International focus

Offered by institutes, universities and companies

Institutional empowerment

In almost all countries of the world, there are special institutions or units within the government in charge of groundwater. Their tasks and responsibilities may include groundwater resources assessment, monitoring, planning, development and/or management, as well as special studies on relevant groundwater topics. For good performance, considerable background knowledge, operational skills and working routines are needed, tailored to the local conditions. If some of these requirements are not completely fulfilled, services may be offered by Dutch institutions and companies that have a long track record in cooperation for institutional strengthening and upgrading.

Depending on the needs, a variety of services can be offered, such as:

- Organizational advice, thereby defining functions, command structure, job descriptions, mandates, etc.
- Assisting in the development of a personnel development plan, based on comparison between observed capabilities and those required by the assigned jobs.
- Assisting in developing strategies, work plans and budgets for the unit considered.
- Coaching colleagues employed by the unit and carrying out on-the-job training programmes.
- Introducing new methodologies and tools for enhanced performance of technical staff.

As a complement to formal training, in-house capacity building has proven in quite a number of countries to produce a long-lasting enhancement of the performance of groundwater institutions. Dutch groundwater related institutes and companies have made significant contributions to these achievements.

QUICK FACTS

Institutional development of groundwater agencies

Organizational advice

Personnel development plans

Strategic and operational plans including budgeting

Performance enhancement by coaching and on-the-job training

In house capacity building

Introduction of new technologies

Flexible and tailor made approach

International cooperation

Situated in the lower reaches of the river Rhine and Meuse, the Netherlands is strongly aware of the necessity of international cooperation in the field of water management with neighboring countries and the importance of exchanging knowledge and expertise to achieve sustainable groundwater management.

Dutch groundwater expertise is already widely in demand in the international market, especially in the large deltas around the world, in areas with serious groundwater pollution and in the arid and semi-arid regions, where groundwater is often the only resource available. The management of the transboundary aquifers in Germany and Belgium has led to the development and implementation of joint management strategies and agreements. This broad experience in international cooperation has led to the implementation of numerous projects in developing countries for a wide range of bilateral and international donor agencies.

Under the new European Framework Directive, Dutch support to the new EU countries in Eastern Europe has increased considerably. The successful involvement of many Dutch institutes and companies is supported by the Dutch Embassies in the concerned countries and is effectively coordinated by the Netherlands Water partnership.

QUICK FACTS

awareness of the need of international cooperation in shared rivers basin and groundwater aquifers

long history in development cooperation amongst the sector

strong support of the Government and Embassies

effective cooperation through the Netherlands Water Partnership (one window)

Input Table Dutch Groundwater publication

This publication has been prepared in a joint effort of the Dutch Groundwater sector united in NWP. For each fact sheet a company or institution has been responsible. Others contributed to the sheet. In the table below the overview of inputs is provided. Information on the individual parties can be found at the NWP website (see acknowledgements).

		Acacia Institute	Alterra/ILRI	BAM/de Ruiter	Boode WWS	DHV	Eijkelkamp	Fugro	Geochem	Grontmij	Haitjema	IF Technology	IGRA C	IHE	ITC	Kiwa Water Research	Logisticon	Microsoft	Norit	Oranjewoud	Royal Haskoning	Sea SpringWater	SG	TNO	VanEssen Instruments	Vitens	Wareco	Waternet	Wavin	Witteveen + Bos
Wells	Horizontal drilling			○								●				○															
	Dutch water wells	○			○						○	●				○								○						○	
	Full services															○									●	○					
Managed Aquifer Recharge and	Urban water supply															○										○			●		
	Agricultural & rural water	●					○	○																							
	Tourism & industry sectors															●	○		○	○				○							
Groundwater policy and plan development	Information management												○					○			○				●						
	Quick scan IGRM	●								○														○			○				
	Groundwater body									○														●	○						
Nonconventional groundwater use	Off shore brackish							●														○									
	On shore brackish					○										○					●										
	Turbid groundwater								○							○	○		●					○							
Groundwater remediation	In situ groundwater									○							○			○				●							●
	Mega sites management																						○	●							
	In situ iron & arsenic removal					○			○																	○		●			
Groundwater and energy	Aquifer Thermal Energy							○				●												○							
	Renewable energy & water	○		●													○														
	CO2 storage																							●							
Institutional development and capacity	Courses ń Training	●	○				○							○	○								●	●							
	Institutional empowerment	○				●															○		○	○							
	International cooperation	●										○											●	●							

● sheet leader - responsible for main text and photograph input and editing
○ contributing parties

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About the NWP

The Netherlands Water Partnership (NWP) is an independent body set up jointly by the Dutch private and public sector to act as a national coordination and information point in relation to water activities overseas. The main aims of the NWP are to harmonize the activities and initiatives of the Dutch water sector overseas and to undertake worldwide promotion of Dutch expertise related to water. The organization acts as a focal point for the exchange of information related to activities and services of government bodies, knowledge and research institutes and businesses involved in the water sector.

Acknowledgements Dutch Groundwater Partners:

Acacia	www.acaciainstitute.nl
Alterra/Ilri	www.ilri.nl/ www.alterra.wur.nl
Bam de Ruiter	www.deruiterhalfweg.nl
Boode WSS	www.boode.com
DHV	www.dhv.nl
Eijkelkamp	www.eijkelkamp.nl
Fugro	www.fugro.com
Geochem	www.geochem.nl
Grontmij	www.grontmij.nl
Haitjema	www.haitjema.nl
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