LIFE FRESHMAN

A European project on
protecting coastal freshwater resources

Freshman
project

> “ A fresh look at coastal water resources. ”

De Watergroep
WATER. VANDAAG EN MORGEN.

dunea
DUIN & WATER

aquaduin
lekker kraanwater,
duurzaam gewonnen

Co-funded by
the European Union

KWR

https://www.dunea.nl/algemeen/life-FRESHMAN

Why LIFE FRESHMAN; rationale and goals of the project

Coastal zones are among the most economically productive and densely populated regions of Europe. Nearly half of the EU population lives within 50 kilometres of the coast, and there is a correspondingly high demand for freshwater to sustain human needs, industry, agriculture and nature.

However, Europe's coastal freshwater resources are under intense pressure, with salinity levels rising in a growing number of coastal aquifers. An aquifer is an underground layer of permeable rock or sediment – such as sand, gravel or fractured rock – that stores and transmits groundwater, acting as a natural underground reservoir supplying wells and springs. These water-bearing layers are essential for drinking water and irrigation and are replenished by rainfall, but they can become depleted if water is extracted faster than they are naturally recharged. Climate change and overexploitation are the key factors contributing to the gradual salinization of these coastal freshwater reserves.

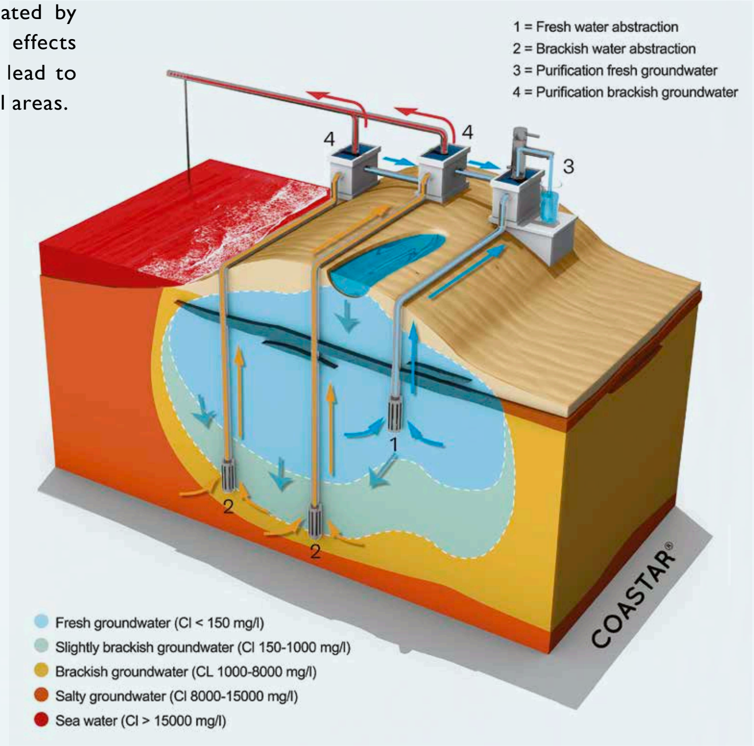
Underground freshwater near the coast usually sits above saltier water from the sea. As long as there is enough rainfall, this balance remains stable. If more freshwater is extracted than is replenished on an annual basis, these freshwater reserves are considered overexploited. When too much water is taken out, seawater can slowly move inland and mix with the freshwater supply, which leads to higher salinity levels in the groundwater and may lead to salinization of extraction wells. This may either result in abandonment of the well field or the need to install desalination in the water treatment train, which is both energy-intensive and expensive.

Salinization therefore represents a significant threat to the security of Europe's drinking water supplies. Seawater intrusion is a natural process, yet it is being accelerated by the overexploitation of freshwater resources and the effects of climate change, such as rising sea levels. This could lead to serious, long-lasting consequences, particularly in coastal areas.

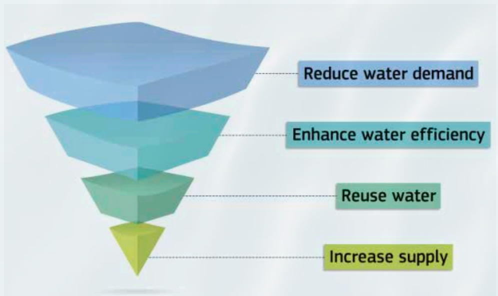
To help protect freshwater supplies in coastal areas, the EU-backed LIFE FRESHMAN project brought together four partners from the Netherlands and Flanders, including three drinking water utilities and a leading water research institute. Their aim was to find a new way to prevent seawater from reaching valuable underground freshwater reserves.

The team developed and tested an innovative method at two pilot sites, one in Belgium and one in the Netherlands. The idea is simple: purified river water is infiltrated in the aquifer to strengthen underground freshwater reserves (push), while brackish groundwater is pumped up from deeper layers below (pull). This creates a protective barrier that helps keep seawater away from the freshwater used for drinking and irrigation. Through this approach, the project hopes to protect coastal freshwater wells from increasing salinity, enlarge underground freshwater reserves and show that the brackish groundwater taken from deeper underground can also be treated and reused as a valuable source of water.

The project closely supports the European Water Resilience Strategy, adopted in June 2025, which aims to strengthen Europe's water security. The strategy focuses on protecting the natural water cycle, encouraging smarter and more efficient use of water, and ensuring that everyone has access to clean and affordable water. The strategy includes more than 30 actions to help Europe use water more wisely and protect existing supplies. It aims to reduce water waste, improve water quality and make sure there is enough freshwater for people, businesses and nature. The strategy is a response to growing concerns about drought, pollution and the effects of climate change across Europe.



The FRESHMAN concept: brackish water extraction from coastal aquifers, to protect freshwater wells from salinization and to increase the freshwater stock in the aquifer.


Water Efficiency First Principle

The water efficiency first principle is the backbone of the EU Water Resilience Strategy.

Introduction to THE LIFE FRESHMAN project team

The LIFE FRESHMAN project brings together four partners, who each bring their own skills, knowledge and experience to the issue of freshwater salinization. The project team includes Dutch drinking water utility Dunea, KWR Water Research Institute, and the Belgian drinking water utilities Aquaduin (formerly known as IWVA) and De Watergroep.

This combination of scientific knowledge and technical expertise is focused on the very practical and pressing problem of freshwater salinization. The project team aims to develop an innovative, cost-effective solution, and to test and refine it over the course of the project, so that it can deliver practical benefits for both people, nature and industry.

The project partners are:

dunea
DUIN & WATER

Dunea is a public water utility which produces and distributes tap water of outstanding quality to next to 1.4 million consumers and businesses in the western part of The Netherlands. Dunea produces drinking water in harmony with nature. The coastal dunes are crucial for the purification process. Moreover, the coastal dunes are very unique and valuable habitats with the highest degree of biodiversity in the Netherlands. Dunea is dedicated to nature as well as drinking water, delivering outstanding quality, sufficient quantity and 24/7 continuity to its clients, its visitors and to society.

KWR

KWR Water Research Institute is the leading knowledge partner of Dutch drinking water utilities and also operates across the wider water sector in the Netherlands and abroad. Building on its strong foundation in drinking water research, KWR translates scientific research into practical knowledge that can be directly applied across the entire water cycle. The organisation has around 200 employees and works closely with utilities, governments and research organisations on topics such as water quality, wastewater treatment and reuse, and resource efficiency.

aquaduin
lekker kraanwater,
duurzaam gewonnen

Aquaduin is a small public drinking water utility, serving the western area of the Flemish coast in Belgium. Aquaduin is a pioneer in wastewater reclamation and groundwater recharge for indirect potable reuse. Its core mission is to provide drinking water in the most sustainable way possible. To achieve this, the utility offers its customers a healthy alternative to bottled water by producing and distributing high-quality, affordable drinking water day and night that does not harm the environment.

De Watergroep
WATER. VANDAAG EN MORGEN.

De Watergroep is the largest drinking water utility in Flanders. It serves around 3 million consumers and thousands of businesses throughout West and East Flanders, Flemish Brabant and Limburg. Its mission is to supply high-quality drinking water at an affordable price. Furthermore, De Watergroep adopts a sustainable closed-loop system to ensure the economically and ecologically responsible management of every link its water chain: rainwater, groundwater and surface water, drinking water and wastewater.

Co-funded by
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https://www.dunea.nl/
https://www.kwrwater.nl/
https://www.aquaduin.be/
https://www.dewatergroep.be/

Leading Researchers

Gertjan Zwolsman (PhD) is coordinator of the FRESHMAN project. He has a long track record in water quality research, integrated water management and water policy in general. Gertjan's professional background is in Environmental Geochemistry (Utrecht University). At Dunea, he mainly works on the protection of current drinking water sources (river water) and the development of new (unconventional) sources of drinking water, such as seawater, brackish groundwater and effluent from municipal wastewater treatment plants.

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Marco Kortleve (MSc) is project manager of the FRESHMAN project. He has long experience in various parts of Dunea's drinking water supply system. He has worked in several roles, both as an expert and as a manager. Marco studied water management at the Technical University of Delft. At Dunea, he is responsible for research and development in both water supply and nature management.

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Ruud Steenbeek (MSc) is a researcher at the brackish water pilot project in Scheveningen. In the project, he is investigating the most efficient way to purify brackish water into drinking water. Ruud has a background in analytical chemistry and environmental sciences (Wageningen University). At Dunea, he primarily focuses on the water quality of current and future sources of drinking water.

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Franca Kramer (PhD) is a researcher at the brackish water pilot project in Scheveningen. Franca helped design the brackish water reverse osmosis (RO-) pilot for drinking water production and also worked to set research goals. Franca has a background in membrane filtration research (Technical University of Delft). She currently works at Dunea on the development of advanced water treatment techniques for the future production of drinking water from various different sources.

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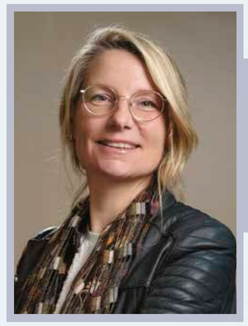

Nicole van Veldhoven (BA) is a communications strategist. She is responsible for the project's visual identity, presence and publicity. As programme manager for sustainable water use at Dunea, she researches ways to reach general and professional audiences, and how they can be encouraged to change their daily behaviour to adapt to climate change and reduce water use. For FRESHMAN Nicole leads the public engagement initiative 'a ton for LIFE', and has aligned the project's water saving goals with those of Dunea.

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Klaasjan Raat (PhD) is a senior researcher and program manager at KWR. He is an expert in the management of water resources, water reuse, and freshwater supply. He carries out this work for, and with, organisations from various sectors—from drinking water to agriculture, and from water authorities to industry. He was one of the driving forces behind the development and practical application of aquifer storage and recovery for greenhouse horticulture. Also, together with water utilities in the Netherlands, he has been leading R&D on alternative water resources, such as brackish groundwater, to safeguard future supplies of drinking water.

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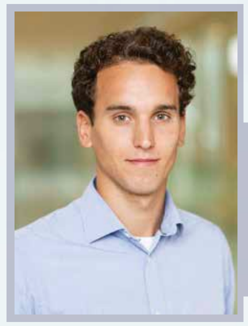

Teun van Dooren (MSc) is a scientific researcher at KWR with a background in hydrogeology. Within the FRESHMAN project, he uses his expertise on coastal groundwater systems and groundwater wells to safeguard and improve fresh groundwater availability. Teun is the leading researcher on the groundwater aspects of the demonstration pilot. He also helps translate the research findings of the FRESHMAN project into practical solutions that can be implemented by Dunea and the water sector at large.

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Emmanuel Van Houtte (MSc) is a geologist at Aquaduin and is responsible for the replication project in FRESHMAN. He has a long track record of work in water quality, water reuse and managed groundwater recharge, all of which are part of his job at Aquaduin.

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Peter Cauwenberg (PhD) is project manager in the innovation department of De Watergoep and coordinates the activities of De Watergroep in the FRESHMAN project. Peter has over 30 years of experience in the execution and management of environmental engineering and water-related projects. For De Watergroep, Peter manages a broad portfolio of innovative projects related to securing drinking water quality and supply.

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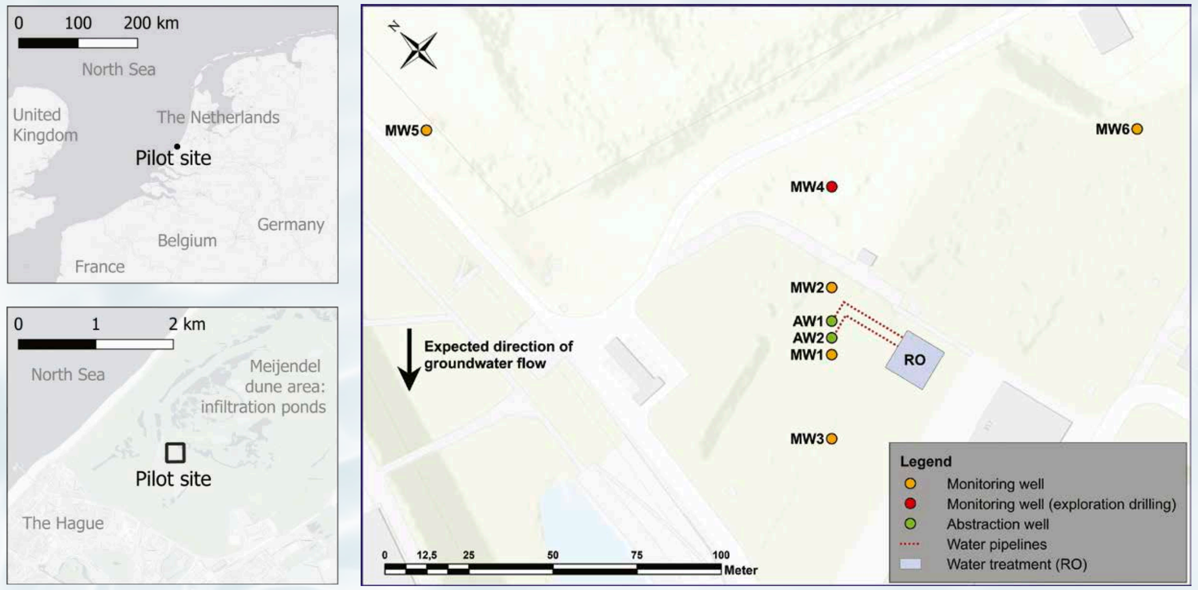
Layout of the pilot sites

The project team has tested the concept at two pilot sites, aiming to refine the approach, demonstrate its effectiveness and assess its wider impact. A demonstration project was conducted in the Dutch coastal dunes of Meijendel, close to the city of The Hague, while a replication project was conducted at Koksijde, a small town on Belgium's North Sea coast.

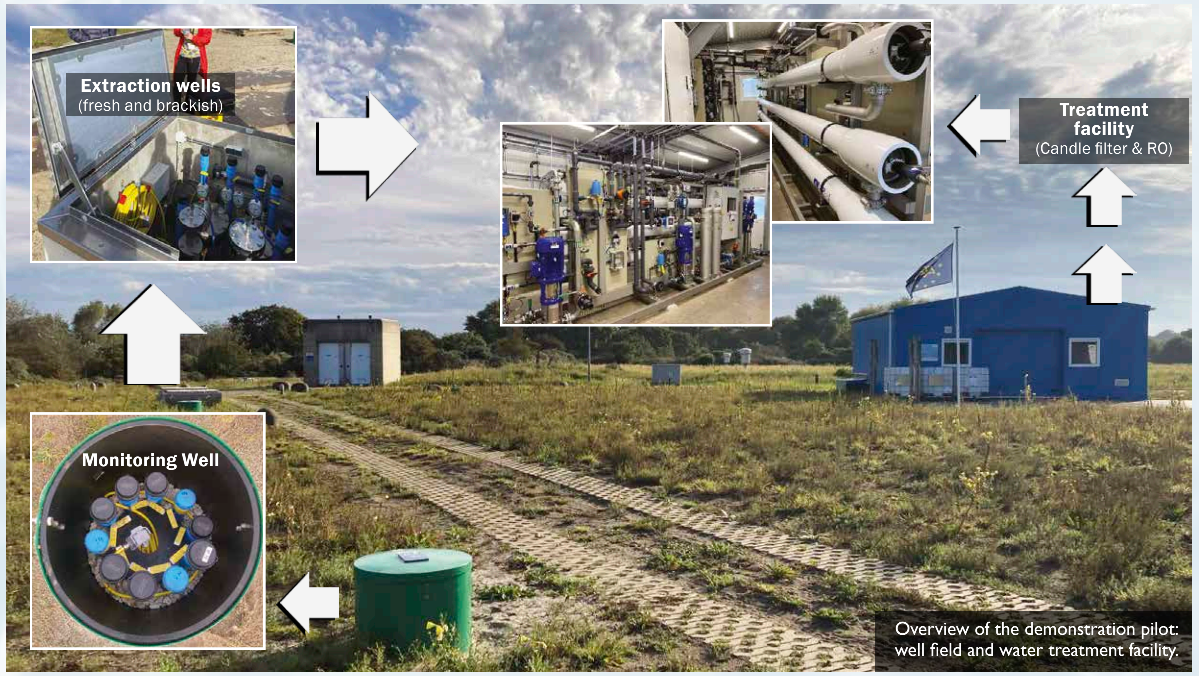
Demonstration project (Meijendel)

The coastal dunes of Meijendel provide a natural source of drinking water for the city of The Hague and surrounding municipalities since 1874. The natural aquifer is supplemented with (purified) river water since 1950. The premises of Dunea's primary drinking water production site, located within this dune area, was chosen as location of the demonstration pilot.

The project team installed two extraction wells at the pilot site between May-August 2021: one to extract fresh groundwater from a depth of 40 to 60 metres below ground level; and one to extract brackish groundwater from a depth of 80 to 100 meters. Brackish water is slightly salty – saltier than freshwater, but not as salty as seawater. Both wells are equipped with multiple extraction screens, which allowed the extraction of groundwater from different depths with varying levels of salinity. Eight monitoring wells were also established around the extraction wells to monitor changes in the salinity distribution of the aquifer during the pilot. For this purpose, all wells were equipped with a variety of monitoring techniques to follow changes in the salinity distribution within the aquifer.

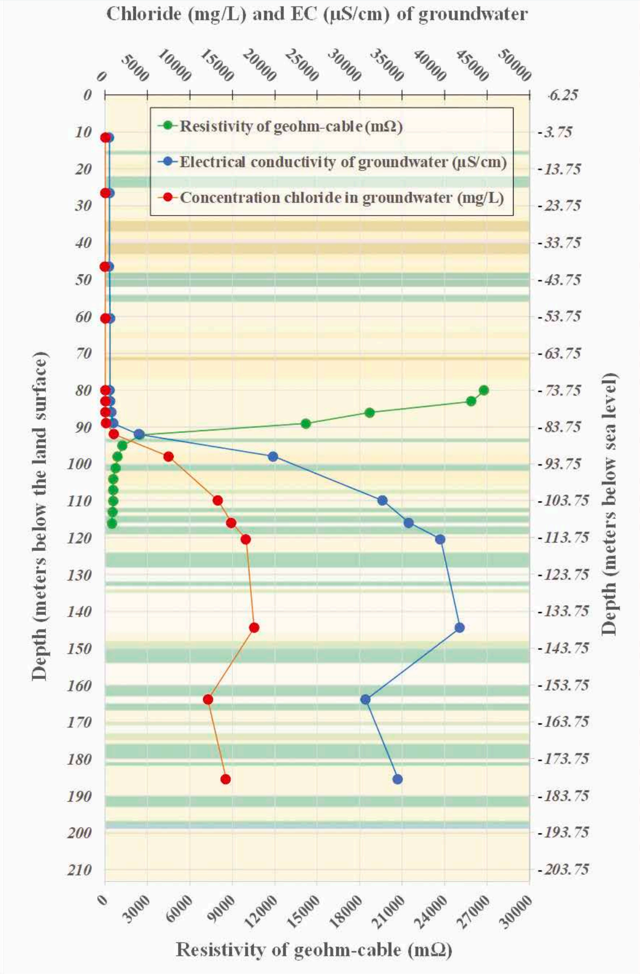


Location and layout of the demonstration pilot.



Overview of the demonstration pilot: well field and water treatment facility.

An exploration well (well P) was drilled in March 2020. In this well, the composition of the soil and the depth of the freshwater lens was measured. The freshwater lens has a depth of 80 meters, at greater depth the groundwater is brackish to saline.



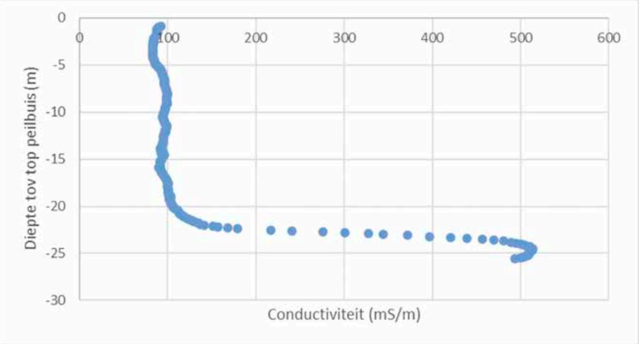
Vertical profile of chloride, resistivity and electrical conductivity at the demonstration test site. Soil composition is also indicated: aquifers are yellow to brown and confining layers (aquitards) are in green.

Replication project (Koksijde)

A replication project has been conducted at Koksijde in Belgium, in a low-lying polder – an area of land reclaimed from the sea – close to the coast. Despite the different geological circumstances (low-lying polder versus coastal dunes), the demonstration and the replication sites face similar challenges with regard to aquifer salinization.

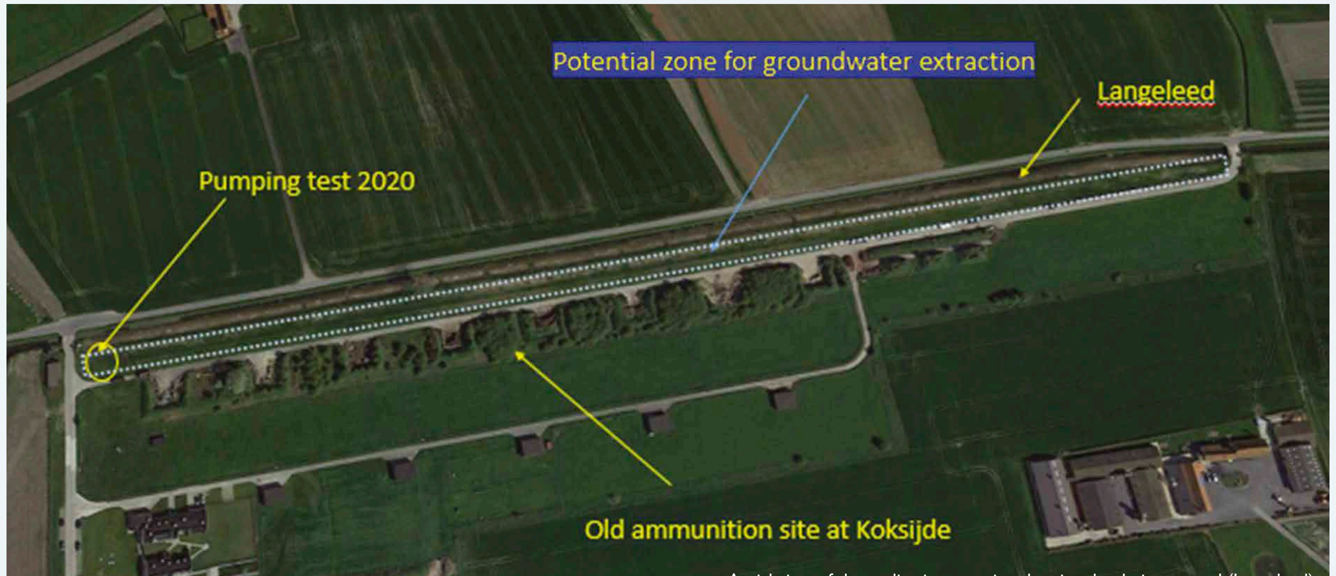
The aquifer at the replication site consists of sand and overlies a Tertiary clay layer. A small clay layer is present at a depth of 12 metres, with a thickness of 50 cm. At the surface a drainage canal drains freshwater from the dunes, flowing from West to East over a length of 600 metres.

The bottom of the aquifer has a depth of around 25 metres, with fresh groundwater on top and brackish water at the bottom. Similarly to the situation at Meijendel, freshwater extraction at Koksijde is threatened by internal salinization, due to the presence of brackish groundwater at the base of the aquifer. This brackish groundwater tends to move upward and may reach the freshwater well as the extraction of fresh groundwater lowers the hydraulic pressure in the aquifer.



Vertical profile of conductivity (a proxy of salinity), in the aquifer at the replication site.

As part of the pilot project, an extra extraction well was installed in the lower (brackish) part of the aquifer, in addition to the existing, shallow extraction well. Three additional monitoring wells were also established at the site to gather data for analysis and provide a comprehensive picture of the quality of the groundwater in the aquifer and its dynamics in space and time.



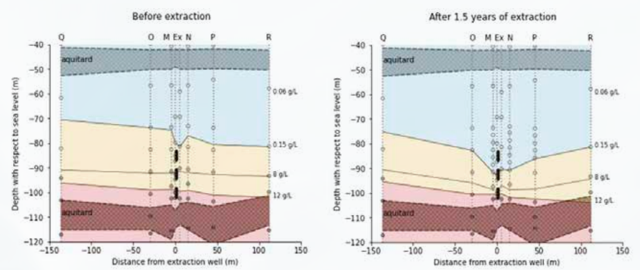
Aerial view of the replication test site, showing the drainage canal (Langeleed) and the potential zone for groundwater extraction along the drainage canal.

Main results of both pilot sites, and their implications for sustainable management of coastal aquifers

Demonstration site (Meijendel)

The project team extracted brackish groundwater and deep fresh groundwater in a series of experiments between January 2022 and June 2025 at the demonstration site in Meijendel, using the two extraction wells that were installed in 2021.

In the first stage, only brackish groundwater was continuously extracted over an 18-month period, followed by a rest phase of around three months. This led to a downward shift of the transition from fresh to brackish groundwater of about 10-15 metres close to the extraction. This freshening of the groundwater was observed to a progressively lesser degree further away from the extraction well. At a distance of 100 metres from the extraction well, the transition zone was not visibly affected by the extraction.



Growth of the freshwater lens (light blue) after 18 months of brackish water extraction. The X-axis shows the distance of each monitoring well to the brackish water extraction well; the Y-axis shows the chloride concentration in the monitoring wells as a function of depth. The 0,15 g/l line (chloride) indicates the transition from fresh (blue) to brackish groundwater (yellow).

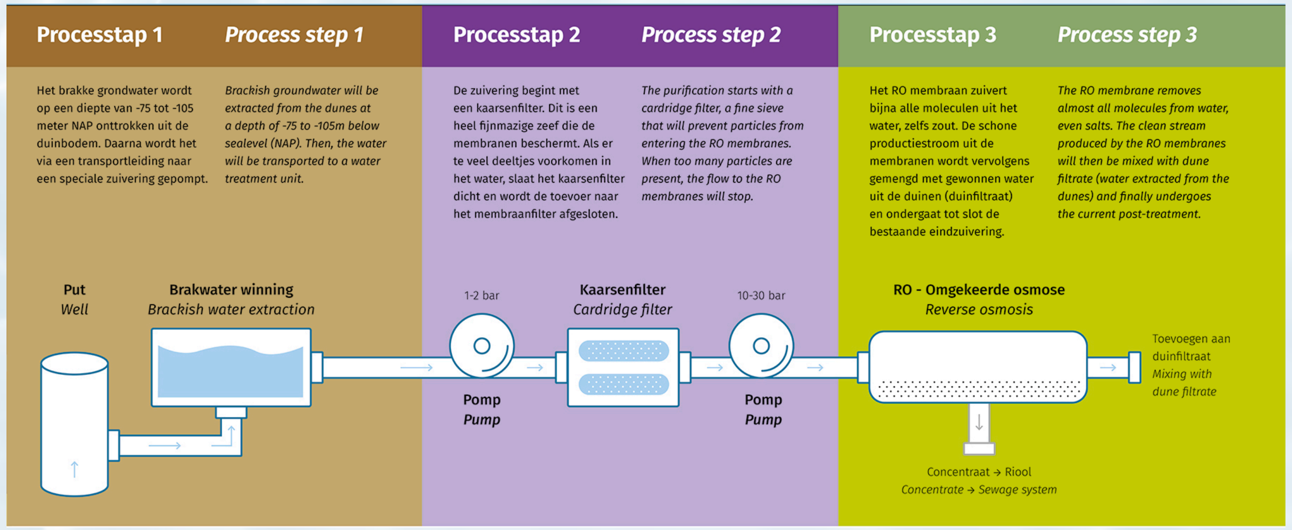
The next phase of experiments started in November 2023. The aim of this phase was to mimic a situation when river infiltration into the dunes is stopped (e.g. due to a pollution incident) while drinking water production continues. In such cases, Dunea switches its extraction regime from shallow wells to deeper freshwater wells. This situation was simulated in the pilot by extracting only deep fresh groundwater for around four months. As a result, the transition from fresh to brackish groundwater moved upwards by 20 metres in comparison to its original position, leading to salinization of the extraction well, with the extracted groundwater becoming unsuitable for drinking water production after approximately 8 weeks. The effects on the salinity distribution in the aquifer were again strongest in the centre of the well field and dissipated further away from the extraction.

After this four-month extraction, the freshwater extraction was stopped and brackish groundwater was extracted again to induce a downward movement of the transition from fresh to brackish groundwater. The aquifer thus freshened again, clearly indicating that the salinization of deep freshwater wells can be reversed through the extraction of brackish groundwater from below.

Subsequently, the freshwater extraction well was operated with the same settings as in the previous phase for a period of four months. However, now both fresh and brackish groundwater were extracted simultaneously. The position and rate of the brackish groundwater extraction was adjusted in order to stabilize the transition from fresh to brackish groundwater, based on continuous recordings of the salinity (conductivity) of the extracted groundwater. This procedure was successful, which opens up the possibility of protecting existing deep freshwater wells in the coastal dunes of Meijendel from internal salinization by upward moving saline groundwater.

The reliability of brackish groundwater as a source of drinking water has also been demonstrated in the project, and the optimal conditions for purification have been assessed. Brackish groundwater was treated with membrane filtration to remove salts and minerals, then after degassing it is mixed with purified water at the existing production location next to the pilot. The study examined how brackish groundwater can be purified as efficiently as possible while keeping the treatment process stable. To achieve efficient purification, four connected aspects are assessed: water quality, energy use, purification efficiency and the use of chemicals.

Based on the results of the pilot, we can conclude that it is possible to treat brackish groundwater with a stable operation, even when the quality of the feedwater fluctuates. The results also show that these settings allow the treatment system to operate well for a long period within its operational limits with an efficiency of 60%; this means that 40% of the raw water is lost as a concentrated side stream containing all the minerals of the feed water.


Processtap 1 *Process step 1*

Het brakke grondwater wordt op een diepte van -75 tot -105 meter NAP onttrokken uit de duinbodem. Daarna wordt het via een transportleiding naar een speciale zuivering gepompt.

Brackish groundwater will be extracted from the dunes at a depth of -75 to -105m below sealevel (NAP). Then, the water will be transported to a water treatment unit.

Processtap 2 *Process step 2*

De zuivering begint met een kaarsenfilter. Dit is een heel fijnmazige zeef die de membranen beschermt. Als er te veel deeltjes voorkomen in het water, slaat het kaarsenfilter dicht en wordt de toevoer naar het membraanfilter afgesloten.

The purification starts with a cardridge filter, a fine sieve that will prevent particles from entering the RO membranes. When too many particles are present, the flow to the RO membranes will stop.

Processtap 3 *Process step 3*

Het RO membraan zuivert bijna alle moleculen uit het water, zelfs zout. De schone productiestroom uit de membranen wordt vervolgens gemengd met gewonnen water uit de duinen (duinfiltraat) en ondergaat tot slot de bestaande eindzuivering.

The RO membrane removes almost all molecules from water, even salts. The clean stream produced by the RO membranes will then be mixed with dune filtrate (water extracted from the dunes) and finally undergoes the current post-treatment.

Treatment of the brackish groundwater.

Replication site (Koksijde)

The primary objective in the replication project at Koksijde is to identify the ideal configuration of extraction wells to extract freshwater. Essentially, the idea is to maintain a stable source of drinking water, despite the potential threat of salinization from the brackish to saline water that lies at the bottom of the aquifer.

Three pumping tests have been conducted at different depths of the shallow aquifer, while researchers have also modelled how groundwater will be extracted in future. In this way the effect of the brackish groundwater present at the lower part of the aquifer on freshwater extraction can be mitigated.

The first pumping test took place in September 2024 and overall three were conducted over the course of the project – one on the shallow well, one on the deeper well, and one on both simultaneously. Each of these tests involved pumping for six to seven weeks followed by a two-week period when no water was extracted.

The results showed that extracting water from the sand package above the small clay layer (at 12 metres depth) resulted in a freshening of water quality up to the filter level of the shallow pumping well, but did not lead to changes in salinity below the clay layer. No upwards movement of the brackish water at the base of the aquifer was observed.

Pumping in the package below the clay layer meanwhile caused the attraction of brackish water at the base of the aquifer, resulting in upwards movement of the brackish water. This resulted in an increase in the salinity of the pumped water, i.e. salinization of the pumping well.

The pumping tests and the geohydrological model results suggest that the pilot replication site could be a viable site for producing drinking water. However, groundwater extraction should be limited to the upper part of the aquifer, as pumping here does not cause upwards movement of brackish water, due to the presence of a small clay layer at 12 metres depth.

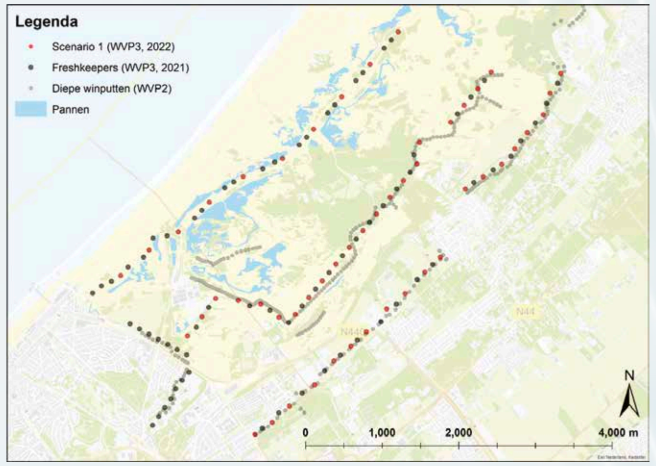
Environmental impacts of the FRESHMAN technology after scaling up

A new source of drinking water could make supplies more reliable in the future. However, it is also important to understand the wider effects of the technology. As part of the LIFE FRESHMAN project, the team looked at how the new system could affect the environment, costs and long-term sustainability.

This includes analysis of brackish water as a source of drinking water, and also of the technology itself. Among the topics the project team addressed were the likely cost of producing drinking water from brackish groundwater, as well as the CO_2 footprint of the technology and its impact on the surrounding environment.

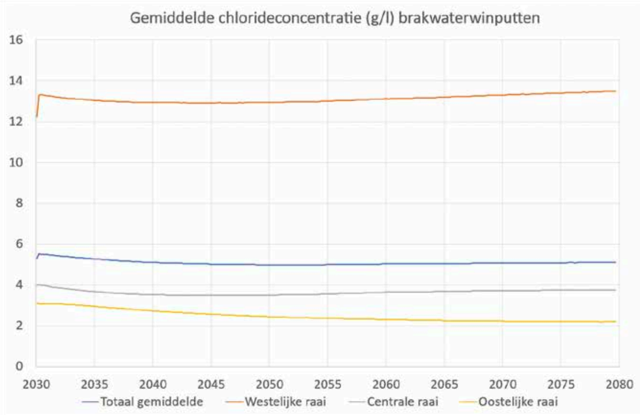
A geohydrological model was set up to assess the effect of continuous extraction of brackish groundwater in the coastal dunes of Meijendel on the environment. For this purpose, a well field was considered, consisting of three rows with 50 wells in total, each with a flow rate of 20 m^3/hour. The model covered a time span of 50 years (2030-2080), and included the expected effects of climate change and sea level rise.

From the extraction wells, the brackish groundwater is pumped via transport pipes to Dunea's production location at Scheveningen. The brackish water is treated with reverse osmosis (RO) to remove salts and minerals. After degassing, the purified water from the membrane filtration is mixed with the purified water from the existing drinking water production process.



The well field which was used as input for the model. Wells are indicated by red dots (the grey dots indicate wells from previous calculations). The western row contains ten wells, the central row contains 21 wells and the eastern row has 19 wells.

With a freshwater recovery rate of 57 percent, 5.0 million m^3 of drinking water can be produced per year, enough to supply 110,000 people. This system was the basis for calculating both the carbon footprint and the operational costs of brackish groundwater as a source of drinking water.



Average chloride concentration of the western well row (orange line), central well row (blue line) and eastern well row (yellow line) during brackish groundwater abstraction over 50 years, as projected by the geohydrological model of the area. The grey line shows the average chloride concentration of all the wells.

Since a well field should be in operation for 50 years, a key concern is the availability of brackish groundwater for exploitation as a source of drinking water over that time. The groundwater modelling shows that brackish groundwater will not run out as a result of 50 years of exploitation, as the body of brackish groundwater extends far beyond the coastal dunes of Meijendel, both out to sea and also into the hinterland.

While analysis shows that around 5 million m^3 of drinking water could be produced annually at Meijendel from brackish water, this would require large amounts of energy and chemicals, which leads to higher CO_2 emissions.

Researchers have worked to calculate the CO_2 emissions that would be caused by producing increased volumes of freshwater in this way, considering factors such as the energy required for reverse osmosis and the chemicals used. The CO_2 emission – or carbon footprint – for the extraction and purification of brackish water has been calculated as 1.7 kg CO_2/m^3.

For comparison, the carbon footprint of Dunea's existing drinking water production – based on the purification of river water – is far lower, at 0.43 kg CO_2/m^3. This disparity is largely attributable to the fact that much more energy is required to desalinate brackish groundwater than to treat and purify river water, the current source of drinking water for Dunea.

Impact of upscaling brackish groundwater extraction on nature values in the dunes

The model used for calculating the impact of brackish groundwater extraction was also used in a first attempt to estimate the effect of brackish groundwater extraction on the shallow groundwater levels within the Meijendel dune area, although the model was not developed for this purpose.

With this limitation in mind, the model results show that extraction of brackish groundwater (50 wells, 1000 m^3/hour) would result in a significant drop of shallow groundwater levels (5-10 cm or even 10-20 cm) in sensitive nature areas with high biodiversity values, such as wet dune valleys and moist dune forest.

This would have serious consequences for the nature values of these sensitive habitats, many of which are part of the Natura 2000 network of protected areas. In the current situation, this implies that no permit can be obtained for brackish groundwater extraction at this scale. However, occasional and local extraction of brackish groundwater may still help protect Dunea's existing deep freshwater wells against salinization, and thereby enlarge freshwater availability.

Drawdown of the shallow groundwater level due to the abstraction of brackish groundwater in the year 2040 (after ten years of operation), relative to the reference situation. Sensitive nature areas are shown in red (moist dune valleys) and green (moist dune forest).

Parnassia, a typical plant in moist dune valleys.

A moist dune valley in the coastal dunes of The Hague (Meijendel).

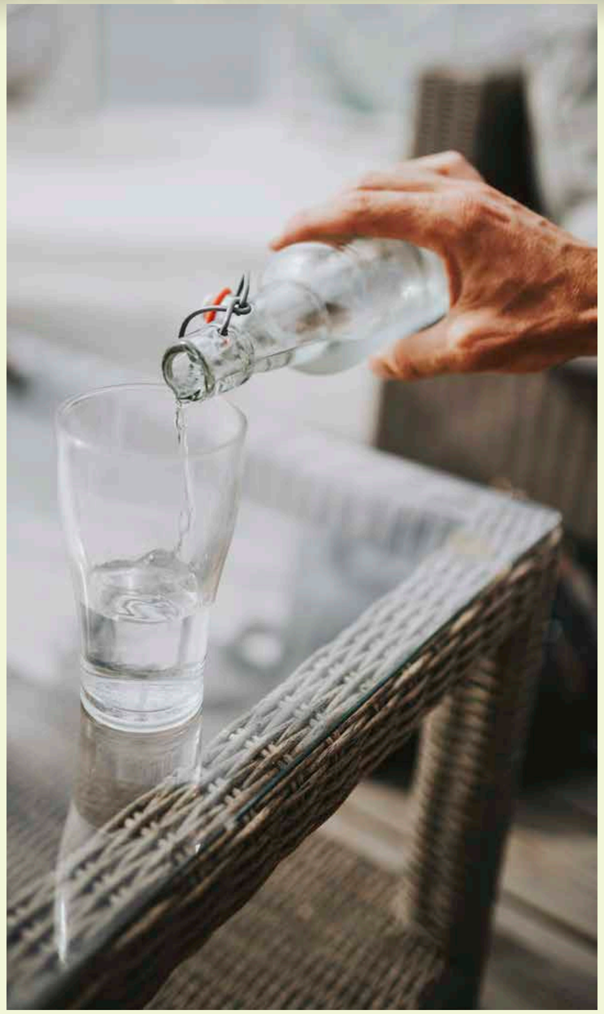
Assessment of the costs of drinking water produced, after implementing/upscaling

A safe and reliable supply of drinking water is essential for everyday life. Shortages or disruptions can have serious consequences, especially during droughts or pollution incidents. At the same time, it is important to consider how much new solutions will cost and what impact they may have on households, businesses and the wider water system.

The operational cost of extracting and purifying brackish water has been calculated as €2.25 per m^3, significantly higher than Dunea's existing drinking water production system at €1.30 per m^3. However, this must be weighed against the long-term benefits of providing a more secure and robust water supply, which will limit the need to take expensive emergency measures in times of disruption.

Water utilities have to consider how they would deal with disruptive events, and what measures they can take to increase the security of water supply. The extraction and treatment of brackish groundwater is one way of dealing with disruptions to intake, yet its potential contribution to overall drinking water production is relatively small in the case of Dunea (max. 5 percent).

The importance of brackish groundwater extraction lies more in its protective effects on the deep freshwater (calamity) wells, which are switched on when the supply of river water to the coastal dunes is interrupted. The demonstration pilot has clearly shown that salinization of deep freshwater wells can be prevented by the simultaneous extraction of fresh and brackish groundwater.



Upscaling the replication pilot

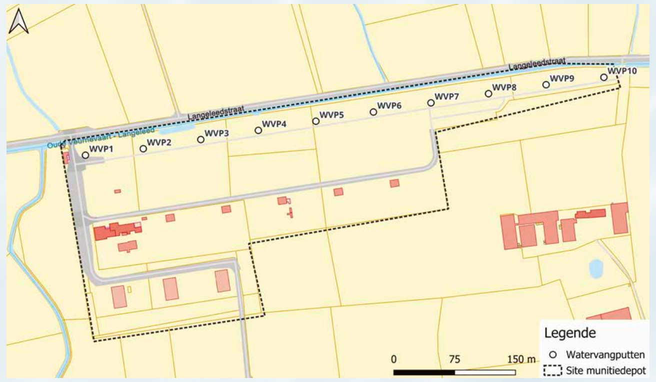
The pumping tests and the geohydrological model results suggest that the pilot replication site could be a viable site for producing drinking water. It was concluded that limited groundwater extraction in the upper part of the aquifer is possible along the entire length of the Langgeleed canal, without major impact on the environment. The presence of a less permeable clay layer at a depth of 12-12.5 m limits the possible negative effects of the presence of brackish water at the bottom of the aquifer.

The Langgeleed Canal draining the dunes from west (De Panne) to east (Nieuwpoort) (info: geopunt.be).

The socio-economic analysis of the replication site also shows that the potential for upscaling the pilot is quite good. The cost to produce drinking water based on brackish water extraction along the Langgeleed Canal and treatment at Water Production Center Torreele was calculated to be 0,20 €/m^3. This is far beyond the current price Aquaduin needs to pay to purchase water from neighbouring water utilities. The carbon footprint for (brackish) groundwater extraction and purification was calculated to be 0,22 kg CO_2/m^3. The current carbon footprint for Aquaduin to produce one cubic meter of drinking water amounts to 0,33 kg CO_2/m^3.

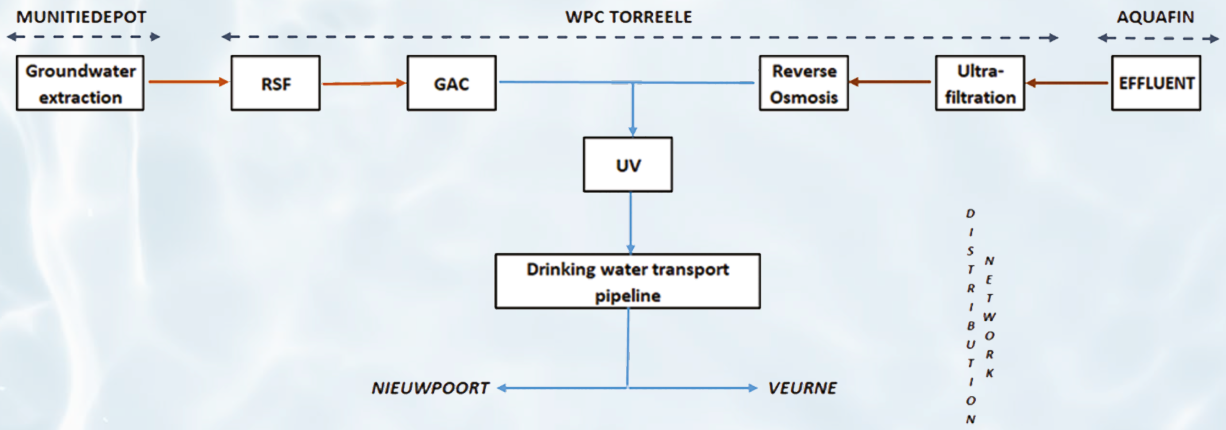
Moreover, contrary to the Meijendel site, the environment at Koksijde is not part of a protected nature area, but primarily used for agriculture.

Based on these considerations, Aquaduin is planning a groundwater extraction facility next to the Langgeleed canal in the near future. The extraction facility will extract water from the phreatic polder aquifer and, via bank infiltration, from the Langgeleed canal. Compared to the other polder water courses in the vicinity, the salinity of the water from the Langgeleed Canal is fairly good. In fact, the water of the canal is essentially fresh (< 150 mg/l chloride). However, the groundwater at the site is slightly brackish, as found during a pumping test performed in 2020 (290 mg/l chloride). But mixing this water with the fresh water produced at WPC Torreele would be sufficient to tackle this problem.



Potential position of the extraction wells.

The intended capacity of this new extraction is 50 m^3/h (438.000 m^3/y), which would increase the water supply capacity of Aquaduin by some 10%. A regional dynamic groundwater model will be developed in the near future which will be used to explore various scenarios in order to achieve the lowest possible impact of the extraction on the environment. The project will strengthen and differentiate the water supply in the region in response to several consecutive years of drought, which is expected to occur more frequently in the future due to climate change.



Water treatment train for the upscaled groundwater extraction at Koksijde. The groundwater is pretreated by rapid sand filtration (RSF) and active carbon filtration (GAC), then it is mixed with reclaimed water from WWTP Torreele. The reclaimed water is pretreated by ultrafiltration and reverse osmosis. The blended water is disinfected by UV-radiation and added to the drinking water distribution network.

Water demand reduction during seasonal water shortage or droughts

A potential shortage of freshwater resources is an increasingly urgent issue which threatens the long-term security of drinking water supplies. While technological innovation is an important part of efforts to address it, individuals and companies can also help by changing their behaviour during times of water stress, such as seasonal shortages or droughts.

Water scarcity is an issue that affects us all, regardless of age, income or status, and so we all have a responsibility to manage the available resources effectively and avoid waste. This starts at home, by taking seemingly small steps that – taken together – can contribute to maintaining a sustainable supply of high-quality drinking water.

Dunea gives concrete advice on what citizens and businesses can do to reduce their consumption of drinking water, especially during long hot and dry spells. For instance, Dunea has developed a water savings check tool to help its clients to reduce their drinking water consumption (www.dunea.nl/waterbespaarcheck). The online tool asks a few questions about domestic water use, suggests alternatives and invites the user to take action.

The daily shower accounts for 50 percent of our water use, and on average takes eight minutes. Dunea instead advises people to take a shorter shower lasting for the duration of one song, and offers a Spotify-playlist with songs lasting between 4-5 minutes. For the toilet, Dunea offers stickers to easily identify the push button that will start the smallest flush, an easy way to reduce water use.

Currently, the average person in the Netherlands consumes 128 litres of drinking water a day. People are incentivised to reduce their water use to under 100 litres per day, and if they manage to do so they receive compliments and rewards, encouraging them to keep up the good work and make these changes part of their everyday habits.

People can also reduce water demand during dry spells by practising sustainable gardening. The team at Dunea recommend installing a rainwater barrel, and they also offer advice about when and how to water plants, as well as which plants to choose.

Ideally these should be plants that thrive in the current climate, while also considering how the climate will change in future. Some species are just not able to cope with dry spells and will become increasingly hard to maintain. Choosing plants that are well adapted to the prevailing climate reduces the necessity to provide additional water.

A ton for LIFE

In 2024 and 2025, Dunea organized a public campaign called 'A ton for LIFE' in collaboration with garden centres across the Netherlands to encourage customers to buy a water barrel. Advice was provided on water use in the garden, with a clear emphasis on the benefits of establishing a water stock for this purpose, not least that plants prefer rainwater!

Customers were offered a discount of 15 percent on the price of a rain barrel, while a further reduction of ten euros brought the price down even more. The freedom to choose from various types made the discount accessible to all types of gardens and budgets, so widening the impact of the campaign, which was also promoted via newspapers and social media.

The campaign proved highly successful, with more than 2,100 Dunea customers purchasing rain barrels, increasing the likelihood of water savings over the long term. The project also had a wider impact in terms of forging relationships with local businesses and raising awareness of water scarcity, which is crucial to changing behaviour.

To reduce water consumption by commercial businesses, Dunea offers a water scan; an appointment with specialists to discuss the use of drinking water within the business's operations. During the scan, specialists pose questions like; how can water use be reduced? Are other, more sustainable sources and options available?

If water is essential to businesses operations, it might be possible to use lower quality water from another source for example, rather than highly valuable drinking water. This might mean gathering rainwater from the premises or tapping into a local water body – these options might offer a more sustainable solution than simply relying on supplies of drinking water.

Potential of the technology in other water-stressed coastal areas of the EU

The FRESHMAN project focused on two sites along the North Sea in The Netherlands and Flanders. Yet this work holds wider implications for the management of coastal aquifers in other areas beyond the low countries, with many European nations dealing with water stress. The long-term aim is to apply this technology more widely in other coastal zones, something the project team is actively pursuing.

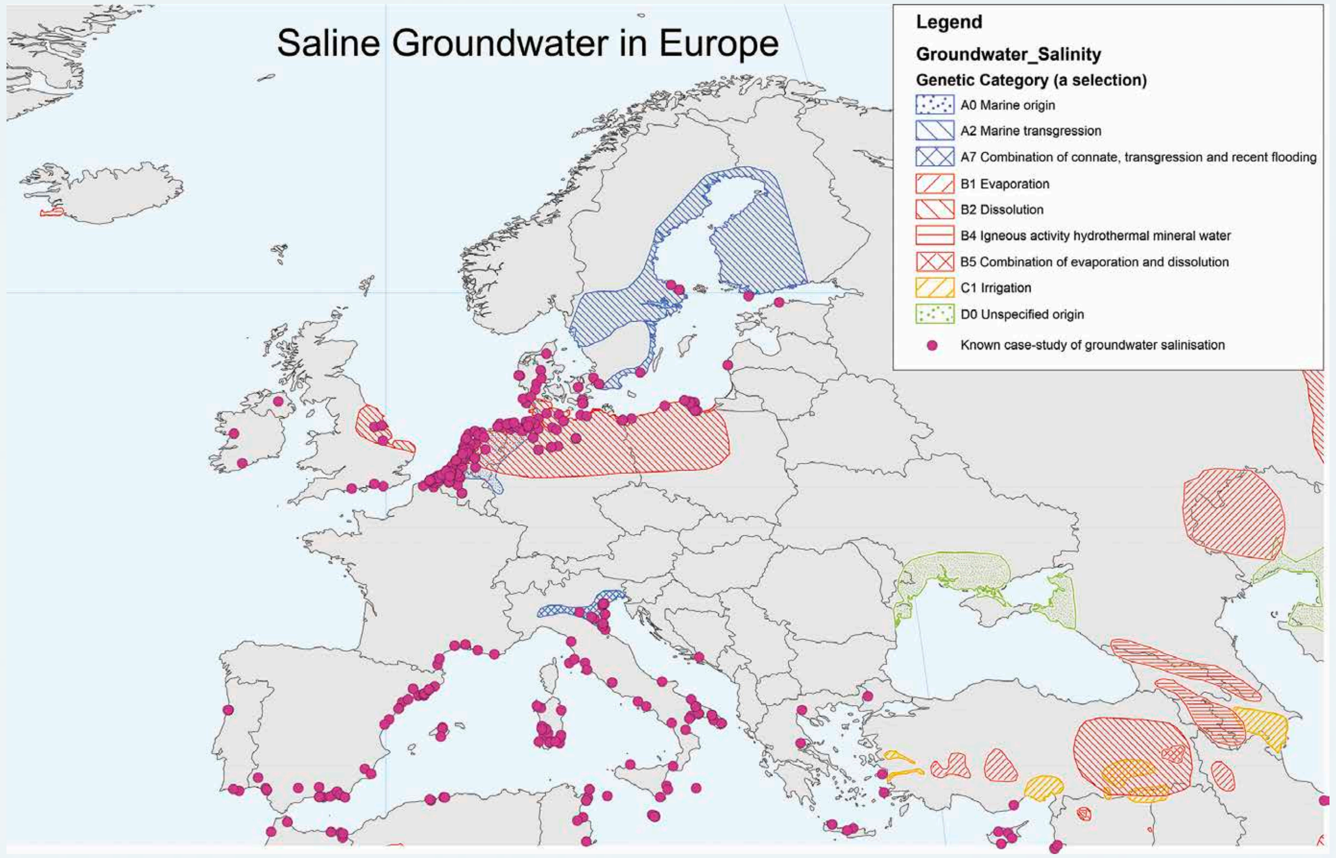
A key step towards this is to demonstrate the effectiveness of the technology in both locations. Validating the project's findings at the two different sites, and demonstrating that it is not limited to a specific location, would then open up the possibility of applying the technology in other coastal areas with sedimentary aquifers and a freshwater source nearby.

There are many other areas around Europe with these characteristics, and the project team is looking to explore the possibility of applying the technology in other locations, including several in Spain. The country currently faces significant challenges with respect to freshwater availability, heightening the need to manage existing resources effectively. Indeed, Spain has a long tradition of water reclamation and managed aquifer recharge, in order to limit salinization of its coastal groundwater resources. The "hydraulic barrier" along the coast of Barcelona is a famous example.

In October 2025, the project team visited several coastal sites in Spain to study their characteristics and assess whether the technology can also be replicated there. For instance, it is conceivable that pumping brackish groundwater (as interception wells) can strengthen Barcelona's hydraulic barrier against salinization. This in the long run could help the country protect and conserve its existing resources, reducing the need to import water or take other expensive measures.

There are also plans to investigate the possibility of implementing this technology in other coastal zones around Europe, with many regions under significant water pressure, particularly around the Mediterranean. The European Environment Agency published a report in 2024, which argued the issue was becoming increasingly urgent and that clear action was required (Europe's state of water 2024 - The need for improved water resilience. EEA report 07/2024).

The project's work represents an important contribution in this respect, with researchers working to improve and refine the push-and-pull concept, so that it can bring practical benefits to consumers.



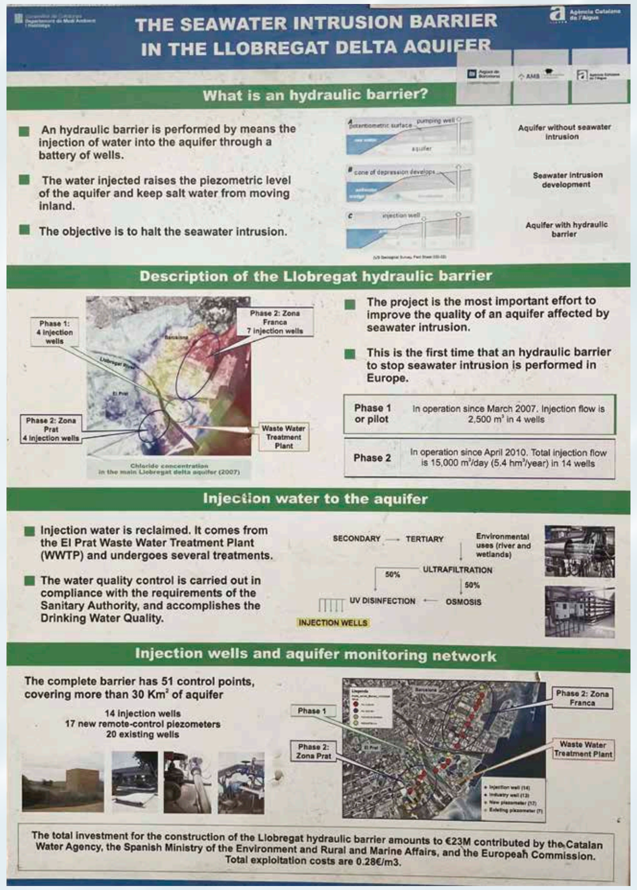
Case studies (not exhaustive) in which groundwater salinization is occurring in the coastal zone around Europe. Taken from Zwolsman et al. (2026), Salinization of coastal groundwaters in the EU – What can we do about it? Open Access Government, January 2026.

Impression of the FRESHMAN study tour to Spain (October 2025)

Information panel at the infiltration pond of the Horizon Europe MARCLAIMED project at Sant Vicenc dels Horts. The project is investigating aquifer recharge of reclaimed water to supply farmers with irrigation water. The reclaimed water comes from the Llobregat WWTP.

Flows of reclaimed water in Barcelona. The reclaimed water is amongst others used to supply the Llobregat hydraulic barrier and to provide irrigation water to farmers via a managed aquifer recharge system (pilot in Horizon Europe project MARCLAIMED).

Infiltration basin along the Llobregat river.



THE SEAWATER INTRUSION BARRIER IN THE LLOBREGAT DELTA AQUIFER

Agència Catalana de l'Aigua

What is an hydraulic barrier?

- An hydraulic barrier is performed by means the injection of water into the aquifer through a battery of wells.
- The water injected raises the piezometric level of the aquifer and keep salt water from moving inland.
- The objective is to halt the seawater intrusion.

Aquifer without seawater intrusion

Seawater intrusion development

Aquifer with hydraulic barrier

Description of the Llobregat hydraulic barrier

Phase 1: 4 injection wells

Phase 2: Zona Franca 7 injection wells

Phase 2: Zona Prat 4 injection wells

Waste Water Treatment Plant

Chloride concentration in the main Llobregat delta aquifer (2007)

- The project is the most important effort to improve the quality of an aquifer affected by seawater intrusion.
- This is the first time that an hydraulic barrier to stop seawater intrusion is performed in Europe.

Phase 1 or pilot	In operation since March 2007. Injection flow is 2,500 m³ in 4 wells
Phase 2	In operation since April 2010. Total injection flow is 15,000 m³/day (5,4 hm³/year) in 14 wells

Injection water to the aquifer

- Injection water is reclaimed. It comes from the El Prat Waste Water Treatment Plant (WWTP) and undergoes several treatments.
- The water quality control is carried out in compliance with the requirements of the Sanitary Authority, and accomplishes the Drinking Water Quality.

SECONDARY → TERTIARY → Environmental uses (river and wetlands)
ULTRAFILTRATION
50% → UV DISINFECTION
50% → OSMOSIS → UV DISINFECTION
INJECTION WELLS

Injection wells and aquifer monitoring network

The complete barrier has 51 control points, covering more than 30 Km² of aquifer

14 injection wells
17 new remote-control piezometers
20 existing wells

Phase 1

Phase 2: Zona Prat

Phase 2: Zona Franca

Waste Water Treatment Plant

The total investment for the construction of the Llobregat hydraulic barrier amounts to €23M contributed by the Catalan Water Agency, the Spanish Ministry of the Environment and Rural and Marine Affairs, and the European Commission. Total exploitation costs are 0.28€/m3.

The Llobregat hydraulic barrier is in full operation since 2010 to counteract seawater intrusion and protect freshwater wells from salinization. Wastewater from the Llobregat WWTP is treated with ultrafiltration and reverse osmosis to comply with water quality standards for aquifer recharge. Each day, 15,000 m³ of this water is injected into the coastal aquifer.

The mouth of the Llobregat river in Barcelona.

Llobregat waste water treatment plant which delivers reclaimed water to Barcelona.

Conclusions and recommendations

The FRESHMAN approach can help increase the amount of usable freshwater in coastal groundwater reserves. At the Dutch test site, pumping brackish groundwater from deeper underground helped create a larger area of freshwater around the freshwater pumping well.

Moreover, extracting brackish groundwater can reverse salinization of deep freshwater wells and can protect them from becoming brackish again in the future. This helps safeguard valuable freshwater resources, allowing water utilities to provide a more reliable and resilient supply of drinking water.

The project also showed that pumping brackish groundwater works best when it is used to protect nearby deep freshwater wells. In the Dutch pilot, the amount of freshwater that could be safely extracted by the deep freshwater well nearly tripled when brackish groundwater was pumped away at the same time (compared to the reference situation without brackish water pumping). Protection of existing freshwater wells may be even more important than using the brackish groundwater itself as a new source of drinking water.

These findings might also work in other coastal regions of the EU, depending on the local geology and freshwater availability. Options for implementation seem particularly good along the Mediterranean Sea.

As climate change and rising sea levels continue to put pressure on coastal water supplies, approaches such as FRESHMAN could become increasingly important. By helping communities make better – more sustainable - use of the water resources they already have, the project offers a practical way to strengthen Europe's long-term water security.

The Freshman project is supported by the EU LIFE Climate Action Programme under Grant Agreement number LIFE19 CCA/NL/001222.