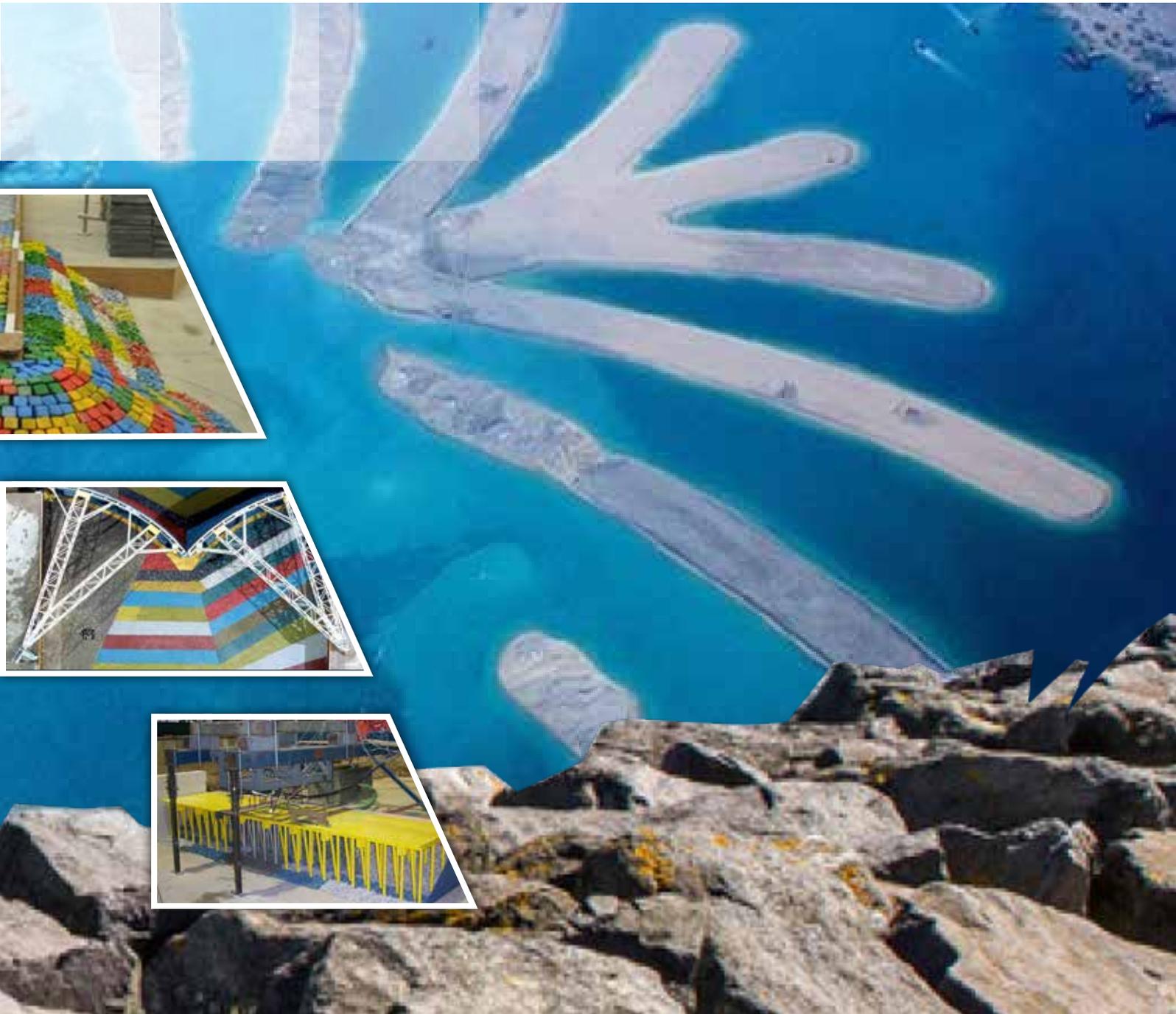


Deltares

Coastal Structures and Waves group



The Coastal Structures and Waves group (CSW) at Deltares focuses on research and consultancy in the field of wave forecasting & wave modelling and the conceptual design, testing and monitoring of coastal and river structures.

The multi-disciplinary teams tackle a diversity of technical aspects and site specific problems. Our effective solutions are supported by latest research, expert opinions, numerical tools and results from high-quality laboratory measurements in wave & current flumes and basins. This approach allows us to provide cost-effective solutions while at the same time reducing uncertainties regarding hydraulic loading and structural response.

provinces, municipalities), research institutes, consultants, contractors, private industrial clients, and project developers. The circumstances in our home country, a delta location with large port & lock development projects that is vulnerable to coastal erosion and flooding, results in a close cooperation with Dutch ministries and local authorities. Our strong performance in serving our local clients in The Netherlands ensures the highest level of technology is developed and also made available to our international clients.

Activities

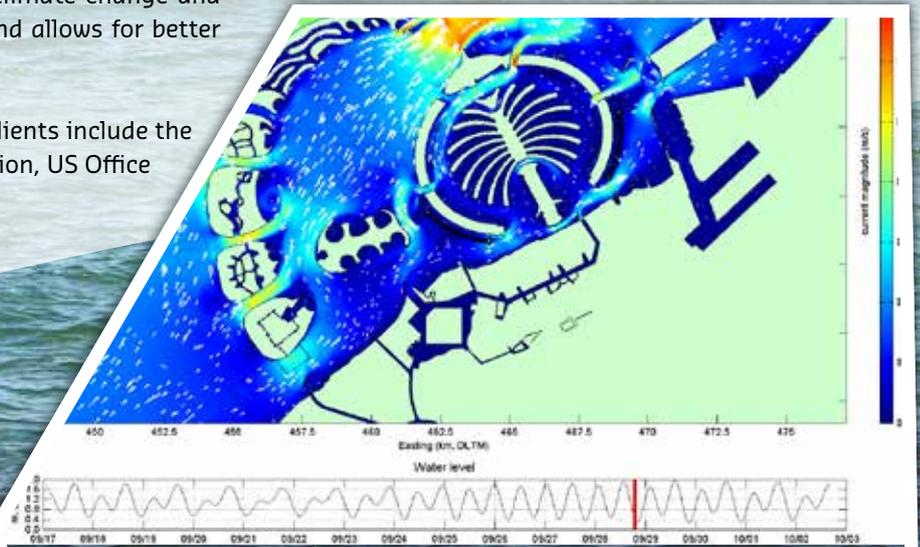
Our activities are focussed on the following subjects:

- **Coastal, river and harbour structures:**
 - breakwaters, piers, jetties, groynes, quays
 - flood barriers
 - dikes and revetments
 - dunes and cobble beaches
 - scour and bed-protections
 - geotubes & geocontainers
 - intake & outfall structures
 - wave energy converters
- **Physical & numerical modelling**
 - hydrodynamics & structural loading
 - wave climate in coastal regions, harbours, lakes and rivers
 - water-soil-structure interaction
 - morphodynamics
- **Risk-based approaches & probabilistic design methods.**
- **Eco(system) engineering & Building with Nature solutions**
- **Measurement & monitoring techniques**

By simultaneously carrying out applied and fundamental research, we directly link the latest technological developments with practical knowhow, which our clients can directly benefit from. Our research is often carried out in close co-operation with private companies, as well as educational and scientific institutes.

The CSW group is dedicated to find sustainable and environmental friendly solutions to its clients needs. A significant part of our research budget is spent on addressing effects of climate change and possible mitigating measures and allows for better risk appraisal.

Our national and international clients include the Commission of the European Union, US Office of Naval Research, governments and local authorities (e.g. ministries,



Multidisciplinary approach

To ensure the best support for our clients the CSW group works closely together with other Deltares expertises on the following topics (for more information it is referred to our website):

- **Harbour layout & navigation**
This includes e.g. port layout, ship navigability & manoeuvring studies, down-time studies, wave penetration into harbours, sedimentation and maintenance dredging, and mooring designs.
- **Geotechnics and soil engineering**
This includes issues of e.g. liquefaction, seismic activity, piping, macro-/microstability around coastal & river structures. Our geotechnical department has its own small and large scale geo facilities and a wide range of geotechnical software.
- **Morphodynamics**
Typical projects address the numerical modeling of coastal processes such as morphodynamics, sediment transport and scour around coastal structures. Numerical models we develop and employ for this purpose are e.g. Unibest, Delft3D and XBeach.
- **Ecology and eco-engineering**
Projects include water and soil quality assessment, environmental friendly & sustainable design and "Building with Nature" solutions.
- **Deltas and rivers**
This includes all subjects related to river engineering, including flood forecasting, river morphology and groundwater control. Typically employed models include SOBEK, WAQUA, FEWS.
- **Intakes and outfalls / flow mechanics**
Intake and outfall structures (e.g. of desalination plants) and pipeline/pump systems are special coastal structures, often protected by breakwaters or rock structures. Their design and stability is typically assessed with numerical models such as OpenFoam, WANDA and CFX/ Star CCM+ or in specific physical scale models.

- **Sluices and locks**
Deltares possesses large knowhow on the design and operation of sluices, locks and gates. Besides specifically designed numerical modelling tools to assess their operation, also physical modelling is employed.
- **Offshore & pipeline structures**
The design of offshore structures and offshore wind farms requires specialized technical knowledge. Typical work includes the assessment of scour protections and its monitoring in the field, the modelling of structural loading (e.g. wave impacts) and structural fatigue, pipeline systems, extend and effect of oil spills.

Monitoring of coastal structures and shorelines

Our state-of-the-art measurement techniques and monitoring tools (<https://www.deltares.nl/en/facilities/>) are used in structural assessments around the world. This includes e.g. the stability of coastal and river structures, the measurement of phreatic line & settlement in dikes, monitoring of shoreline changes & erosion, analysis of satellite and lidar data, wave & current monitoring in the open sea.

Facilities and instrumentation

Deltares has a strong track record regarding physical modelling of coastal and river, harbour, offshore and geo-engineering structures from small to prototype scale based on commercial & research projects throughout the world. To satisfy the needs of our clients we can offer small and large scale modelling facilities (see <https://www.deltares.nl/en/facilities/>), manned by our experienced technical





staff. The physical modelling facilities are suited to model 2D and/or 3D structures, single and multi-phase flows, waves and currents, intake and outfall structures (incl. pump sumps), ecological and soil properties. The facilities are typically used for a wide variety of research/commercial needs, e.g. modelling of morphology, modelling of soil-water-structure interaction (e.g. structural stability, hydrodynamics, scour), ship manoeuvring, and ecological modelling. Modelled structures include e.g. dunes, breakwaters and jetties, dikes & revetments, offshore platforms, intake & outfall structures, sluices & locks, geobags & geocontainers and wave energy converters.

Our modelling facilities are equipped with the latest measurement techniques and instruments, many of which have been developed in-house, to match the increasing demand for accuracy, speed and flexibility in model testing. Instruments are available to measure e.g. flow and wave forces, discharge coefficients, structural displacement and accelerations. Instruments are either mechanical, electro-magnetic, laser (2D and 3D), acoustically, radar or glassfiber based. Photographic methods include standard cameras and camcorders, stereo-photography and high speed cameras / PIV. Deltares continually develops and upgrades its stock of instrumentation (for laboratories and field applications), which is also sold worldwide.

Our coastal facilities are equipped with second-order wave generation and active wave absorption.

A detailed overview of our instrumentation and test facilities it is also available at our website.

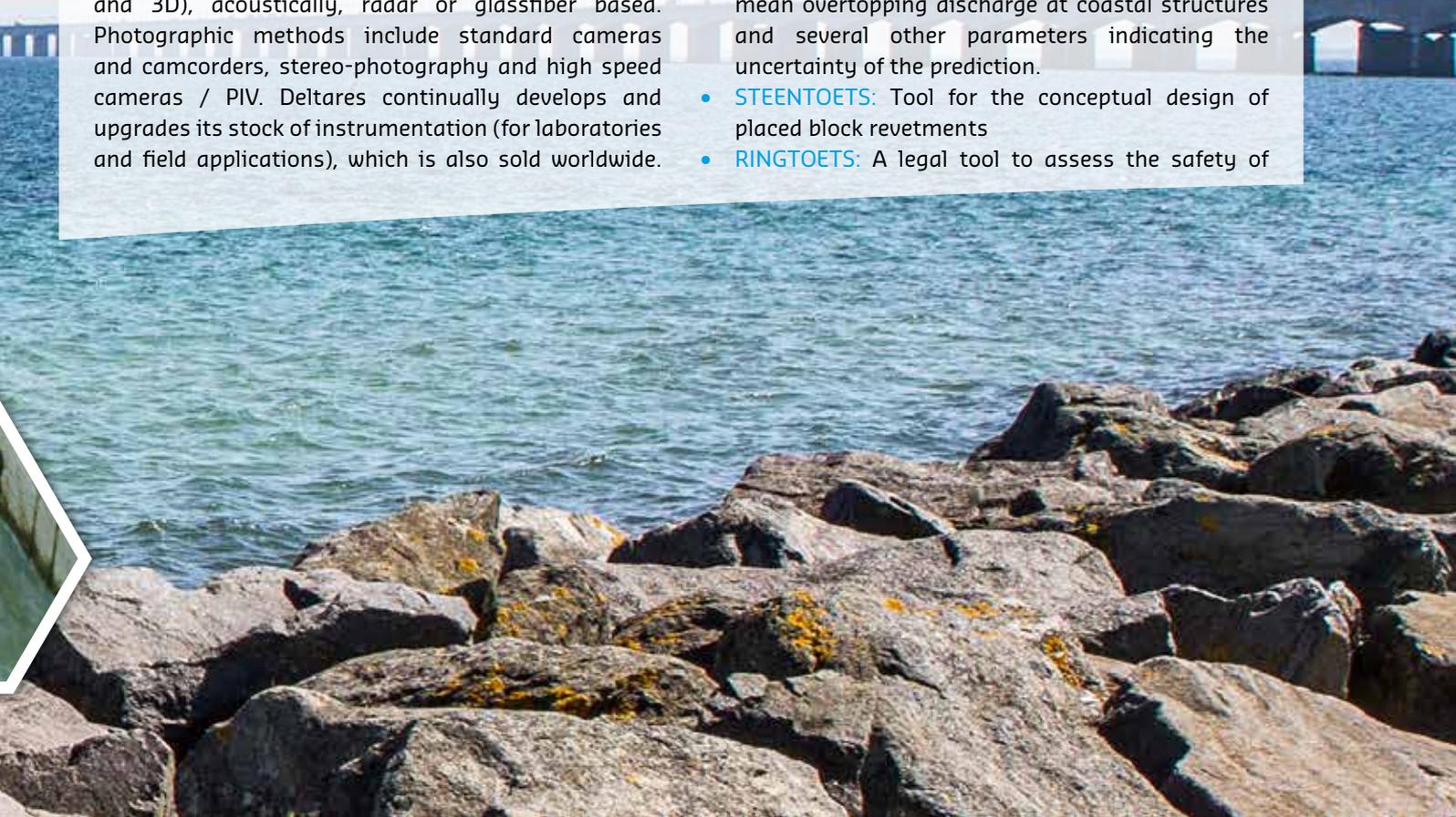
For a cost efficient model set-up we also use our numerical flume facilities, which allow us to model the most significant modelling aspects (e.g. foreshore layout and locations of instrumentation) prior to the start of actual physical modelling.

Software Systems

Deltares develops, operates and maintains a wide range of dedicated software packages, reflecting the specialist knowledge which our institute has built up over many years. Under the name of Deltares Systems our software is used in more than 60 countries around the world. The software encompasses our complete working field, e.g. structural design, hydrodynamics, morphodynamics, geotechnics, flood forecasting and operational water quality management systems, river dynamics, pipeline systems. For more information, it is referred to our website (<https://www.deltares.nl/en/software-solutions/>)

Software packages developed and used by the Coastal structures and waves group are:

- **BREAKWAT:** Tool for the conceptual design of breakwaters. This contains, amongst other aspects, the hydrodynamic performance of coastal structures (e.g. wave run-up, wave overtopping and wave transmission) and the structural performance (e.g. stability of rubble mound structures)
- **Overtopping Neural Network:** Tool to predict the mean overtopping discharge at coastal structures and several other parameters indicating the uncertainty of the prediction.
- **STEENTOETS:** Tool for the conceptual design of placed block revetments
- **RINGTOETS:** A legal tool to assess the safety of



primary flood defences by comparing the hydraulic loads and the resistance of trajectories. As a side product the hydraulic loads, in terms of local water levels and wave conditions, can be computed separately.

- **Wave models:** Suite of wave models for a wide variety of problems related to wave propagation in coastal regions (SWAN and TRITON), wave penetration in harbours (PHAROS and TRITON) and wave interaction with structures (OpenFOAM):
 - DELFT-AUKE: Software for wave generation and wave analysis in coastal research facilities (second-order wave generation with active wave absorption in wave flumes and wave basins)
 - Delft3D-Waves / SWAN: Third-generation wave model that computes random, short-crested wind-generated waves in coastal regions and inland waters.
 - PHAROS: Mild-slope equation model for wave propagation of short- and long waves in harbours
 - TRITON: Time-domain Boussinesq-type wave model for applications in coastal regions and harbours
 - OpenFOAM: CFD model based on the Volume of Fluid (VOF) approach for the numerical modelling of free surface waves including wave impact on structures and porous flow.
 - ORCA: Tool for analysis, classification and transformation of metocean data
- **XBeach:** Numerical model for the calculation of dune erosion and wave overtopping which are important features of coastal safety. The model includes infragravity waves, non-hydrostatic waves, sediment transport, dune avalanching, vegetation and many other relevant physical processes.

- **Morphan:** User Interface for coastal zone managers to assess the state of their coast. The model includes dune safety tools, tool to analyze the development of coastline and sediment volume and tool to analyze the development of the foreshore zone.
- **AeoLiS:** AeoLiS is a process-based model for simulating aeolian sediment transport in (nourished) coastal environments where limitations in sediment supply (e.g. due to moist and shells) are important.
- **DELFT-3D:** for 2D/3D modelling system to investigate hydrodynamics, sediment transport and morphology and water quality for fluvial, estuarine and coastal environments.



Information

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About Deltares

Deltares is an independent institute for applied research in the field of water, subsurface and infrastructure. Throughout the world, we work on smart solutions, innovations and applications for people, environment and society. Our main focus is on deltas, coastal regions and river basins. Managing these densely populated and vulnerable areas is complex, which is why we work closely with governments, businesses, other research institutes and universities at home and abroad.



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