

1D/2D/3D Modelling suite for integral water solutions

DELFT3D FLEXIBLE MESH SUITE

Deltares systems



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Wind, waves and currents shape our coasts. Climate change and rising sea levels add further to this pressure. To enable us to live safely along our shores, we need effective coastal and marine management. Moreover, these coastal processes do not present the only threat. We must also protect ourselves against excess river water, while on the other hand we need that water for transport, irrigation, energy, cooling, recreation, environmental protection and as a source of drinking water. Consequently, design and management procedures become more complex and require an integrated approach. In response to this challenge, Deltares has developed a powerful modelling suite called Delft3D Flexible Mesh (Delft3D FM), focusing primarily on coastal, estuarine, river and urban environments.

GENERAL

The Delft3D Flexible Mesh (Delft3D FM) Suite is the successor of the structured Delft3D 4.xx Suite. Like Delft3D 4.xx, the Delft3D FM Suite can simulate storm surges, hurricanes, tsunamis, detailed flows and water levels, waves, sediment transport and morphology, water quality and ecology, and is capable of handling the interactions between these processes. The suite is designed for use by domain experts and non-experts alike, which may range from consultants and engineers or contractors, to regulators and government officials, all of whom are active in one or more of the stages of the design, implementation and management cycle.

Within the Delft-FEWS operational framework, Delft3D FM can offer 24/7 forecasts. Forecasts, predictions and uncertainties can easily be visualized on dedicated websites, using the Delta Viewer technology. Designed for policymakers, Delft3D FM is available on a Touch Table for interactive modelling with all the stakeholders.

The key component of Delft3D FM is the D-Flow Flexible Mesh (D-Flow FM) engine for hydrodynamical simulations on unstructured grids in 1D-2D-3D. D-Flow FM is the successor of Delft3D-FLOW and SOBEK-FLOW. It is the result of five years of research funded by Deltares and the Dutch Ministry of Infrastructure and Environment.

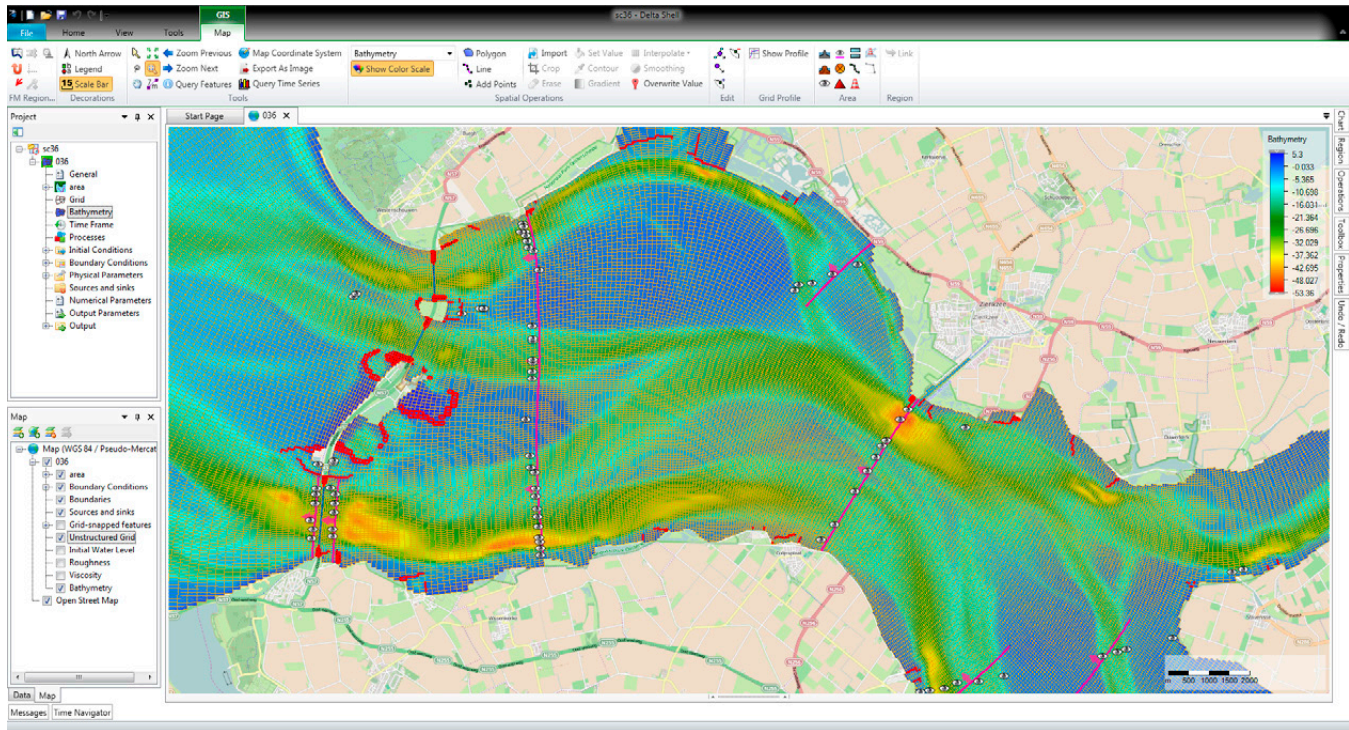
Some areas of applications

- Tide and wind-driven flow;
- Drying and flooding of inter-tidal flats;
- Density driven flow due to density gradients of non-uniform temperature and salinity concentration distributions;
- Horizontal transport of matter on large and small scales;
- Hydrodynamic impact of engineering works such as land reclamation, breakwaters and dikes;
- Thermal recirculation of cooling water discharges from a power plant.

Features

Some of the typical key features of Delft3D FM are:

- the suite gives direct access to state-of-the-art process knowledge, accumulated and developed at one of the world's most renowned hydraulic institutes;
- the Graphical User Interface (GUI) is one of the most user-friendly in the market:
 - Central map with spatial editor
 - Customizable and dockable window views
 - Connectivity to online data bases
 - Batch running through Python scripting interfaces
- all modules show a high degree of integration and interoperability.



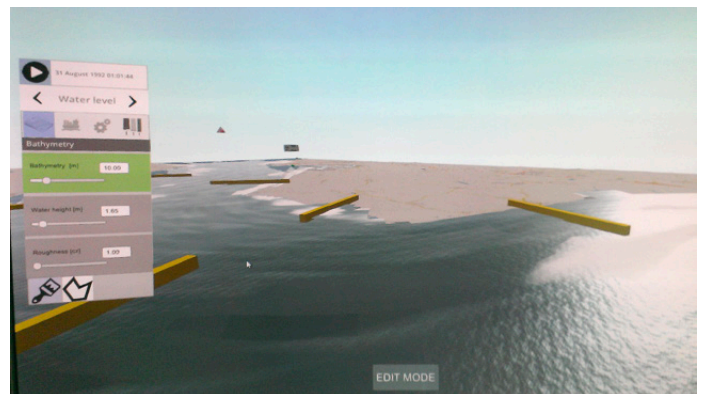
Delft3D Flexible Mesh - Eastern Scheldt (Scaaloost)

MODULES

Delft3D FM allows you to simulate the interaction of water, sediment, ecology, and water quality in time and space. The suite is mostly used for the modelling of natural environments like coastal, estuarine, lakes and river areas, but it is equally suitable for more artificial environments like harbours, locks, urban areas, etc. Delft3D FM consists of a number of well-tested and validated modules, which are linked to and integrated with each other. These modules are further described separately hereafter.

D-FLOW FLEXIBLE MESH

Like Delft3D-FLOW, D-Flow FM is capable of handling curvilinear grids that provide very good performance in terms of computational speed and accuracy. In addition to this, the grid may also consist of triangles, quads, pentagons and hexagons. This provides optimal modelling flexibility and ease in setting up new model grids or modifying existing ones, or locally increasing resolution. 1D- and 2D grids can be combined, either connecting adjacent grids or a 1D grid overlying a 2D grid. Both Cartesian and spherical coordinate systems are supported. This facilitates tidal computations on the globe with tide generating forces, thus without imposing open boundary conditions. The grid generation tool RGFRID includes new grid generation algorithms for the construction of orthogonal unstructured grids.



Delft3D Flexible Mesh - 3D interactive modelling - Western Scheldt

Flow solver

D-Flow FM implements a finite volume solver on a staggered unstructured grid. The higher-order advection treatment and near-momentum conservation make the solver very suitable for supercritical flows, bores and dam breaks. The handling of wetting-and-drying makes it suitable for flooding computations. The continuity equation is solved implicitly for all points in a single combined system. Optionally, non-linear iteration can be applied for very accurate flooding results. Furthermore, Coriolis



forcing, horizontal eddy viscosity, tide generating forces and meteorological forcings were added, making the system suitable for tidal, estuarine or river computations.

For three-dimensional modelling, three turbulence models are available: algebraic, k-epsilon and k-tau. Vertical transport can be solved both explicitly and implicitly. First sigma layers were implemented, with the anti-creep option based upon the Delft3D-FLOW algorithm. Fixed z-layers are also available, and z- and sigma-layers can be combined in one single model domain, but this is still ongoing research. Temperature modelling is supported either using the composite heat flux model or the excess heat flux model, which can both be driven by space-and-time varying meteorological datasets.

Time integration is done explicitly for part of the advection term, and the resulting dynamic time-step limitation is automatically set based on the Courant criterium. The possible performance penalty can often be remedied by refining and coarsening the computational grid at the right locations.

Parallelization

D-Flow FM models can be run as parallel computations on distributed-memory high-performance computing clusters. The parallel version is based on the familiar MPI standard, and partitioning of the model domain can be done automatically

by the (included) METIS-partitioner, and/or defined by the user. Parallel computing is functional both on Windows and Linux. On Linux the PETSc matrix solver library can be coupled, and this is the preferred way for good performance.

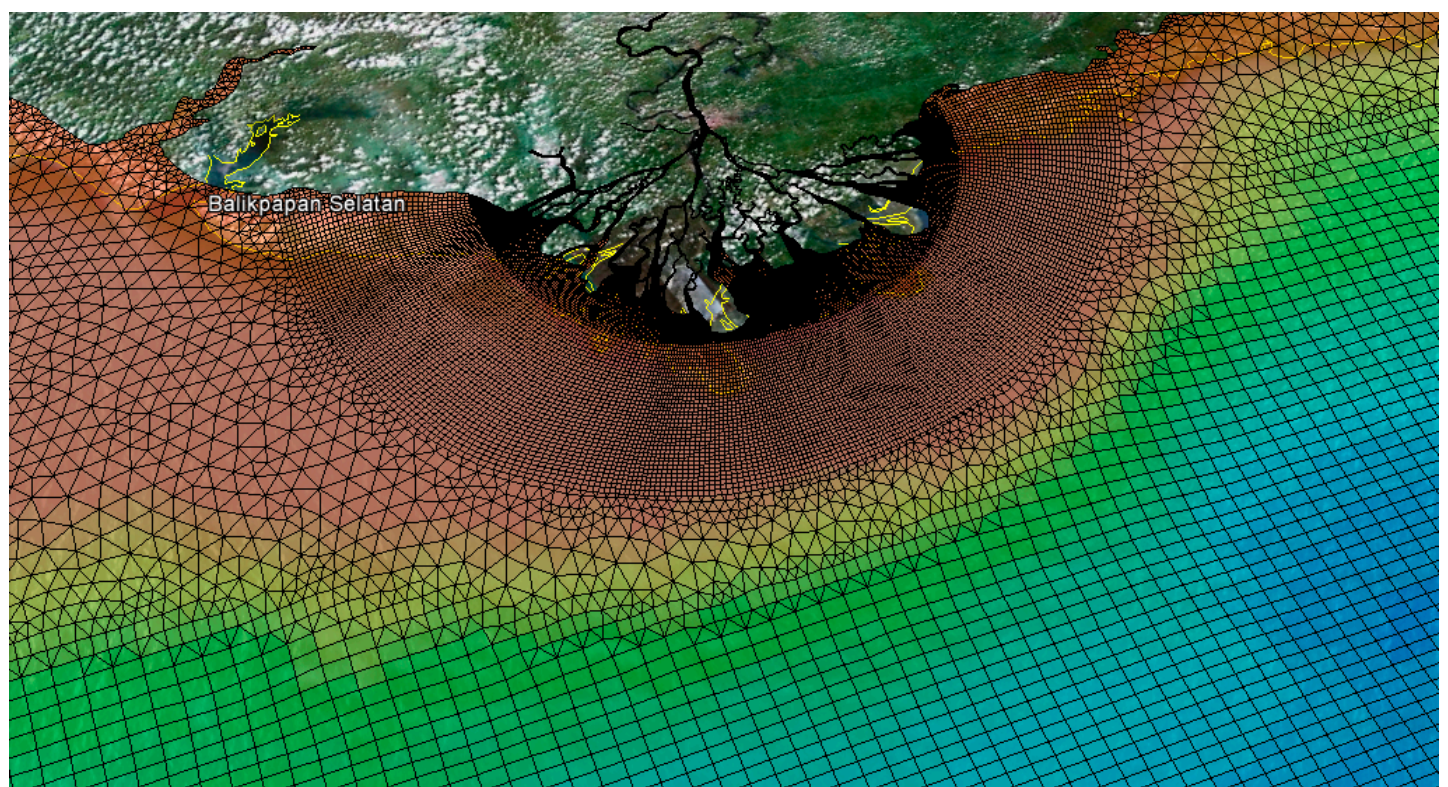
On single machines with multi-core processors speedup can also be achieved by D-Flow FM's built-in OpenMP-multithreading option, which is the default setting.

D-WAVES

D-Waves computes the non-steady propagation of short-crested waves over an uneven bottom, considering wind action, energy dissipation due to bottom friction, wave breaking, refraction (due to bottom topography, water levels and flow fields), shoaling and directional spreading. The module is based on the spectral model SWAN. This model is a development of the Delft University of Technology, which is a close partner of Deltares in a number of research fields. For many decades, both institutes have been prominent in the field of wave modelling.

D-REAL TIME CONTROL

Real time control often saves money in the construction, alteration and management of the water system infrastructure. The D-Real Time Control module shows to what extent the



existing infrastructure can be used in a better way. It allows you to simulate complex real-time control of all hydraulic structures in reservoirs and estuarine, river and canals systems. This module allows the system to react optimally to actual water levels, discharges and (forecasted) rainfall, by controlling gates, weirs, sluices and pumps. The D-Real Time Control module, using the open source RTC-Tools engine, can be coupled for controlling of hydraulic structures with various triggering mechanisms, also for parallel models if needed.

D-WATER QUALITY

This module simulates the far- and mid-field water and sediment quality due to a variety of transport and water quality processes. To accommodate these, it includes several advection diffusion solvers and an extensive library of standardised process formulations with the user-selected substances. Default processes allow you to simulate for instance the decay of BOD and nitrification, elementary growth of algae and nutrient cycling, exchange of substances with the atmosphere, adsorption and desorption of contaminant substances and the deposition and re-suspension of particles and adsorbed substances to and from the bed. Deltares' unsurpassed level of knowledge in the field of water quality is made available to the professional world by means of this module. The D-Water Quality module is also available as add-on for TELEMAC users. D-Water Quality is including the D-Water Quality Open Processes Library. This is an open system to define additional substances, processes acting on new and existing substances, additional coefficients to be used in the formulae, the external forcing and auxiliary output. For grid aggregation we offer a powerful tool called DIDO.

D-SEDIMENT TRANSPORT

This sub-module of D-Water Quality simulates the transport, erosion and settling of cohesive and non-cohesive, organic or inorganic, suspended or bed sediments. The module includes several standard transport formulae and considers different particulate fractions independently. The effect of changes in bottom topography is neglected, so that only short-term transport can be assessed. As sediment is a dominating factor in water quality and ecology studies, the inclusion of Deltares' leading edge knowledge of sedimentation and silt transport processes makes this module the vital base tool for a large range of environmental studies.

D-ECOLOGY

A variety of algae growth and nutrient dynamics models have been incorporated into this sub-module of D-Water Quality. For instance, models describing the governing processes of biotic and abiotic ecosystems and the interaction between these have been

inserted into the process library, all of which are relevant to the study of eutrophication phenomena. This sub-module includes all algae connected water quality processes considered in the D-Water Quality module plus a variety of more detailed processes.

D-PARTICLE TRACKING

This short-term, near-field water quality module estimates the dynamic, spatial (on a sub-grid scale) concentration distribution of individual particles by following their tracks in time. The waste substances may be conservative or subject to a process of simple, first order decay; a typical application is oil spill modelling. The module is also used for near-field fate simulations of dredging spillage.

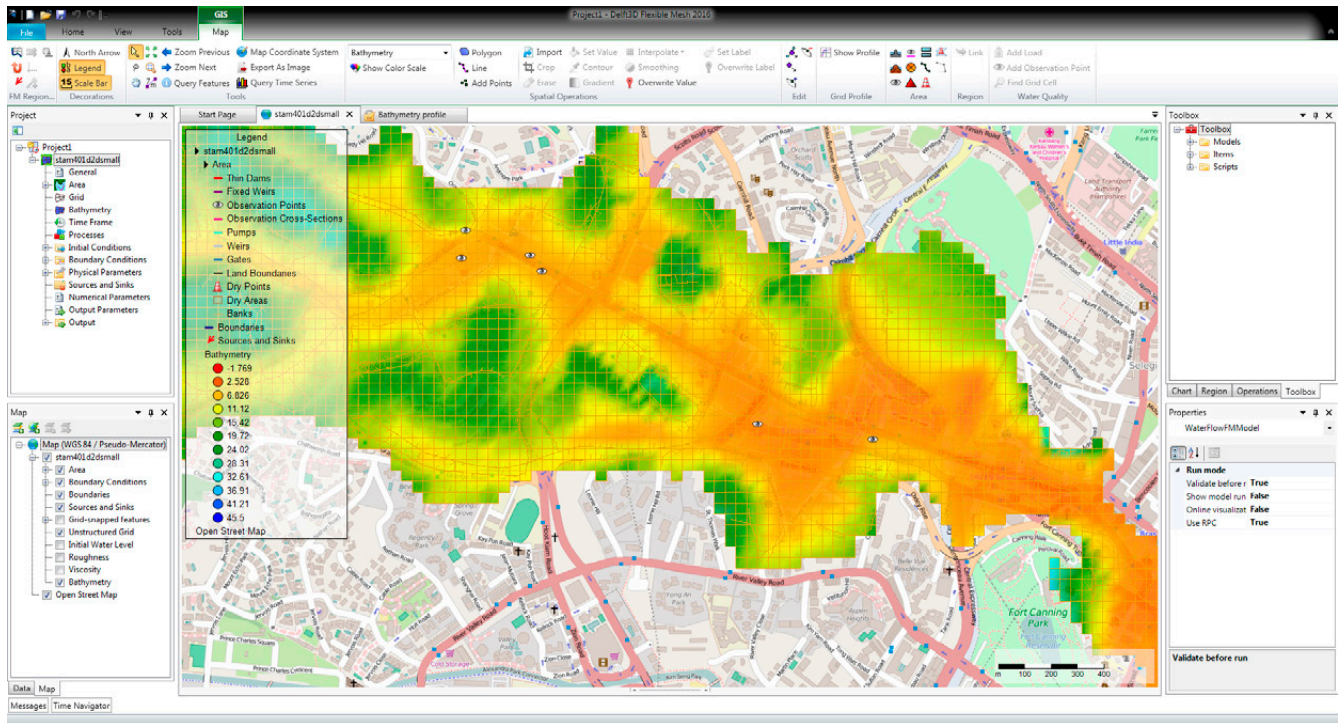
This module is not yet available in Delft3D FM, only in the Delft3D 4.xx Suite. For our beta testing programme, please contact sales@deltaressystem.nl

D-MORPHOLOGY

This module computes sediment transport (both suspended and bed total load) and morphological changes for an arbitrary number of cohesive and non-cohesive fractions. Both currents



Slufter, The Netherlands



Delft3D Flexible Mesh - Singapore - Urban catchment - 1D2D flooding

and waves act as driving forces and a wide variety of transport formulae have been incorporated. For the suspended load this module connects to the 2D or 3D advection-diffusion solver of the D-Flow FM module; density effects may be taken into account.

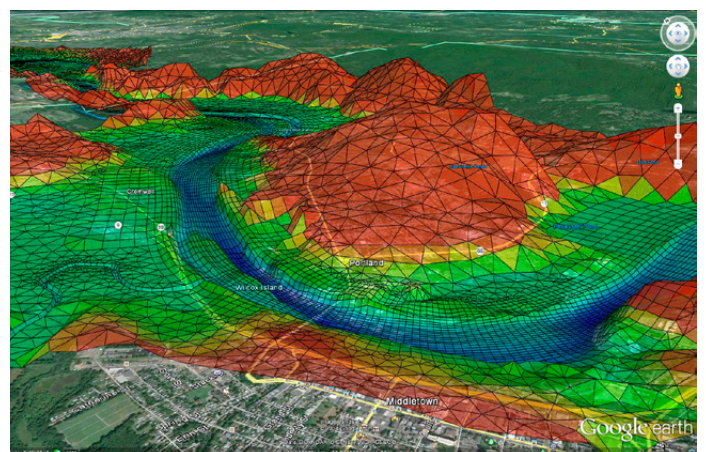
An essential feature of this module is the dynamic feedback with the D-Flow FM and D-Waves modules, which allow the flows and waves to adjust themselves to the local bathymetry and allows for simulations on any time scale from days (storm impact) to centuries (system dynamics). It can keep track of the bed composition and thus build up a stratigraphic record. The module includes extensive features to simulate dredging and dumping scenarios. For over 30 years, Deltares has been at the forefront in the development of this type of combined morphological simulation techniques.

This module is not yet available in Delft3D FM, only in the Delft3D 4.xx Suite. For our beta testing programme, please contact sales@deltaresystems.nl

GRAPHICAL USER INTERFACE

The Delft3D FM Graphical User Interface (GUI) is based on the Delta Shell Framework and is one of the most user-friendly in the market. Under the umbrella of this GUI, the modules combine to form an exceptionally versatile, powerful and easy-to-use suite. The GUI allows for complete model construction starting

from zero, or by importing existing models or data from external databases such as boundary conditions from the Topex-Poseidon database. It supports the visualization of model input, reference data and simulation results as time series and animations of 1D, 2D and 3D data sets. The user can also gather a wide, overhead perspective of his entire system or, by contrast, zoom in on a site of particular relevance or difficulty. Delft3D FM is open to various data visualizations. One of the most powerful tools is the option to export data to Google Earth through Python scripting.



Delft3D Flexible Mesh and OpenEarthTools - Connecticut river - USA

VALIDATION

The validation of a modelling system such as Delft3D FM requires continuous attention. Even though the individual modules of the suite have been thoroughly tested during their development and maintenance, the suite as a whole requires intensive testing and also validation. To this end, a regular programme has been established and tests of many of the most likely combinations are continually performed. As a policy, new versions are released only after an extensive beta testing period, to ensure that our users are provided with stable and validated products.

SYSTEM REQUIREMENTS

Delft3D FM is supported on both Microsoft Windows and Linux. The advised minimum requirements:

	Minimal	Preferred
Processor	1 GHz	2 GHz
Memory	1 GB	4 GB
Disk free	1 GB	100 GB

SERVICE PACKAGES

Deltares offers high quality services to consultancy firms, governmental organizations, universities and research institutes worldwide.

Several Delft3D service packages, including fully validated high quality Delft3D FM distributions, are available to suit your specific needs:

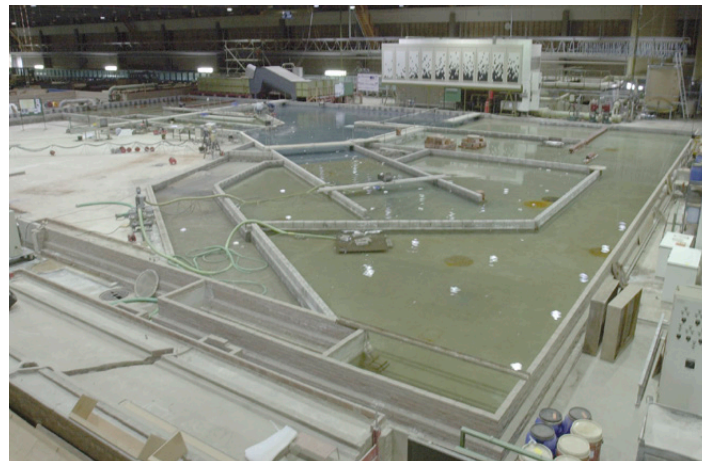
- For consultancy firms, governmental organizations and research institutes worldwide, we have designed our
 - Basic Service Packages,
 - Advanced Service Packages,
 - Professional Service Package,
 - Premium Service Package and
 - Enterprise Service Package.
- For universities and schools, we offer our Education Service Package.
- Code developers are supported with our Developer Service Package.

Designed with you in mind, they offer you your requested level of convenience.

As long as not all anticipated functionality of the Delft3D 4.xx Suite is included in the Delft3D FM Suite, we will include both:

1. the fully validated Delft3D FM Suite and
2. the Delft3D 4.xx Suite

in the above Delft3D Service Packages.



Scale experiments for model validation

USER MEETINGS

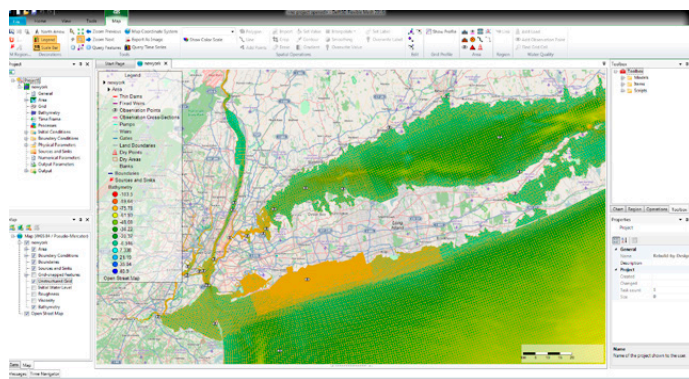
Deltares organizes the annual international Delft3D user meeting during the Delft Software Days (www.dsd-int.nl). Several smaller Delft3D user meetings are organized at international conferences worldwide. These are excellent venues for receiving updates on the latest developments and for meeting other Delft3D users.

DELTAES ACADEMY

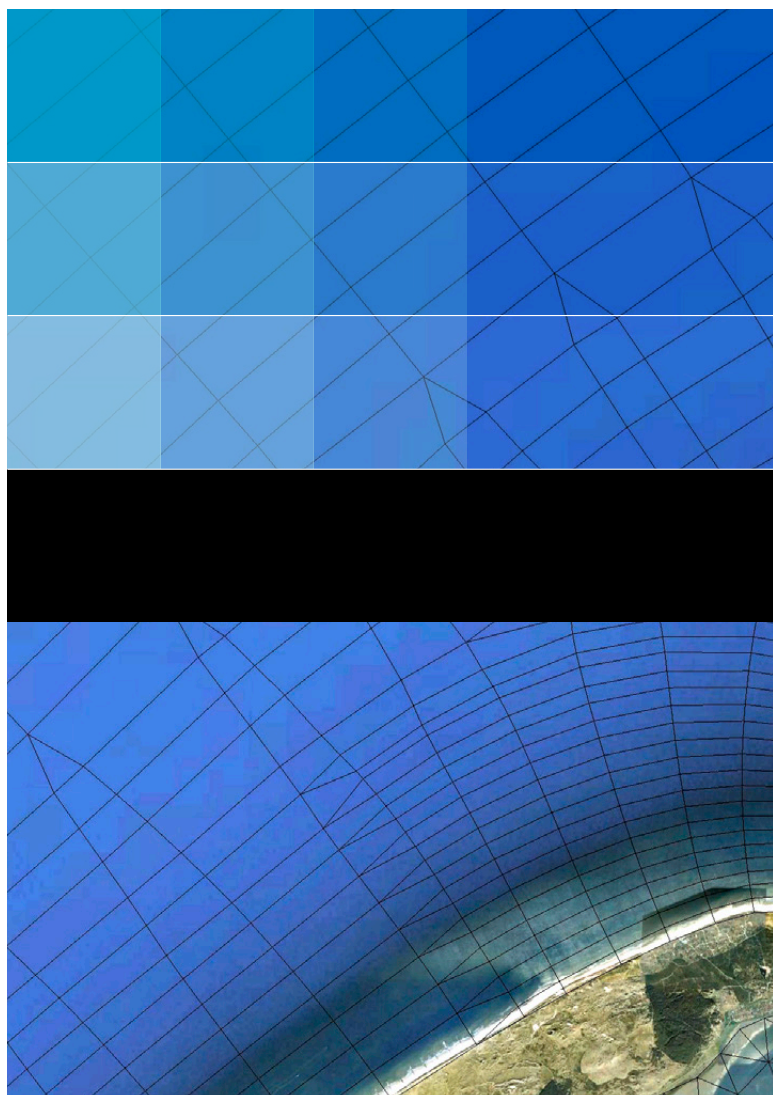
Please visit the www.deltaresacademy.com for all information about our Delft3D training courses.

DELFT3D IN OPEN SOURCE

Delft3D is Open Source Software. To enhance collaboration, to combine the unique expertise of researchers worldwide and to further expand the modelling suite, the source code can be downloaded. For more information, please visit our Deltares open source community portal (<http://oss.deltares.nl/>) or the Delft3D open source website (<http://oss.delft3d.nl/>) directly. More than 10,000 software developers and users worldwide have daily access to the source code.



Delft3D Flexible Mesh - Rebuild by Design - New York - Long Island



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