MIKE

Powered by DHI

MIKE Zero

Project Oriented Water Modelling

Step-by-step training guide

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1 Introduction

This Step-by-step training guide relates to the fixed link across the Sound (Øresund) between Denmark and Sweden.

Figure 1.1 Øresund, Denmark

1.1 Background

In 1994 the construction of a fixed link between Copenhagen (Denmark) and Malmö (Sweden) as a combined tunnel, bridge and reclamation project commenced. Severe environmental constraints were enforced to ensure that the environment of the Baltic Sea will remain unaffected by the link. These constraints implied that the blocking of the uncompensated design of the link should be down to 0.5 %, and similarly, maximum spillage and dredging volumes were enforced. To meet the environmental constraints and to monitor the construction work, a major monitoring programme was set up. The monitoring programme included more than 40 hydrographic stations collecting water level, salinity, temperature and current data. In addition, intensive field campaigns were conducted to supplement the fixed stations with ship-based ADCP measurements and CTD profiles. The baseline monitoring programme was launched in 1992 and continued into this century.

By virtue of the natural hydrographic variability in Øresund, the blocking of the link can only be assessed by means of a numerical model.

Amongst the comprehensive data sets from the monitoring programme, which form a unique basis for modelling, a three-month period was selected as 'design' period, such that it reflected the natural variability of Øresund. The design period was used in the detailed planning and optimisation of the link, and to define the compensation dredging volumes, which were required to reach a so-called Zero solution.

1.2   Objective

The objective of this Step-by-step training guide is to create and use a MIKE Zero Project in aid of the process of creating a numerical model investigation from scratch and to the final report is presented.

Attempts have been made to make this exercise as realistic as possible although some short cuts have been made with respect to the data input and numerical simulation. This mainly relates to quality assurance, pre-processing of raw data to bring it into a format readily accepted by the MIKE Zero software and the actual numerical modelling setup considerations.

Depending on the amount and quality of the original data sets this can be a tedious, time consuming but indispensable process. For this example guide the 'raw' data has been provided as standard ASCII text files.

The files used in this Step-by-step training guide are a part of the installation. You can install the examples from the MIKE Zero start page.

Please note that all future references made in this Step-by-step guide to files in the examples are made relative to the main folders holding the examples.

User Guides and Manuals can be accessed via the MIKE Zero Documentation Index in the start menu.

The actual work with importing raw data into MIKE Zero format files and setting up the numerical model are described in the Step-by-step training guide for MIKE 21 Hydrodynamic model (HD), which can be accessed via the MIKE Zero Documentation Index in the start menu:

MIKE 21 Flow Model, Hydrodynamic Module, Step-by-Step Training Guide

You do not have to generate all the MIKE Zero input parameters yourself from the included raw data. All the MIKE Zero input parameter files needed to start the numerical simulation are included.

2 Creating a Project File

2.1 The Role of MIKE Zero Project in this Example

MIKE Zero enhances the ability to control and organise information related to almost all kinds of engineering studies including model simulations.

A MIKE Zero project is a collection of files, positioned in one or several folders recursively under a folder where the overall project file is positioned. To help setting up the structure, MIKE Zero comes with a pre-defined project template that provides a good overview for the various files included and necessary to complete the investigation. For example, a DHI project will typically hold separate folders for measured data, model input, model results and documentation, respectively. You may modify the template as desired, for instance by deleting folders or adding new folders.

The logical organisation of the project folders helps streamline the work by adding informative, intuitive and helpful features.

2.2 Template Description

In an investigation of the impact of a fixed link between Denmark and Sweden one of the first tasks is to establish a model that can simulate the hydrodynamic flow field in the Øresund Area. It is this task we will focus on in the present example.

The main folders in the 'General' template are

- External Data
- Final Report
- Model
- Project Documents
- Results

The Project Documents folder has been designed to store data concerning the administration of the project, e.g. Client communication, minutes of meetings, photographs, presentations and status reports. This folder structure (with added files) will normally be active throughout the entire timeframe of the investigation.

The External Data folder has been designed to contain data such as bathymetry, measurements and other external data that provide the basis of the input parameters and data for calibration purposes, focusing on hydrodynamic modelling. This folder structure will normally just be active in the beginning of the investigation.

The project will be modified to include yet another main folder, i.e. Model Analysis.

The Model folder, Result folder and Model Analysis folders are designed to co-exist, such that the model setups and model inputs are saved in the Model folder, the simulation results are saved in the Results folder and the analysis of the results are created and processed using the Model Analysis folder. These folders will be used during and after the numerical model simulations, thus covering both the calibration phase and production phase.

New project subfolders will be created to support a hydrodynamic simulation, i.e. folder names such as Bathymetry and Boundary indicate that these data are needed to perform a simulation.

In the end the final report can be written and saved in the Final Report folder.

2.3 Creating the Project File

To create a new project file, open the MIKE Zero shell and click File->New->Project… to open the New Project Dialog, see Figure 2.1.
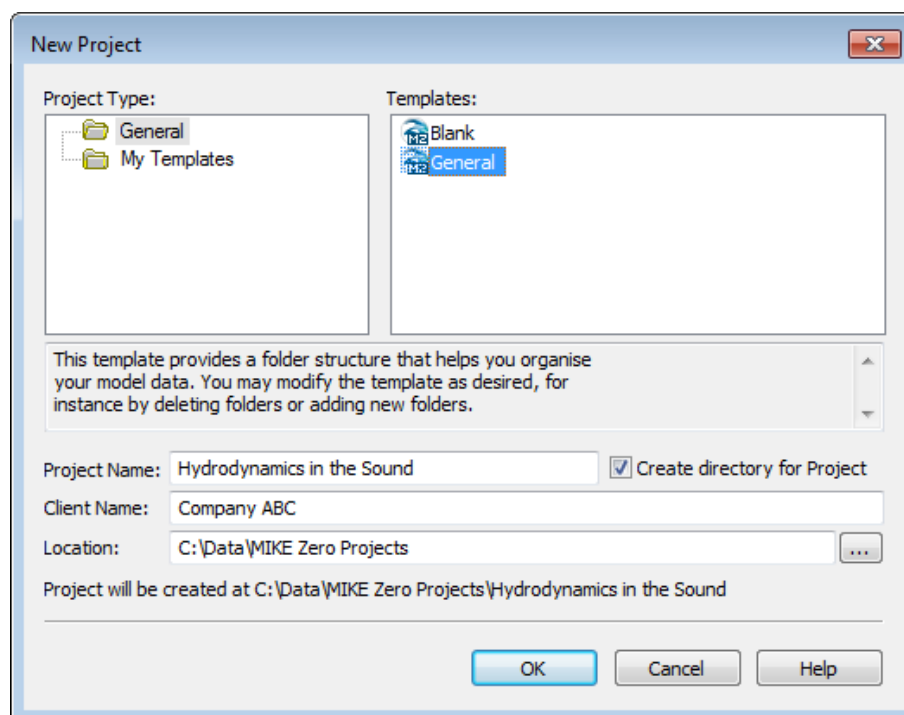

Figure 2.1   Creating a new MIKE Zero project file

In the New Project dialog, select 'General' as Project Type, and choose the template 'General' that contains a pre-defined folder structure.

You can specify the Project Name and Location of the project file anyway you like.

The selected project template will now automatically create folders, which will help organise future data files that are used in the project, see Figure 2.2.

It is the intention that all files created and used in the investigation will be located in these folders. Additional folders and subfolders can be created during the following data processing if necessary.
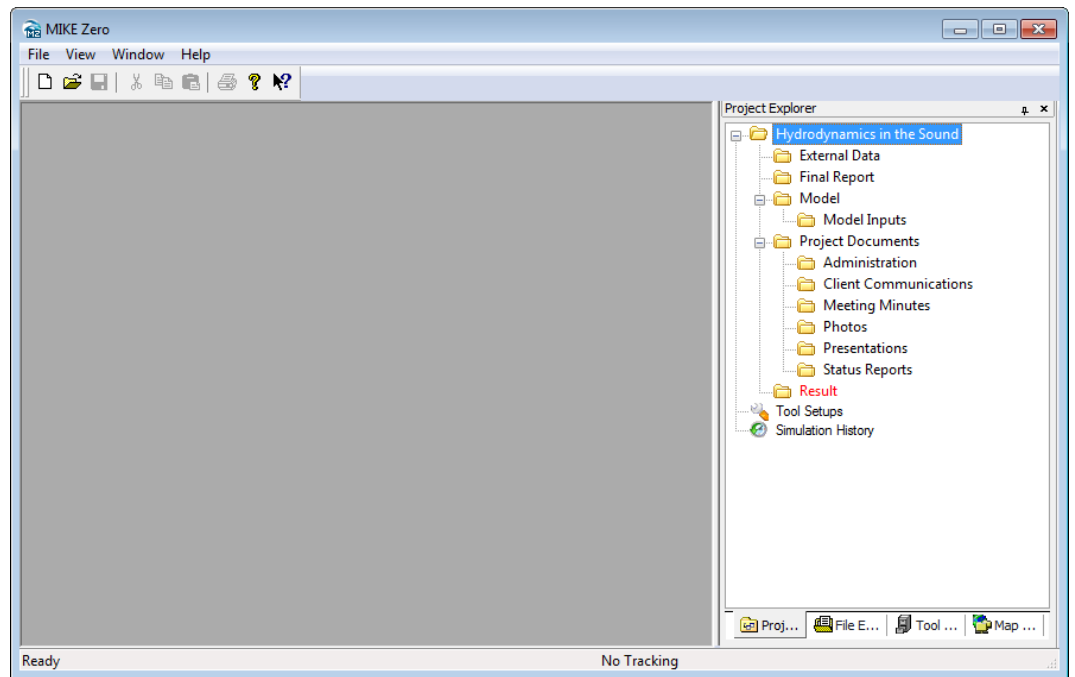
Figure 2.2   Project Explorer view showing new folders

3 Processing External Data

Before you set up the model you must process the available data. This applies to descriptive data, such as maps and photographs, as well as data needed to carry out a hydrodynamic investigation. The latter are typically bathymetry data and measurements of water levels, flow velocities or wind data.

In this example, the available data are located in the following folder:

.\MIKE_Zero\Projects\Oresund\External Data

3.1 Bathymetry Data

The data concerning the bathymetry of the area should be located in the folder Bathymetry Data, which is a subfolder to the main folder External Data. This example includes a rectified map (2 files) and some bathymetry data (3 xyz files).

Select the folder External Data in the Project Explorer in MIKE Zero. Right-click and select 'Add Folder…', see Figure 3.1.
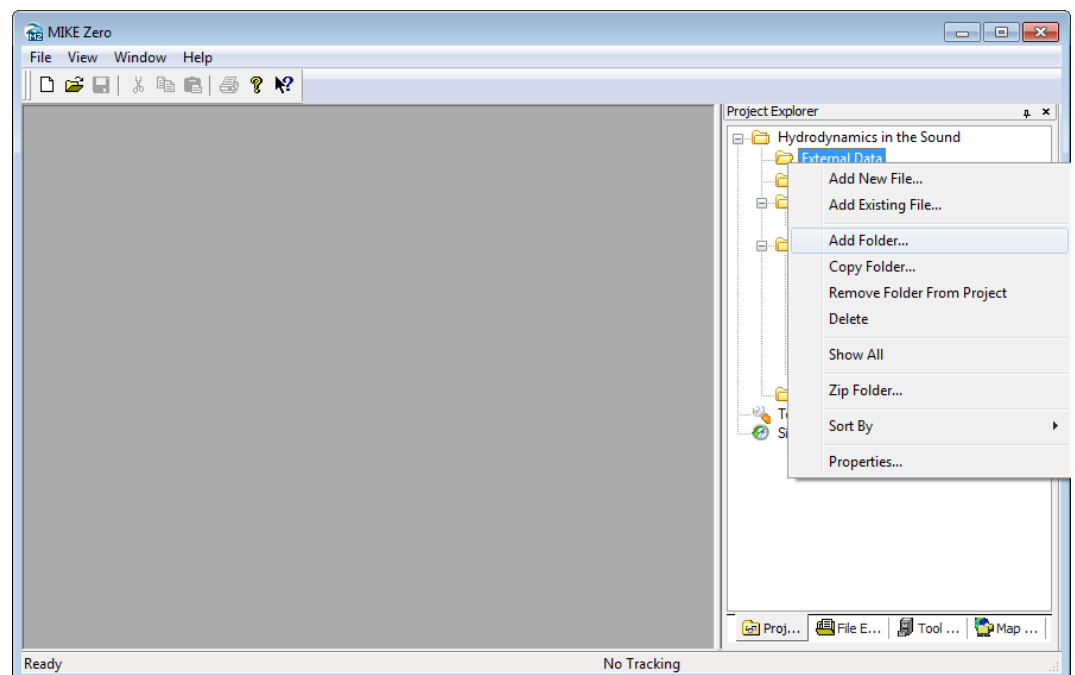

Figure 3.1   Add folder to project

In the New Folder dialog specify the folder name 'Bathymetry Data' and press OK, see Figure 3.2.
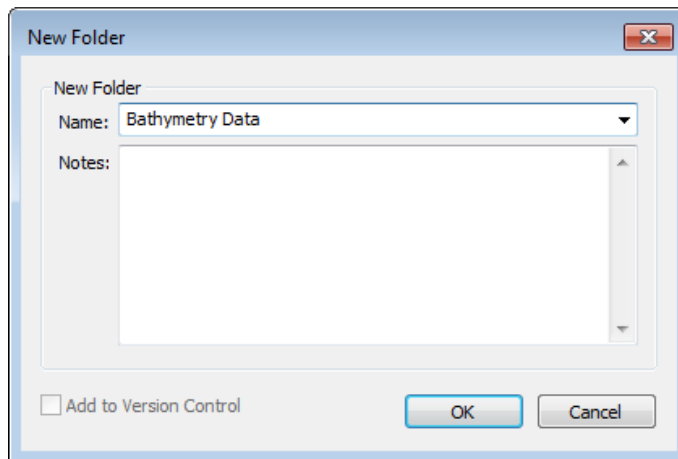
Figure 3.2   Specify name of new folder

Now select the new folder Bathymetry Data in the Project Explorer in MIKE Zero. Right-click and select 'Add Existing File…', see Figure 3.3.
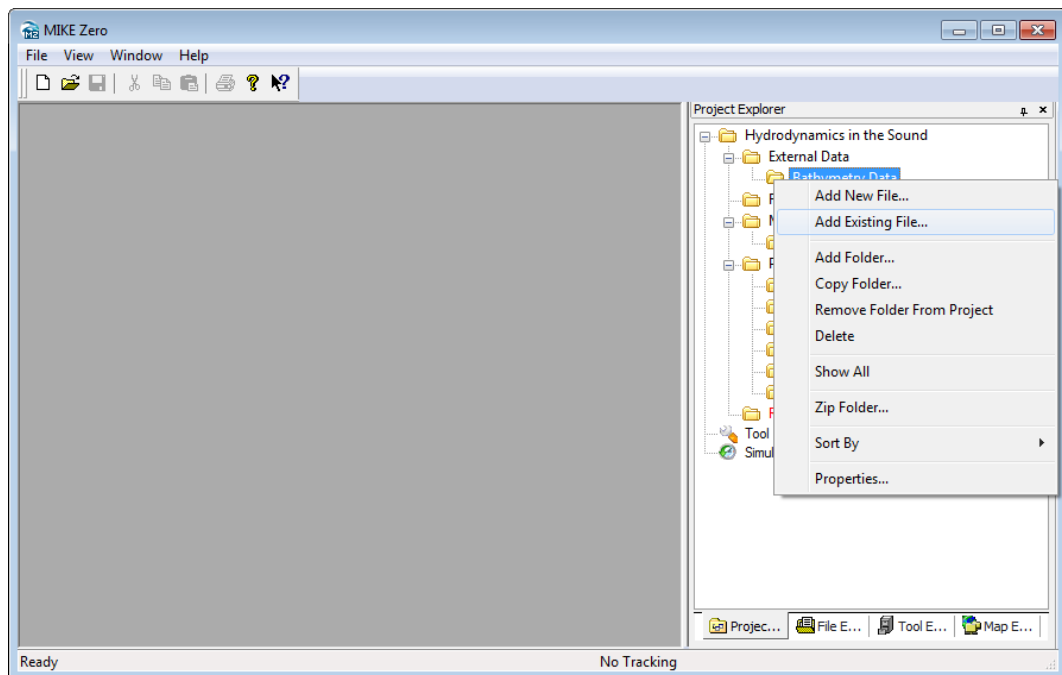

Figure 3.3   Add existing file to project

In the Add Existing File dialog select the file 'map.gif' in the Bathymetry Data folder and enable the 'Make copy' option in the dialog, see Figure 3.4.
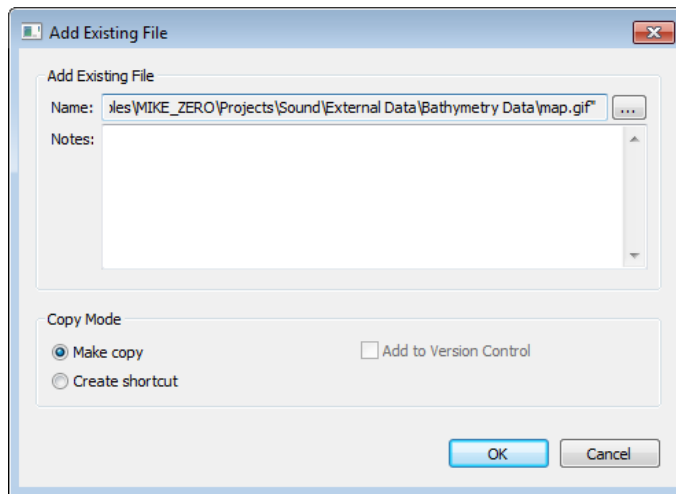
Figure 3.4   Select file to copy into the project

This will copy the file into the project folder on the hard disk and insert the file name in the project file.

Repeat the process to add the remaining files in the Bathymetry Data folder to the project folder. Now the Project Explorer should look like shown in Figure 3.5.
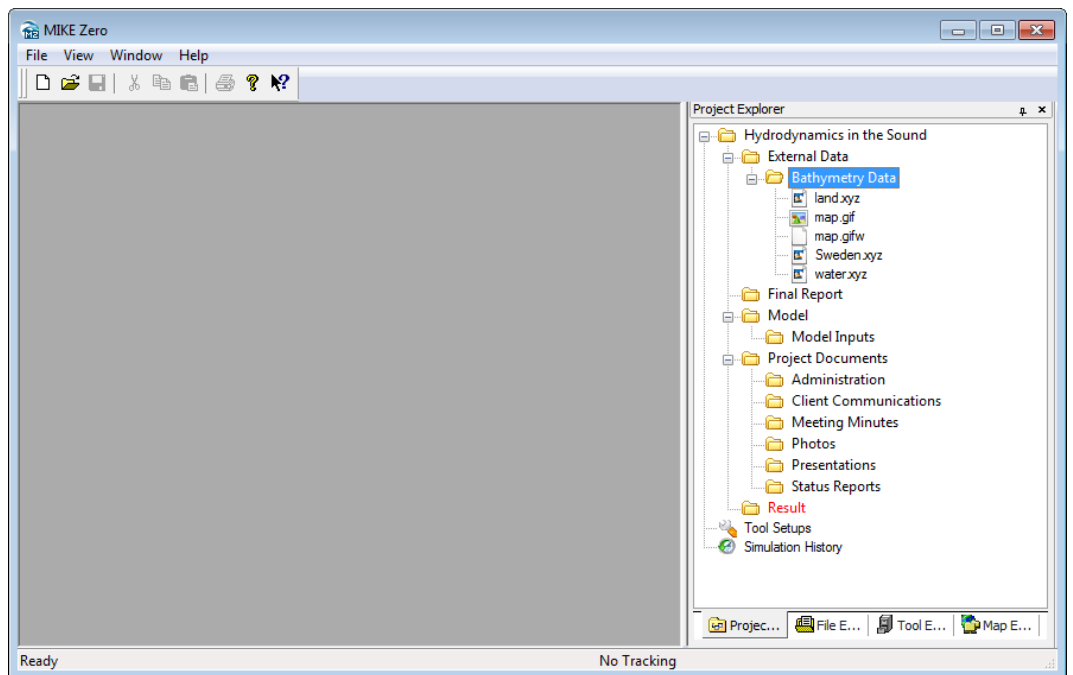

Figure 3.5   Imported external bathymetry data

3.2   Measurements

Extensive measurements of water levels, flow velocities and wind conditions were carried out before, during and after the planning phase of the fixed link between Denmark and Sweden. Some of these data form the basis of the simulation.

Create a new Measurements subfolder in the folder External Data and add the txt files that contain data measurements of water level, current data and wind conditions (in a similar way as in the bathymetry data example). Enable the 'Make copy' option on the Add Existing File dialog to copy the files into the project folder on the hard disk.

Continue by adding the file 'Positions.txt', which contains the positions of the measurements stations.

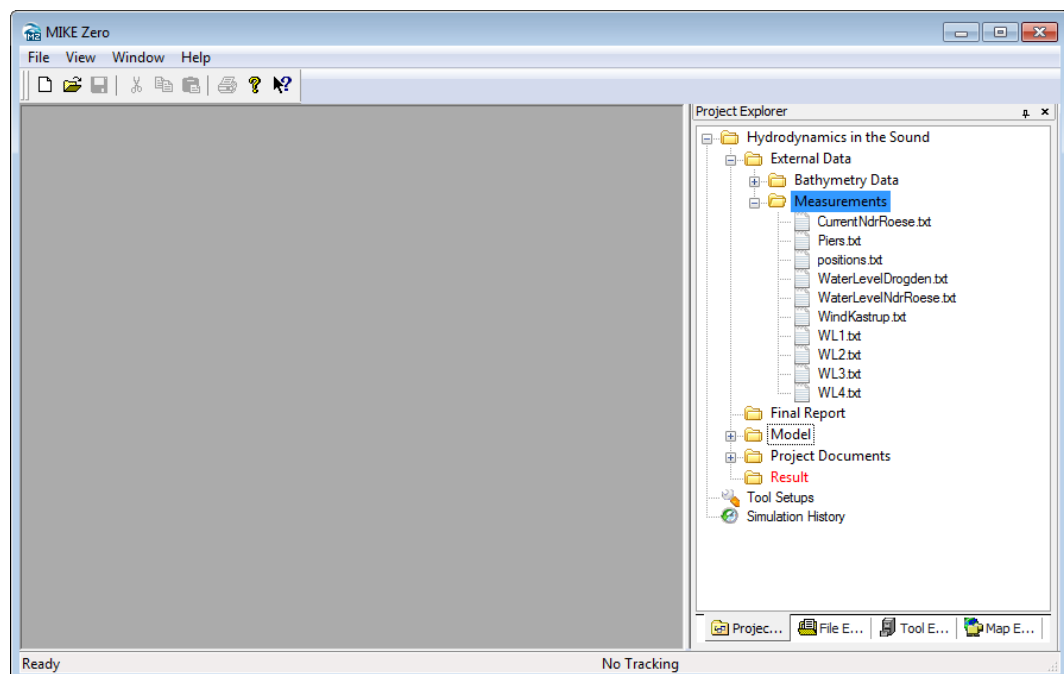Now the Project Explorer should look like illustrated in Figure 3.6.

Figure 3.6   Imported measurements data

4 Setting Up the Model

Before you can form a complete hydrodynamic setup you need to create a numerical bathymetry setup and some boundary conditions that can make the water move.

The input data files required for the model simulations are stored in a subfolder under Model called Model Inputs.

4.1 Create Bathymetry

The setup of a bathymetry is created by importing geographical data with soundings based on a survey or digitised data from nautical charts. The bathymetry in this example is created on basis of the bathymetry xyz files already contained in the External Data Bathymetry data folder.

The files created during the generation of the bathymetry will be stored in the Bathymetry folder, which is a subfolder of the Model Inputs folder.

To create a new bathymetry setup, select the Bathymetry folder and by right-clicking the mouse select 'Add New File…' and choose to create a Bathymetries (.batsf) document under MIKE Zero (see Figure 4.1).
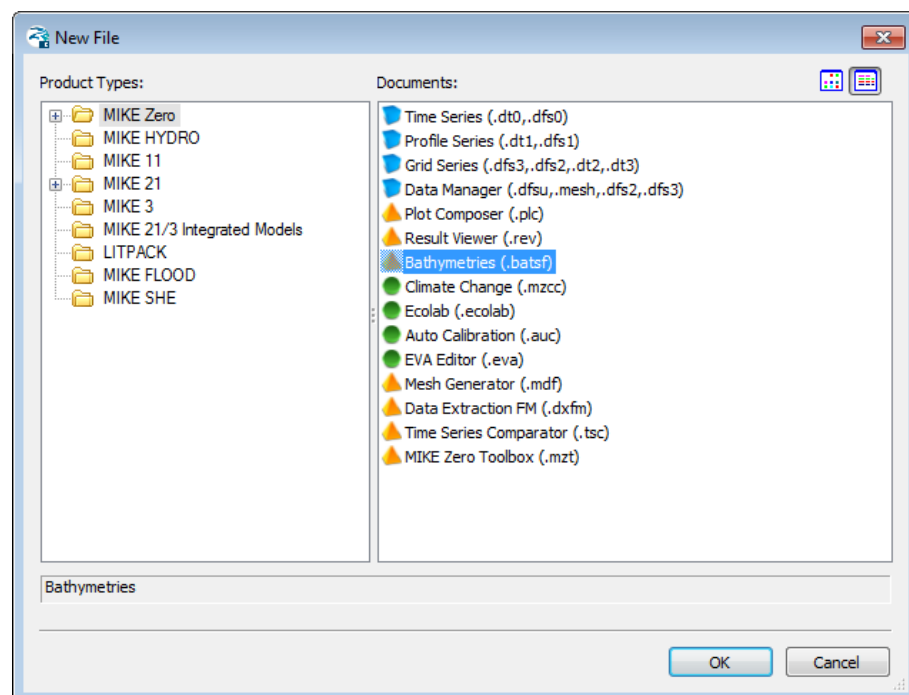

Figure 4.1   Create a new bathymetry setup

Continue to set up the bathymetry using the bathymetry data xyz files stored in the External Data folder. For details regarding how to create a bathymetry, please refer to the Step-by-step guide for the MIKE 21 Hydrodynamic Model.

The final bathymetry setup file (.batsf) and the resulting bathymetry file should be saved in a new subfolder called Bathymetry, which should be placed in the Model Inputs folder as shown in Figure 4.2

(NOTE: If you do not wish to create the files yourself, the resulting files can be copied from the Installation Examples directory.)

If the generated dfs2 file is not added into the project automatically, you should add the file manually.
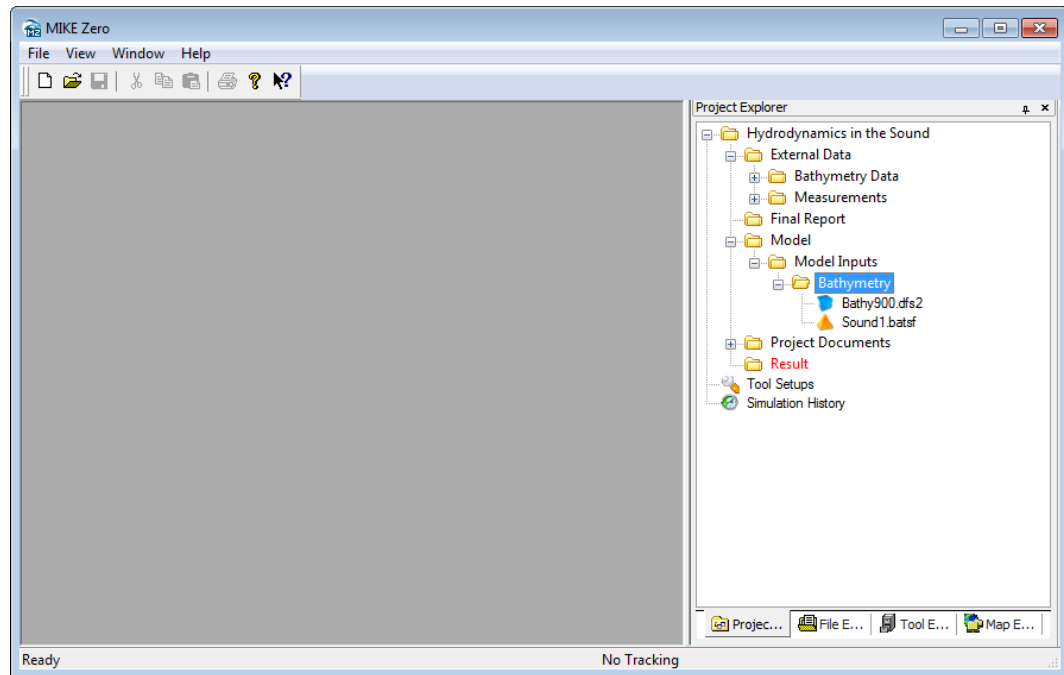

Figure 4.2   Files added to the project during bathymetry file generation

4.2 Create Boundary Conditions

The boundary conditions for a hydrodynamic model are defined by water levels, water flux or land. In this example, the boundaries are defined by water levels at the south and north of Øresund. An additional wind will add to the driving force on the water surface.

To include these data into the numerical model, it is necessary to insert the data into time series data files (dfs0).

The files created during the generation of the boundary conditions will be stored in a new subfolder called Boundary, which should be placed in the Model Inputs folder.

To create the boundary data, i.e. a new time series data file, select the Boundary folder and by right-clicking the mouse select 'Add New File…' and choose to create a Time Series (.dfs0) document under MIKE Zero (see Figure 4.3).
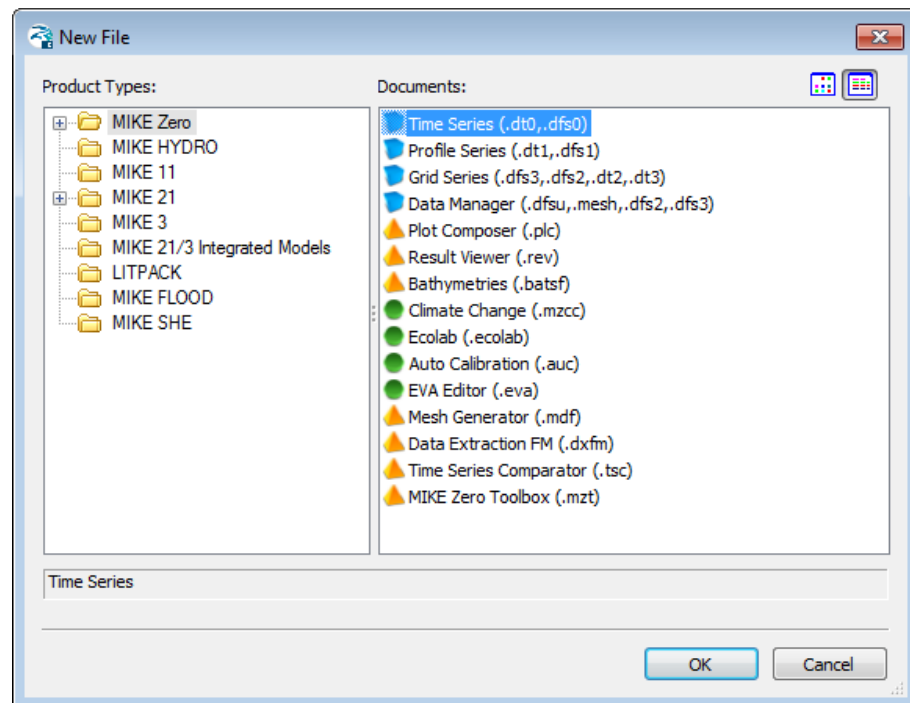

Figure 4.3   Create a new time series file

Select the 'From ASCII file' option and continue to create the time series file as described in the Step-by-step guide for the MIKE 21 Hydrodynamic Model. Follow the instructions in the guide to create the four time series data files, which in turn are applied to create the line series data files that describe the boundary conditions for the north and south boundary lines, respectively.

The resulting files should be saved in the Boundary folder as shown in Figure 4.4

(NOTE: If you do not wish to create the files yourself, the resulting files can be copied from the Installation Examples directory.)
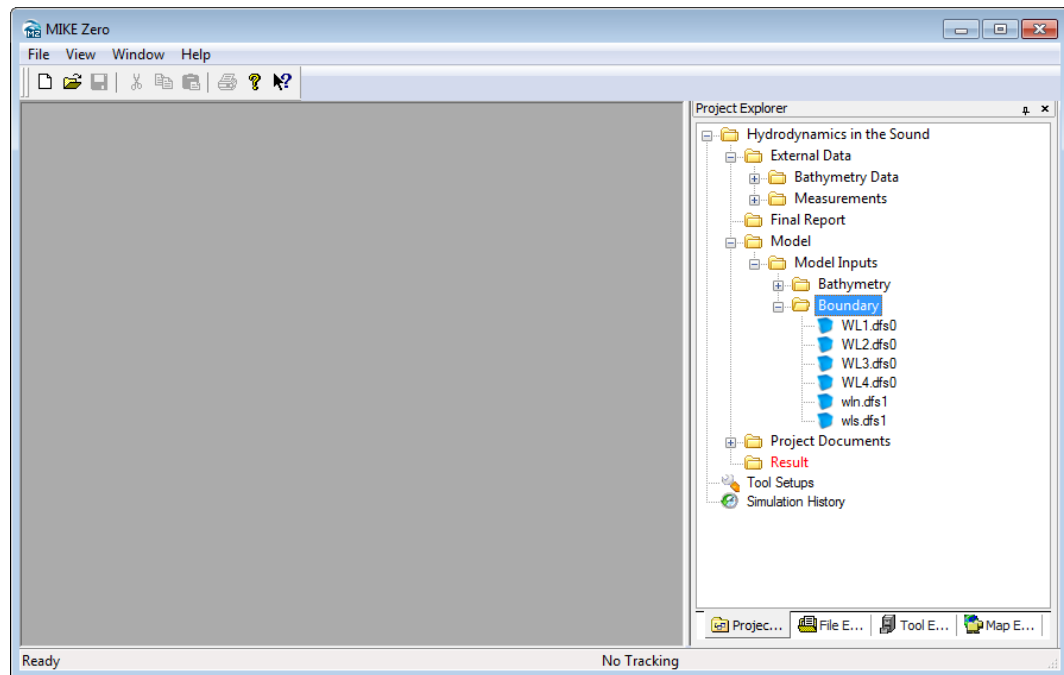
Figure 4.4   Files added to the project during boundary file generation

Now, in a similar way, create the time series data file containing the wind conditions to be positioned in a new subfolder called Meteorology, which should be placed in the Model Inputs folder.

4.3   Model Setup

Having created the bathymetry and boundary conditions it is now possible to set up the numerical model.

The model setup file should be placed in the Model folder such that the input data files are positioned in the same folder structure.

To create a new MIKE 21 HD model setup, select the Model folder and by right-clicking the mouse select 'Add New File…' and choose to create a Flow Model (.m21) document under the MIKE 21 product type. This will open an empty MIKE 21 HD model setup file in MIKE Zero.

For inserting values to the model setup, please follow the instructions in the Step-by-step guide for the MIKE 21 Hydrodynamic Model.

The definition of the output data files is described in Section 5.

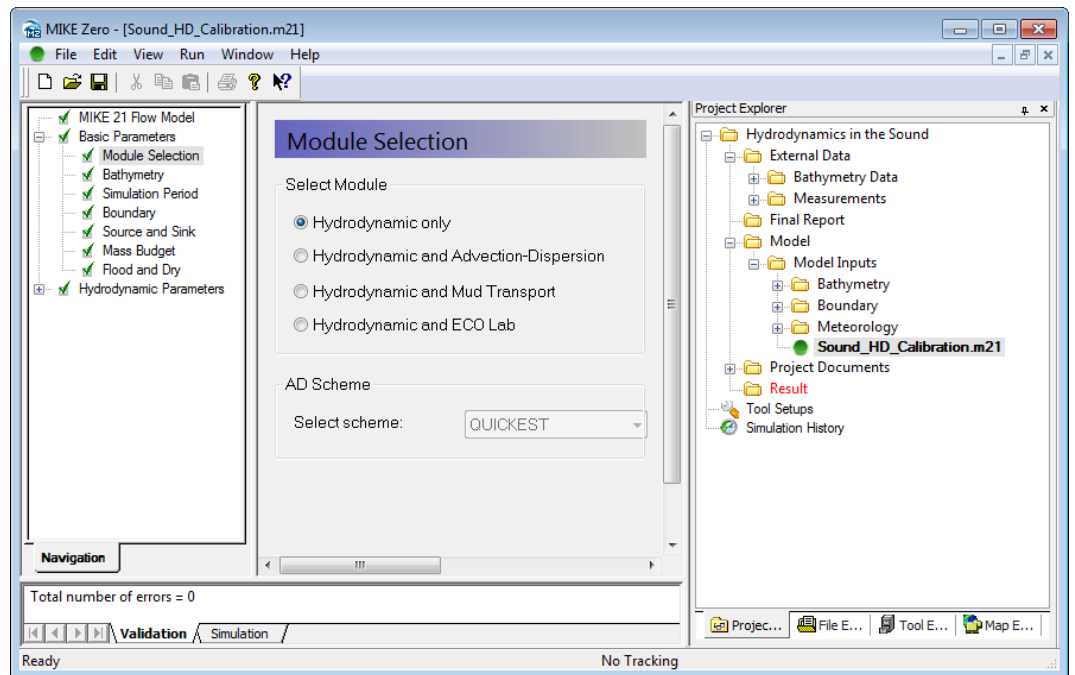Save the model setup file in the Model folder as shown in Figure 4.5.

Figure 4.5   Creating the MIKE 21 Flow Model setup file

5 Simulating Hydrodynamics

The idea behind the template design is that for each simulation you may create a new subfolder under the Result folder to organise the output result files. If you use local output names new subfolders, named after the setup file, will automatically be generated.

In this particular study we will use local output names, i.e. the path for the location of the output files will automatically be determined by the definition of the Result folder.

5.1 Define Result Data Files

As a first attempt the default Manning number (32 $m^{1/3}$/s) is chosen for the resistance.

Three result files should be generated: one 2D file containing the hydrodynamics for the entire area, and two time series files including the water levels and current conditions, to be used for calibration purposes, for the positions at Ndr. Roese and Drogden, respectively.

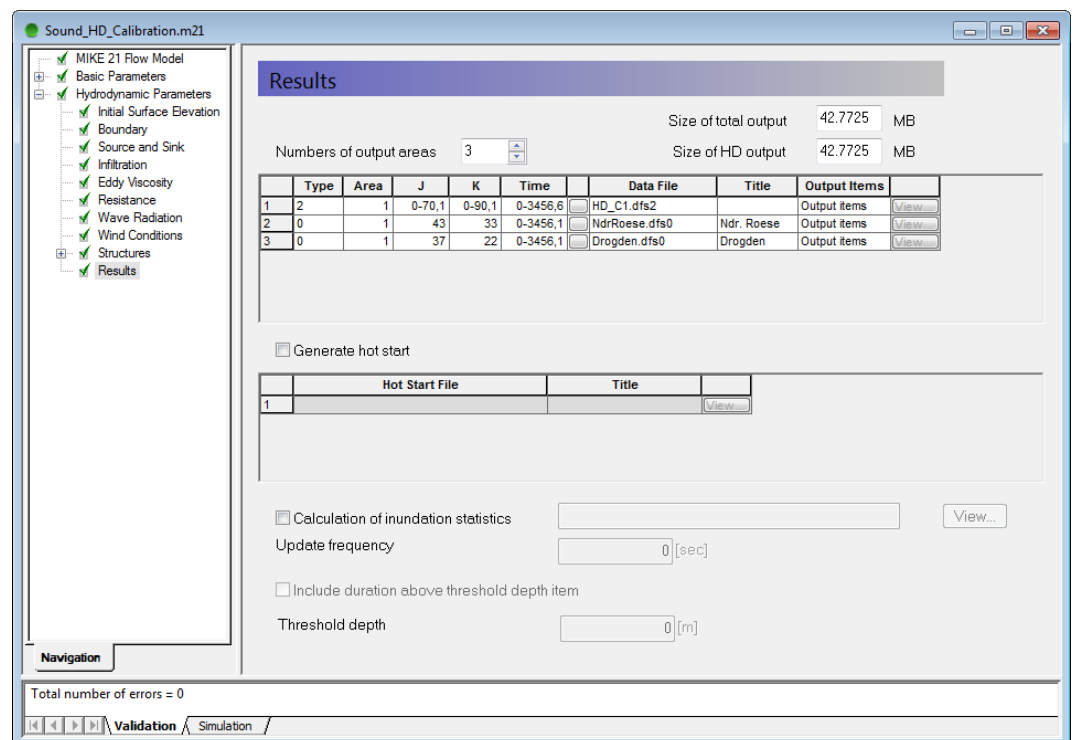Define the result files to be stored locally, see Figure 5.1.

Figure 5.1   Defining result files by local file names

The output files that are generated during a simulation are not automatically included in the project. Files that are located in the Result folder will automatically be displayed in the Project Explorer, even if they are not a part of the project. However, the icons are grey to indicate this condition.

You can view all files in any folder by right-clicking the folder and enable 'Show All'. This will list all files in the folder on the hard disk, both those that are included in the project and those that are not. A file not included in the project has a blank icon, see Figure 5.2.
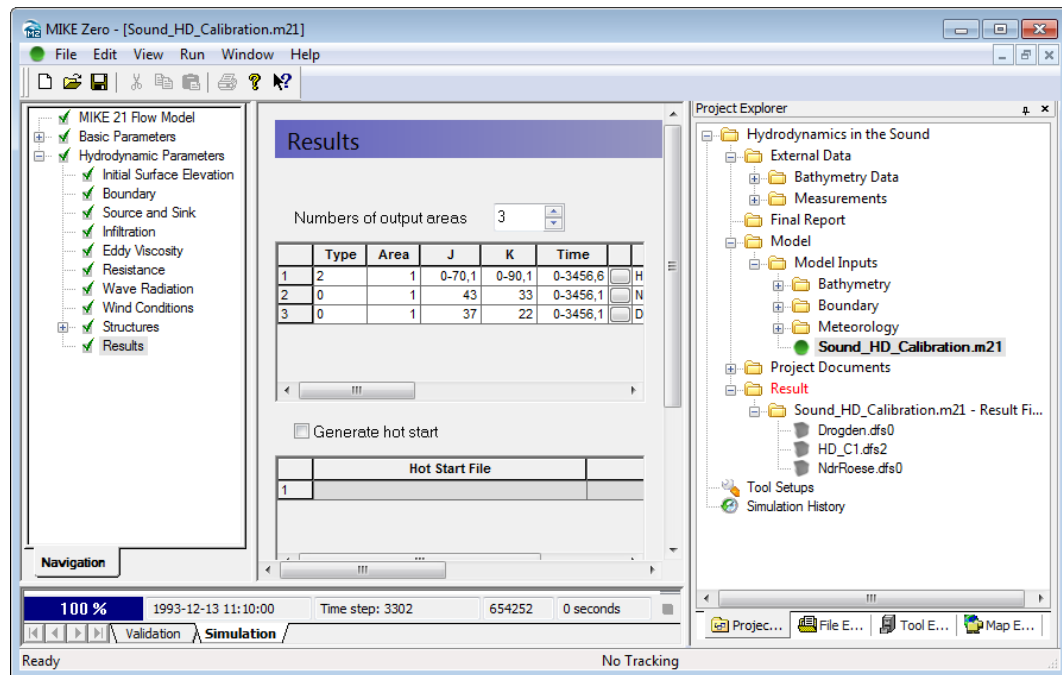

Figure 5.2   Generated output data files shown in the Project Explorer

To include the result files into the project file you should right-click on the files in the Project Explorer and select 'Insert in Project'.

You can now analyse the results as described in Section 6.

5.2   Calibrating the Model

Next you should try to carry out a second calibration run with the resistance defined by a Manning factor of 44 $m^{1/3}$/s. All other input data are kept the same.

- Save the setup file Sound_HD_Calibration.m21 under a new name: Sound_HD_Calibration_2.m21. (the file will per default be located in the same directory as the original file)

- Edit the bed resistance to a Manning number of 44 $m^{1/3}$/s and the local output data file name to HD_C2.

After the calibration, the result files can be seen in the new folder for Calibration 2, see Figure 5.3.
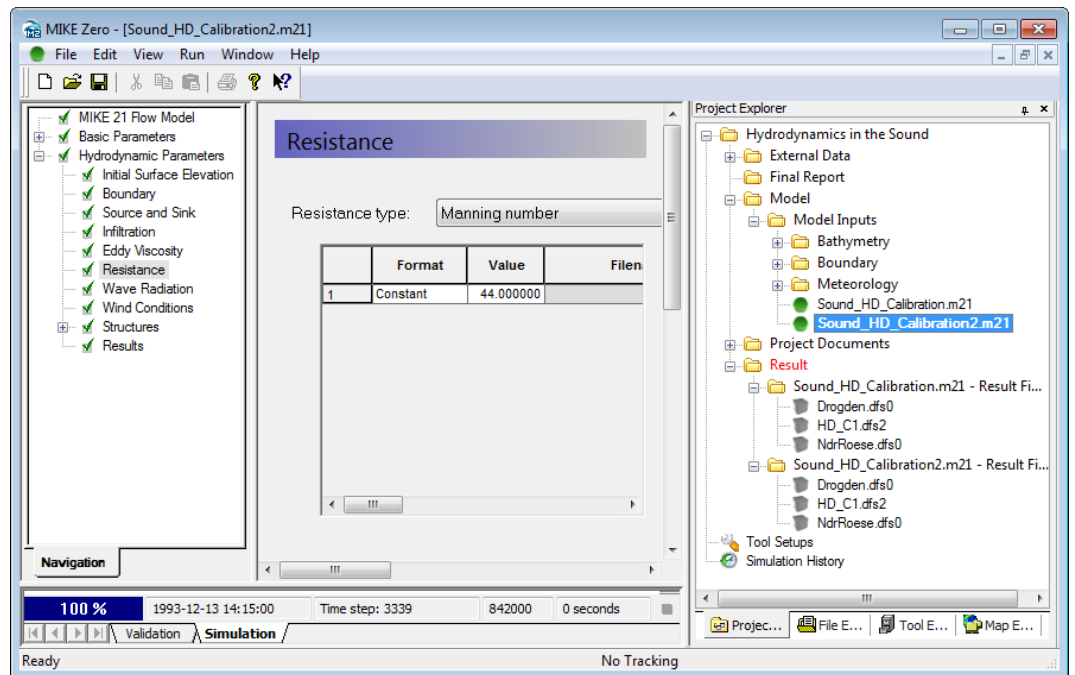
Figure 5.3   Generated output files for Calibration run 2

5.3   Production Runs

After the model calibration, you can continue with the production runs. For each run the output data files should be saved in a separate subfolder under Result. In this case the output data file names are defined locally, so this is done automatically.

5.4   Simulation History

After each simulation, the program writes the simulation data in the Simulation History window, which is accessed through the top toolbar.

Use this facility to follow your simulations and record your observations. This will help you in assessing the value of future calibration parameters, and it automatically creates an overview of the calibration process and execution of production runs, see Figure 5.4.
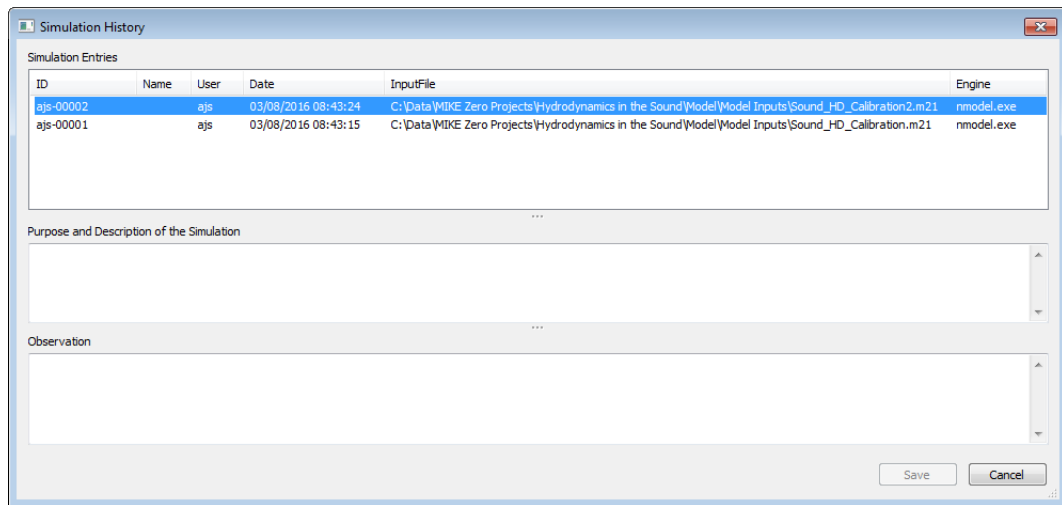
Figure 5.4   Simulation History window

6 Analysing Results

For the calibration and verification of the hydrodynamic model we need simultaneous measurements of water levels and/or current speed inside the model area.

Some of the external data files contain measurements of water levels at Ndr. Roese and Drogden. In addition, current measurements are available for Ndr. Roese. We can use these data to calibrate and verify the model.

In order to store the files you have made during the analysis processes in one location, create a new main folder called Model Analysis in the project.

6.1 Reviewing the Model Setup

The first task after a model simulation is to ensure that the simulation has completed in a normal manner, and to consider any warnings given. Thus, you need to review the .log file, which is generated during the simulation. This will appear in the Project Explorer pane only if you have set the folder option to 'Show All'. To open and review the file contents double-click the file.

Use the graphical visualisation tools in the Plot Composer for review and presentation of your results.

The created plot definition files can be stored in a new subfolder called Plot Definition Files, which should be placed under the Model Analysis folder. By gathering all plot definition files in one place, you can benefit from being able to re-use existing setups and colour palettes.

To create a plot of the flow field from the simulation result, right-click the folder Plot Definition Files and select 'Add New File…'. Select a Plots (.plc) document under MIKE Zero and continue to generate a grid plot showing the current speed and water level in the model.

Once you are satisfied with the colour scheme you may even export the plot to a graphics file, which can be stored in a new folder called Images and imported into the project for future use in the report.

The result of these actions could be similar to the one shown in Figure 6.1.
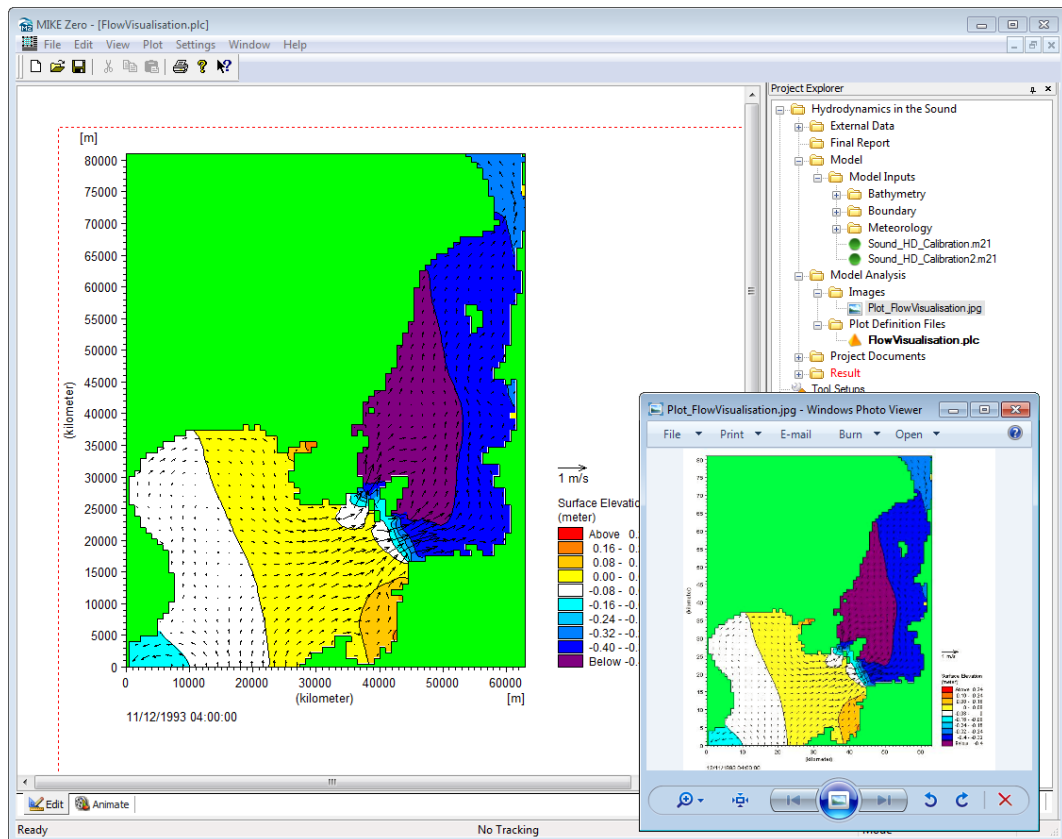
Figure 6.1   Image file created using the plot of results in the Plot Composer.
The .jpg image file has not yet been imported into the project

6.2   Creating Calibration Data

Before comparing the measured data with the simulation results, the .txt files containing measurement data need to be transferred into time series data files in a similar way as the boundary conditions time series files were created. Please refer to the Step-by-Step guide for MIKE 21 Flow Model HD for further details.

Create and store the calibration data in a folder called Calibration Data under External Data, see Figure 6.2. As these are not input files to the model, they should not be positioned in the Model folder structure.
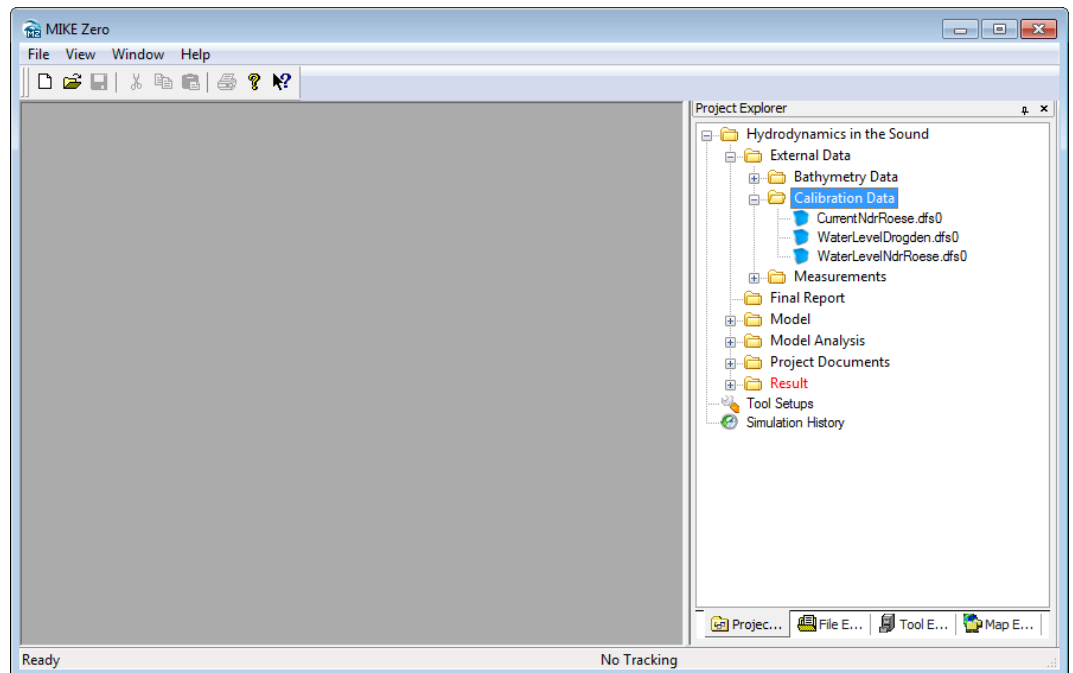
Figure 6.2   Calibration data of measured water levels and current speed

You can now compare the measured data to the simulated data in order to calibrate and verify the model setup.

6.3   Validation of Results

To create a plot of the water levels found in the measurements and the model simulation, respectively, right-click the folder Plot Definition Files and select 'Add New File…'. Select a Plots (.plc) document under MIKE Zero and continue to generate a time series plot showing the water levels for Ndr. Roese, measured and simulated.

The measured data are found in the Calibration Data subfolder under External Data, and the simulated data are found in the Calibration subfolder under Results.

By adding an extra time series plot showing the water levels for Drogden, the result may resemble the plot shown in Figure 6.3. It seems like the data used in the simulations are in good agreement with the measurements.
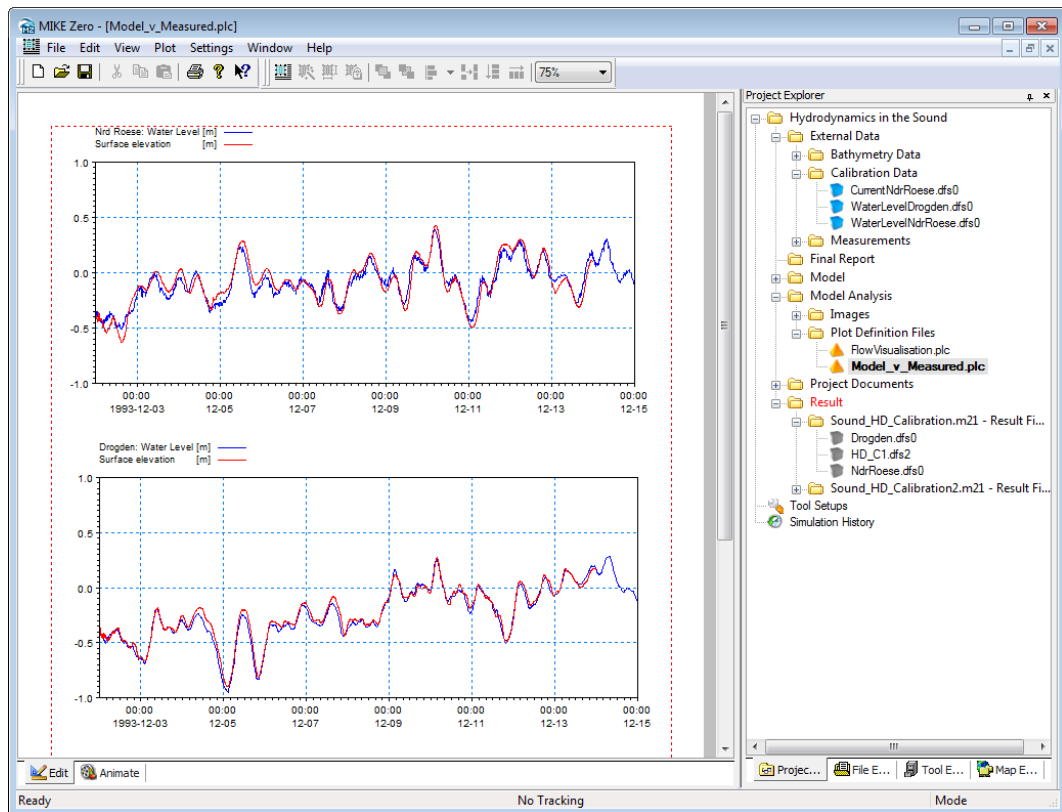
Figure 6.3   Plot file showing water levels at Ndr. Roese and Drogden

Once you are satisfied with the colour scheme, you should export the plot to a graphics file, which can be stored in the Images folder and imported into the project for future use in the report.

6.4   Production Runs

After the calibration of the model, you can continue with the production runs.

You can use the previously generated plot setup files as templates for your plot presentation of the final results. By storing all images in the same folder (or a number of subfolders) you have an overview of the modelling status.

Also use the Simulation History overview to follow the process of modelling.

7 Writing Final Report

Once the final simulations have been made and the analyses of the results are ready, you can write a final report on the findings.

For larger projects it wise to write Status Reports, where findings of sub-tasks can be discussed. These can be stored in the Status Reports subfolder under Project Documents and can thus easily be accessed when the writing of the final report commences.

Also presentations created during the modelling phase may be of use and may have been stored in the subfolder Presentations.

Likewise images, generated during the Model Analysis phase and stored in the Images folder under Model Analysis, can easily be accessed.

Once the Final report is finished you can save the document in the Final Report folder.

Following the guidelines in this Step-by-step training guide you now you have all files related to the investigation gathered in one place and listed in the project file.

8 Archiving Data

Once the investigation has been finalised and the final report accepted by the Client, there is no more work to be carried out on the project. Now, the next phase is to archive the data, both for saving the data for future use and to clear some space for new investigations.

Having all files related to the investigation gathered in one place and listed in the project file you may use the Zip Folder facility that zips all files within the given folder structure.

To save all files to a zip file select the Project Folder in the Project Explorer view, right-click and select 'Zip Folder…'. Specify the .zip file name and maybe activate to include reference files.

In this way you will have saved all files and the folder structure connected to the project in one zip file.