



MIKE 21

Hydrodynamic Module Step-by-step training guide



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1 Introduction

This training example relates to the fixed link across the Sound (Øresund) between Denmark and Sweden.



Figure 1.1 The Sound (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 remains 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 had been 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. Furthermore, the hydrography of Øresund calls for a three-dimensional model. Hence, DHI's three-dimensional model, MIKE 3, was set up for the entire Øresund in a nested mode with a horizontal resolution ranging from 100 m in the vicinity of the link to 900 m in the remote parts of Øresund, and with a vertical resolution of 1 m. MIKE 3 was subsequently calibrated and validated based upon the intensive field campaign periods.

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 of Training Example

The objective of this training example is to set up a simplified MIKE 21 Flow Model for Øresund from scratch and to calibrate the model to a satisfactory level.

The exercise has been made as realistic as possible, although some short cuts have been made with respect to the data input. This mainly relates to quality assurance and pre-processing of raw data to bring it into a format readily accepted by the MIKE Zero software. Depending on the amount and quality of the data sets this can be a tedious, time consuming but indispensable process. For this example 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.

If you are already familiar with importing data into MIKE Zero format files, 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 run the example are included and the simulation can start immediately if you want.

1.3 Tasks to be completed to form a Complete Hydrodynamic Setup

Bathymetry setup

Set up of Bathymetry by importing geographical data with soundings based on a survey or digitised from nautical chart

Creation of boundary conditions

- Set up water levels at the boundaries
- Set up of Wind condition

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

Creation of verification data

- Create data set with current speed and direction
- Create data set with water levels



2 Creating the Bathymetry



Figure 2.1 Chart covering the area of interest



D.C. M. L. A

Define Working Area			Denne Working Area		
Geographical origin	Spatial extent		Geographical origin	Spatial extent	
Map Projection			Size		
Туре:	UTM-33	▼	Width:	120000	[m]
Orinin]	Height:	120000	[m]
Geographical Co	ordinatos				
Geographical Co	ordinates				
Type of input:	Decimal degrees	•			
Longitude:	11.70156489310659	[deg]			
Latitude:	55.18191655733086	[deg]			
Map Projection C	Coordinates				
Easting:	290000	[m]			
Northing:	6120000	[m]			
Validation Status					
OK!					
Import from dfs-file					
	ОК	Cancel Help			OK Cancel Help

Based on the sea chart we define our working area in the Bathymetry Editor

Figure 2.2 Defining the Working Area

Define the Working Area (UTM Zone 33) with origin at Easting 290000 and Northing 6120000 and with a width of 120000 m and a height of 120000 m. (See Figure 2.2) The resulting Working Area is show in Figure 2.4.

Import digitised shoreline data (land.xyz) and digitised water data (water.xyz) from ASCII files (see example in Figure 2.5). Remember to convert from geographical co-ordinates (WorkArea \rightarrow Background Management \rightarrow Import). See Figure 2.6.

📕 water.xyz - No	tepad		
<u>File E</u> dit F <u>o</u> rmat	⊻iew <u>H</u> elp		
12.16805	56.17699	-20.00	
12.16665	56.17715	-20.00	
12.16609	56.17762	-20.00	
12.16637	56.17808	-20.00	
12.16749	56.17871	-20.00	
12.16972	56.18011	-20.00	
12.17084	56.18027	-20.00	
12.17168	56.18011	-20.00	
12.17140	56.17933	-20.00	
12.17196	56.17855	-20.00	
12.17364	56.17824	-20.00	
12.17420	56.17793	-20.00	•

Figure 2.3 ASCII file describing the depth at specified geographical locations (Longitude, Latitude and Depth)

L)

C













音 Open									×
Look in:	퉬 bathy		•	G	ø	Þ	•		
Recent Places	land.xyz water.xyz								
Desktop									
Libraries									
Computer									
Network									
THE WORK	File name:	water xyz				•		Open	
	Files of type:	MIKE 21 XYZ Files (* xyz)				•]	Cancel	
	Convert from:	LONG/LAT				•			
	Unit of X and Y:	degree				•]		
	Unit of Z:	meter				•			

Figure 2.6 Import digitised Shoreline and Water Depth from ASCII files



Figure 2.7 Working Area after import of land and water data



Grid Bathymetry Management			×
Grid bathymetry list:			New
At (337100.000 m,6122900.000 m)	Rotated 329.104 Deg.	63900.000 m X 83700.000	New
			Edit
			Delete
			Export
			Interpolate
			ОК
٠ m		•	Cancel

Next define the Bathymetry (WorkArea \rightarrow Grid Bathymetry Management \rightarrow New)



Specify the Bathymetry as follows:

- Grid spacing 900 m
- Origin in 337100 m East and 6122900 m North
- Orientation 327 degrees.
- Grid size 72 in x-direction and 94 in y-direction.

Map Projection			Geographical origin	ordir but hymoury properties	
			Grid Spacing		
Туре:	UTM-33	*	DX:	900	[m]
			DY:	900	[m]
Origin and Orientation					
Geographical Coordina	ates		Grid Dimensions		
Type of input:	Decimal degrees	•	X points:	72	
Longitude:	12.43874160117924	[deg]	Y points:	94	
Latitude:	55.22570782643504	[deg]	Land Value		
North to Y orientation:	327	[deg]		10	[m]
Map Projection Coordin	nates		Display		
Easting:	337100.000000126	[m]		📝 Display Border	
Northing:	6122900.0000042	[m]		Display Grid Point	s
Grid rotation:	329.104289814532	[deg]			
Validation Status					
OK!					
Import from dfs-file					

Figure 2.9 Defining the bathymetry





Figure 2.10 Working Area with imported depth values and defined bathymetry (the black rectangle)

The Working Area will now look like the one illustrated in Figure 2.10, where a bitmap actually has been included as a background image (map.gif). The image can be used for manual digitising or adjusting some areas using some of the tools on the menu bar.

Now import data from background (click on 'Import from Background' and drag mouse over points of interest, selected points are now changing colour, finally click on 'Import from Background' once more). Now we are ready for interpolation of the xyz data to grid points (WorkArea \rightarrow Bathymetry Management \rightarrow Interpolate). Save the bathymetry specification file and load the generated dfs2 file into the Grid Editor, for example.





Figure 2.11 Grid Editor showing the interpolated bathymetry

Make some adjustment in order to obtain only two boundaries, namely the northern and southern boundary. Close the eastern boundary by assigning land at the southern part of the eastern boundary and fill up the small lakes around in the bathymetry and inspect the land water boundary carefully. Furthermore, inspect the bathymetry close to the boundaries avoiding areas with deeper water just inside the boundaries. Adjust the north boundary so it is open from 60 to 69 along line 93. Adjust the south boundary so it is open from 1 to 30 along line 0. Use land values to fill the areas close to the boundaries as shown in Figure 2.11.

The Grid Plot control in Plot Composer can now be used to make a plot of the bathymetry. Select File \rightarrow New \rightarrow Plot Composer. From the menu bar select Plot \rightarrow Insert New Plot Object. Select Grid Plot. Right-click on the Plot Area, select properties and select the Master file.





Figure 2.12 Plot of the adjusted Bathymetry



3 Creating the Input Parameters

3.1 Generate Water Level Boundary Conditions

Measured water level recordings from four stations located near the open model boundaries force the Øresund model. Due to strong currents and because the influence of the Coriolis effect is significant, water level recordings at each end of the open boundary are required.

The objective of this example is based on measured recordings from four stations to create two line series with water level variations. The locations of the four stations are listed in Table 3.1.

		Pos	ition
Station	Station Data File	Easting (m)	Northing (m)
WL1	WL1.txt	385929	6243197
WL2	WL2.txt	338957	6220549
WL3	WL3.txt	348310	6225949
WL4	WL4.txt	362880	6137713

Table 3.1 Measured water level data





Figure 3.1 Map showing the individual stations (LH = Light House)

3.1.1 Importing measured water levels to time series file

Open the Time Series Editor. Select the ASCII template. Open the text file WL1.txt. Change the time description to 'Equidistant Calendar Axis' and click OK. Then right-click on the generated data and select properties change the type to 'Water Level'. Save the data in wl1.dfs0. Repeat these steps for the remaining 3 stations.



N	VL1.tx	t - Note	pad					_ 🗆 🗙
Eile	<u>E</u> dit	F <u>o</u> rmat	⊻iew	<u>H</u> elp				
Wa	ter le	vel rea	ordin	gs fron	n St 1			_
time	e	Eleva	ation					
199	3-12-	02 00:	00:00		-0.33			
199	3-12-	02 00:	30:00		-0.362			
199	3-12-	02 01:	00:00		-0.3965			
199	3-12-	02 01:	30:00		-0.3929			
199	3-12-	02 02:	00:00		-0.4278			
199	3-12-	02 02:	30:00		-0.4378			
199	3-12-	02 03:	00:00		-0.4393			
199	3-12-	02 03:	30:00		-0.473			
199	3-12-	02 04:	00:00		-0.4984			
199	3-12-	02 04:	30:00		-0.4977			-



Time Series Edi	tor: Import fro	m ascii			×
Description—					
File name:	C:\0\0training\e	xample\data	WWL1.txt		
Delimiter:	Tab	•	Time description:	Equidistant Calendar Axis	
Treat cor	nsecutive delimiter	sasone	Start Time:	08-12-2003 20:08:06	
🗌 Ignore de	limiters in begining	g of line	Time Step:	0 [days]	
🔽 Delimiter	between time and	first item		00:00:10 [hour:min:sec]	
Delete value:	-16	÷030		[fraction of sec.]	
				Time Series Export ASCII Format	
Preview Water level r time Ele 1993-12-02 (1993-12-02 (1993-12-02 (1993-12-02 (1993-12-02 (ecordings from St evation 10:00:00 10:30:00 11:00:00 11:30:00 12:00:00 12:30:00	1 -0.33 -0.362 -0.3965 -0.3929 -0.4278 -0.4278			
time	e Elevati	on			
1993-12-02	00:00:00 -0.33	_			
1993-12-02	01:00:00 -0.3965	;			
1993-12-02	01:30:00 -0.3929)			
1993-12-02	02:00:00 -0.4278 02:30:00 -0.4378	}			
		OK	Ca	ncel	





File Properties					<u>?</u> ×
General Information		udinas from Ct 1			ОК
nice:	Jwater level reci	ordings from St T			Cancel
Axis Information					Help
Axis Type:	Equidistant Cale	endar Axis 📃 💌			
Start Time:	02-12-1993 00:	00:00			
Time Step:	0	[days]			
	00:30:00	[hour:min:sec]			
	0.000	[fraction of sec.]			
No. of Timesteps:	577		Axis Units:	7	
- Item Information					
Nam	e	Туре	Unit	TS TJ	
1 Elevation	N Water Lev	el	💌 meter		
•				▶	
Insert	Append	<u>D</u> elete	[Item <u>F</u> iltering	





Figure 3.5 Time Series Editor with imported Water Levels from Station 1



To make a plot of the water level time series, open the plot composer select 'plot' \rightarrow 'insert a new plot object' and select 'Time Series Plot' (see Figure 3.6). Right-click on the plot area and select properties. Then find the actual time series file and change some of the properties for the plot, if any (see Figure 3.8).

Insert Plot Object		×
Insert		
Single Plot Maximized		
Single Plot Sized:	w: 100 [mm] h: 100	[mm]
Multiple Plots Tiled:	nx: 2 ny: 2]
Standard Graphics Mark Standard Graphics Mark Standard Graphics Mark Grid Plot Mark Grid Plot Mark Series Plot Mark Advanced Graphics Mark ADCP 2D Plot Mark ADCP 2D Plot Mark Standard Graphics Mark Standard Graphics		
i 1 V Polar Plot	ОК Са	ncel

Figure 3.6 Plot Composer inserted a new Plot Object as Time Series

If several time series files are to be plottet in the same plot, right-click on the plot area and select new item (see Figure 3.7).

ime Series Plot Properties											
Items X-Axis Y-Axis Curves Text Annotations											
ltem D	Item Definition										
							· t				
	Item name	Items	File name	Item type	Unit	Glb min	Glb				
1	ST 1: WL (m)	ST 1: WL (m)	ata\wl1.dfs0	Water Level	meter	-0.57990002	0.5716				
•							F.				
			OF	Ca	ancel	Apply	Help				





Look in:	🎳 Data	- 😋 💋 📂 🛄 -	
(Ana	Name	Date modified	Туре 🔺
	CurrentNdrRoese.dfs0	16-12-2013 18:50	MIKE Z
lecent Places	SalinityNdrRoese.dfs0	16-12-2013 18:50	MIKE Z
	SalinityNorthBnd.dfs0	16-12-2013 18:50	MIKE Z
-	SalinitySouthBnd.dfs0	16-12-2013 18:50	MIKE Z
Desktop	TemperatureNorthBnd.dfs0	16-12-2013 18:50	MIKE Z =
—	TemperatureSouthBnd.dfs0	16-12-2013 18:50	MIKE Z
	🦻 WaterLevelDrogden.dfs0	16-12-2013 18:50	MIKE Z
Libraries	WaterLevelNdrRoese.dfs0	16-12-2013 18:50	MIKE Z
	WaterLevelViken.dfs0	16-12-2013 18:50	MIKE Z
	WindKastrup.dfs0	16-12-2013 18:50	MIKE Z
Computer	🝺 wl1.dfs0	16-12-2013 18:50	MIKE Z
	🝺 wl2.dfs0	16-12-2013 18:50	MIKE Z
	📄 wl3.dfs0	16-12-2013 18:50	MIKE Z 👻
Network	•		*
	File name: wl1.dfs0	-	
	Files of two:		
	New Data Files (.dtsu)	•	
	Select Item Period Info. Item Info. Constra	aints Info.	
	Title: Water level recordings fro	om St 1	-
	File Type: Equidistant Time Avis		-
	The type. Equidicate time rives		
		Any Item Type	-
	ST 1: WL (m)	V	
			Cance

Figure 3.8 Plot Composer properties select time series to plot

Figure 3.9 and Figure 3.10 show the measured water levels at the two boundaries.



Figure 3.9 Combined Time Series at the North Boundary Station 1 and 2



Figure 3.10 Combined Time Series at the North Boundary Station 3 and 4



3.1.2 Creating boundary conditions

Now you must define the boundary in a shape that correlates to the bathymetry.

Determine the width of the two boundaries (use for instance Grid Editor). Load Profile Series and select 'Blank ...'. Fill in the required information:

North boundary

- Start date 1993-12-02 00:00:00
- Time step: 1800s
- No. of time steps: 577
- No. of grid points: 10 (60 69 line 93)
- Grid Step: 900m

Load Station 1 (WL1.dfs0) and copy and paste the water levels to the profile Series Editor at point 0. Next load Station 2 (WL2.dfs0) and copy and paste the levels into point 9 (see Figure 3.12). Then select tools and interpolate the profile series. Save the profile series as WLN.dfs1 (see Figure 3.13).

						? ×
ı						ОК
Water Level No	rth Boundary (m)					Cancel
						Help
Equidistant Cale	endar Axis 💽					
02-12-2003 00:1	00:00					
1800		Number of Grid	Points:	10		
577		Grid Step: (m)		900		
e	Туре	U	Init	Min		
n Brid Water Lev	el	met	ter ()	0	
1						
Append	<u>D</u> elete			Item Filte	ring	
	Water Level No Equidistant Cale 02-12-2003 00: 1800 577 e h Bnd Water Lev	Water Level North Boundary (m) Equidistant Calendar Axis 02:12:2003 00:00:00 577 1800 577 e Type h Bnd Water Level	Water Level North Boundary (m) Equidistant Calendar Axis 02-12-2003 00:00:00 1800 Number of Grid 577 Grid Step: (m) e Type h Bnd Water Level met Append Delete	Water Level North Boundary (m) Equidistant Calendar Axis 02:12:2003 00:00 1800 Number of Grid Points: 577 Grid Step: (m) e Type Ind Water Level meter h Bnd Water Level meter Append Delete	Water Level North Boundary (m) Equidistant Calendar Axis 02-12-2003 00:00.00 1800 Number of Grid Points: 10 577 Grid Step: (m) 900 e Type Unit Min h Bnd Water Level meter 0	Water Level North Boundary (m) Equidistant Calendar Axis 02:12:2003 00:00 Image: State of Grid Points: 1800 S77 Grid Step: (m) 900 Image: State of Grid Points: Image: State of Grid Points:

Figure 3.11 Profile Series Properties



B MIKE Zero - ProfileEdit1 File Edit View Options Tools Window Help □ ☞ ■ & 陶 酏 ● ? 校	- 68 🗆 🗲 🗡						
ProfileEdit1 - Modified							
Time Step: 02/12/02 00:00:00	Time	0	1	2	3	4 ^	
1.00	0 02/12/03 00:0	-0.33					
 WL North Bhd [meter] 	1 02/12/03 00:3	-0.362					
	2 02/12/03 01:0	-0.3965					
	3 02/12/03 01:3	-0.3929					
0.80	4 02/12/03 02:0	-0.4278					
	5 02/12/03 02:3	-0.4378					
	6 02/12/03 03:0	-0.4393					
0.60	7 02/12/03 03:3	-0.473					
	8 02/12/03 04:0	-0.4984					
	9 02/12/03 04:3	-0.4977					
	10 02/12/03 05:0	-0.4941					
0.40	11 02/12/03 05:3	-0.4797					
	12 02/12/03 06:0	0:00 -0.5139					
	13 02/12/03 06:3	-0.4961					
0.20	14 02/12/03 07:0	-0.4671					
-	15 02/12/03 07:3	-0.4647					
	16 02/12/03 08:0	-0.4612					
	17 02/12/03 08:3	-0.4366					
0.00 +	18 02/12/03 09:0	-0.4592					
0.0 2.0 4.0 6.0 8.0	I ■ III					►	
eady	07-12	1993 19:19:29 -0.41	.0434			Se	elect Mi

Figure 3.12 Copying WL1 and WL2 into Profile Series Editor



Figure 3.13 Interpolated Water Level at the North boundary



Repeat the same steps with the southern boundary with the similar information except the number of grid points and using the recorded water levels at station 3 (WL3.dfs0) and 4 (WL4.dfs0) and save the resulting file as WLS.dfs1.

South boundary

- Start date 1993-12-02 00:00:00
- Time step: 1800s
- No. of time steps: 577
- No. of grid points: 30 (1 30 line 0)
- Grid Step: 900m

3.2 Initial Surface Level

The initial surface level is calculated as a mean level between the northern and the southern boundary at the beginning of the simulation. Load the two boundary files and approximate a mean level at the start of the simulation. We will use -0.38m.

3.3 Wind Conditions

Wind recordings from Kastrup Airport will form the wind condition as time series constant in space. Load the time series editor and import the ASCII file 'WindKastrup.txt' as equidistant calendar axis. Save the file in 'WindKastrup.dfs0'. Time series of the wind speed and direction is shown in Figure 3.14, Figure 3.15 and Figure 3.16.

A more descriptive presentation of the wind can be given as a wind speed diagram. Start the 'Plot composer' insert a new plot object select 'Wind/Current Rose Plot' and then select properties and select the newly created file 'WindKastrup.dfs0' and change properties to your need. The result is shown in Figure 3.17.

📕 WindKastrup.txt - Notepad					<u>_ ×</u>
<u>File Edit</u> F <u>o</u> rmat <u>V</u> iew <u>H</u> elp					
Wind data					▲
Time Speed Direction					
Unit 100002 2000	0	100003	2401	0	
1993-12-02 00:00:00	9.294	184.26			
1993-12-02 00:30:00	10.066	186.689			
1993-12-02 01:00:00	10.655	189.167			
1993-12-02 01:30:00	11.22	191.531			
1993-12-02 02:00:00	11.802	193.665			
1993-12-02 02:30:00	11.202	193.254			
1993-12-02 03:00:00	10.367	192.226			
1993-12-02 03:30:00	9.659	189.522			
1993-12-02 04:00:00	9.011	186.016			-

Figure 3.14 ASCII file with Wind speed and direction from Kastrup Airport





Figure 3.15 Measured wind direction at Kastrup Airport



Figure 3.16 Measured wind speed at Kastrup Airport



Figure 3.17 Wind Rose from Kastrup Airport



3.4 Density Variation at the Boundary

As the area of interest is dominated with outflow of fresh water from the Baltic Sea and high saline water intruding from the Ocean measurement of salinity and temperature has taken place at the boundaries. Depth average values of these measurements are given as ASCII files named: SalinityNorthBnd.txt, SalinitySouthBnd.txt, TemperaturNorthBnd.txt and TemperaturSouthBnd.txt. Examples are shown in Figure 3.18. Import these ASCII files with the time series editor and save the files with the same name but with extension dfs0. Remember to change the time description to 'equidistant calendar axis'.

TemperatureNorthBnd.txt - N	lotepad		
<u>File Edit Fo</u> rmat <u>V</u> iew <u>H</u> elp			
Mean Temperature North Bo	oundary (degree C)		
Time North Bnd	_		
Unit 100006 2800	0		
1993-12-02 00:00:00	5.69176		
1993-12-02 00:30:00	5.57791		
1993-12-02 01:00:00	5.6602		
1993-12-02 01:30:00	5.76629		
1993-12-02 02:00:00	5.75775	_	Δ
🐌 SalinitySouthBnd.txt - Notepa	ad		
SalinitySouthBnd.txt - Notepa File Edit Format View Help	ad		
Eile Edit Format View Help Mean Salinity South Bounda	ad ary (psu)		
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SalinitySouthBnd.txt - Notepa Eile Edit Format View Help Mean Salinity South Bounda Time South Bnd Unit 100024 6200 1993-12-02 00:00:00 1993-12-02 00:30:00 1993-12-02 01:00:00	ad ary (psu) 0 6.46113 6.47687 6.48		
SalinitySouthBnd.txt - Notepa File Edit Format View Help Mean Salinity South Bounda Time South Bnd Unit 100024 6200 1993-12-02 00:00:00 1993-12-02 01:30:00 1993-12-02 01:00:00 1993-12-02 01:00:00	ad ary (psu) 0 6.46113 6.47687 6.48 6.4718		

Figure 3.18 ASCII files with average temperature at the North boundary (A) and average salinity at the South boundary (B)



A plot of the measured data is shown in Figure 3.19 and Figure 3.20.







Figure 3.20 Measured average salinity at the North and South boundary



4 Model Setup

4.1 Flow Model

We are now ready to set up the model using the above boundary conditions and forcing. Initially we will use the default parameters and not take into account the effect of the density variation at the boundaries. The setup consists of the following parameters:

Parameter	Value		
Module	Hydrodynamics only		
Bathymetry	Bathy900		
Simulation Period	1993-12-02 00:00 – 1993-12-14 00:00		
Time step	300s		
No. of Time steps	3456		
Enable Flood and Dry	Drying depth 0.2 Flooding depth 0.3		
Initial surface level	0.38		
North Boundary	(60 – 69) along line 93		
North Boundary	Type 1 data: WLN.dfs1		
South Boundary	(1 – 30) along line 0		
South Boundary	Type 1 data: WLS.dfs1		
Eddy Viscosity	Smagorinsky formulation, velocity based. Constant 0.5		
Resistance	Manning number. Coefficient 32		
Result file	HD01.dfs2		

In the following, screen dumps of the individual input pages are shown and a short explanation is provided.



b b 101	
MIKE 21 Flow Model → Basic Parameters → Module Selection → Bathymetry → Simulation Period → Simulation Period → Mass Budget → Roor and Sink → Hydrodynamic Parameters → Initial Surface Elevation → Boundary → Source and Sink → Source and Sink → Resistance → Wave Radiation → Wind Conditions → Structures → Results	Module Selection Select Module Hydrodynamic only Hydrodynamic and Advection-Dispersion Hydrodynamic and Mud Transport Hydrodynamic and ECO Lab AD Scheme Select scheme: QUICKEST •
Navigation	HII.
Total number of errors = 0	



Specify Hydrodynamics only

hd01.m21		
MIKE 21 Flow Model	Bathymetry	<u>^</u>
Module Selection M Bathymetry Simulation Period M Boundary Communication	Type © Cold start [©] Hot start	Number
Mass Budget Mass Budget Hydrodynamic Parameters Minitial Surface Elevation Moundary Source and Sink	Additional information Map projection: UTM-33 Apply Coriolis forcing: V Multi-cell ov Landslides:	verland solver for inland applications:
	Bathymetry 1 C:\Data\\data\Bathy900.dfs2	Origin Enclosing Area
Navigation	·	
Total number of errors = 0	n /	

Figure 4.2 Flow Model: Bathymetry

Specify the bathymetry Bathy900.dfs2. The projection zone will be defined as UTM-33 automatically.



hd01.m21					- • •
MIKE 21 Flow Model	Simulation Peri	od			
Module Selection Modu	Simulation Time step range: Time step interval: Simulation start date: Simulation end date:	First: 0 300 02-12-1993 00:00:00 14-12-1993 00:00:00	Last:	3456	
	Warm-up Period Time step range:	First:	Last:	0	
Navigation	Courant Number Max Courant No:	6.60639 Area	a:	1	
Total number of errors = 0	1				

Figure 4.3 Flow Model: Simulation period

Specify a time step, which will result in a Courant between 1 and 7. Start with a time step of 300s. The time step range must be specified to 3456 time steps in order to simulate a total period of 12 days.

hd01.m21		- • ×
MIKE 21 Flow Model	Boundary	
Module Selection	Location O User specified Program detected	Number
Mass Budget Masses Masses	First point Last point 1 (60,93) (69,93) 2 (1,0) (30,0)	
Navigation		
	<u>_</u> /	



Select Program detected boundary conditions. If you have more than two boundaries, you must inspect you bathymetry again.



• hd01.m21					
MIKE 21 Flow Model	ource and Sink				
Module Selection Modu	umber of source sink pairs 0				
Mass Budget	Туре	Sou	irce	Sir	ık
Flood and Dry		Point	Area	Point	Area
Navigation		m			۴
Total number of errors = 0					

Figure 4.5 Flow Model: Source and Sink

If you have any sources or sinks these have to be specified. Here in our case we do not have any.

hd01.m21	
MIKE 21 Flow Model Main Basic Parameters Module Selection Mathymetry Minulation Period Main Boundary	Flood and Dry Enable flooding and drying Drying depth: 0.2
✓ Source and Sink ✓ Mass Budget ✓ Flood and Dry ✓ Hydrodynamic Parameters	Flooding depth: 0.3
✓ Initial Surface Elevation ✓ Boundary ✓ Source and Sink ✓ Eddy Viscosity ✓ Resistance ✓ Wave Radiation ✓ Wind Conditions ✓ Structures ✓ Results	
Navigation	



Specify Flooding and Drying depth. In our case, select the default values.



• hd01.m21				- • •		
MIKE 21 Flow Model	al Surface Elev	vation				
Bathymetry	Given as:	Value	File name			
Simulation Period	Constant value	-0.380000				
Boundary						
Source and Sink						
Mass Budget						
Hydrodynamic Parameters						
Initial Surface Elevation						
Boundary						
Source and Sink						
M Eddy Viscosity						
Wave Radiation						
Wind Conditions						
🗄 🗹 Structures						
Results						
Navigation						
Total number of errors = 0						
Validation / Simulation /						

Figure 4.7 Flow Model: Initial Surface Level

After inspection of the boundary condition at the simulation start time decide the initial surface level, or if the variation is large decide for an initial surface level map. In this case we will use a constant level of -0.38m, which is the average between our north and south boundary at the start of the simulation.

MIKE 21 Row Model Mike Saic Parameters Module Selection Mathymetry Simulation Period Boundary Source and Sink Mass Budget Modula Selection Mass Budget Modula Selection Mass Budget Mass Budget Modula Selection Mass Budget Modula Selection Modula Selection Mass Budget Mass Budget Modula Selection Mass Budget Massinget Source and Sink <th>🔵 hd01.m21 - Modified</th> <th></th> <th></th> <th></th>	🔵 hd01.m21 - Modified			
Maxingation	MIKE 21 Flow Model	Boundary		
	Module Selection Medule Selection Medu	Boundary 1 : (60,93) - (69,93) Formulation: Type 1 Data file: FAB type: No tilting No user defined flow direction Relaxation factor Boundary 2 : (1,0) - (30,0) Formulation: Type 1 Data file: FAB type: No tilting No user defined flow direction Relaxation factor	Level C:\Data\\data\win.dfs1 12 0.5 Level C:\Data\\data\wis.dfs1 12 0.5 0.5	
K K K K K K K K K K K K K K K K K K K	Validation Simulation	1		

Figure 4.8 Flow Model: Boundary

Specify the type of boundary as a type 1 profile time series and select wln.dfs1 at the northern and wls.dfs1 at the southern boundary.



• hd01.m21			- • •
MIKE 21 Flow Model	Boundary		
Bathymetry	Boundary 1: (60,93) - (69,93) Formulation:	Level	
Boundary	Type 1 Data file:	C:\Data\\data\win.dfs1	View
Mass Budget	Constant: Sine Series:	12	
Hydrodynamic Parameters	Type 0 data file: Type 1 Data file:	0.5	View
✓ Boundary	Boundary 2 : (1,0) - (30,0)	1	
Source and Sink	Formulation:	Level	
- 🗹 Eddy Viscosity	Type 1 Data file:	C:\Data\\data\wls.dfs1	View
- 🖌 Resistance	FAB type:	12	
Wave Radiation	No tilting		
Wind Conditions	No user defined flow direction		View
🗄 🖌 Structures	Relaxation factor	0.5	
Navigation			
Total number of errors = 0			
Validation Simulation]		

Figure 4.9 Flow Model: Boundary Type

To select the boundary type, move the cursor to the type field and click on this then select Type 1 Data file.

音 Open			
Look in:	🕌 Data	▼ 🥝 🏂 📂 🛄▼	
Æ	Name	Date modified	Туре
2	🝺 wln.dfs1	24-06-2013 19:01	MIKE Zerc
Recent Places	🝺 wls.dfs1	24-06-2013 19:01	MIKE Zerc
Desktop			
Libraries			
Computer			
computer			
Network			,
	File name: wln.dfs1	•	
	Files of type: Profile (*.dfs1;*.dt1)	-	
	Select Item Period Info. Item Info. Constraints	s Info.	
	Title: Interpolated water level nort	h boundary (m)	-
	File Type: Equidistant Time Axis		-
	Boundary WI-N (m)	Item	
	boundary were (iii)		
			Cancel
			UK

Figure 4.10 Flow Model: Boundary Select File



● hd01.m21	Source and Sin	k				
✓ Module Selection ✓ Bathymetry ✓ Simulation Period ✓ Boundary ✓ Source and Sink ✓ Mass Budget ✓ Elocd and Dov	Given a Precipitation: Consta Include Evaporation: Consta	is Value nt	File name	recipitation o	n dry land	
Hydrodynamic Parameters Hydrodynamic Parameters Hydrodynamic Parameters Mental Surface Elevation Mental Surface Eleva	Source Sink	Туре	Magnitude	Velocity	Outlet Dir.	E
Navigation						•
Total number of errors = 0	n /					

Next, locate the appropriate data file in the file box to the right.

The discharge magnitude and velocity for each source and sink is given here. But, since we do not have any sources, leave it blank.

hd01.m21		
MIKE 21 Flow Model	Eddy Viscosity	
	Given as Smagorinsky Formula Type of Formulation Velocity based	
	Smagorinsky Constants 1 0.500000	
Navigation		
Total number of errors = 0		



Change the default Eddy viscosity to Smagorinsky formulation with a coefficient of 0.5.

Figure 4.11 Flow Model: Source and Sink



hd01.m21				- • ×
MIKE 21 Flow Model	Resistance			
Module Selection Bathymetry Simulation Period Boundary	Values given as: Ma	nning number 🔻		
Source and Sink	Format	Value	Filename	Pier re
Flood and Dry	1 Constant	32.000000		Wiew
Navigation	•			Þ
Total number of errors = 0				
	1			

Figure 4.13 Flow Model: Bed Resistance

We will start the default Bed Resistance with a value given as a Manning number at $m^{1/3}$ /s. Later on we will use this value for calibration purposes.

hd01.m21			
MIKE 21 Flow Model	Wind Condition	S	
Bathymetry	Wind		
M Boundary	wind type. Speed:	Lonstant in 5	pace
Mass Budget	Direction:	270	
	Data file:	E_21\FlowM	odel\HD\Sound\Data\WindKastrup.dfs0
Boundary	Neutral pressure:	1013	View
Eddy Viscosity	molude all pressure	e conection	
Wave Radiation	Friction Friction type:	Constant	
Wind Conditions	Constant:	0.0026	
™ Kesults	, .	Speed	Friction
	Linear variation using:	24	0.0016
Navigation			
Total number of errors = 0			
Validation Simulation			

Figure 4.14 Flow Model: Wind Conditions

To use the generated wind time series, we specify 'Constant in Space' and locate the time series WindKastrup.dfs0. Use the default value for the friction.



• hd01.m21								x
MIKE 21 Flow Model	Results							ĥ
Module Selection				Size	of total output	42.6142	ΜВ	
Simulation Period	Numbers of output are	as 1	* *	Size	of HD output	42.6142	MB	
Source and Sink	Type Area	J	К	Time	Data	File		
Mass Budget		0-70,1	0-90,1	0-3456,6	hd02.dfs	2	_	
Hydrodynamic Parameters								E
Boundary	(1					Þ	
 ✓ Source and Sink ✓ Eddy Viscosity ✓ Resistance 	Generate hot start							
Wave Radiation		Hot Start File	•		Title			
						Vie	W	
Results								
	Colordation of inves	J-12						1
	Update frequency	lation statistic:	s	0				+
Navigation	∢ [m				Þ	1
Total number of errors = 0								
	n_/							

Figure 4.15 Flow Model: Result

Specify one output area and specify the resulting output file name. The actual output size is calculated on beforehand. Make sure the required disk space is available on the hard disk.

Sub Area fo	r Output				×
J direction: K direction:	First Point: 0 0	Last Point: 71 93	Interval:	Range: 0 - 71 0 - 93	
Time:	0	3456	6	0 · 3456	
			ОК	Cancel	



Reduce the output size to a reasonably amount by selecting an output frequency of 1800s which is a reasonably output frequency for a tidal simulation. As our time step is 300s then the specified output frequency is 1800/300 = 6. Area-wise, select the full area.



Save As			<u>?</u> ×
Savejn: 隘	HD	- 🖬 🖛 📼	<u>.</u> .
File <u>n</u> ame:	hd01.dfs2		<u>S</u> ave
Save as type:	Result files(*.dfs2)	- 0	Cancel

Figure 4.17 Flow Model: Result Output File Name

Specify the file name HD01.dfs2 for our first simulation.

Now we are ready to run the MIKE 21 Flow model.

After the simulation use the Plot Composer (or Grid Editor, Data Viewer) to inspect and present the result. Two plots are shown below; one with current towards North (Figure 4.18) and one with current towards South (Figure 4.19).



Figure 4.18 Current Speed and Water Level during current towards North





Figure 4.19 Current Speed and Water Level during current towards South

4.2 Model Calibration

In order to calibrate the model we need some measurements inside the model domain. Measurements of water level and current velocities are available.

4.2.1 Measured water levels

Measurements of water level are given at station Drogden (WaterLevelDrogden.txt) and Ndr. Roese (WaterLevelNdrRoese.txt) import these ASCII files using the Time Series Editor, cf. Figure 4.20 and Figure 4.21.





Figure 4.20 Drogden: Measured Water Level



Figure 4.21 Ndr. Roese Measured Water Level

4.2.2 Measured current velocity

To calibrate the current velocity, measured current is given at station Ndr. Roese (CurrentNdrRose.txt) Import this file with the Time series Editor. Plots of current velocity and current speed and direction are shown in Figure 4.22, Figure 4.23 and Figure 4.24.

Furthermore, a Speed/Direction diagram of the measured current is shown in Figure 4.25.



Figure 4.22 Ndr. Roese Measured Current Velocity East and North Component













Figure 4.25 Ndr. Roese Current Rose



4.2.3 Model extraction

Now we are ready to extract water level and current speed from the simulation at the points corresponding to Ndr. Roese: Point (43,33) and Drogden Point (37,22). Start the 'MikeZero Toolbox' then click on the + sign in front of Extraction and select 'Time Series from 2D files'. Figure 4.28 to Figure 4.34 show the corresponding dialogue pages for extracting the results.

😚 New File		×
Product Types: MIKE Zero MIKE HYDRO MIKE 11 MIKE 21 MIKE 21 MIKE 21/3 Integrated Models LITPACK MIKE FLOOD MIKE SHE	Documents: Time Series (.dfs0) Profile Series (.dfs1) Data Manager (.dfsu,.mesh,.dfs2,.dfs3) Grid Series (.dfs3,.dfs2) Plot Composer (.plc) Result Viewer (.rev) Bathymetries (.batsf) Climate Change (.mzcc) Ecolab (.ecolab) Auto Calibration (.auc) EVA Editor (.eva) Mesh Generator (.mdf) Data Extraction FM (.dxfm) MIKE Zero Toolbox (.mzt)	
MIKE Zero Toolbox		
	ОК	Cancel

Figure 4.26 Select MIKE Zero Toolbox

II mzt1	- • -
Concatenation Extraction Profileseries from 2D files Profileseries from 3D files Timeseries from 1D files Timeseries from 2D files Timeseries from 2D files Timeseries from 2D files Timeseries from 3D files File Converter GIS Hydrology Statistics Time Series Transformation	
Tool List Setup List	
New Edit Delete Up	Down Run

Figure 4.27 Select Time Series from 2D files



Setup Name		X
	MIKE Zero Data Extraction Tool	
	This tool extracts point timeseries from timeseries of 2D spatial data.	
	Setup Name:	
	Extraction from HD result]
	< Back Next > Cancel He	p

Figure 4.28 Name of the Time Series Extraction

Specify Input Data			
On this page you select the file you either type the full pa	2D data you want to extra ath or you browse for the fi	ct point timeseries fr le.	om. To select the
Specify the Input File Name	e:		
C:\0\Training\Data\HD\hd01.	.dfs2		

Figure 4.29 Specify the Hydrodynamic Result file



Subseries Specification	X
Specify Intepolation Method and Subseries On this page you specify the temporal period for the extraction, i.e. the start and end time and date.	
Extraction Period Start: 0 1993/12/02 00:00:00 End: 576 - 1993/12/14 00:00:00	
Data Information	
< <u>B</u> ack <u>N</u> ext > Cancel Help	

Figure 4.30 Specify the Extraction Period

Select Items: On this page you select w	yhat items you want to extract.	
H water depth	 ✓ Surface elevation ✓ Velocity X-dir 	
🗖 Q Flux	 Velocity Y-dir Velocity user direction Speed 	Direction : 1
	Direction	Invert direction (rotate 180°)

Figure 4.31 Specify the items to extract



Point Selection Select Points On this page you specify the points in the 2D matrix from where you want to extract timeseries.	×
X Y 1 43 33 2 37 22 Y-Range: 0 - Y-Range: 0 -	
< <u>B</u> ack <u>N</u> ext > Cancel Help	



Output File Selection	x
Specify Dutput Data	
On this page you specify the name of the data file you are generating. You can also give a data title and description of each item in the data file.	
Specify Name and Title for the Output Data File:	
Name: C:\0\Training\Data\HD\hd01.dfs0	
Title: extraction from hd01	
< <u>B</u> ack <u>N</u> ext > Cancel Help	

Figure 4.33 Specify the Time Series Output file



Status	×
Setup Status If you want to review or change any settings, click Back. If you are satisfied with the settings click Finish to save the setup.	
Name: Extraction from HD-result Log/pfs-file location C:\0\Training\Data\HD\	
Setup:	
Input Data C:\0\Training\Data\HD\hd01.dfs2	
Subseries Selection First timestep: 0 Last timestep: 576	
Selected Items:	
< <u>B</u> ack Finish Cancel Help	

Figure 4.34 Click Execute to extract the selected data

4.2.4 Compare model results and measured values

Compare the extracted values with measured values. Use the Plot Composer to plot the simulated and measured water level and current.

The comparison is shown in Figure 4.35 for water level at Drogden and for Water Level at Ndr. Roese on Figure 4.36. Current comparison for Ndr. Roese is shown in Figure 4.37.



Figure 4.35 Water Level comparison at Drogden









Figure 4.37 Comparison of Current Velocity North at Ndr. Roese. Simulated with a Manning number of 32 m^{1/3}/s.

The comparison between measured and calculated water level shows a reasonable agreement. But the current velocity shows that the calculated speed is too low. To adjust this we make a new calibration with a new Manning number of 44 m^{1/3}/s to decrease resistance to the flow. Load the former simulation specification HD01.M21 and change the Manning number to 44 m^{1/3}/s. Change the output file name to HD02.dfs2. Save the specification as HD02.M21 and run the simulation with the new specification.





Figure 4.38 Status window for execution of HD model

Extract the new time series similar to the former one and make a new plot of the comparison. The result is shown in Figure 4.39.



Figure 4.39 Comparison of Current Velocity North at Ndr. Roese with a Manning number of $44 \text{ m}^{1/3}/\text{s}$.

The calculated current speed is closer to the measured, but still we need a little more calibration. Including the density variation at the boundary will also improve the calibration. Try to make the calibration by increasing the Manning number and reducing the Eddy coefficient. For each calibration only change a single parameter and track the changes in a log.

A major improvement in the calibration process could be obtained by using variable wind friction.