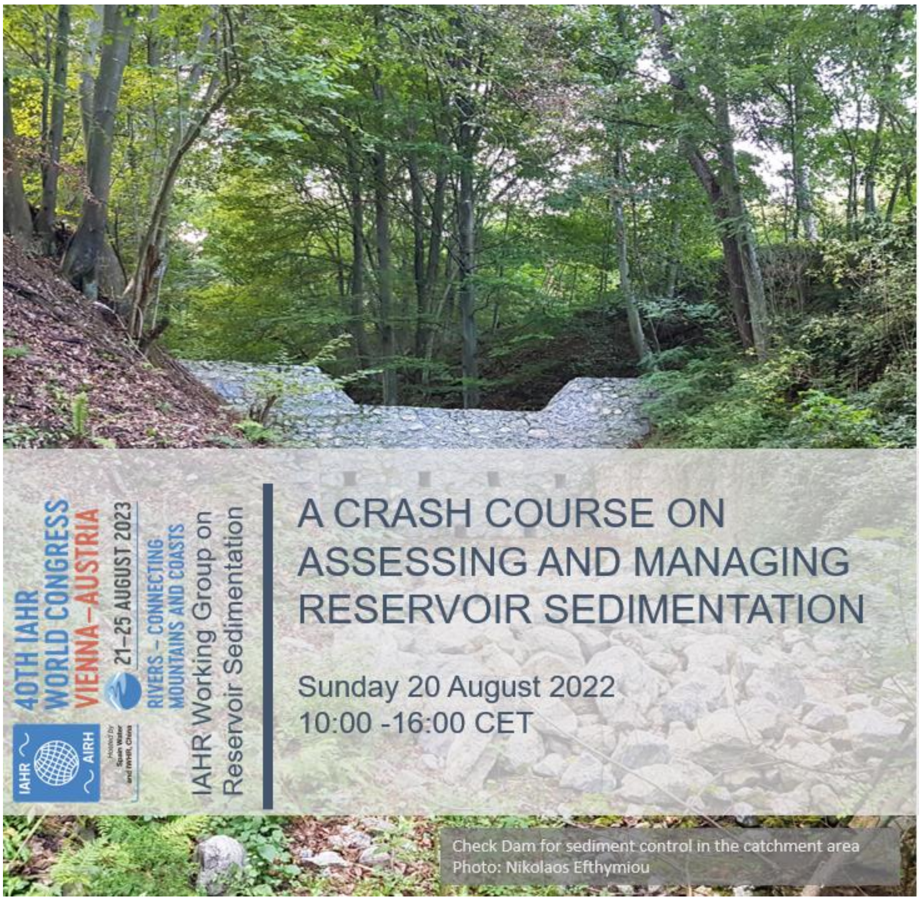
A crash course on assessing and managing reservoir sedimentation

Exercise Delft3D-FM SED/MOR

Amgad Omer (Deltares)
Sanjay Giri (RHDHV)



Deltares

Title
Crash course on reservoir sedimentation Delft3D-FM SED/MOR (IAHR 2023)

Pages
20

Keywords
Reservoir sedimentation, gates operation, Dflow-FM, Morphology, Modelling

Summary
Dams and reservoirs provide a great service to society. Their number continues to increase because of growing demands for water and energy. However, they disturb river flow and morphological processes and thus produce impacts on river system and ecology. Besides, the reservoirs themselves suffer from loss of storage and contamination due to sedimentation. The reduction of storage capacity poses challenges to dam authorities. The requirements for minimizing storage loss (i.e. sediment management) as well as impacts on the downstream ecosystem lead towards the approach of optimum reservoir operational rules. Sediment management practices, such as sluicing and flushing, may generate undesired morphological changes in the reach downstream of the dam. The gate operation rule and patterns are expected to influence this.

Deltares has developed a modelling approach to simulate reservoir gate operation of the dam to understand the effect of different gate opening patterns on the morphological processes at upstream (the reservoir) and downstream river reach. Such modelling capability provides possibility to generate the gate operation rule for the desired reservoir water levels. The aim here is to seek improvements of the flushing process and to understand how this process affects the morphological changes downstream of the dam.

Expected gain:

1. Short background about sediment-induced problems in reservoirs and their management (Sluicing, flushing, dredging, etc.)
2. A rapid hands-on experience of using Delft3D-Flexible Mesh model (D-FM) with gate operation (RTC).

References
1000173-002

Version	Date	Author	Initials	Review	Initials	Approval	Initials
	Nov 2018	Amgad Omer					
		Sanjay Giri					

State
Draft

Contents

1 Introduction

Dams and reservoirs provide a great service to society. Their number continues to increase because of growing demands for water and energy. However, they disturb river flow and morphological processes and thus produce impacts on river system and ecology. Besides, the reservoirs themselves suffer from loss of storage and contamination due to sedimentation. The reduction of storage capacity poses challenges to dam authorities. The requirements for minimizing storage loss (i.e. sediment management) as well as impacts on the downstream ecosystem lead towards the approach of optimum reservoir operational rules. Sediment management practices, such as sluicing and flushing, may generate undesired morphological changes in the reach downstream of the dam. The gate operation rule and pattern are expected to influence this.

Deltares has developed a modelling approach to simulate reservoir gate operation of the dam to understand the effect of different gate opening patterns on the morphological processes at upstream (the reservoir) and downstream river reach. Such modelling capability gives the possibility to generate the gate operation if the reservoir water level is given. The aim here is to seek improvements of the flushing process and to understand how this process affects the morphological changes downstream of the dam

The objective and expected gain of the exercise are as follows:

- Providing a brief background about sediment-induced problems in reservoirs and their management practices (sluicing, flushing, dredging, etc.)
- Familiarizing with Delft3D-Flexible Mesh model (D-FM) with gate operation tool (RTC) including a rapid hands-on exercise

The study area is a reservoir in Tenryuu River (Japan). The dam has 9 gates and powerplant with one turbine. The model domain has been simplified to suit the time allocated for the breakout session, Therefore, instead of 9 gates, three gates will be used and every gate represents the discharge of three gates. In addition, the reservoir length and the downstream reach have been shortened. The figure below shows the model simplification.

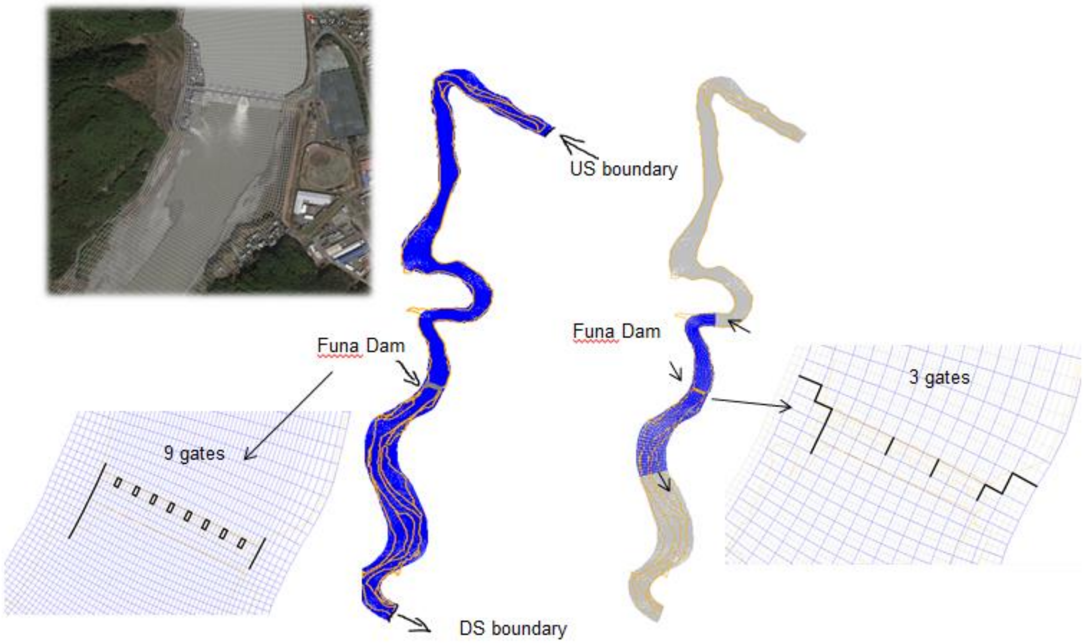


Figure 1.1 The model domain simplification

Many input files have already been prepared in order to have the model running with the available time of the session. Ideally, these files have to be prepared from scratch based on the row data. However, in order to set-up a model with morphology the following steps shall be followed:

1) Generate/upload the grid
2) Generate/upload the bed level
3) Prepare/upload the upstream boundary
4) Prepare/upload the downstream boundary
5) Prepare/upload the gates and gates operation
6) Add/upload sediment and morphology
7) Add the time-step, roughness, physical parameters, output intervals, observations (stations and cross-sections) processes that you want to model
8) Run the model and check the results

In this exercise, you will be able to add, step 2, 3 (partially), 4 (partially), 5 (partially) and 6. For step 3, 4 and 5 you should add the location of the boundary and the gates in addition to the input data of them. We already added the locations and you will upload the input data.

2 Exercise: Funa Model

2.1 Open Delta-shell and create project (already done for you)

Open Delft3D FM suite of 2019. Normally you create a new model, but in this exercise, we will open an existing model, partially, prepared due to the limited session time.

1) Go to open folder as shown in Figure 2.1 with number (1).
2) Go to the directory and select the file with the name *Funa00* (see Figure 2.2).

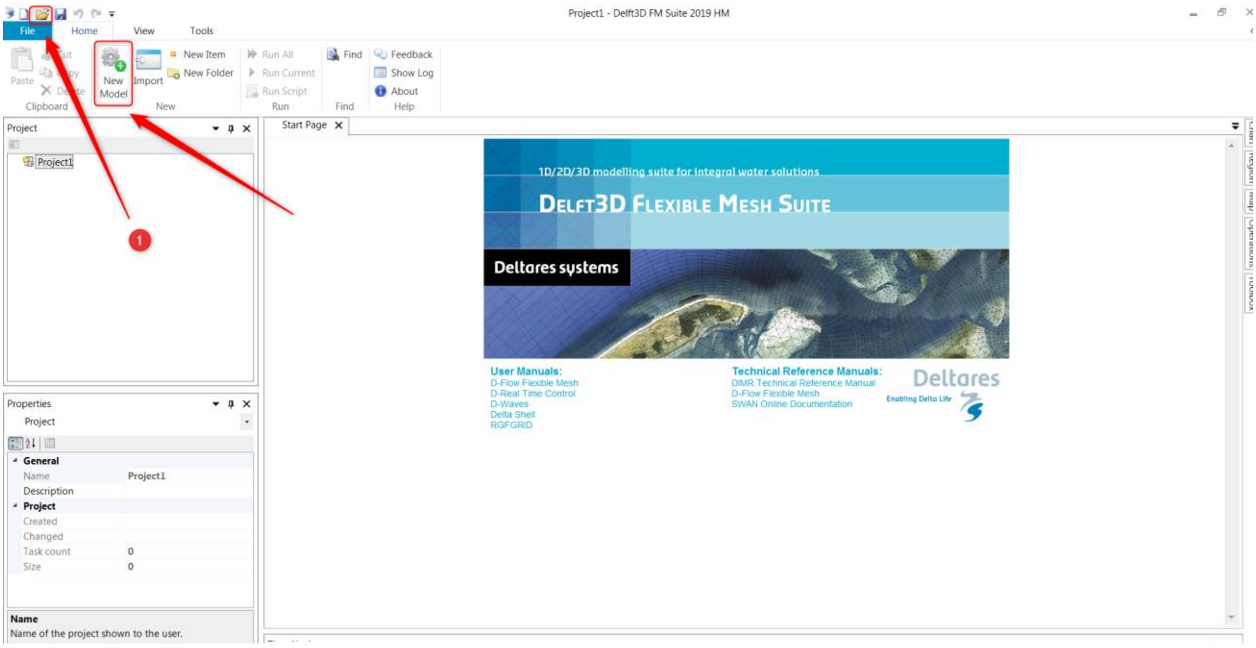


Figure 2.1 Upload a model or create a new model

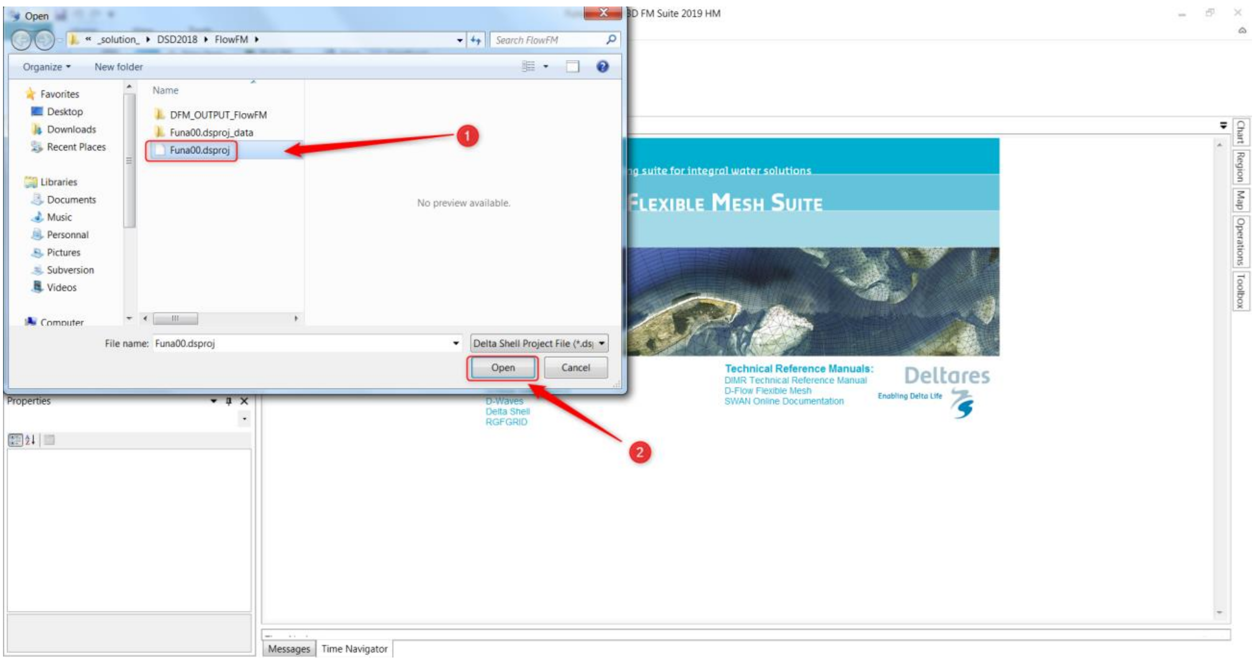


Figure 2.2 Selecting the model and opening it

2.2 Generate/upload the grid. (Done for you)

You can generate the grid using grid Grid. However, in this exercise, the grid has already been made ready for use. Please go to *".. \input\1-grid* " to upload the grid file with the name of "*FlowFM_net.nc*".

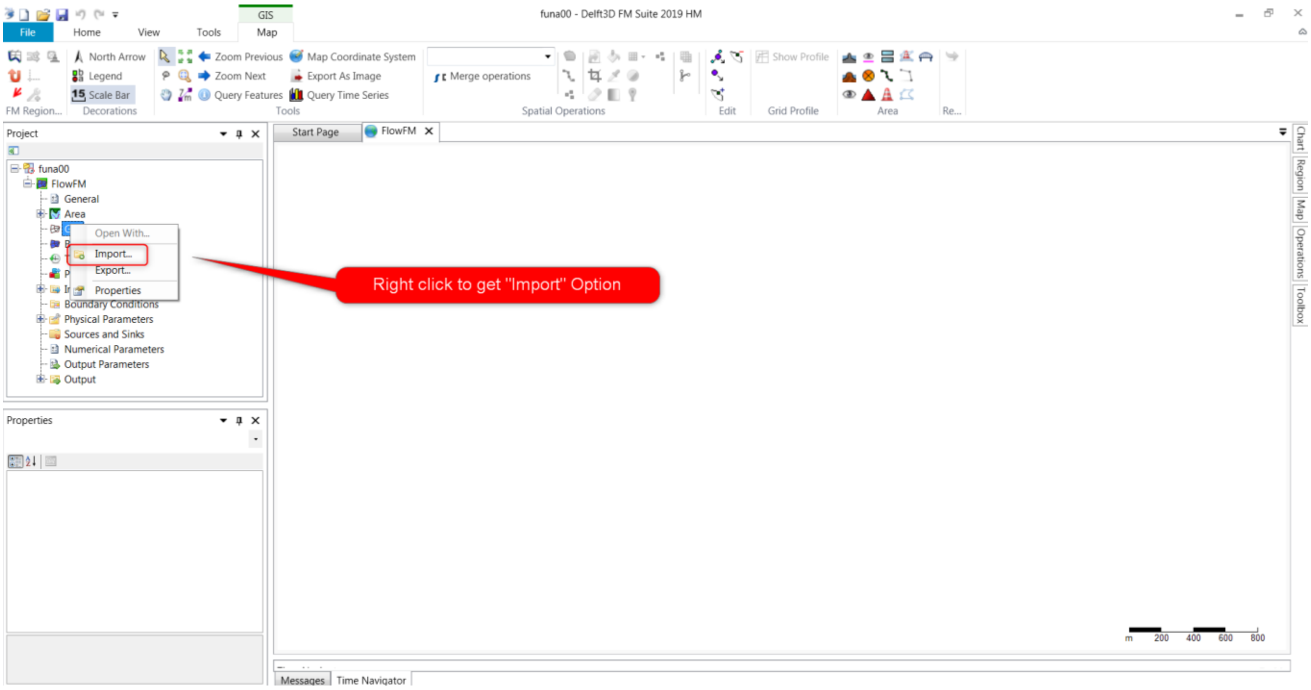


Figure 2.3 Import the grid by selecting the file of the grid.”FlowFM_net.nc”.“

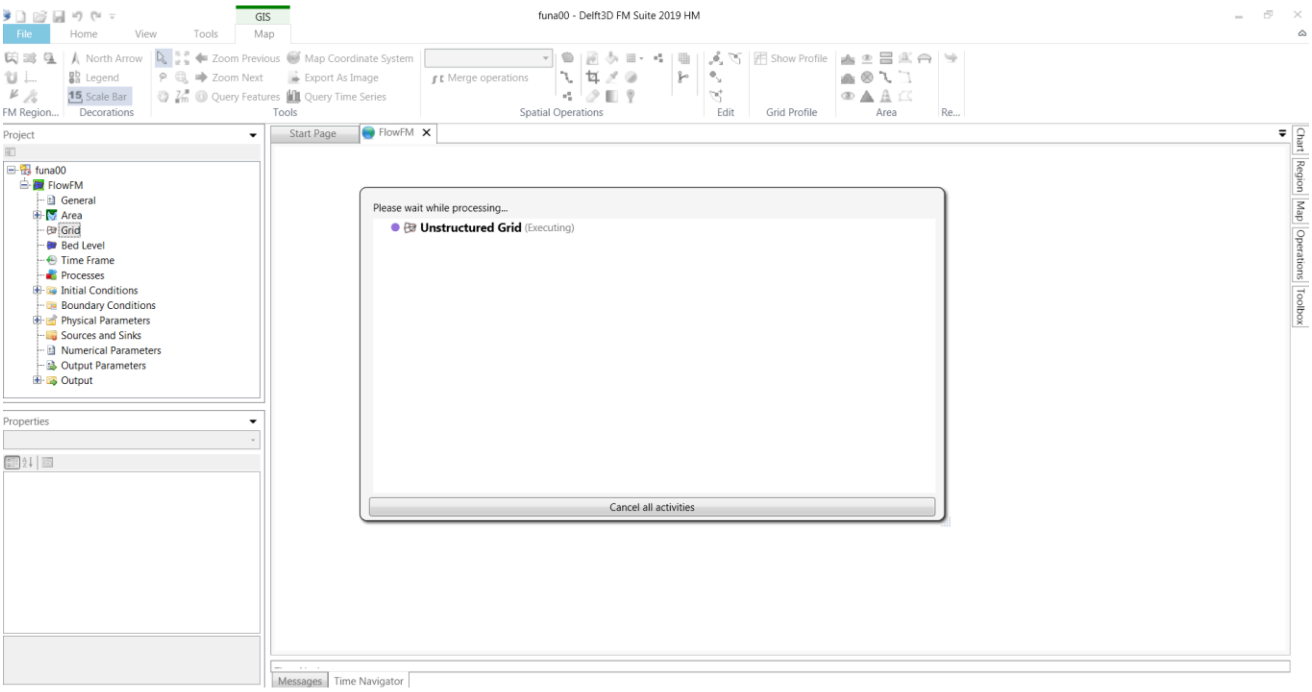


Figure 2.4 The grid is being imported

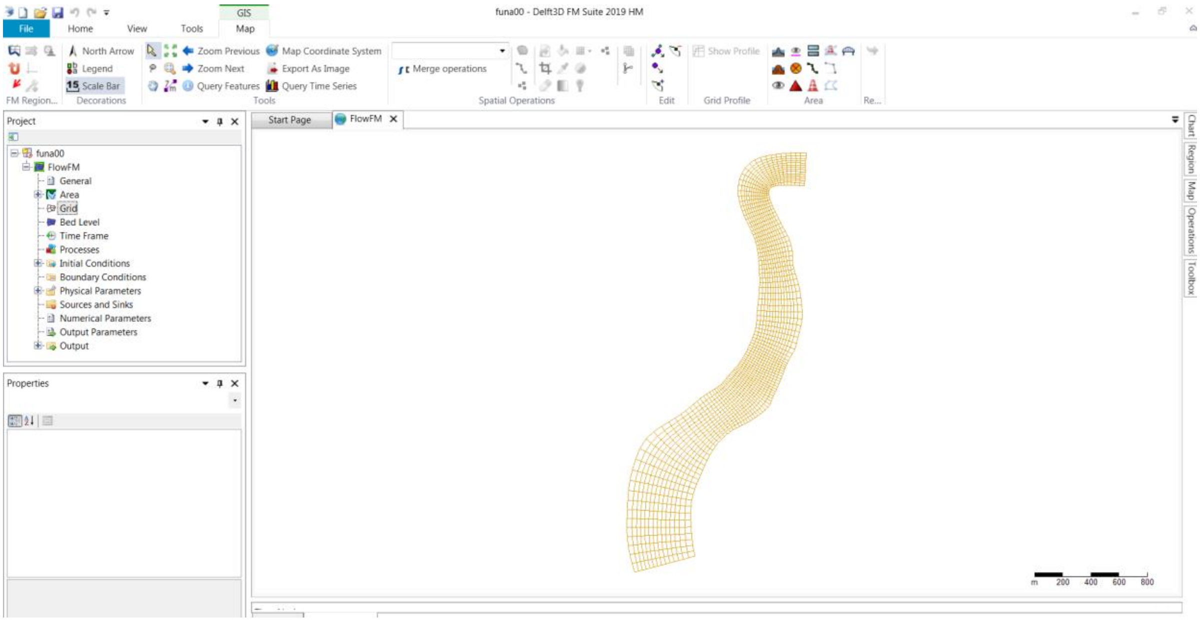


Figure 2.5 The grid is imported

2.3 Generate/upload the bed level

Normally, the bed level is prepared in format of samples. The samples can be uploaded using the spatial operation in the map icon.
Select bed level in the spatial operation and import the samples as shown in Figure 2.6.
Move to operation window on the right side of Delta-shell to see the samples. (see Figure 2.8)
Interpolate the samples to the grid to generate the bed topography (see Figure 2.7 to Figure 2.10)
Save the model with bed topography (see Figure 2.11).

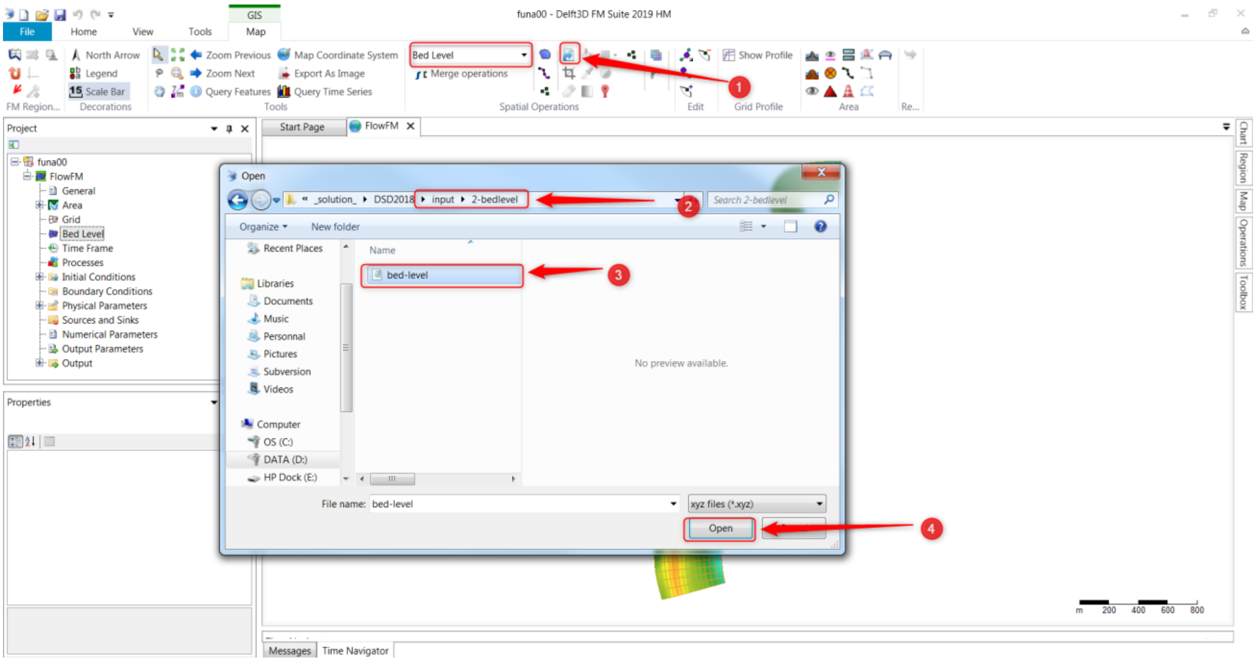


Figure 2.6 Importing the samples to create the bed topography.

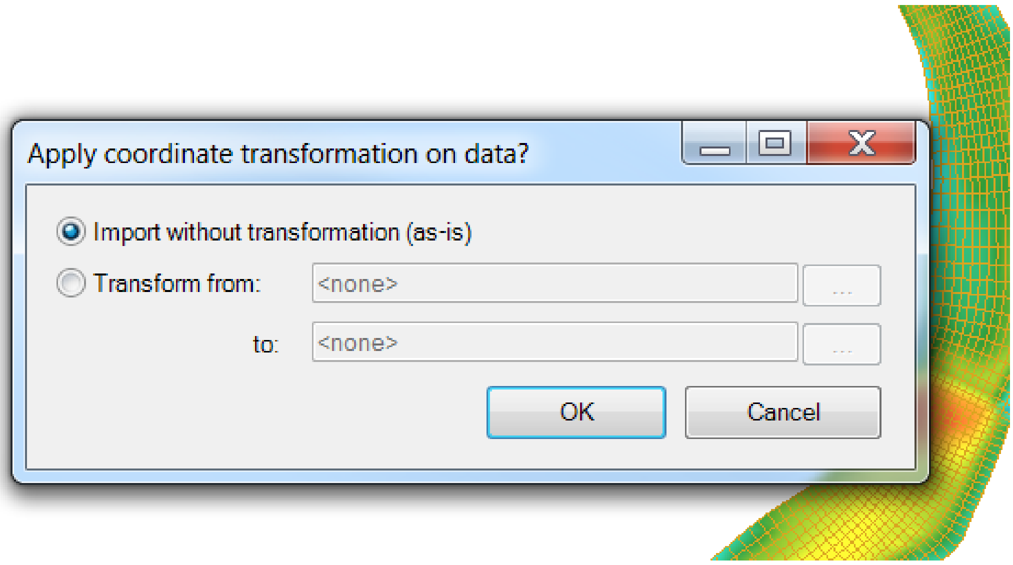


Figure 2.7 Applying the coordinates transformation if needed.

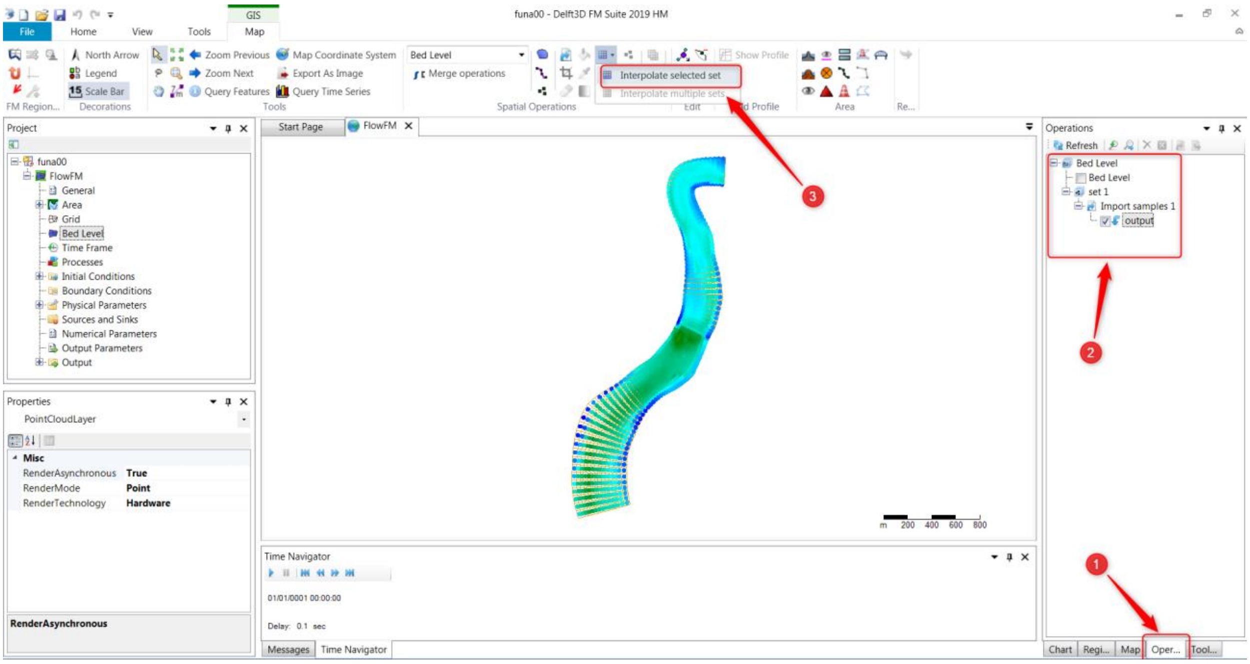


Figure 2.8 visualizing the samples and start the interpolation

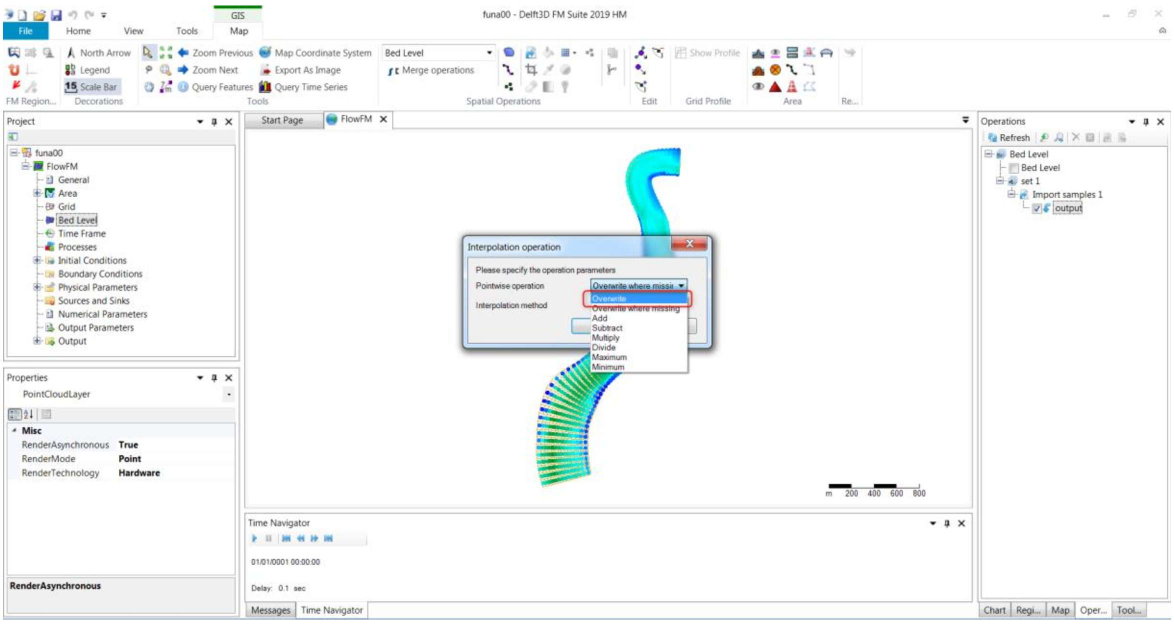


Figure 2.9 Interpolation operation to select “Overwrite” option

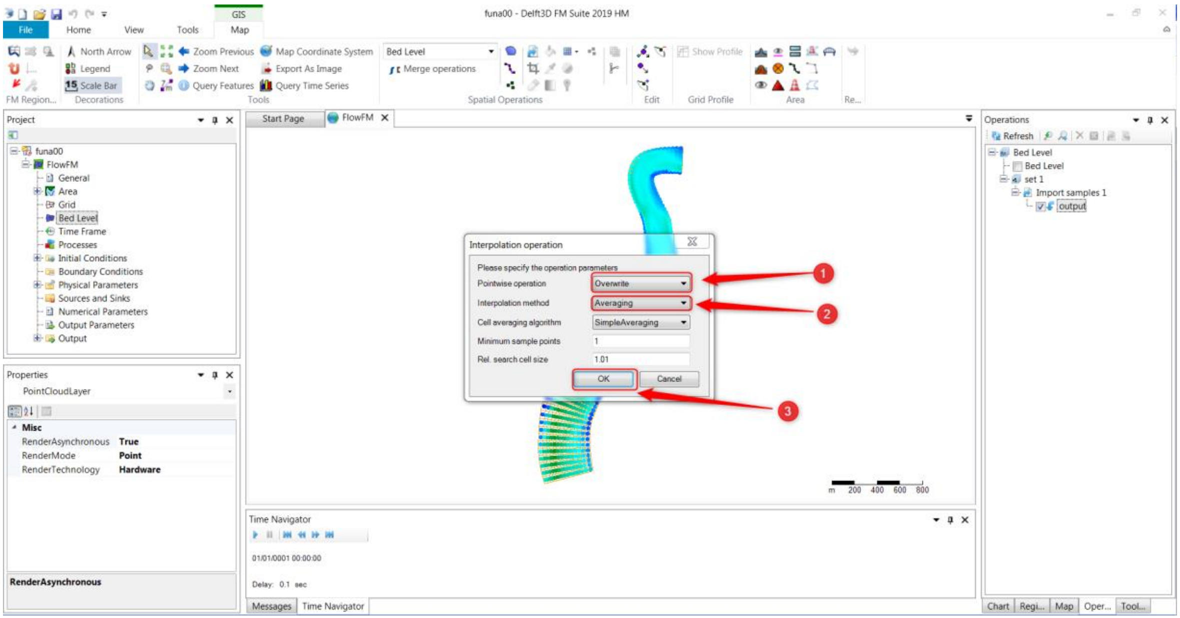


Figure 2.10 Interpolation method and options (select "Averaging")

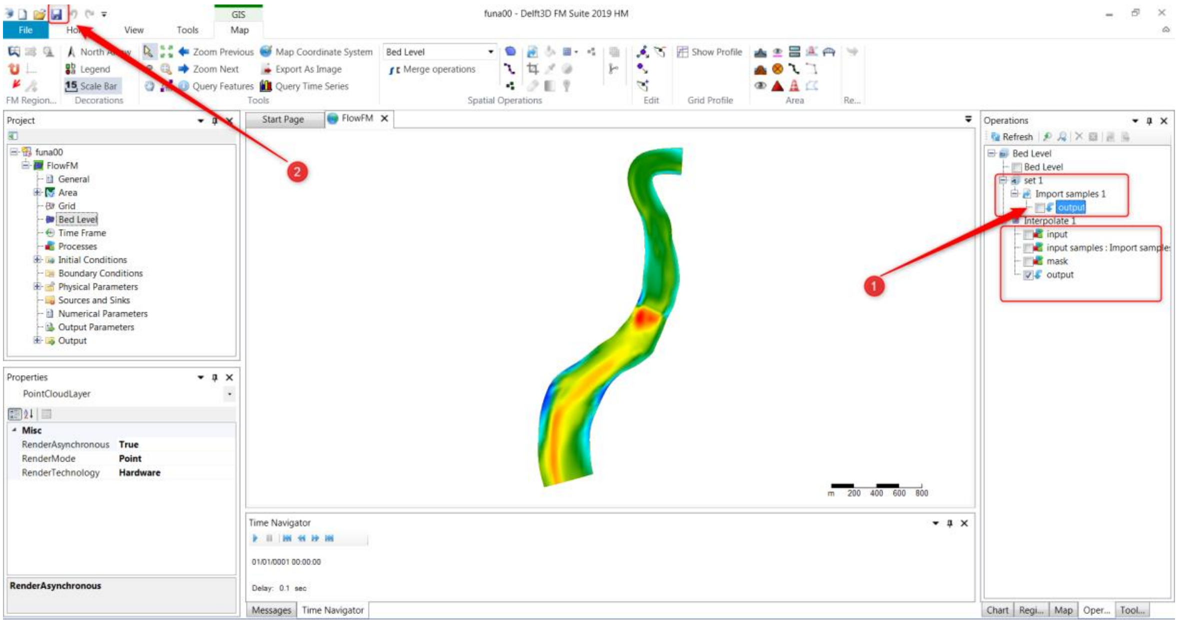


Figure 2.11 Saving the bed topography

2.4 Boundaries

The boundary locations have been already added in this exercise. Normally, you need to add the boundary location yourself. In this exercise, we will only add input data of the boundaries.

2.4.1 Upstream boundary

Go to project window of Delta-shell and click on "*Boundary Condition*". Then select "*Boundary 01*". The boundary window will pop up, click on "*Csv import*" icon to add a csv file contains the boundary. When you click it then you a wizard window (see Figure 2.13) will pop up, you need to click next and follow the instructions to upload the file (*upstream-boundary.csv*) which is located at your directory *"...\input\3-upstream-boundary\".* The boundary is steady-state discharge time series with a value of 310 m^3/s as shown in Figure 2.14.

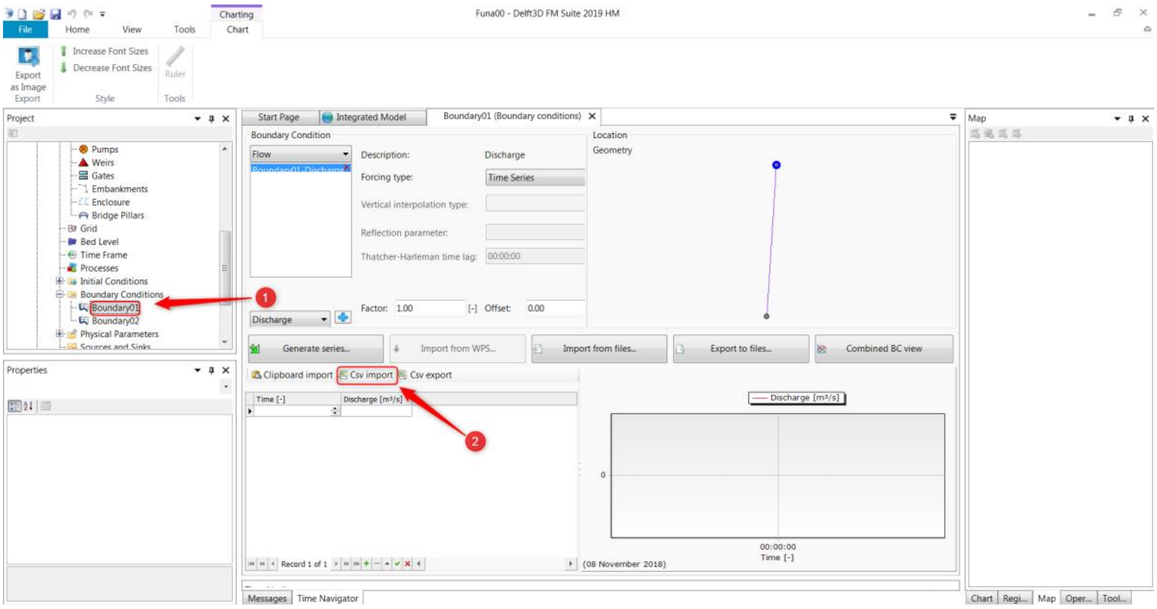


Figure 2.12 Adding the upstream boundary input data.

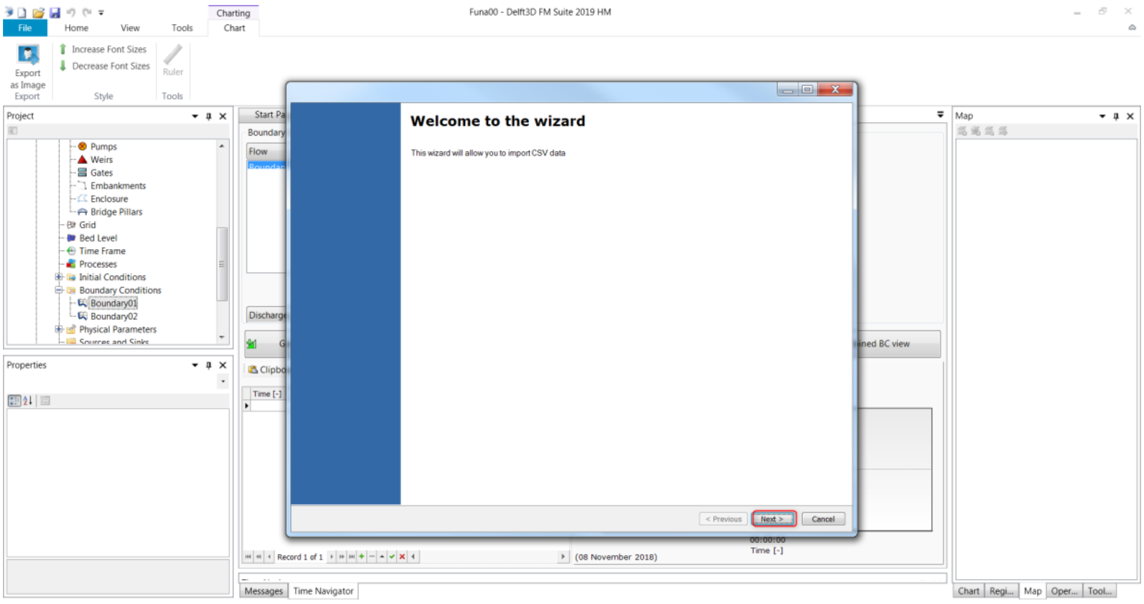


Figure 2.13 uploading the boundary data through the wizard.

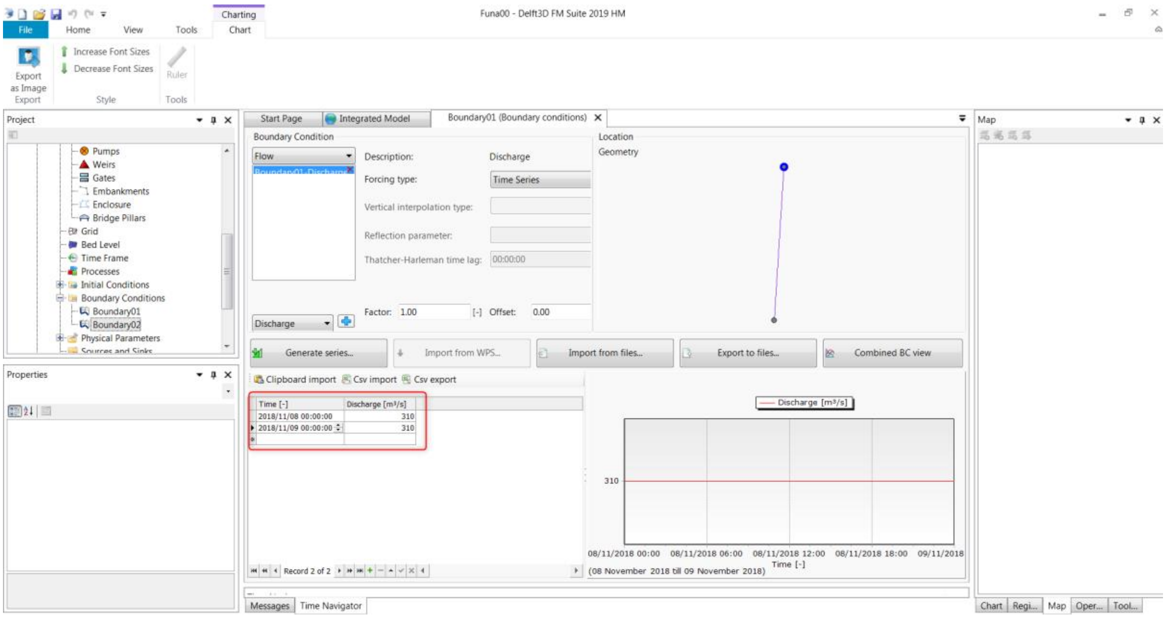


Figure 2.14 The upstream boundary has been added

2.4.2 Downstream boundary

Go to project window of Delta-shell and click on "*Boundary Condition*". Then select "Boundary 02". The boundary window will pop up, click on "Csv import" icon to add a csv file contains the boundary. When you click it then you a wizard window (see Figure 2.13) will pop up, you need to click next and follow the instructions to upload the file (*downstream-boundary.csv*) which is located at your directory *"...\input\4-downstream-boundary\"*. The boundary is a Q-h relation and after uploaded successfully it will be seen as shown in Figure 2.16.

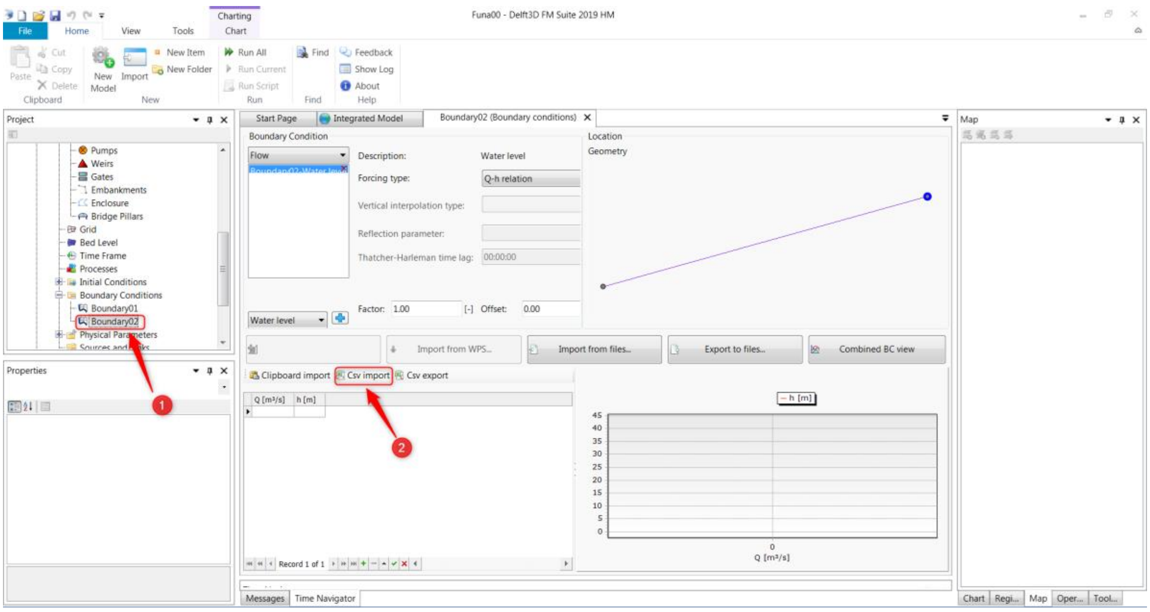


Figure 2.15 Adding the downstream boundary input data.

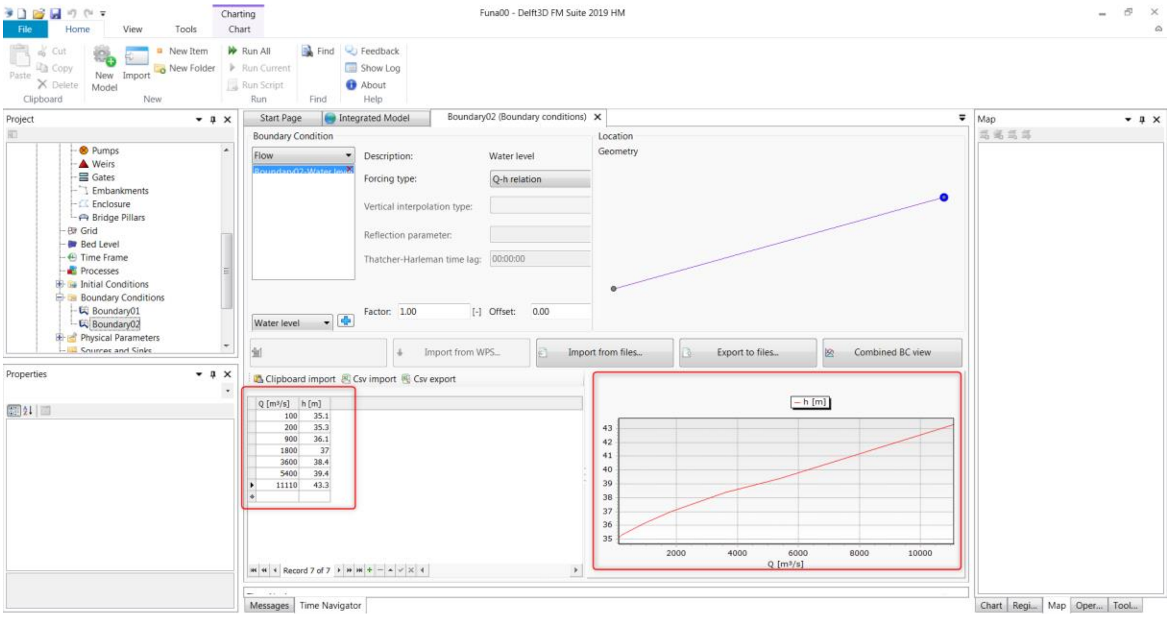


Figure 2.16 The downstream boundary has been added

2.5 Gates operation

The gates locations have been already added to the model because of limited time fo the session. 3 gates will be used in the mode. In this exercise, you will add the input data if the gates.

Go to "**Project**" window and click on "**Area**", then click on "**Gates**". The Gates window will pop up in the middle of Delt-shell screen.
Use right click at every gate and go to "**Open view**" to see the gate input data as shown in Figure 2.19. Click on lower edge level – Time series to add the gate input. Awizard window will pop up follow the instructions to upload the data from csv file (vertical-gate-opening.csv) locationed in your directory "…\input\5-gates\". **Repeat** the bove steps for every gate. Finally, the three gates will have same time series as shown in Figure 2.20.
Save the model.

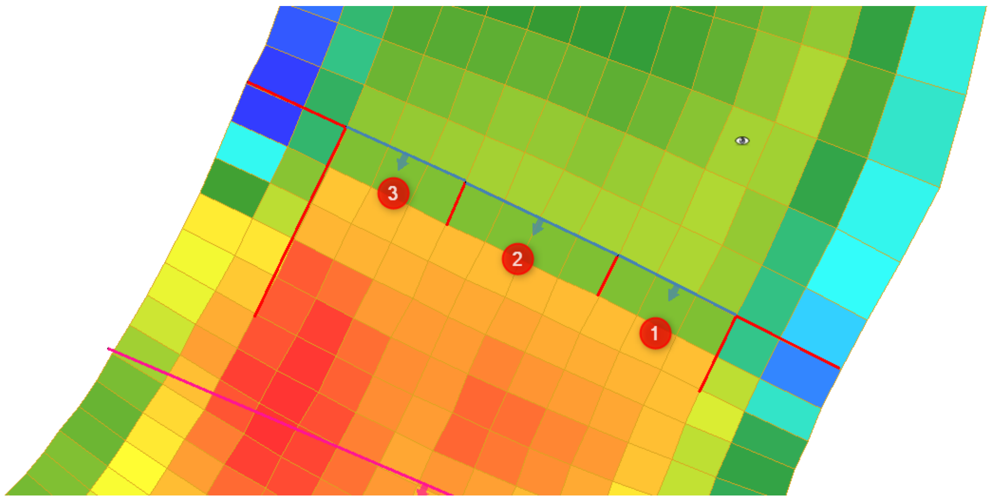


Figure 2.17 The dam gates location and shape in the model (the operation is similar to sliding gates)

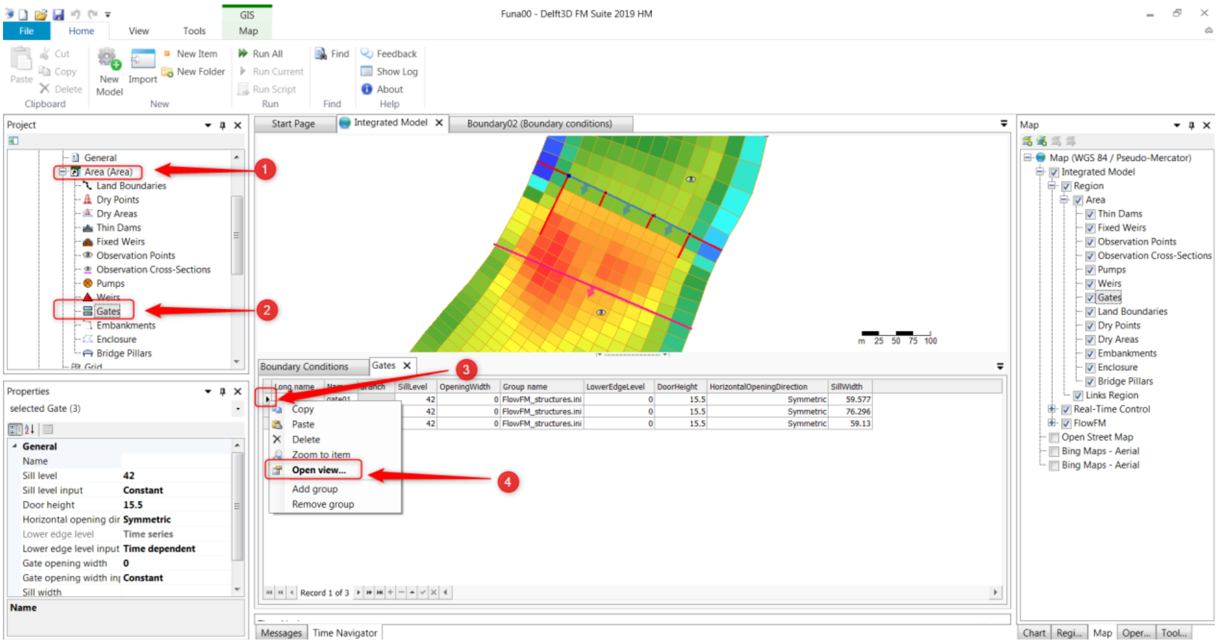


Figure 2.18 Opening the gate properties to upload the gates operation time series

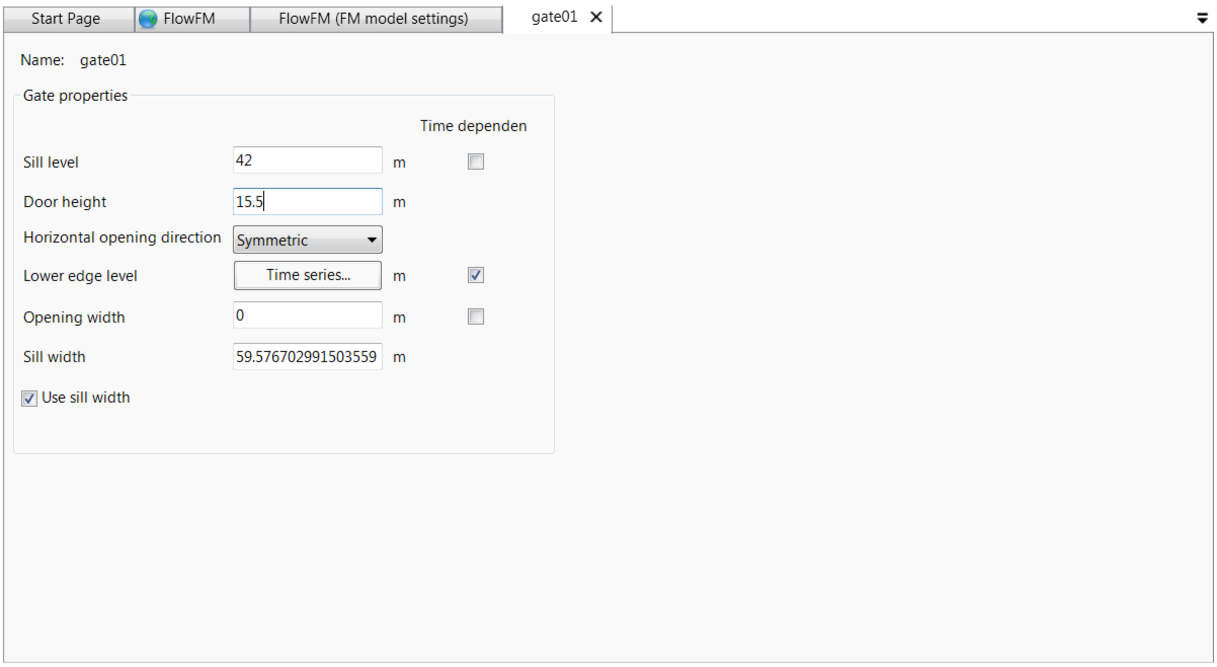


Figure 2.19 An example of gate properties input window

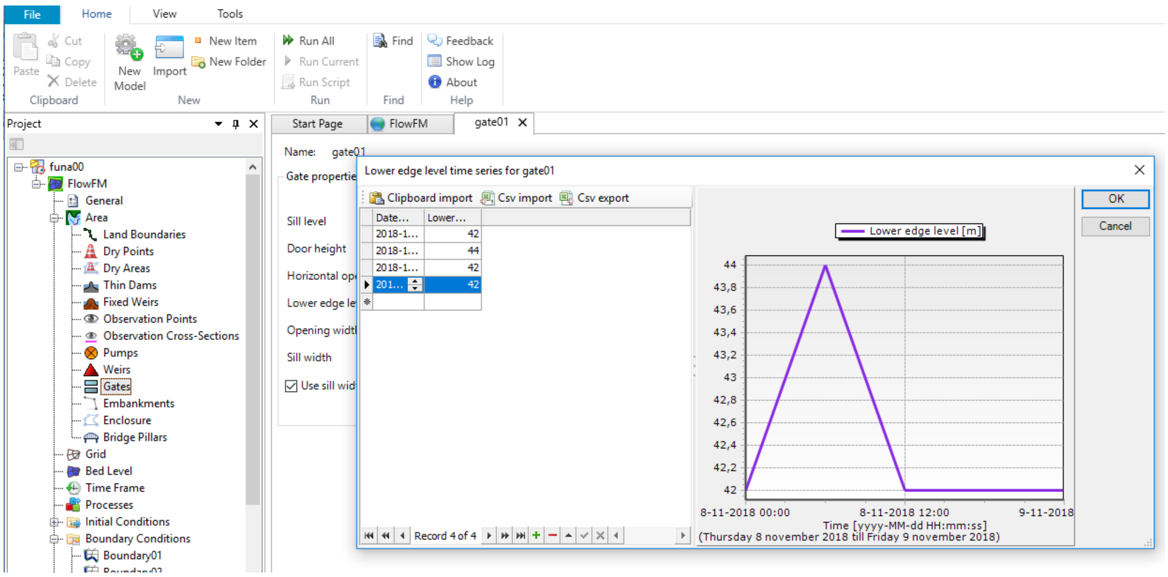


Figure 2.20 Gate operation time series (import ready file "vertical-gate-opening.csv")

2.6 Sediment and Morphology

2.6.1 Sediment

In this exercise, we will add one type of sediment "*sand01*" Go to "*Sediment*" window (that you see after double clicking on "*General*") and type "*sand01*" and click on "*New*". The sediment characteristics will be shown. Please change the D50 from 0.0002 to 0.0001. The rest setting keep it as default.

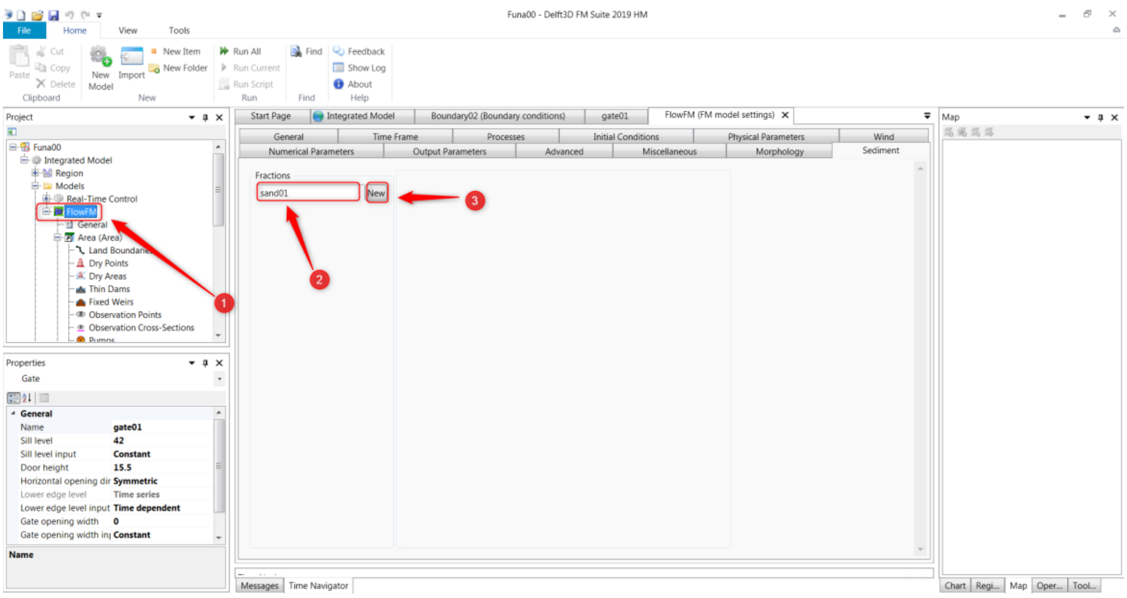


Figure 2.21 Add sediment fraction

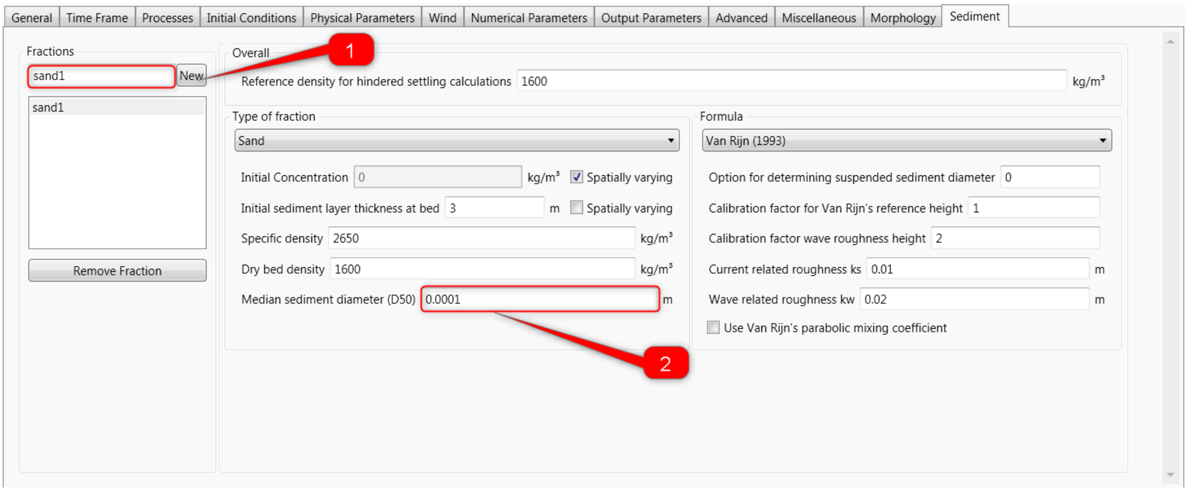


Figure 2.22 Add the sediment characteristics

2.6.2 Morphology

Go to "*Morphology*" window and change the setting as follows (see: Figure 2.23)

1. Morphological scale factor to 10
2. Spin-up before morphological changes to 120 min
3. Current related transport vector factor to 10
4. Factor for erosion of adjacent dry cell to 0.5
5. **Save the model**

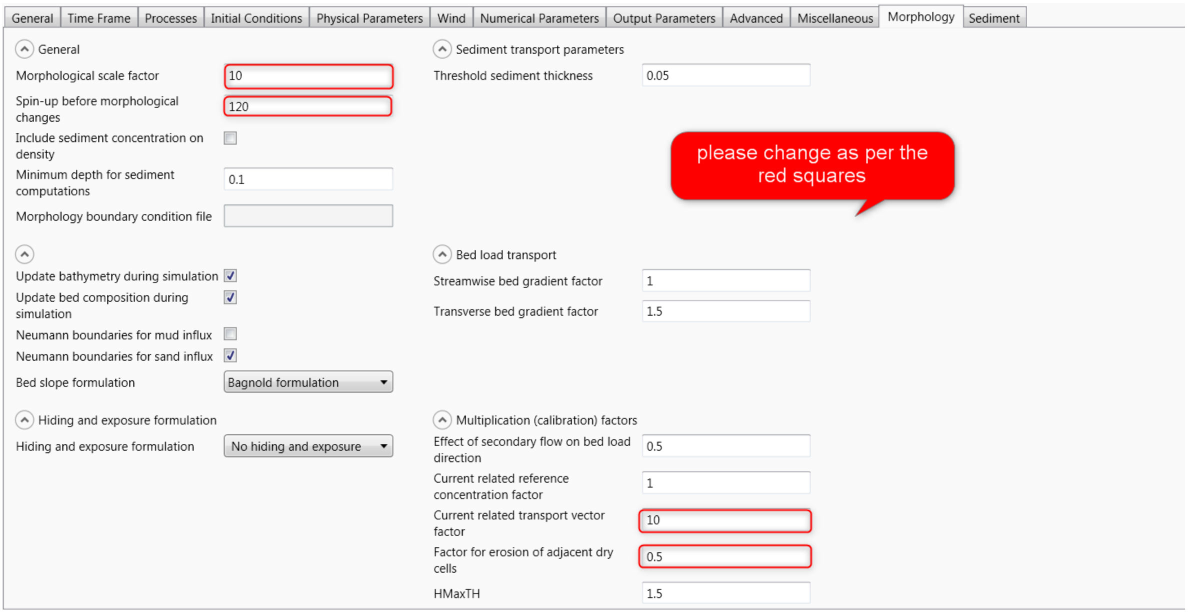


Figure 2.23 The morphology setting

Tips:

- **Save the model**
- Check the time step is equal to 5 min (in "*Time Frame*" window)

2.7 Start simulation

Before you run the mode, you need to validate the model. Go to the “*Project*” window:

- Right click on the “*FlowFM*”
- Click on “*Validate*” as shown in Figure 2.24
- New window will pop up as shown in Figure 2.25. If model is ok then all the validation results will be with green icons. Otherwise, you may need to check the model based on the error that would be shown in the validation screen.
- Run the model: right click on the FlowFM”
- Click on “Run Model as shown in Figure 2.26. A new screen will pop up to show the the simulation progress (see Figure 2.27).
- Wait until the model simulation is finished to see the results.

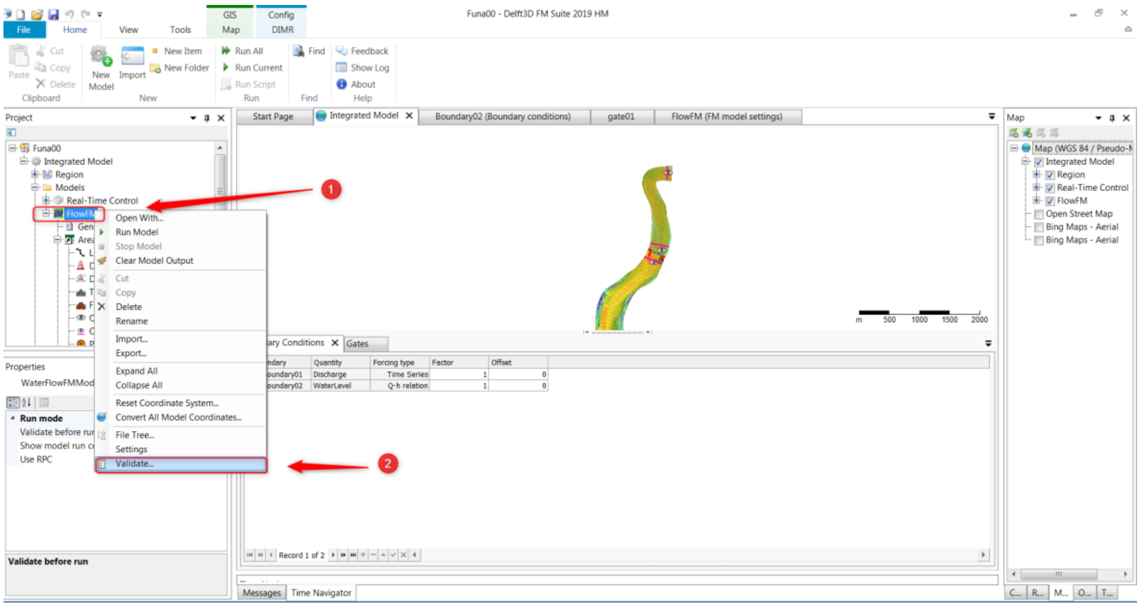


Figure 2.24 validation of the model

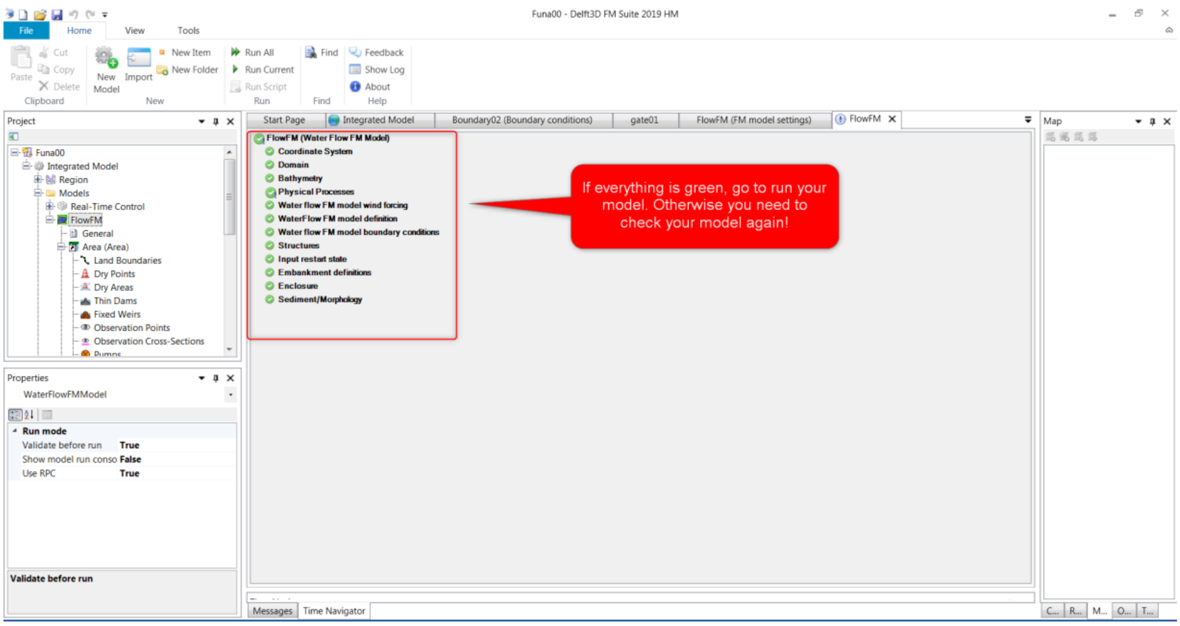


Figure 2.25 Check validation results

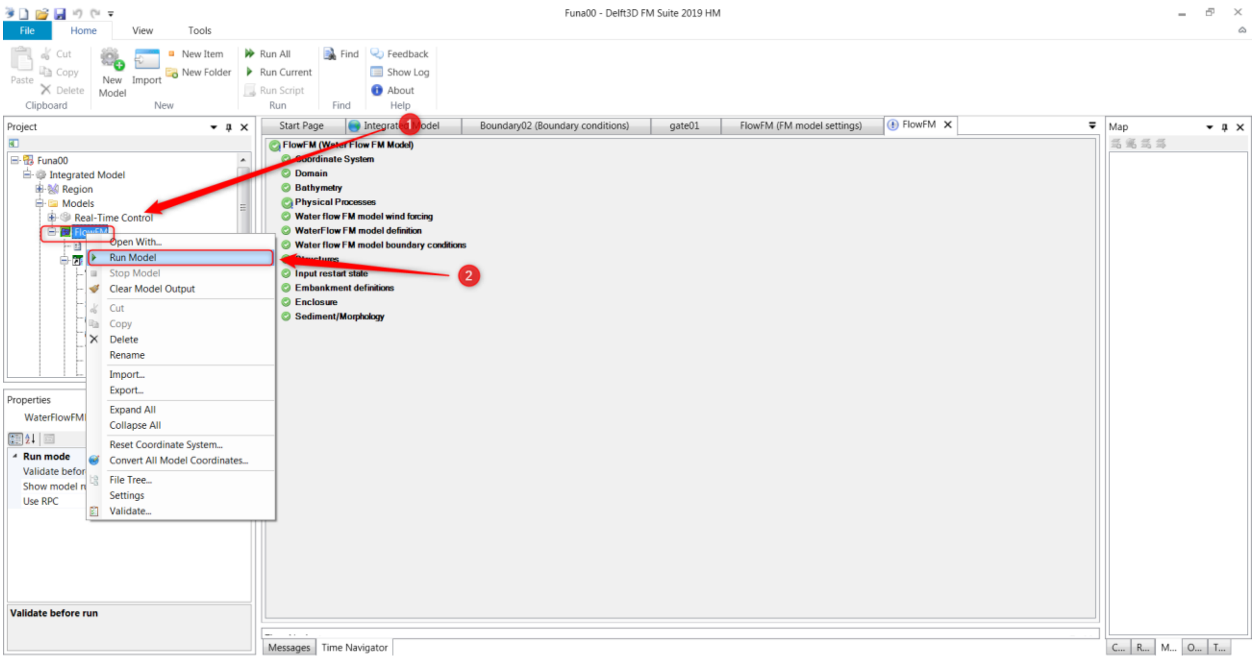


Figure 2.26 Run the model

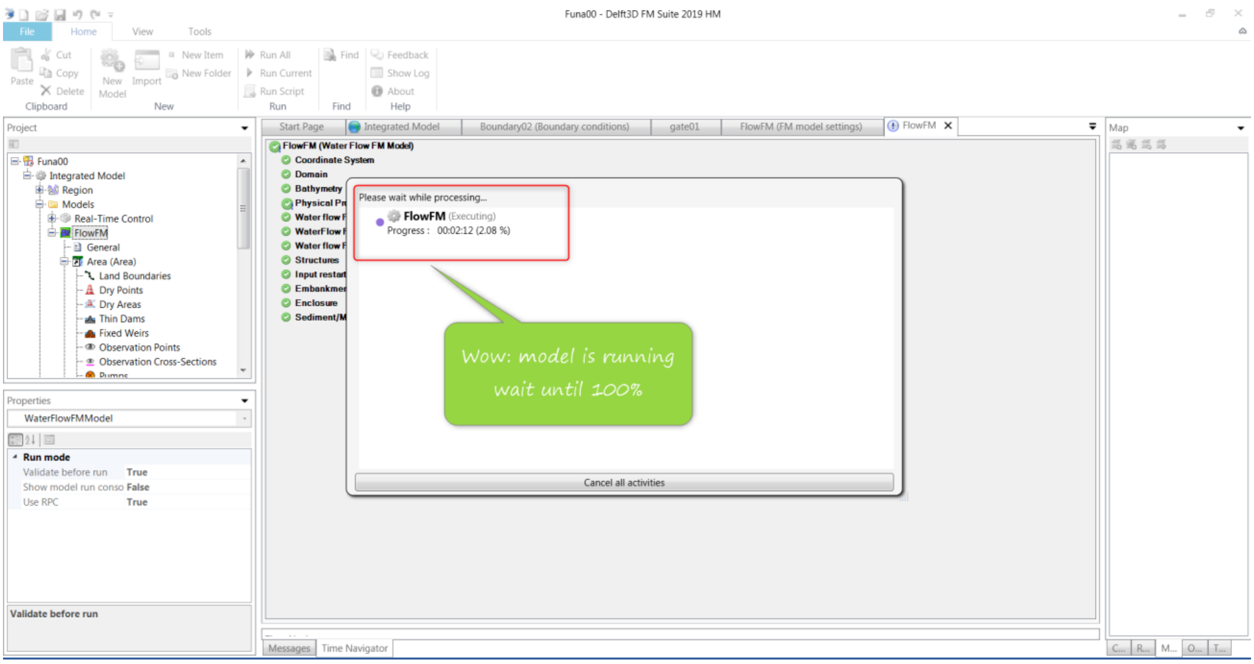


Figure 2.27 Model is running.

3 Explore the model results

3.1 Visualizing the results (Delta-shell)

After the simulation is finished you can see the model results as follows:

- Go to the “*Project*” window and click on “*Output*”.
- Double click on one of the results, for instance, “*Water level*”.
- Use the “*Time Navigator*” at the bottom to run the change of water level in time.
- Go to the “Map” at the right side of Delta-shell window to explore the output of the map file and the history file as shown in Figure 3.1.
- You may also click on the Open-street map to see the simulated results on it (if it is not there, you can activate by clicking in an icon at “*Map*” window as shown in Figure 3.2.
- You can print the results as “*png*” as shown in Figure 3.3.
- Figure 3.4 and Figure 3.5 show examples of the model results.

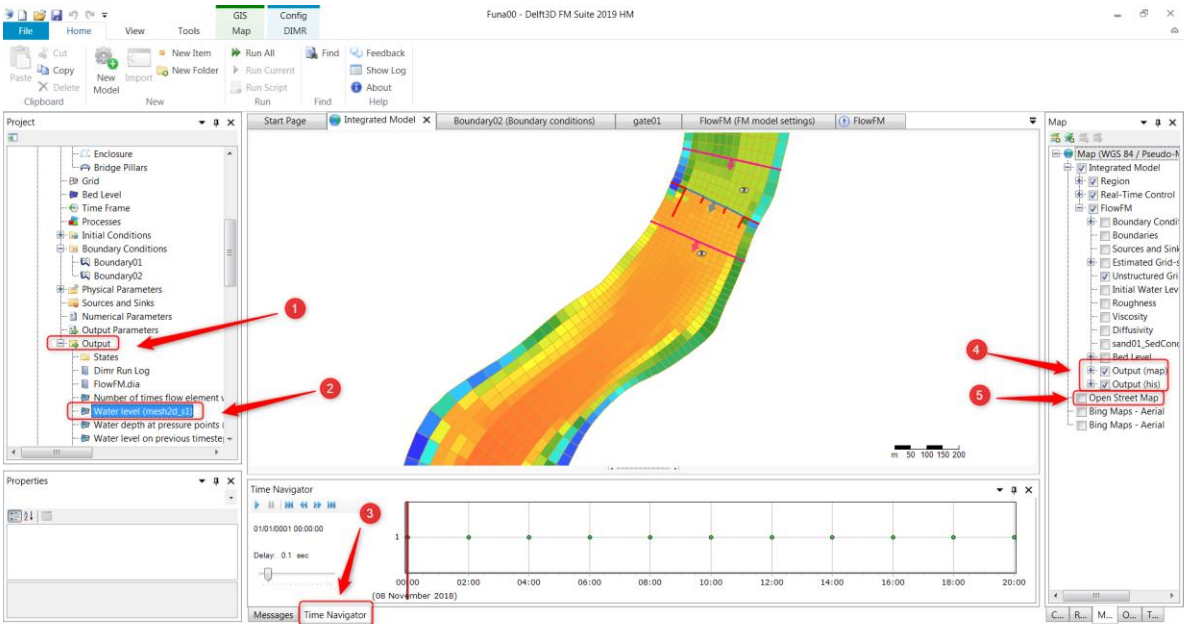


Figure 3.1 Exploring the model results.

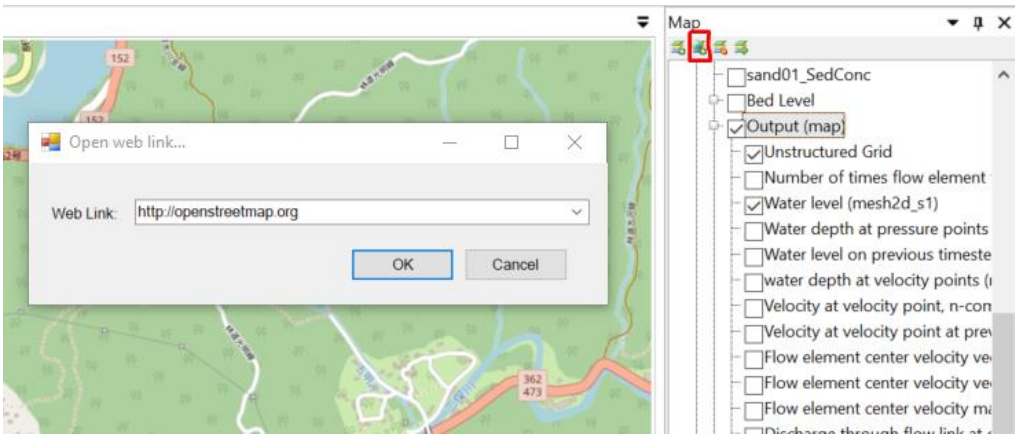


Figure 3.2 Activating Open street map (or other maps like Bing map)

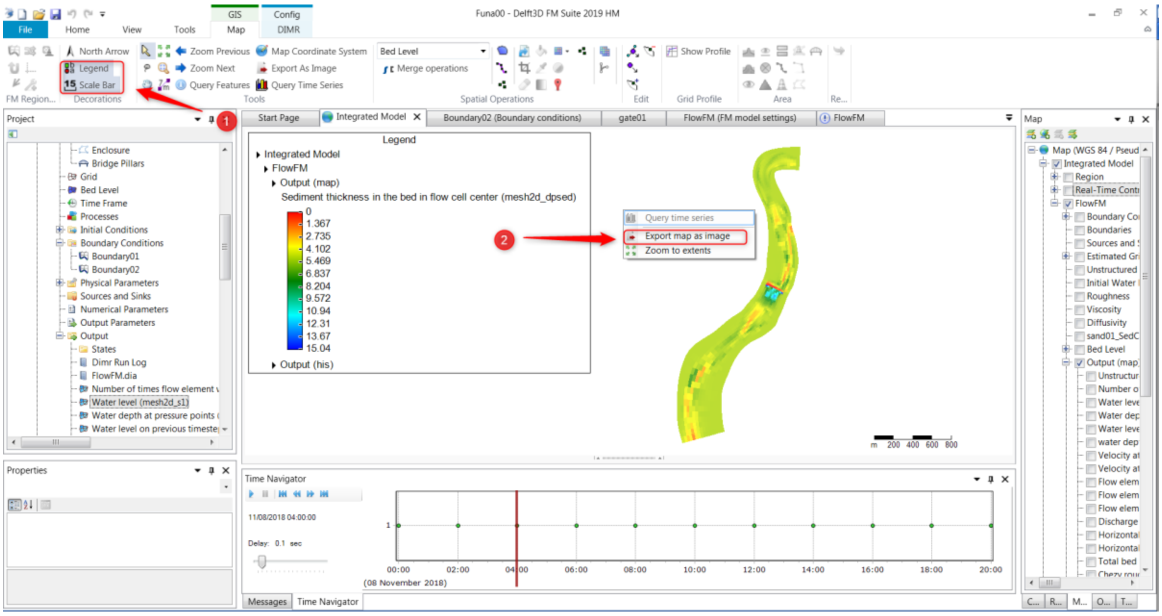


Figure 3.3 Print the model results

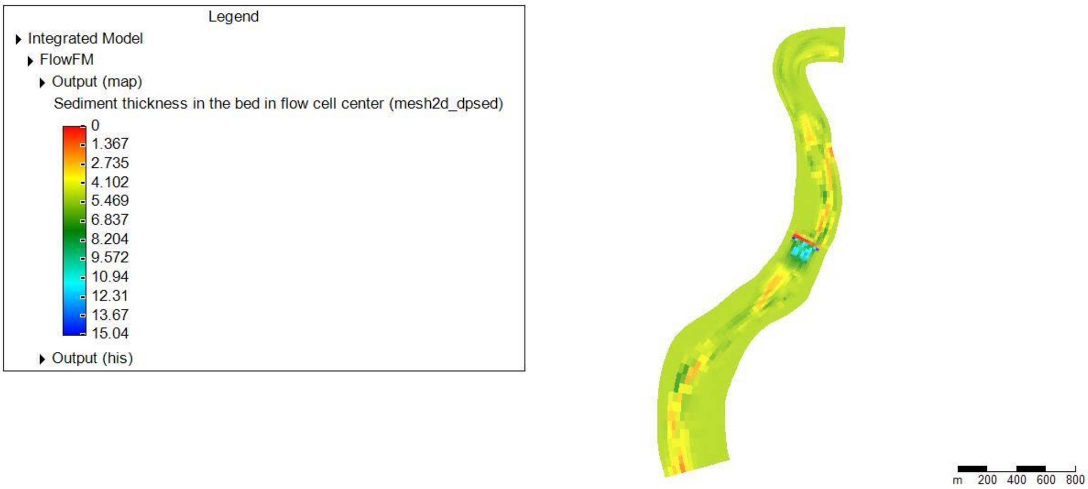


Figure 3.4 Sediment thickness after model simulation time.

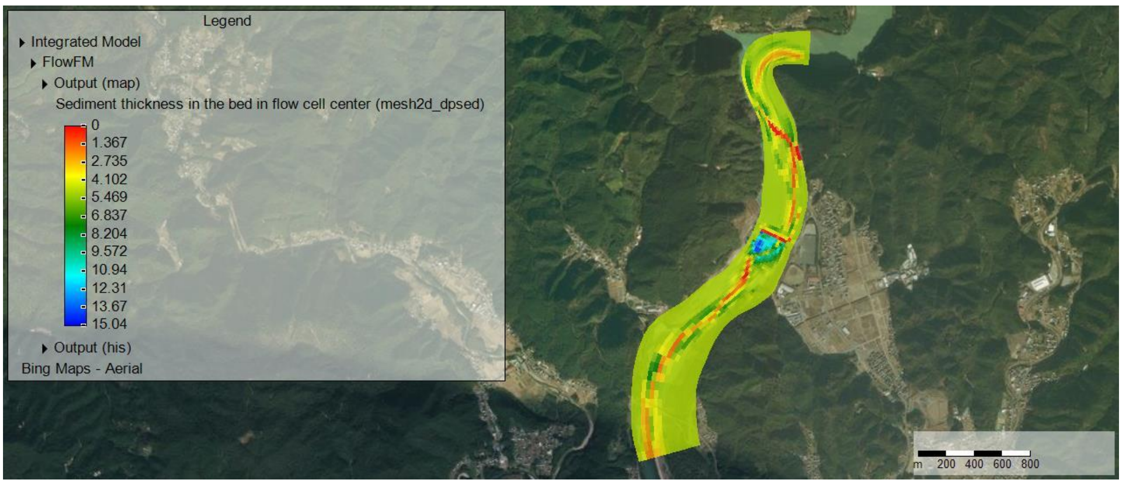


Figure 3.5 Sediment thickness after model simulation (with background of “Bing Maps-Aerial”)

Check the history file:
You can also plot the time-series of many components (at observation point or cross-section location) to compare the results. For instance, you can see the time-series of simulated water level upstream of the dam by:

- Selecting the observation point and then the "*Query time series*" (see Figure 3.6).
- Then select the type of the data you want to explore (see Figure 3.7).
- Click *Ok* to visualize the results (see Figure 3.8).

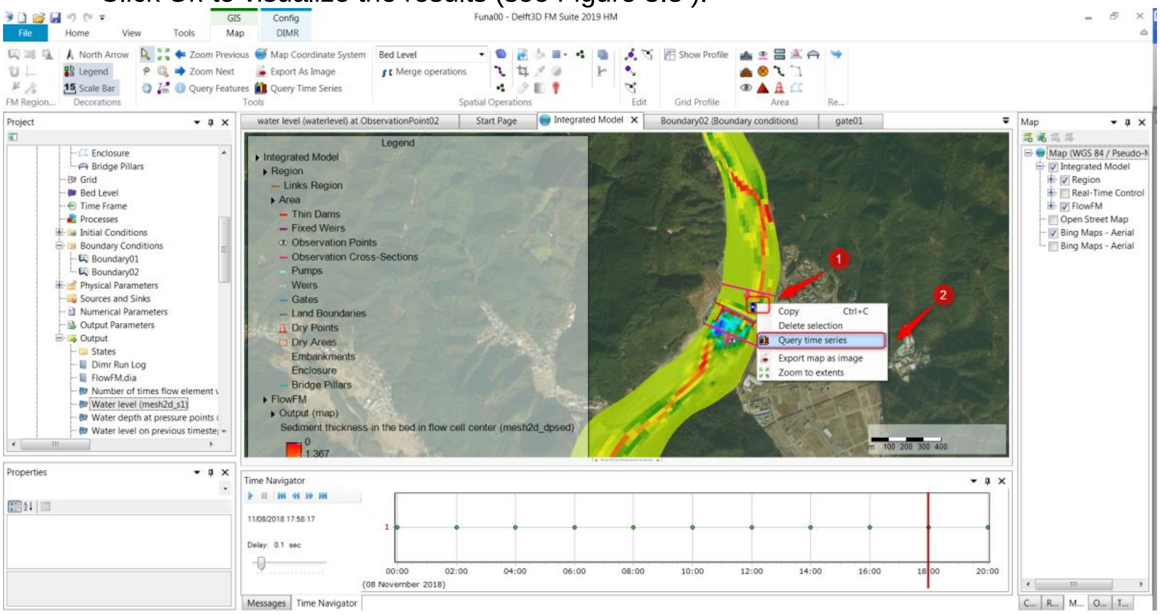


Figure 3.6 History file: check the water level upstream the dam (step A: select the observation point)

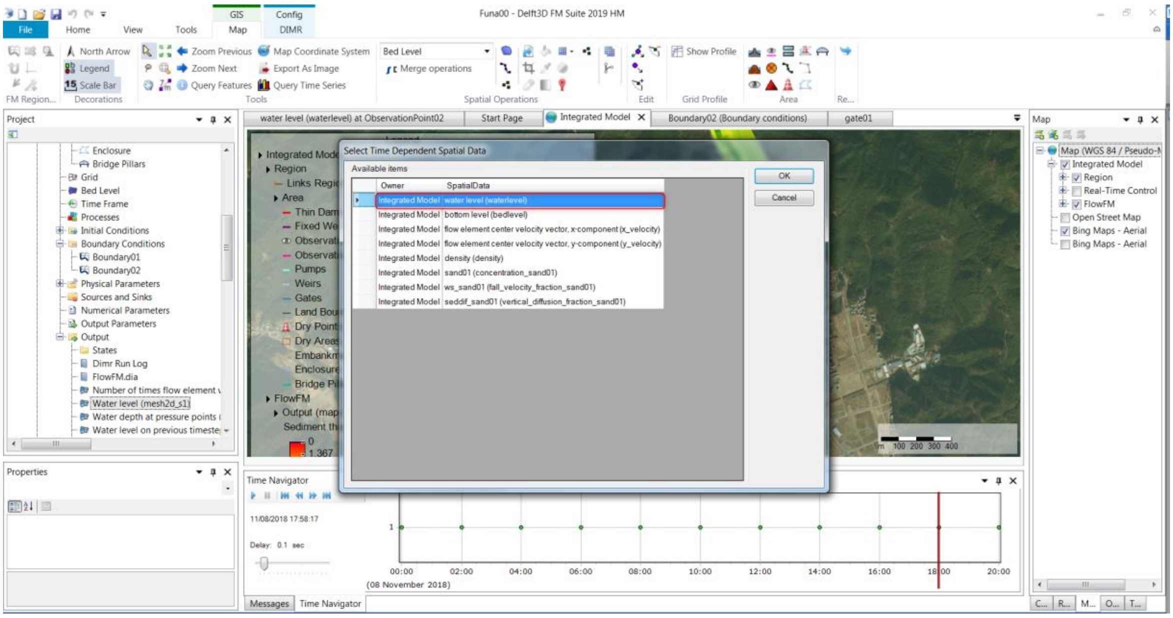


Figure 3.7 History file: check the water level upstream the dam (step B: select the water level)

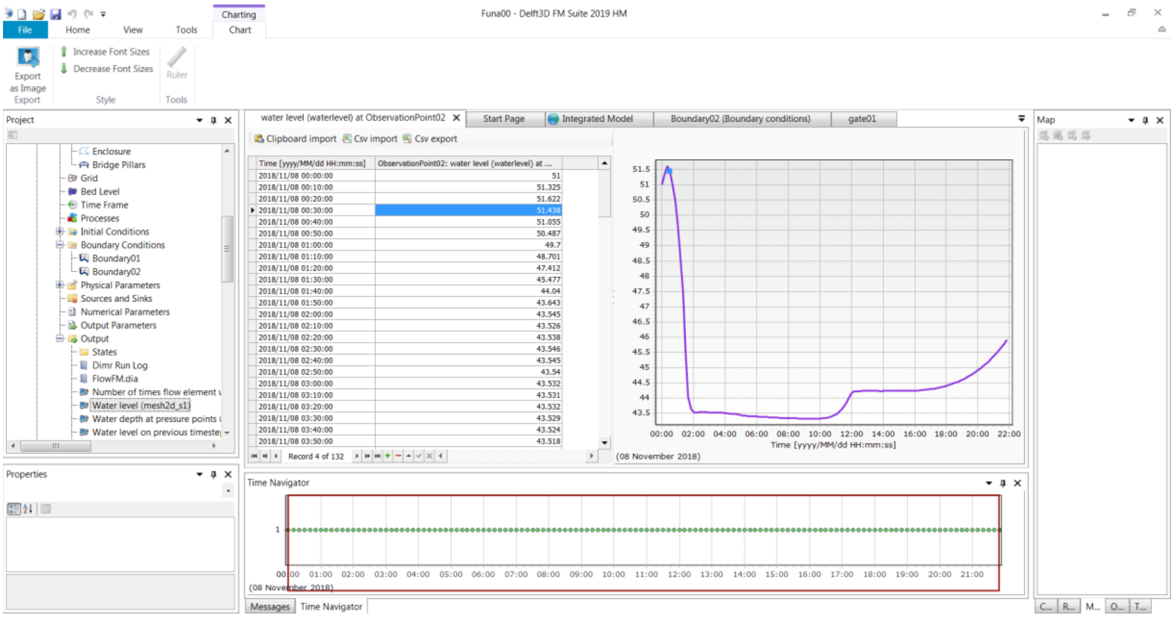


Figure 3.8   History file: check the water level upstream the dam (step C: visualize the results)

3.2 Visualizing the results using QuickPlot

You can also see the results using another postprocessing tool, namely QuickPlot. You can load the map and history files in QuickPlot to check the results.

First load the map file. This file stores the results for every grid point. The easiest way to check the hydrodynamic/ morphological results for this 2D-model is to view results along one grid line. Make sure that you specify the line (xy) and check the variation of the water level, water depth and depth-averaged velocity along the flume.

Now load the history file. This file stores the time series of the results for the observation stations and cross-sections. From the station list, select a station. From the field list, select again any component and plot for the time series.

Question 1
Are the hydrodynamic results as expected?

Question 2
Try to make a colour plot of the magnitude of the velocity in the plane for same line. Describe your findings. Also, try to add the velocity vectors to this plot.

Beside the hydrodynamic results, the map file stores sediment-related outputs as well, e.g. concentration and sediment transport. The name of sediment fraction is also in the list of output fields (in our case "*sand01*"). This field contains the concentration of this fraction.

Question 3
Try to make a colour plot of the suspended sediment concentration in the plane for the same line. Describe your findings.