Deltares

enabling delta life

Deltares

Delft3D FM 1D

Webinar

Victor Chavarrias

23-04-2021

Who am I?!

I really like rivers!

- Civil engineer UPC (Barcelona)
- PhD TU Delft

Deltares: morphodynamics, 3D flow, salinity intrusion…

RiverLab

Community of users and resources: https://oss.deltares.nl/web/riverlab-models

- Forum
- Webinars
- Models
- Processing tools

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Today

You will find answers to the questions:

1. Why 1D modelling?
2. Which software can I use?
3. How do I create a simple hydrodynamic model?
4. How do I extend it for modelling morphodynamics?

Difficult to read your emotions remotely.
Dare to participate!

1D modelling

Physical processes - flow

1D, 2D, or 3D, in all cases we deal with free-surface shallow flows.

Physical processes - flow

1D, 2D, or 3D, in all cases we deal with free-surface shallow flows.

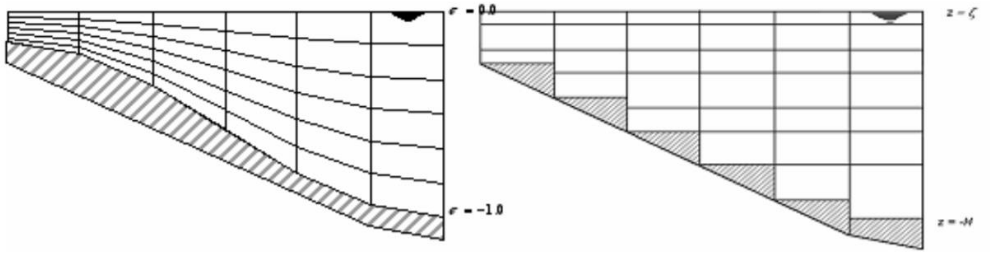
Shallow water approximation:
- Horizontal length scale >> Vertical length scale
- Vertical flow accelerations are small (but not zero!)
- Hydrostatic pressure

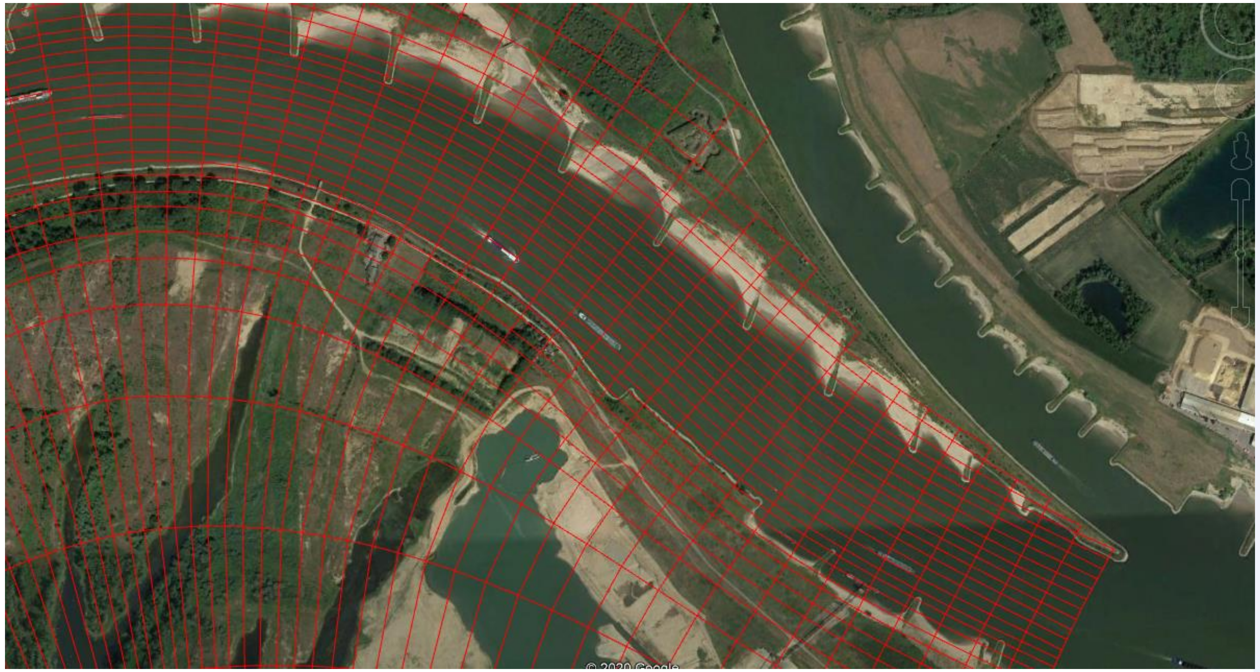
This is not the case for flow over:
- Steep bed topography gradients,
- Structures (e.g., bridge piles),
- …

Physical processes - flow

3D: Turbulence is filtered. Vertical velocities are computed using the continuity equation once the horizontal velocities are obtained. I.e., quasi-3D flow.

sigma z





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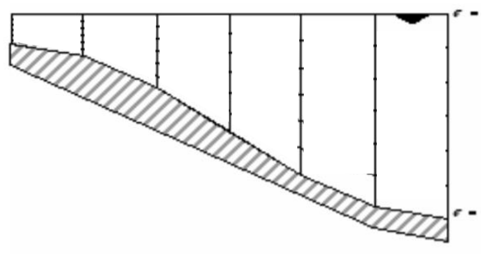
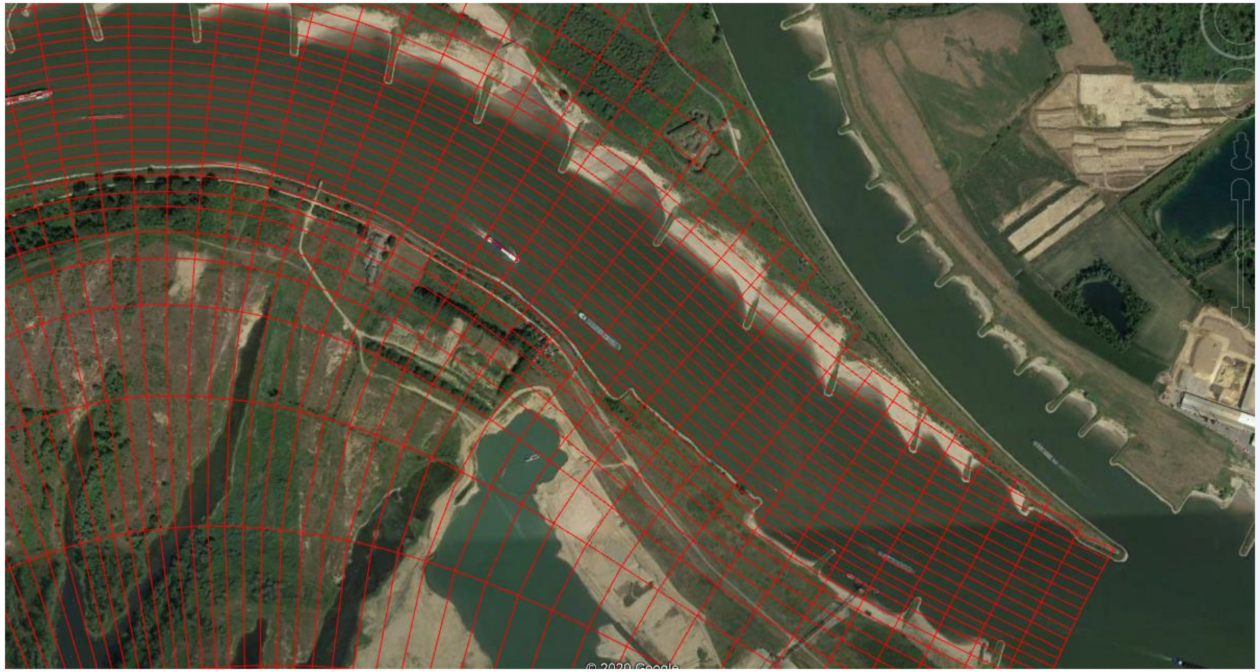
Physical processes - flow

3D: Turbulence is filtered. Vertical velocities are computed using the continuity equation once the horizontal velocities are obtained. I.e., quasi-3D flow.

2D: Depth-averaging of the 3D equations yield extra terms in the equations. Three-dimensional processes (e.g., secondary flow) are not resolved and need to be parametrized.





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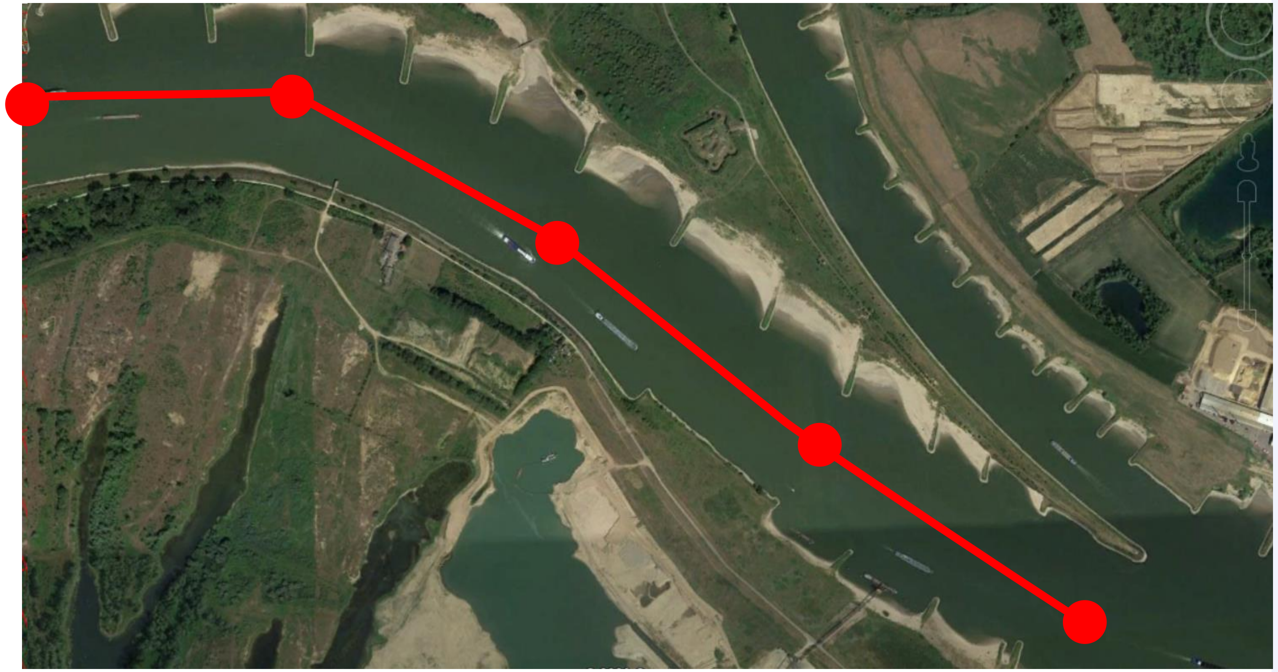
Physical processes - flow

3D: Turbulence is filtered. Vertical velocities are computed using the continuity equation once the horizontal velocities are obtained. I.e., quasi-3D flow.

2D: Depth-averaging of the 3D equations yield extra terms in the equations. Three-dimensional processes (e.g., secondary flow) are not resolved and need to be parametrized.

1D: Cross-sectional average of 2D equations

(i.e., De Saint-Venant (1871) equations).



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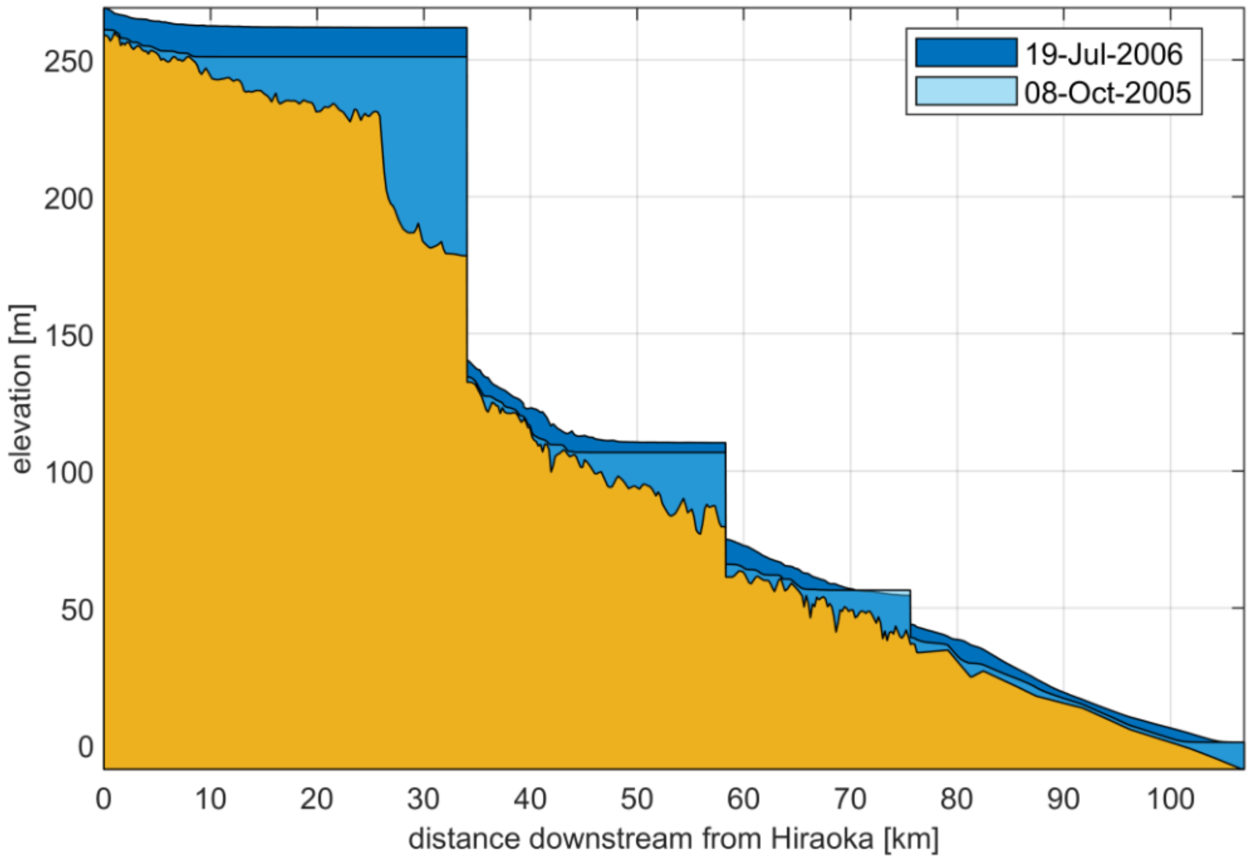
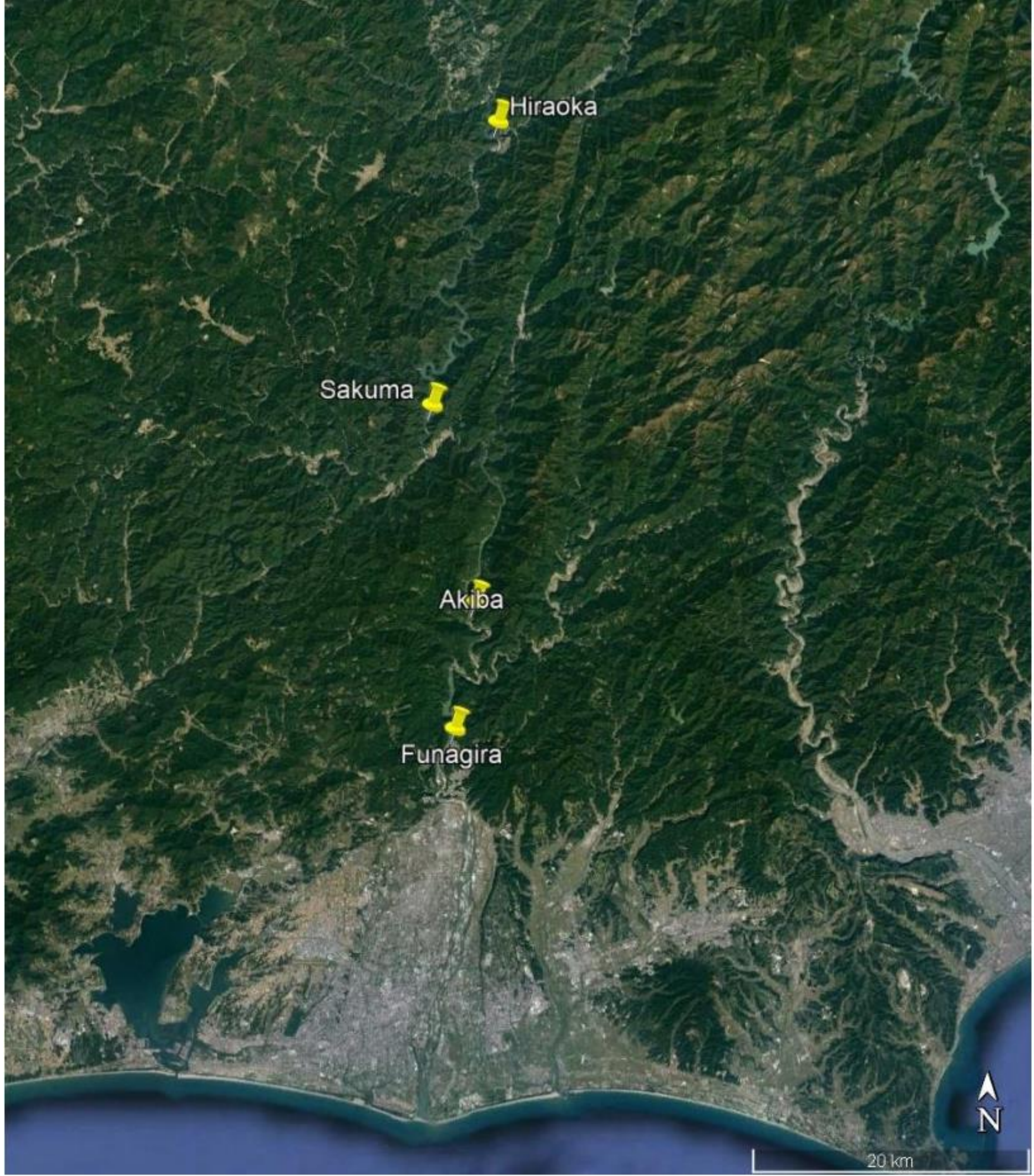
1D modelling

- Length scale of interest in 3D > 2D > 1D.
- 1D model allows for less and larger cells.
- If our questions concerns large length scales and a cross-sectional average is representative: choose 1D.

Example 1D modelling

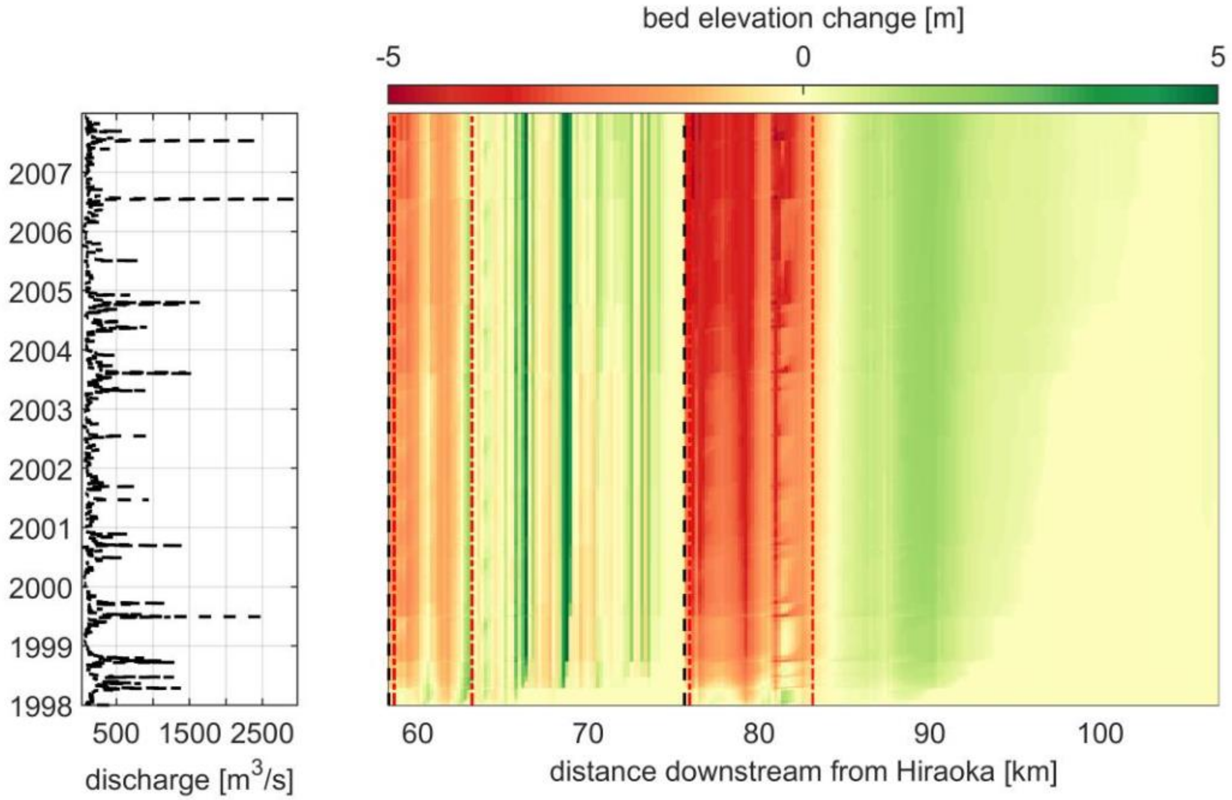
- Large scale impact of nourishment strategy.

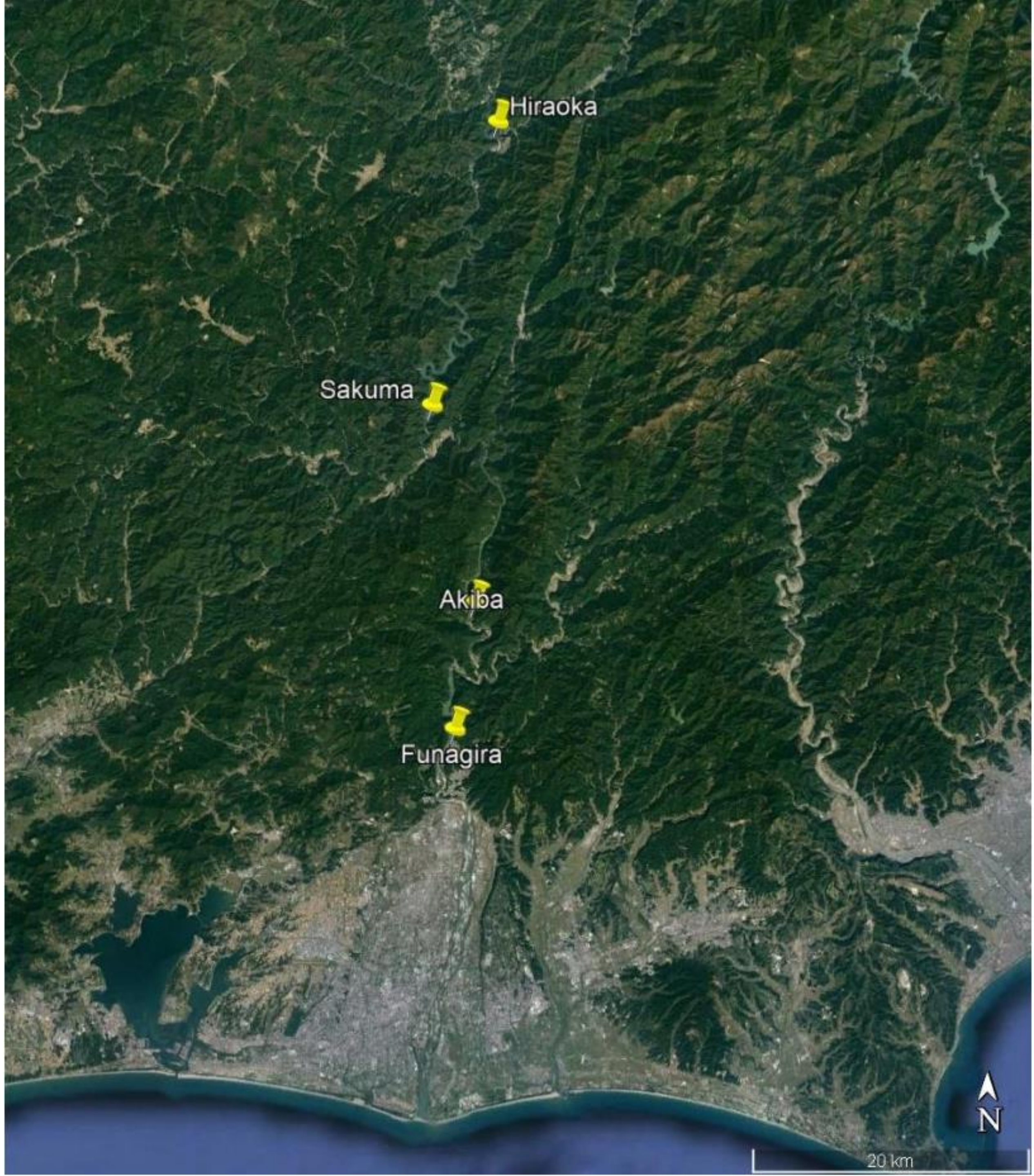




Example 1D modelling

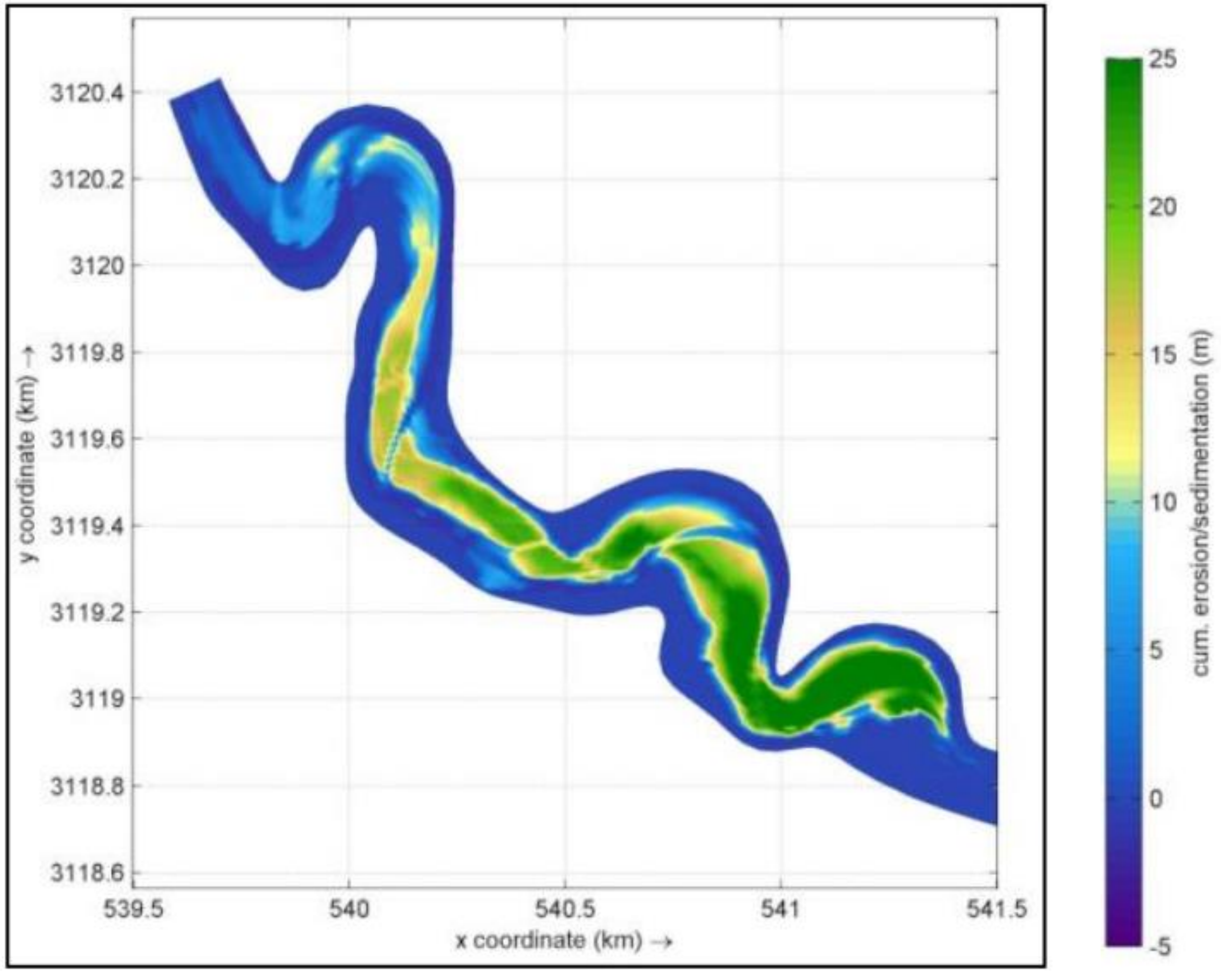
- Large scale impact of nourishment strategy.

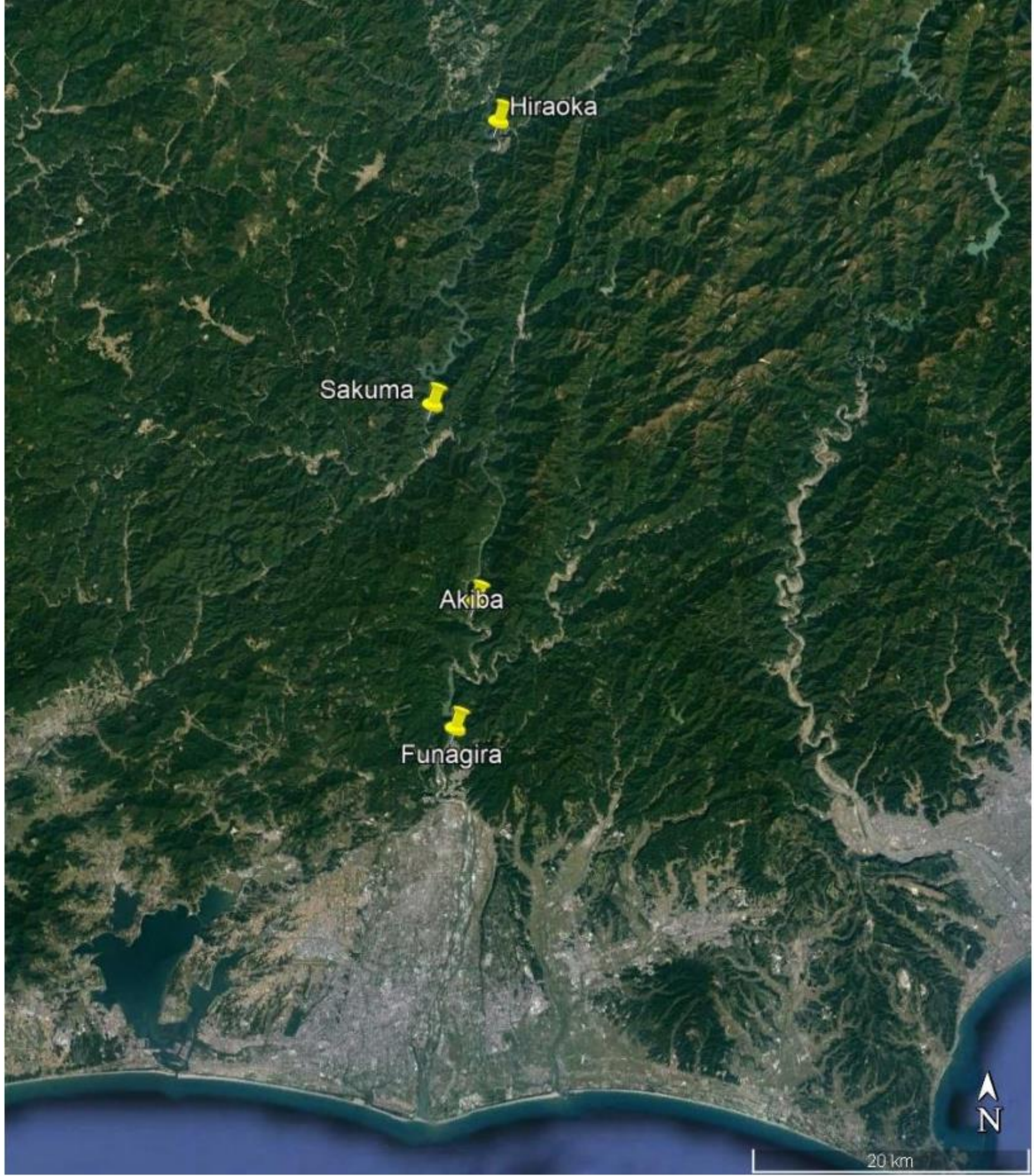




Example 2D modelling

- Small scale impact of nourishment strategy.





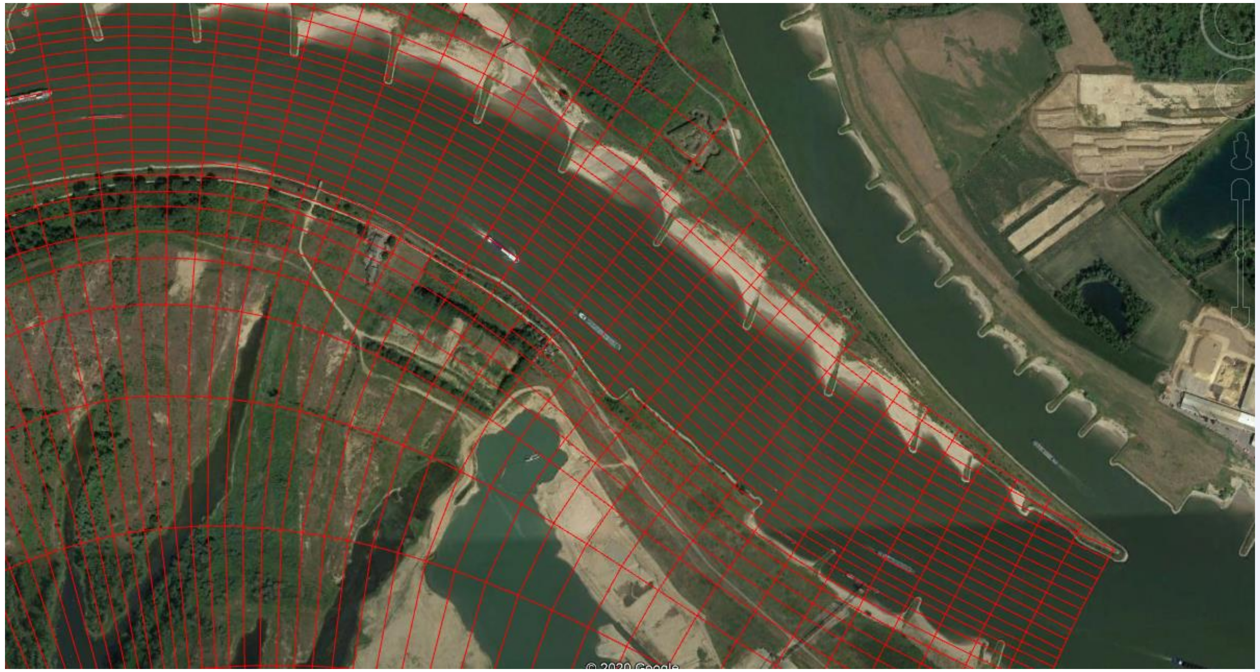
Software

Source: Carlos Dominguez Puig

Software available

1) Delft3D-Flow (Delft3D-4, Delft3D, Delft3D curvilinear)

- Being developed for decades.
- Morphodynamics ‘online’ since beginning 2000.
- 2DH, 2DV, 3D hydrostatic (sigma-layers, z-layers, non-hydrostatic correction).
- Curvilinear grid.
- ADI scheme.



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Software available

1) Delft3D-Flow (Delft3D-4, Delft3D, Delft3D curvilinear, …)
2) Delft3D Flexible Mesh (D-Flow-FM, D-Hydro, Flexible Mesh, …)

- Being developed for the last 10 years. Most features are beta.
- 1D, 2DH, 2DV, 3D hydrostatic (sigma-layers, z-layers, sigma-z-layers).
- Flexible mesh.
- Explicit scheme.

Software available

1) Delft3D-Flow (Delft3D-4, Delft3D, Delft3D curvilinear, …)
2) Delft3D Flexible Mesh (D-Flow-FM, D-Hydro, Flexible Mesh, …)
3) Coupling modules.

- Real Time Control
- Water quality
- …

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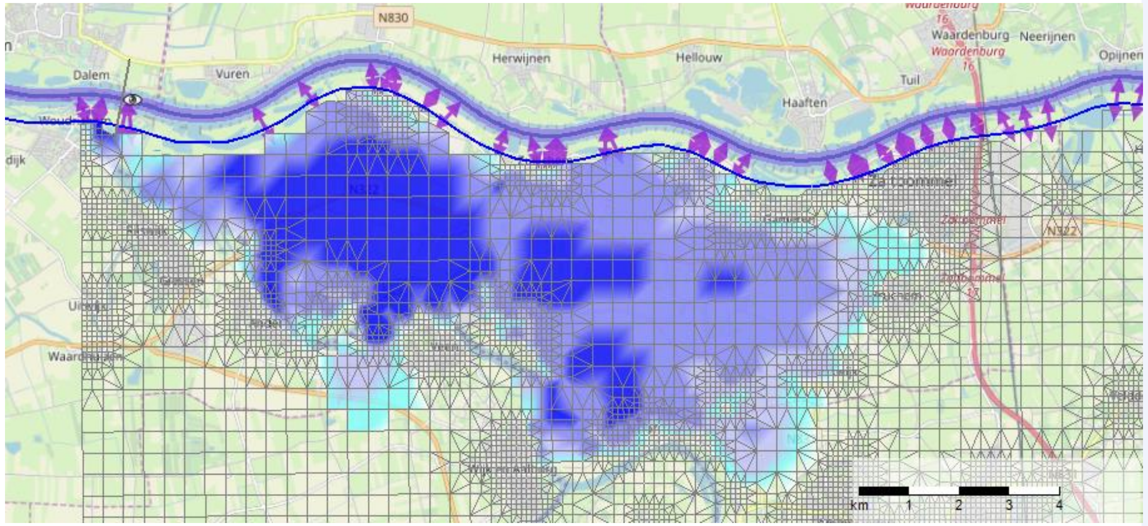
Software available

1) Delft3D-Flow (Delft3D-4, Delft3D, Delft3D curvilinear, …)
2) Delft3D Flexible Mesh (D-Flow-FM, D-Hydro, Flexible Mesh, …)
3) Coupling modules.
4) SOBEK-2, SOBEK-3

- 1D-2D.
- Hydrodynamics only (hidden functionality for morphodynamics).
- Explicit scheme.



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Software available

1) Delft3D-Flow (Delft3D-4, Delft3D, Delft3D curvilinear, …)
2) Delft3D Flexible Mesh (D-Flow-FM, D-Hydro, Flexible Mesh, …)
3) Coupling modules.
4) SOBEK-2, SOBEK-3
5) SOBEK-RE

- 1D.
- 90's.
- Unconditionally stable scheme.
- Currently being phased out.
- Morphodynamics.

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Software available

1) Delft3D-Flow (Delft3D-4, Delft3D, Delft3D curvilinear, …)
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4) SOBEK-2, SOBEK-3
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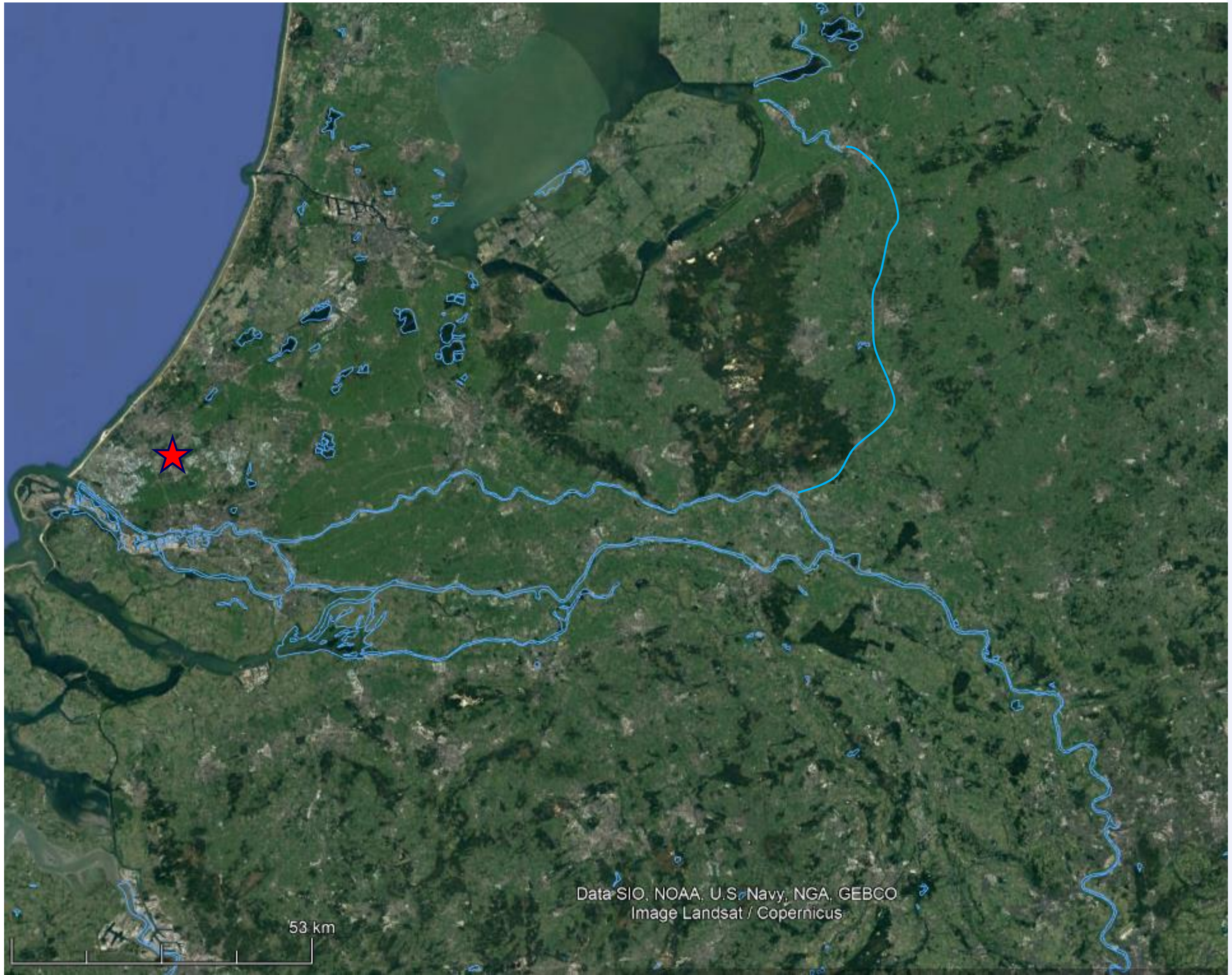
- 1D.
- 90's.
- Unconditionally stable scheme.
- Currently being phased out.
- Morphodynamics.

Software available

Delft3D FM 1D: Awesome but beta.

Idealized hydrodynamic simulation

Inspiration



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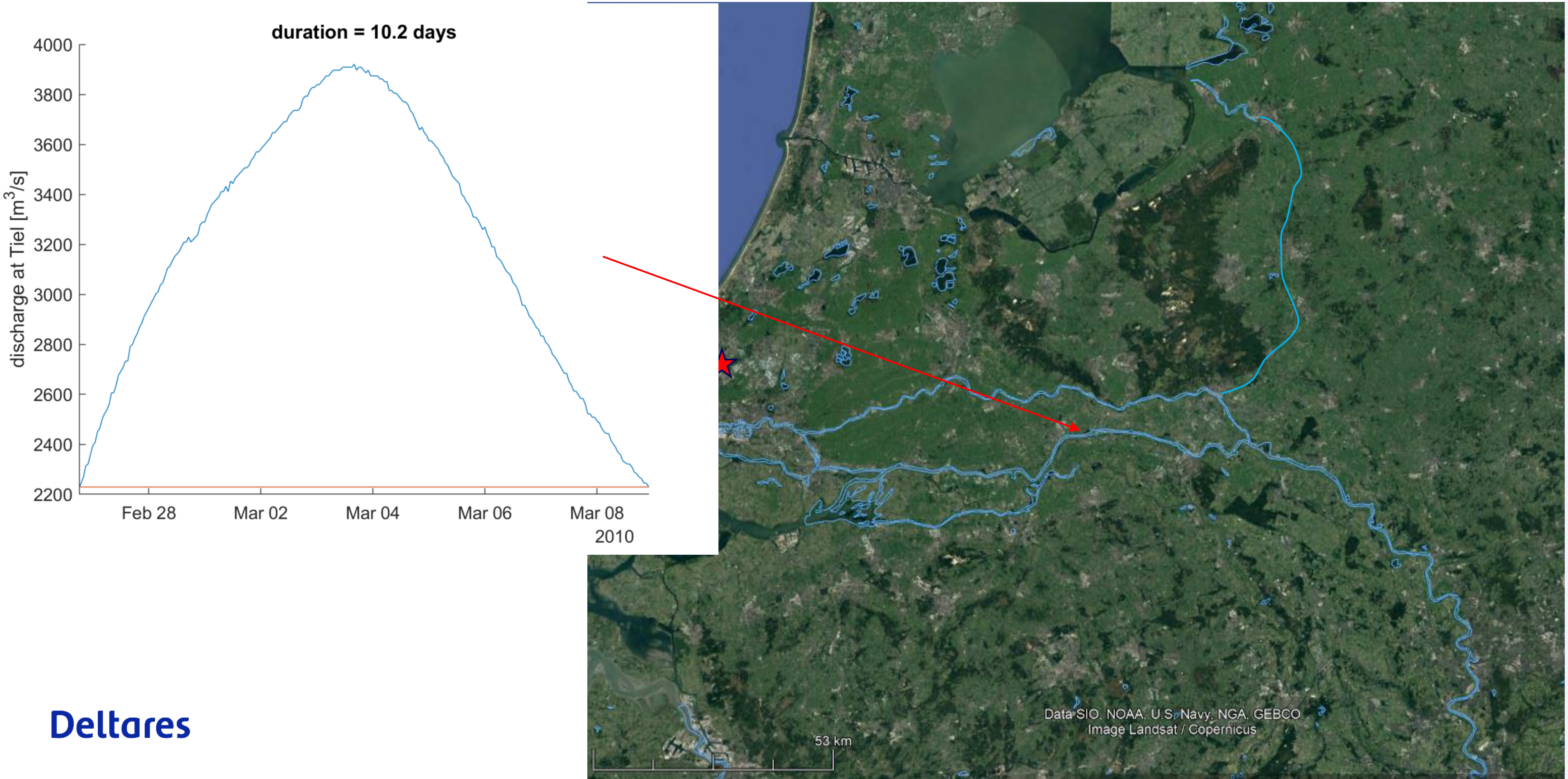
Inspiration



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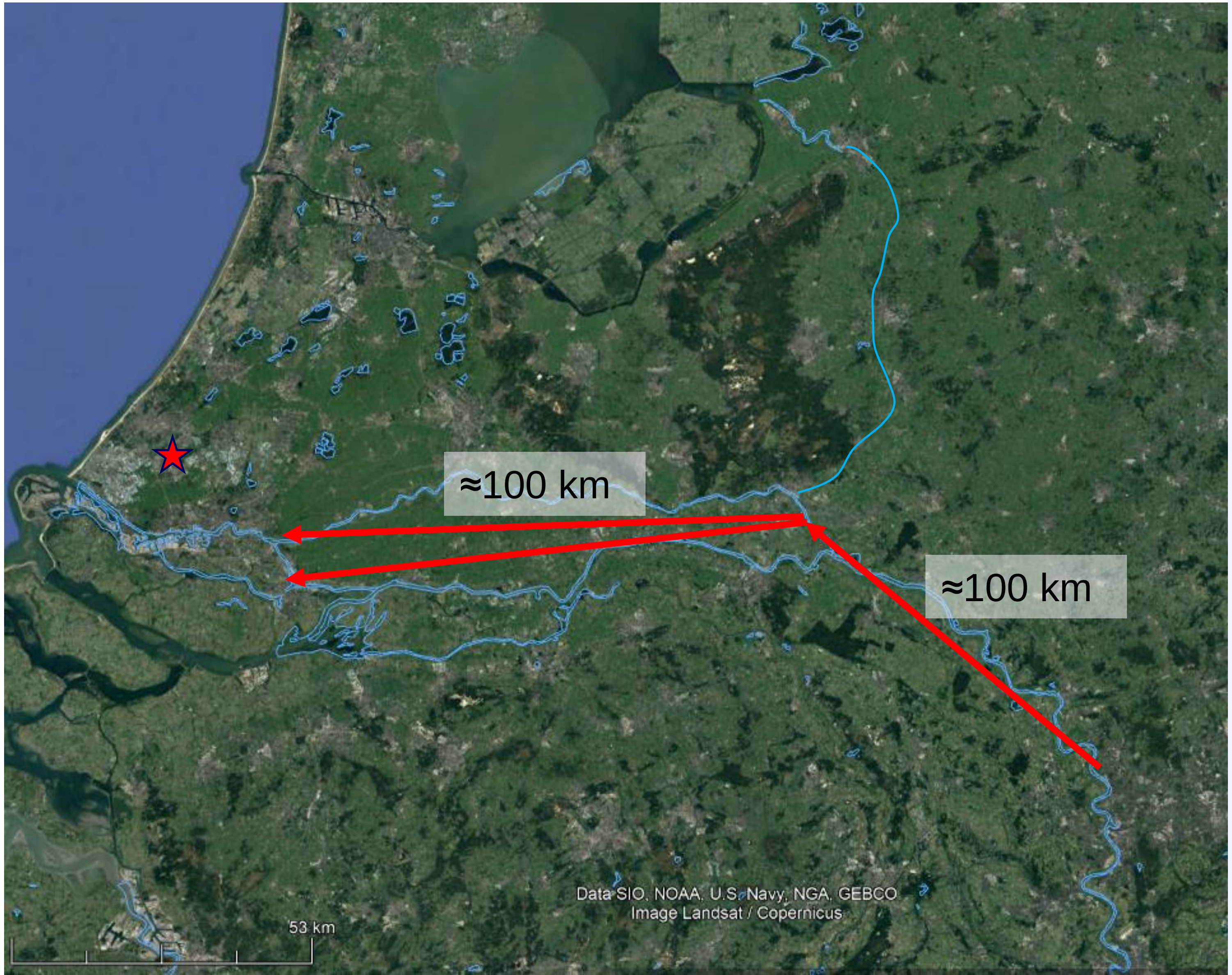
Inspiration

- Rectangular cross-section
- Constant friction
- …

Whatever resemblance to reality is pure chance ☺!



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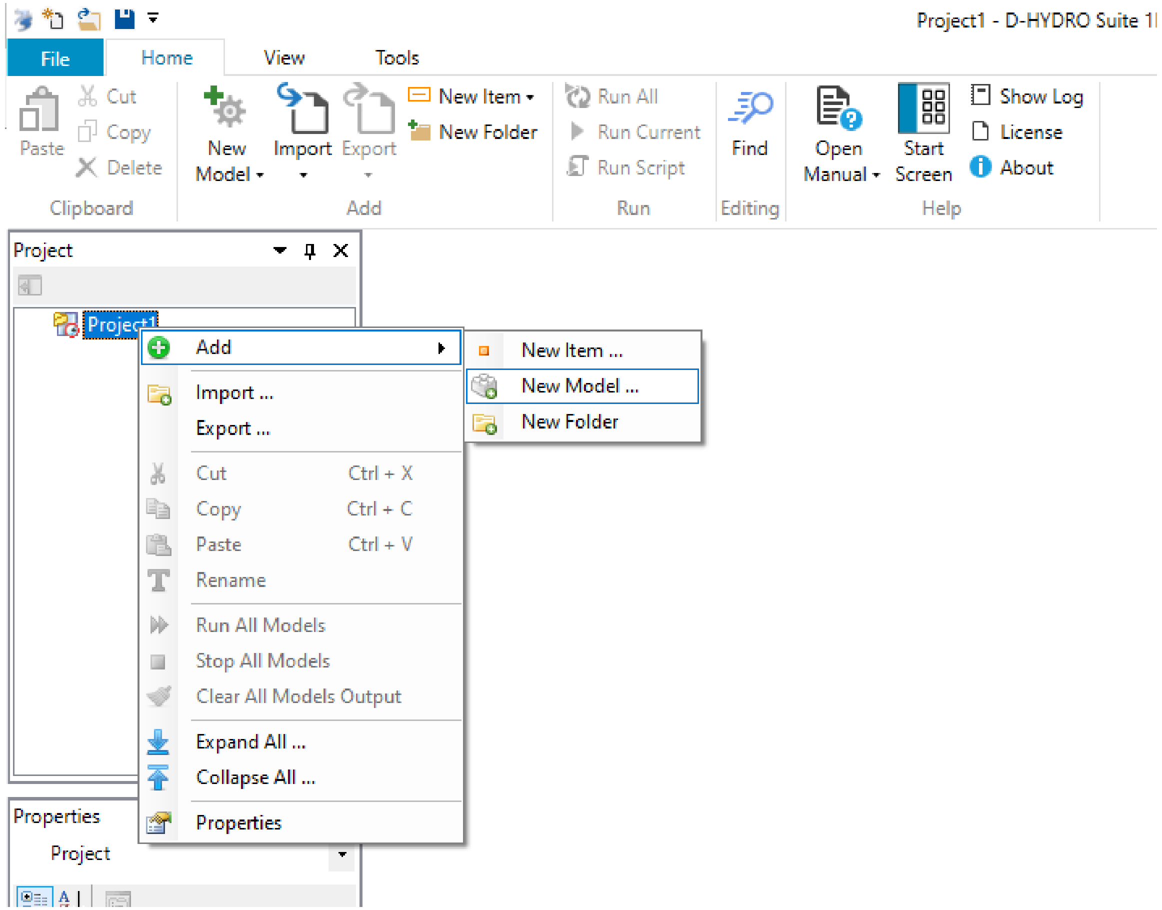
Create FM model

1. "c:\Program Files (x86)\Deltares\D-HYDRO Suite 1D2D (Beta) (0.9.9.52575)\bin\DeltaShell.Gui.x86.exe"
2. Empty project
3. Add -> New Model -> Flow Flexible Mesh Model



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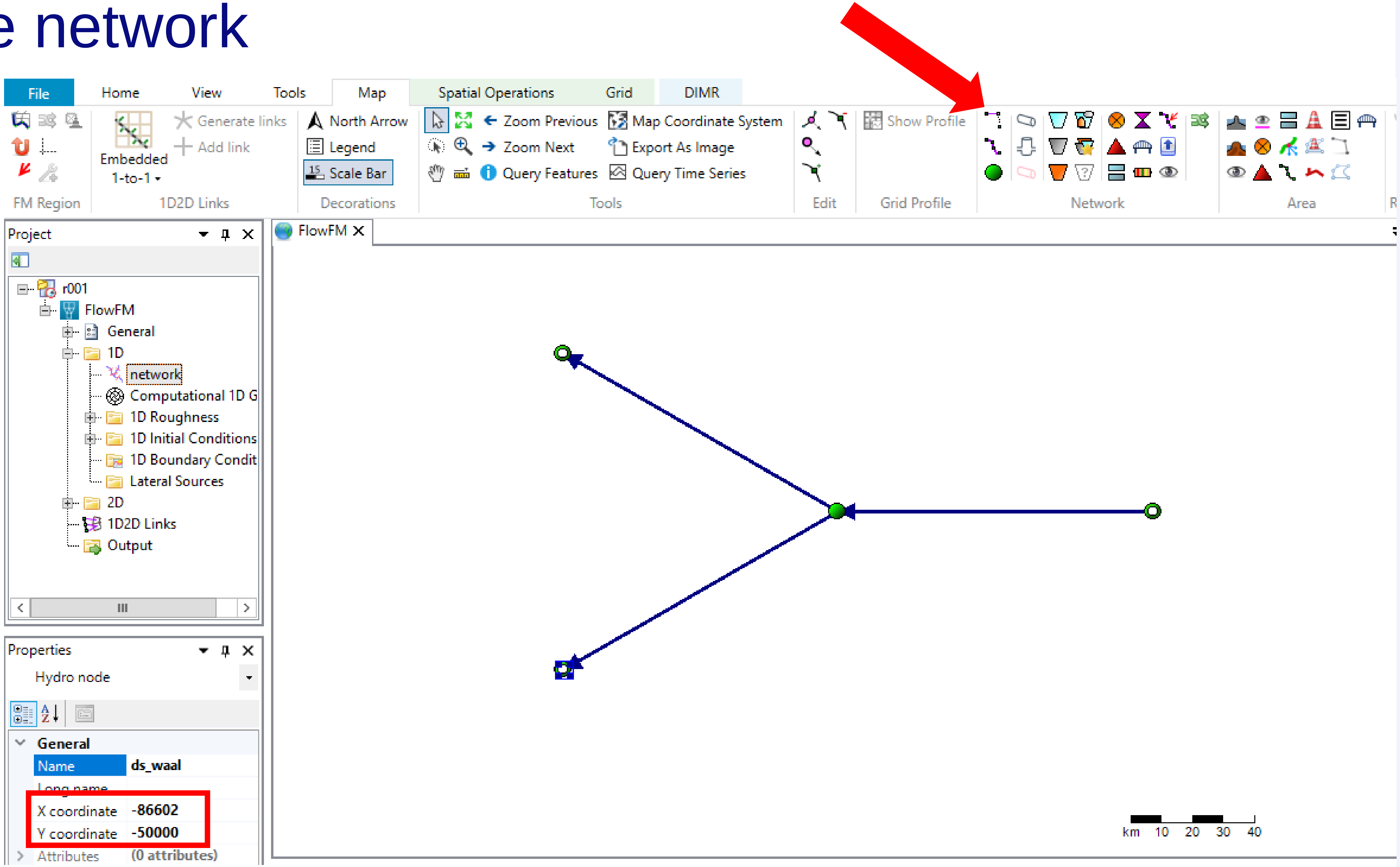
Create network



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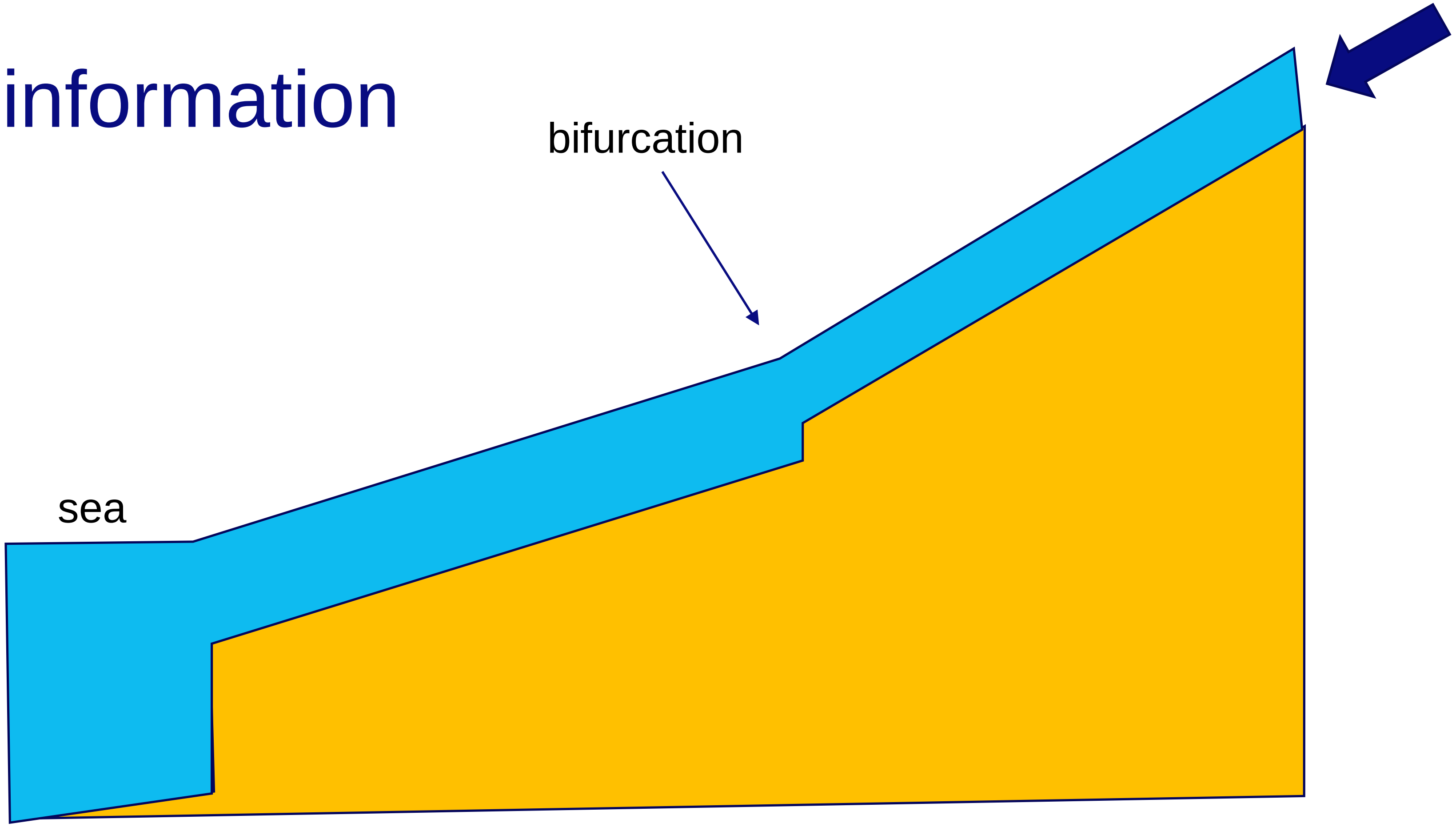
Cross-sectional information

Script available

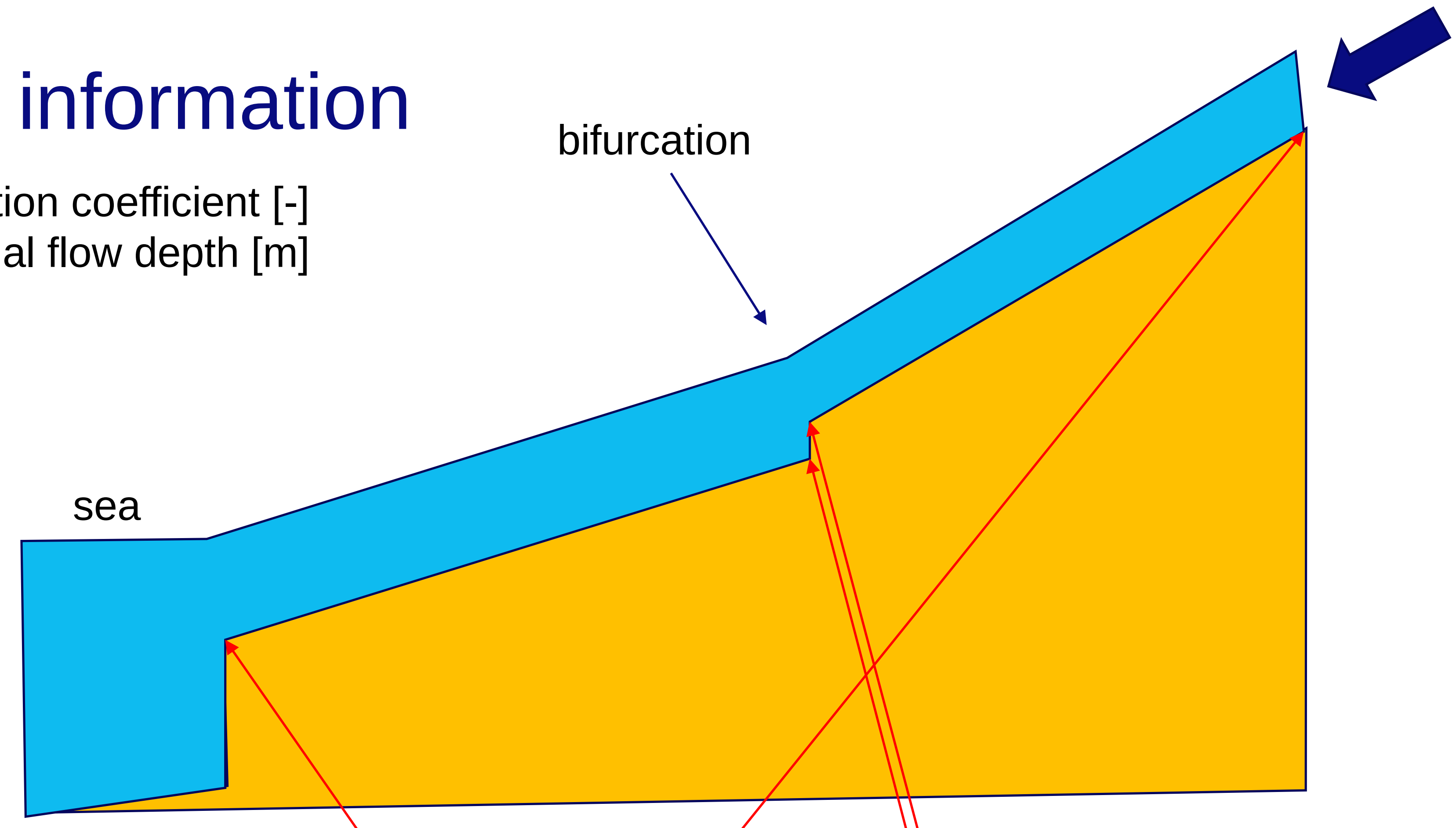


%[us,ds_1,ds_2]

- C=31; %chezy [m^(1/2)/s]
- g=9.81; %gravity [m/s^2]
- Q=2000.*[1,2/3,1/3]; %discharge of each branch [m^3/s]
- B=[300,200,100]; %width of each branch [m]
- s=[1e-4,5e-5,6e-5]; %slope of each branch [-]
- L=100000*[1,1,1]; %length of each branch [m]
- detab_b_1=0.5; %bed level step from branch ds_1 to branch us

Cross-sectional information

- Cf=g/C^2; %non-dimensional friction coefficient [-]
- h=(Cf.*(Q./B)./g./s).^(1/3); %normal flow depth [m]



- etab_0=-round(h(2:3)*10)/10; %bed level at mouth [m]
- etab_b_ds=etab_0+L(2:3).*s(2:3); %bed level at downstream part of bifurcation [m]
- etab_b_us=etab_b_ds(1)+detab_b_1; %bed level at upstream part of bifurcation [m]
- etab_us=etab_b_us+L(1)*s(1); %bed level at upstream end [m]

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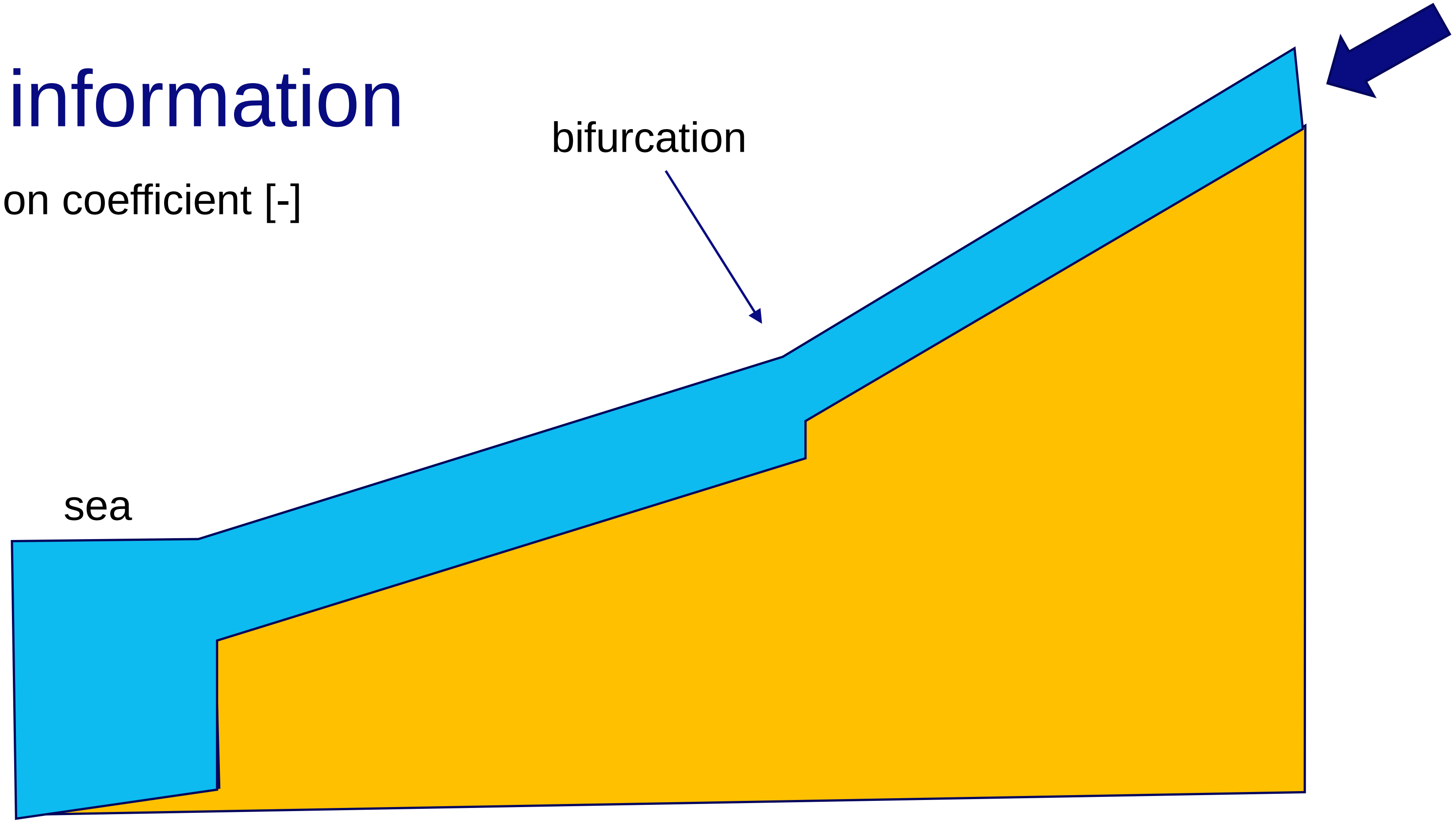
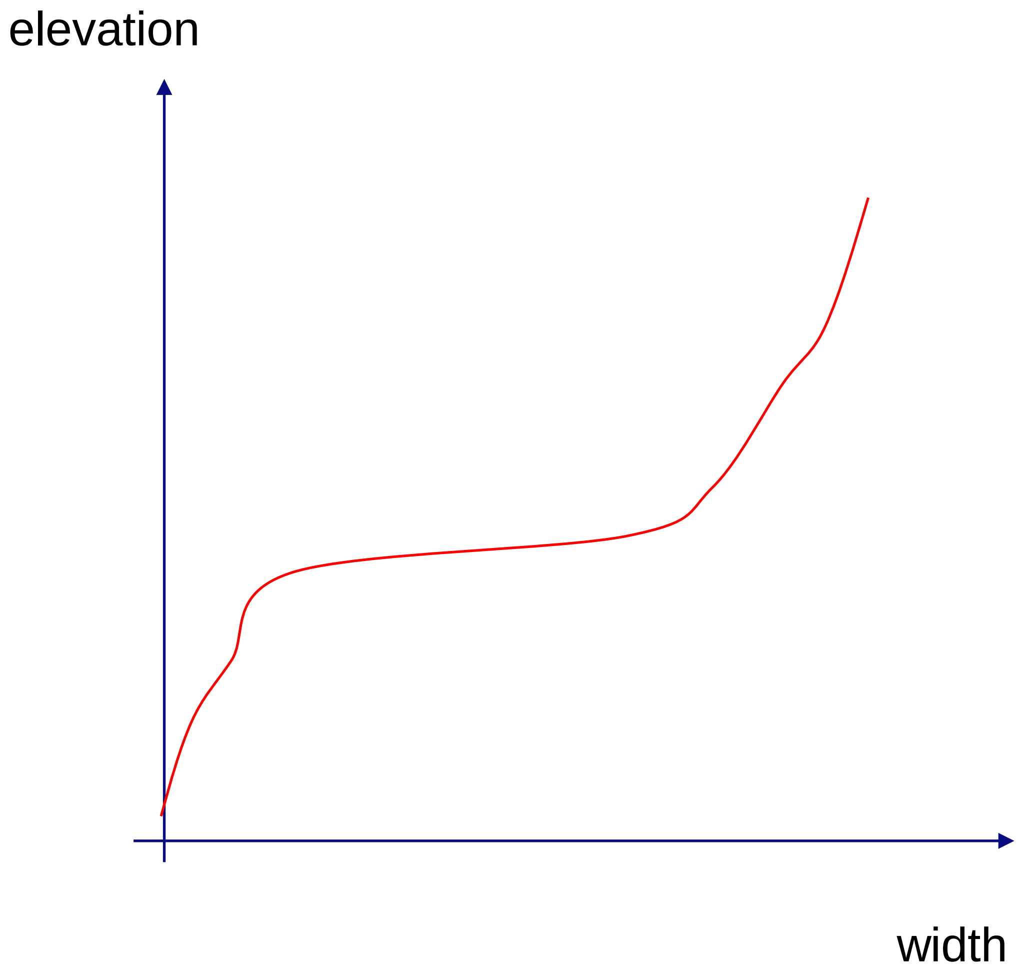
Cross-sectional information

- Cf=g/C^2; %non-dimensional friction coefficient [-]
- h=[4.11,5.18,4.87] m



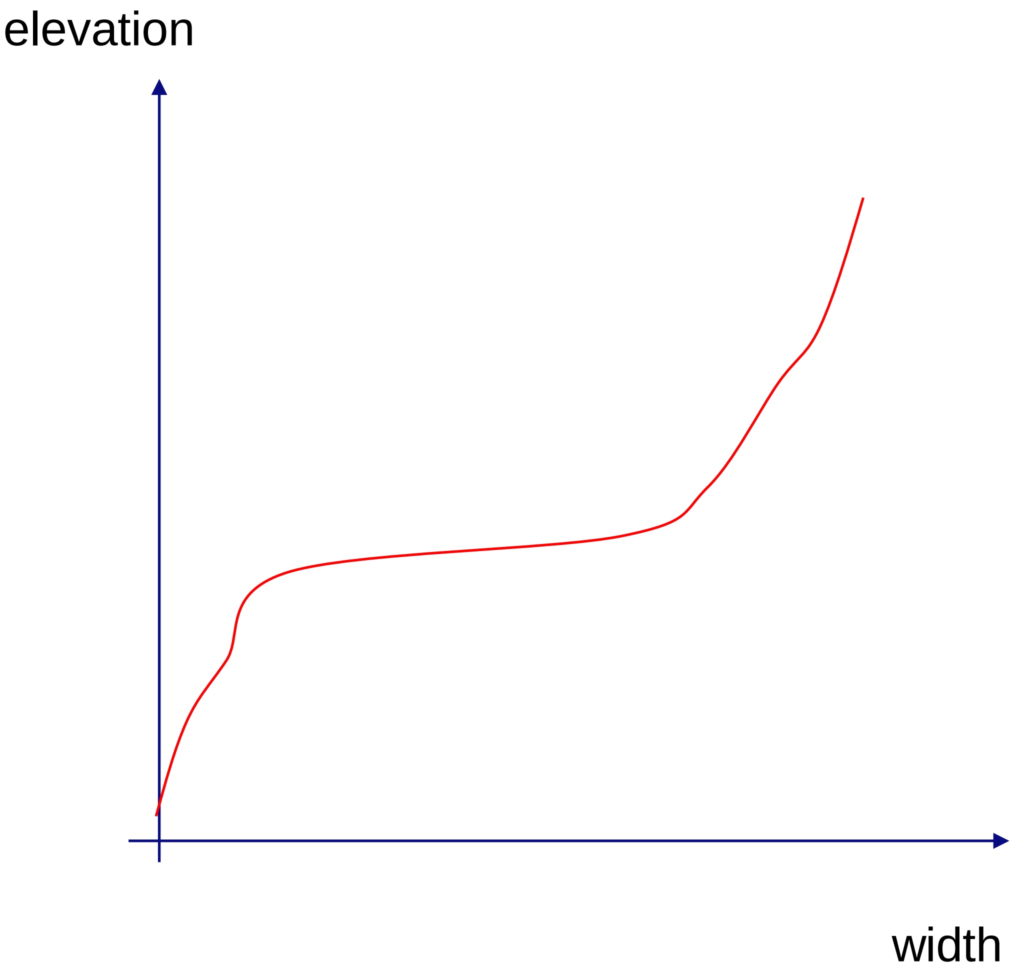
- etab_0=[-5.20,-4.90] m
- etab_b_ds=[-0.2,1.1] m
- etab_b_us=0.3 m
- etab_us=10.3 m

Cross-sectional information

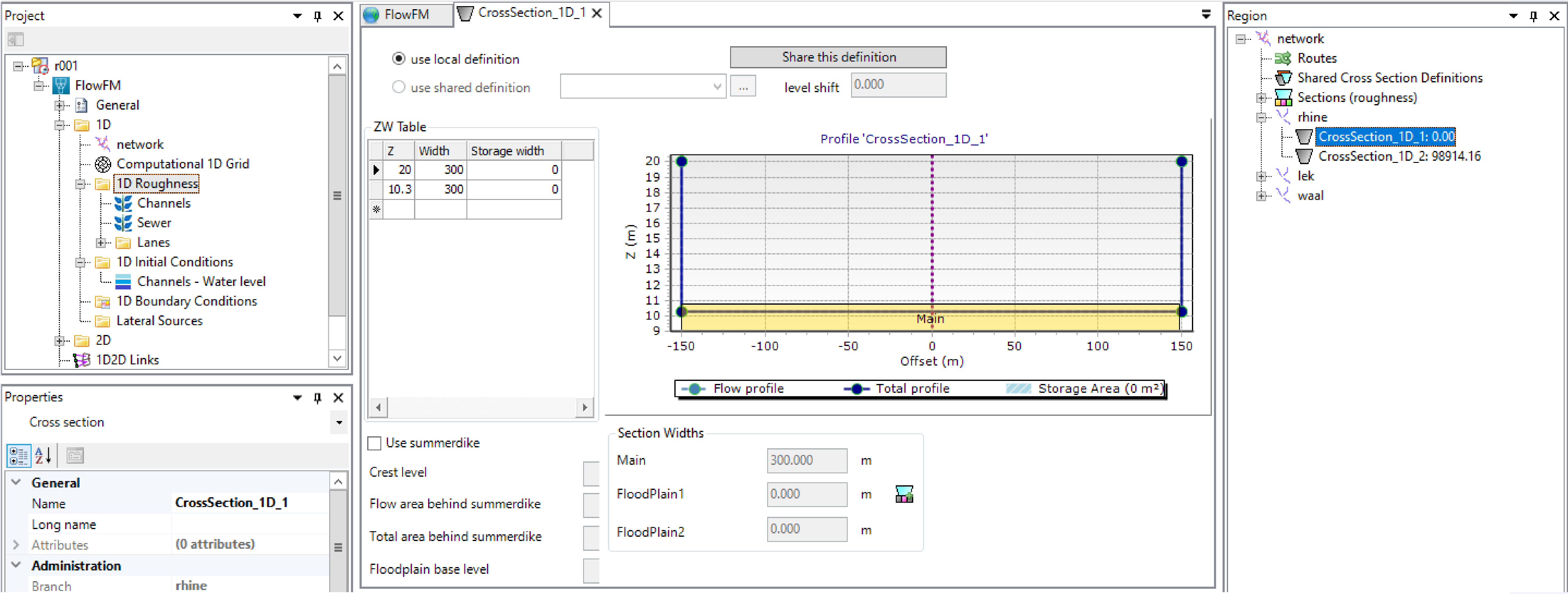


Cross-sectional information

Add one at beginning and end of each branch.
Right click -> Edit -> Cross-section



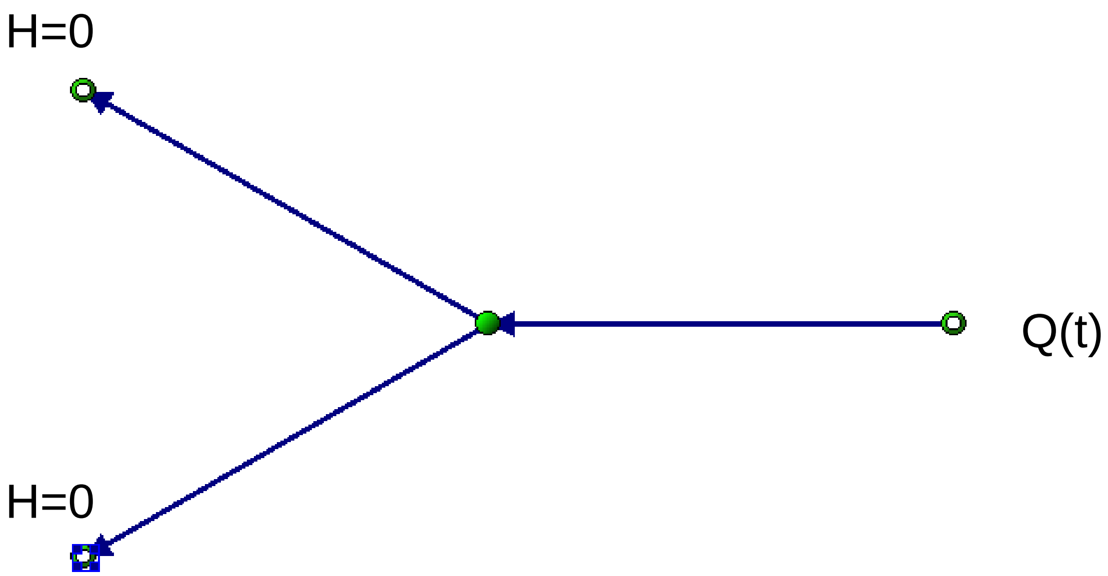
Cross-sectional information



Boundary condition

Channels | Boundary Data 1D

	Name	DataType	Outlet Compartment
	us - Q(t)	Q(t) : Flow time series	
	Node002 - None	None	
▶	ds_lek - H: 0 m	H : Constant water level	
	ds_waal - H: ...	H : Constant water level	



Boundary condition

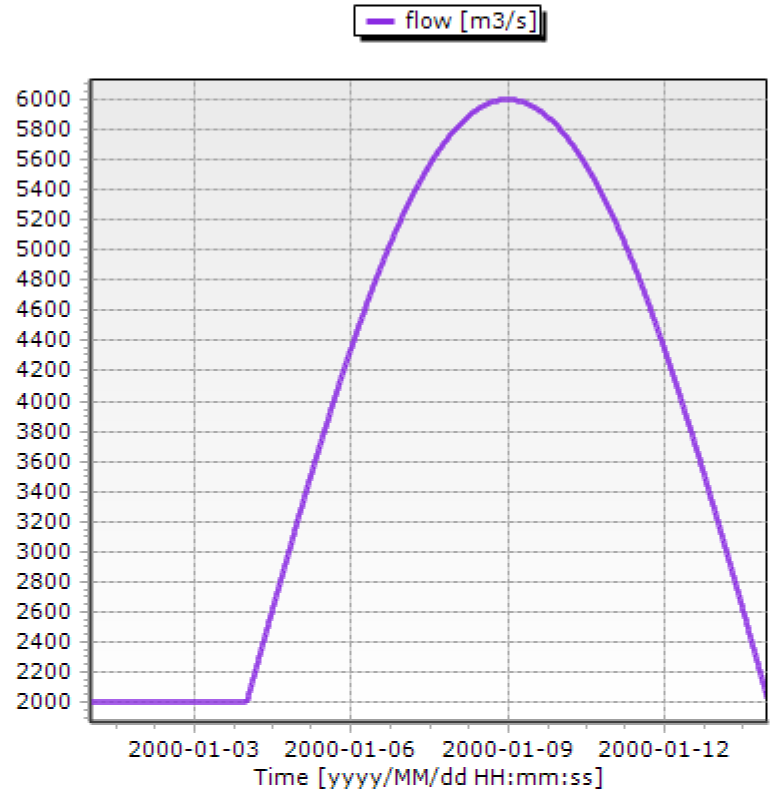
Script available

Flow Data

Type Q(t) : Flow time series

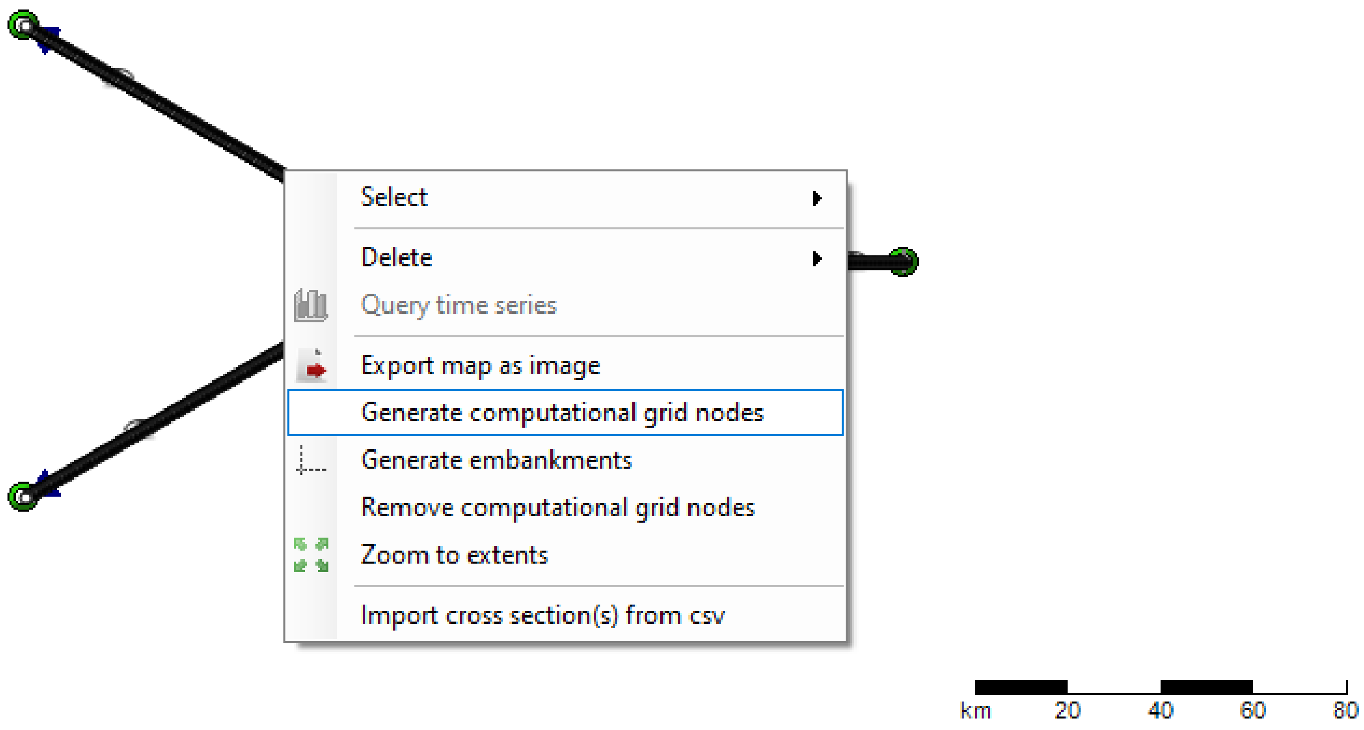
Clipboard import | Csv import | Csv export

Time [yyyy/MM/dd HH:mm:ss]	flow [m3/s]
2000/01/01 00:00:00	2000
2000/01/01 00:05:00	2000
2000/01/01 00:10:00	2000
2000/01/01 00:15:00	2000
2000/01/01 00:20:00	2000
2000/01/01 00:25:00	2000
2000/01/01 00:30:00	2000
2000/01/01 00:35:00	2000
2000/01/01 00:40:00	2000
2000/01/01 00:45:00	2000
2000/01/01 00:50:00	2000
2000/01/01 00:55:00	2000
2000/01/01 01:00:00	2000
2000/01/01 01:05:00	2000
2000/01/01 01:10:00	2000
2000/01/01 01:15:00	2000
2000/01/01 01:20:00	2000
2000/01/01 01:25:00	2000
2000/01/01 01:30:00	2000
2000/01/01 01:35:00	2000
2000/01/01 01:40:00	2000



Grid

- Interested in 10 km long features -> 1000 m cells

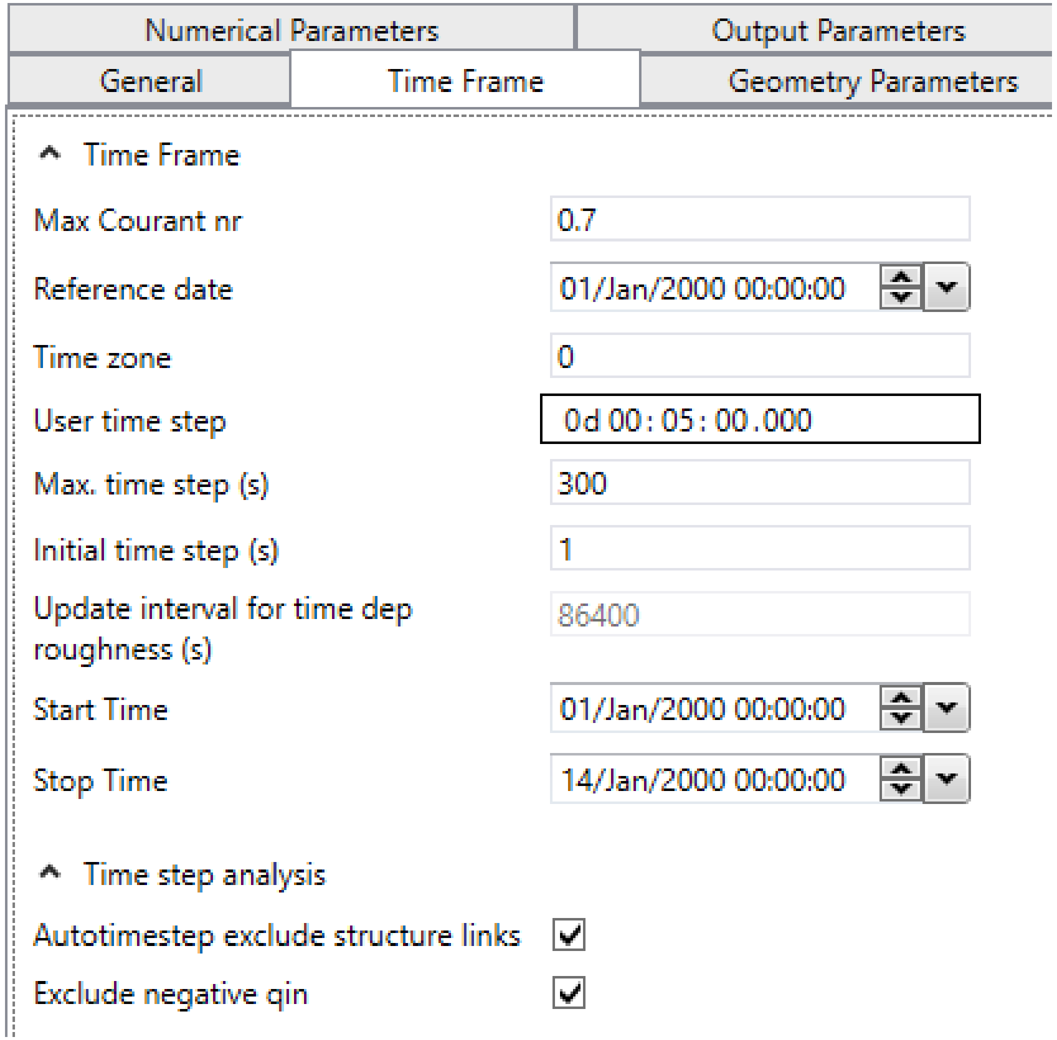


Output

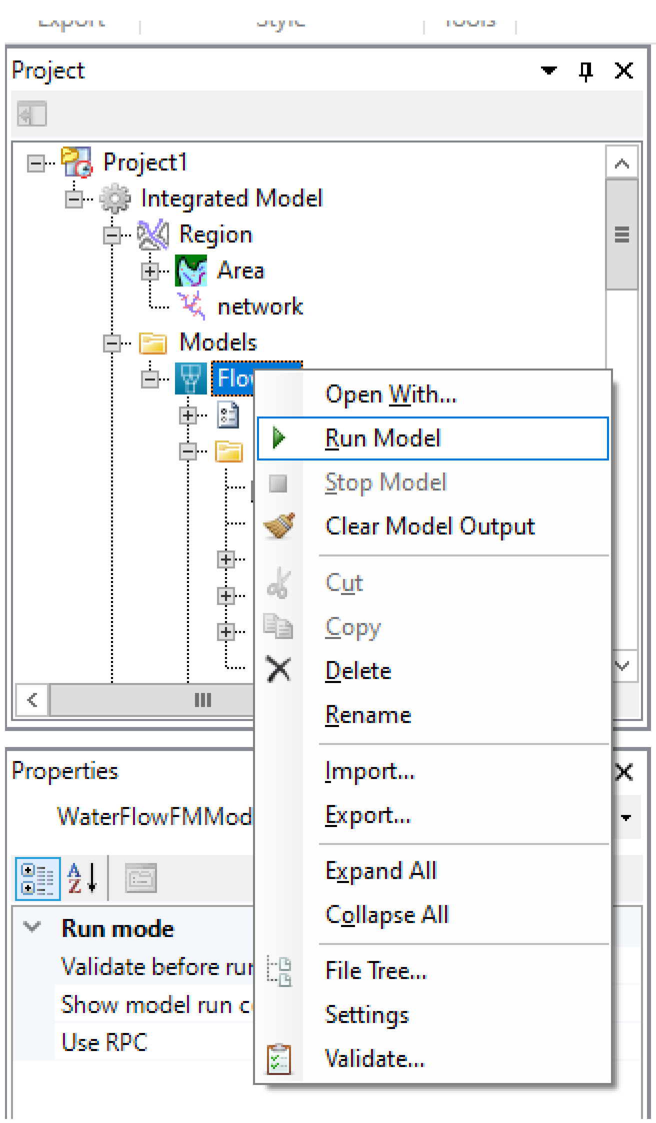
- History file (at observation stations, more frequent)
- Map file (entire domain, less frequent)

General

Physical parameters -> Chezy = 31
Initial conditions -> Water depth = 5
Output parameters -> history to 15 min, map to 1 h



Run



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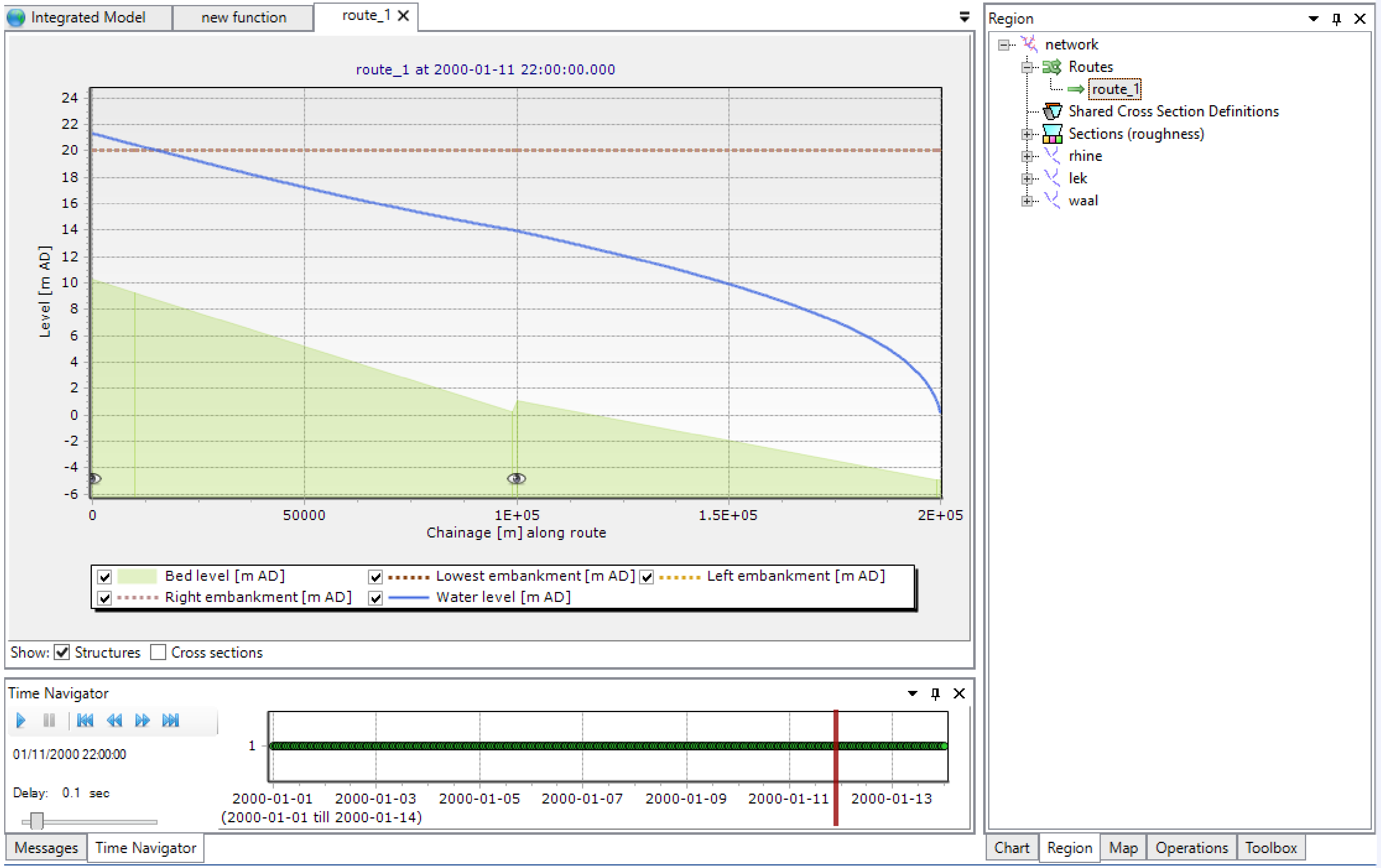
Results

- Observations (his)
- Routes (map)



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Extension to morphodynamics

File-based

Kernel allows for much more than the GUI.

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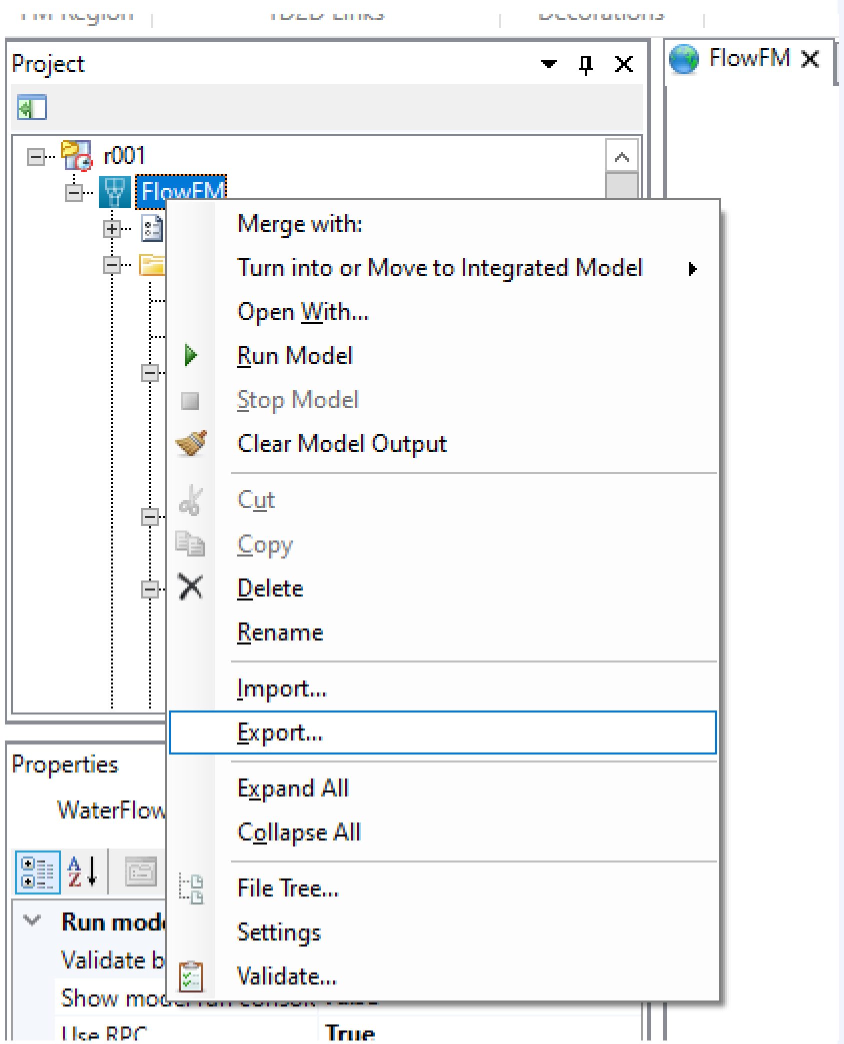
Export

Export DIMR configuration



Inspect files

Export DIMR configuration

[..]	
[output]	
branches	gui
crsdef	ini
crsloc	ini
FlowFM	cache
FlowFM	mdu
FlowFM_bnd	ext
FlowFM_boundaryconditions1d	bc
FlowFM_lateral_sources	bc
FlowFM_meteo	bc
FlowFM_net	nc
initialFields	ini
InitialWaterDepth	ini
obsFile1D_obs	ini
roughness-Channels	ini
roughness-Main	ini
roughness-Sewer	ini
routes	gui
structures	ini

VTools

- A collection of Matlab scripts without any warranty ☺ (let me know if something does not work).
- Available in the Open Earth Tools:
  - https://svn.oss.deltares.nl/repos/openearthtools/trunk/matlab

- How to check out the OET (as the RiverLab repository):
  - https://oss.deltares.nl/web/riverlab-models/accessing-models

- You do **not** need a Matlab license, I have compiled some of them (and can compile all of them):
  - https://svn.oss.deltares.nl/repos/openearthtools/trunk/matlab/applications/vtools/D3D/deploy

Cross-section interpolation

- A cross-section is needed at every cell center.
- A matlab script is available for that (`D3D_interpolate_crosssections`)

Adding morphodynamics

- Modify mdu-file

```
[sediment]
MorFile                 = mor.mor
SedFile                 = sed.sed
Sedimentmodelnr         = 4
```

Adding morphodynamics

- Create mor-file and sed-file (copy example!)
- Think about boundary conditions

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Run batch file

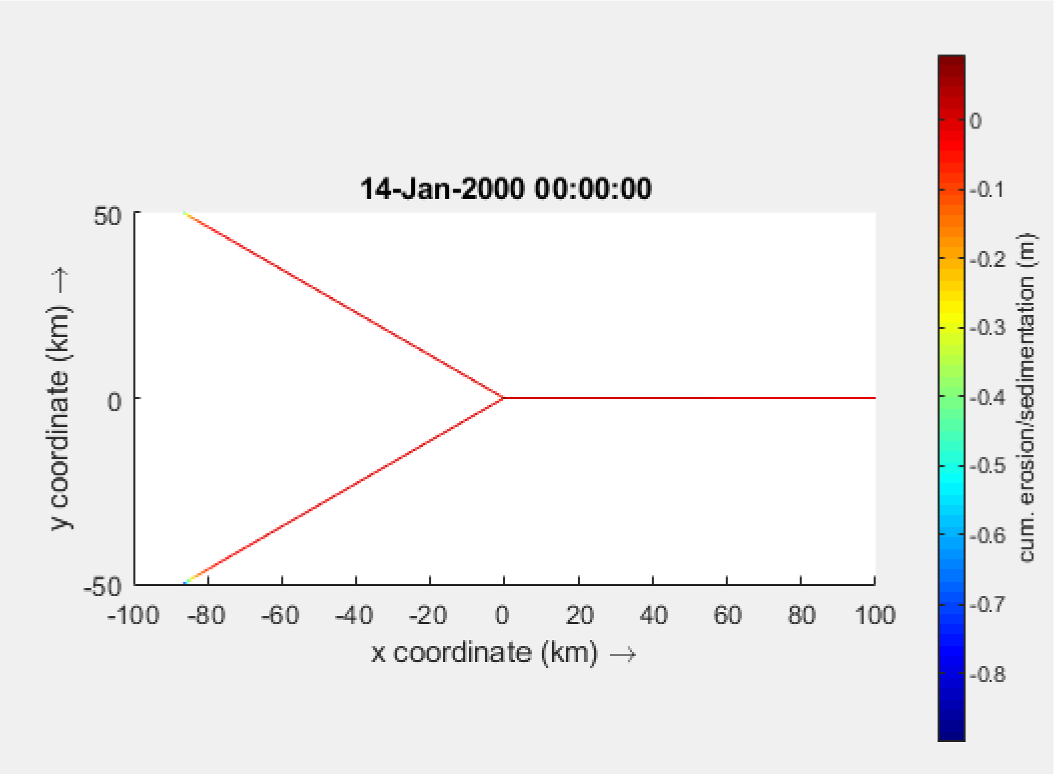
- Create and execute a batch file

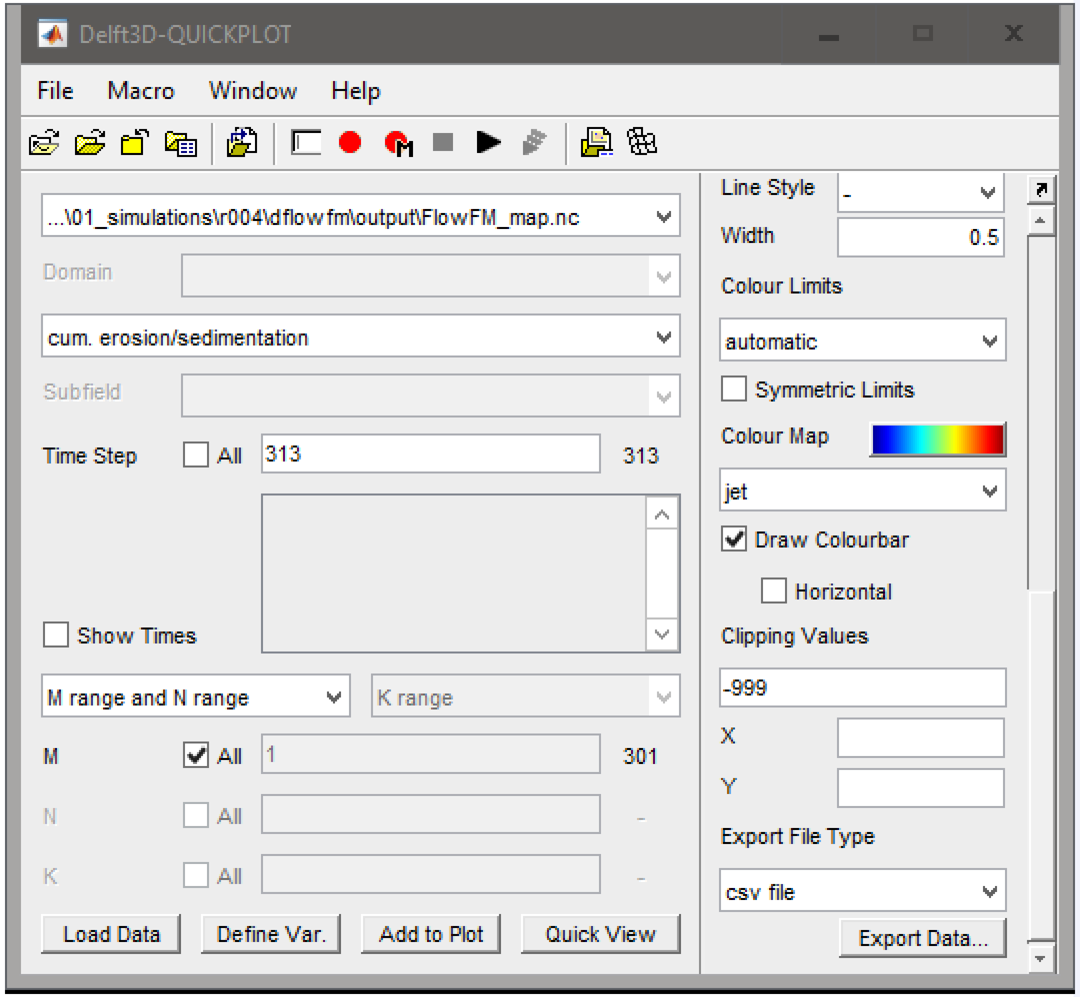
```
@ echo off
call "c:\Program Files (x86)\Deltares\D-HYDRO Suite 1D2D (Beta) (0.9.9.52575)\plugins\DeltaShell.Dimr\kernels\x64\dimr\scripts\run_dimr.bat" dimr_config.xml
:end
```

- Check the dia-file

Visualize results

- QuickPlot





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Visualize results

- Matlab routines (also compiled)

Sediment hump

- Add cross-sections
- Run hydrodynamics
- Interpolate cross-sections

Much more!

- Why this boundary conditions?
- How do we model mixed-size sediment?
- Nodal point relation?
- How can we accelerate morphodynamic simulations?

End

Boundary conditions

Boundary conditions

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Boundary conditions

I know *h, u,* z_b everywhere for a given time.

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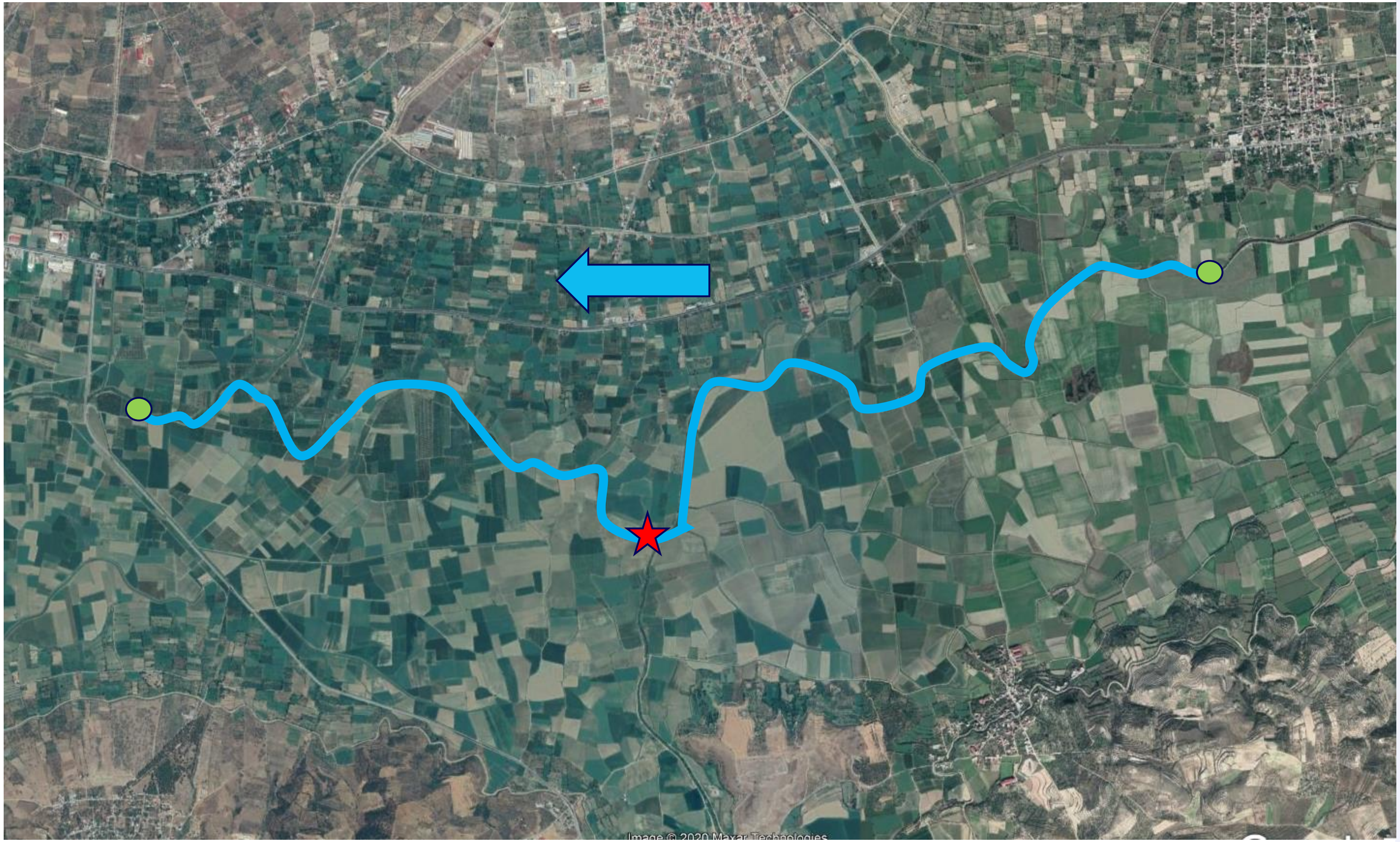
Boundary conditions

I know *h, u,* z_b everywhere for a given time.

Can I know the state at the star after some time?



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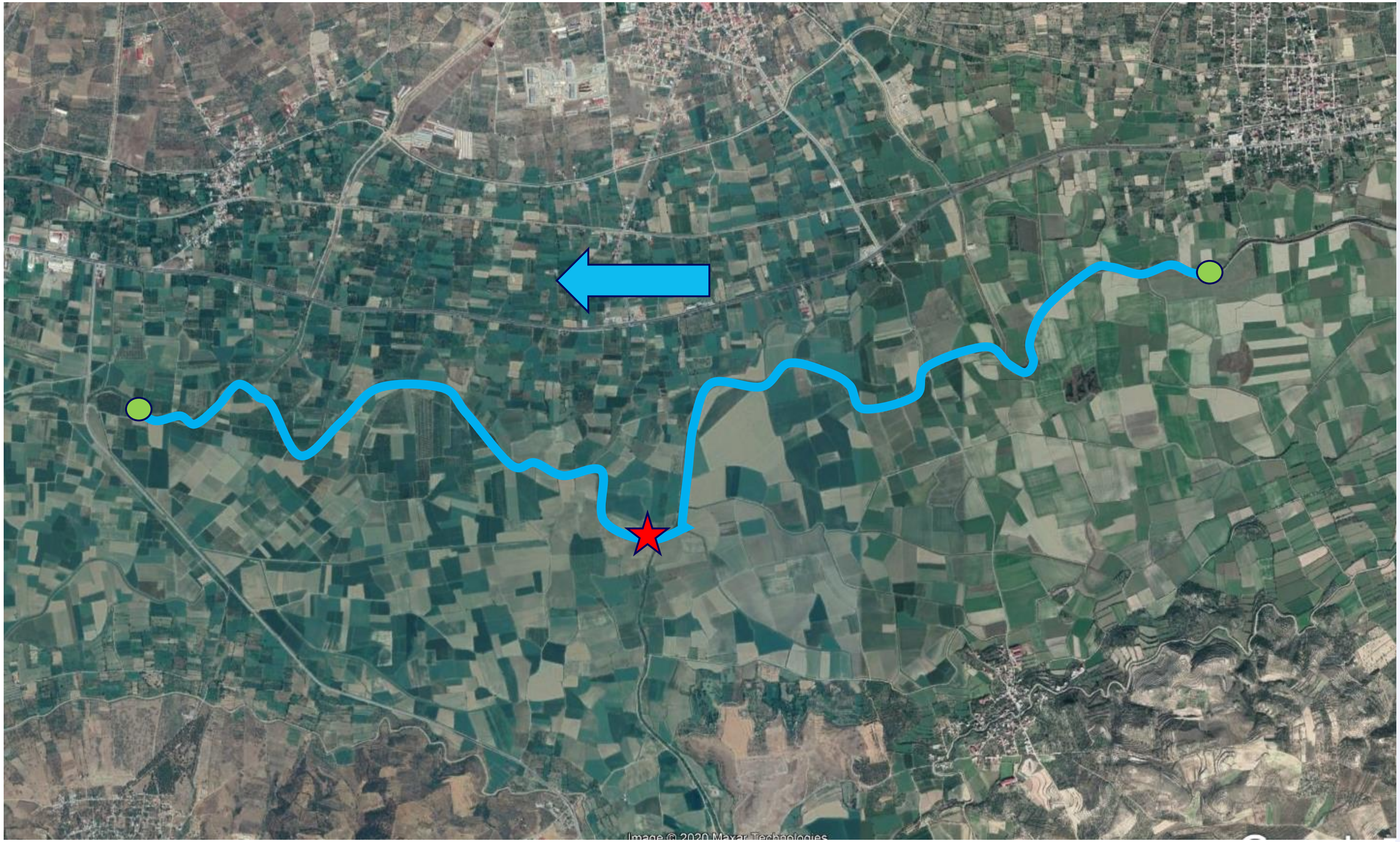
Boundary conditions

I know *h, u,* z_b everywhere for a given time.

Can I know the state at the star after some time?

Depends on the time…



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Boundary conditions

Saint-Venant - Exner

$$\frac{\partial h}{\partial t}+\frac{\partial q}{\partial x}=0$$

$$\frac{\partial q}{\partial t}+\frac{\partial}{\partial x}\left(\frac{q^2}{h}+\frac{gh^2}{2}\right)+gh\frac{\partial z_b}{\partial x}=-ghS_f$$

$$\frac{\partial z_b}{\partial t}+\frac{1}{1-p}\frac{\partial q_b}{\partial x}=0$$

Boundary conditions

Saint-Venant - Exner

$$\frac{\partial h}{\partial t}+\frac{\partial q}{\partial x}=0$$

$$\frac{\partial q}{\partial t}+\frac{\partial}{\partial x}\left(\frac{q^2}{h}+\frac{gh^2}{2}\right)+gh\frac{\partial z_b}{\partial x}=-ghS_f$$

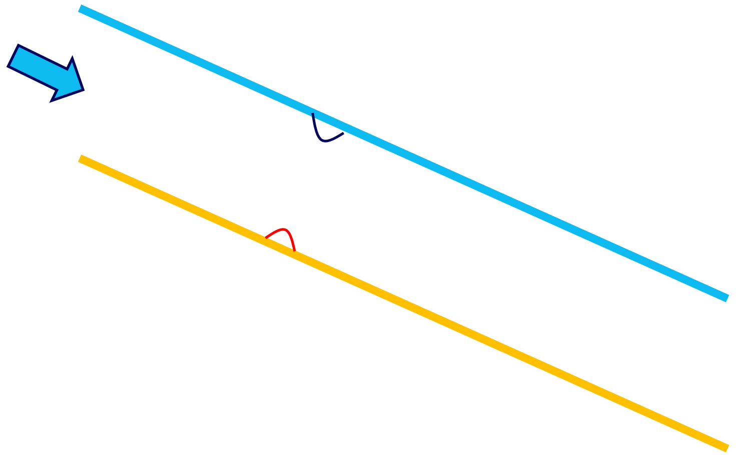
$$\frac{\partial z_b}{\partial t}+\frac{1}{1-p}\frac{\partial q_b}{\partial x}=0$$

Linearization and matrix formulation

$$\frac{\partial \mathbf{Q}'}{\partial t}+\mathbf{A}_0\frac{\partial \mathbf{Q}'}{\partial x}=\mathbf{0}$$

$$\mathbf{A}_0=\begin{pmatrix} 0 & 1 & 0 \\ gh_0-u_0^2 & 2u_0 & gh_0 \\ \left.\frac{\partial q_b}{\partial h}\right|_0 & \left.\frac{\partial q_b}{\partial q}\right|_0 & 0 \end{pmatrix}$$

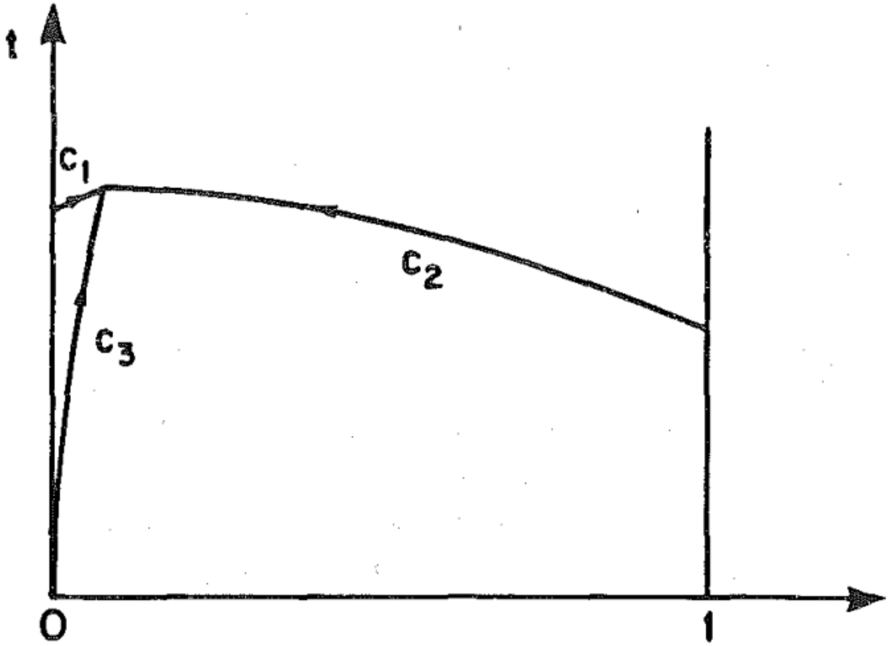
$$\mathbf{Q}'=\begin{bmatrix} h' \\ q' \\ z_b' \end{bmatrix}$$



Boundary conditions

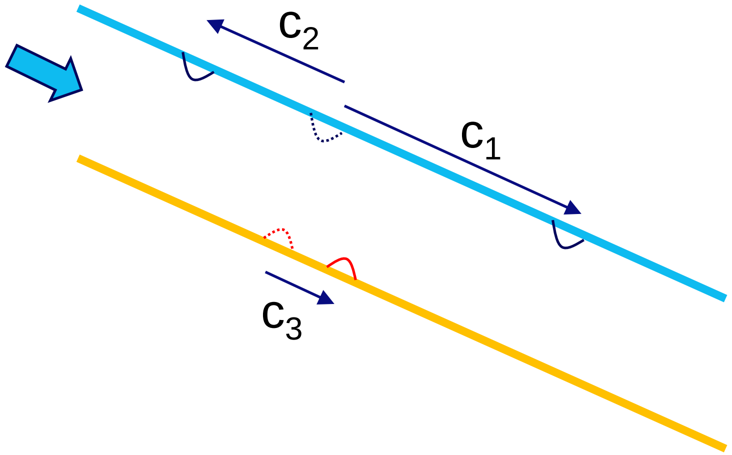
Saint-Venant - Exner

$$\mathbf{A}_0 = \begin{pmatrix} 0 & 1 & 0 \\ gh_0 - u_0^2 & 2u_0 & gh_0 \\ \left.\frac{\partial q_b}{\partial h}\right|_0 & \left.\frac{\partial q_b}{\partial q}\right|_0 & 0 \end{pmatrix}$$



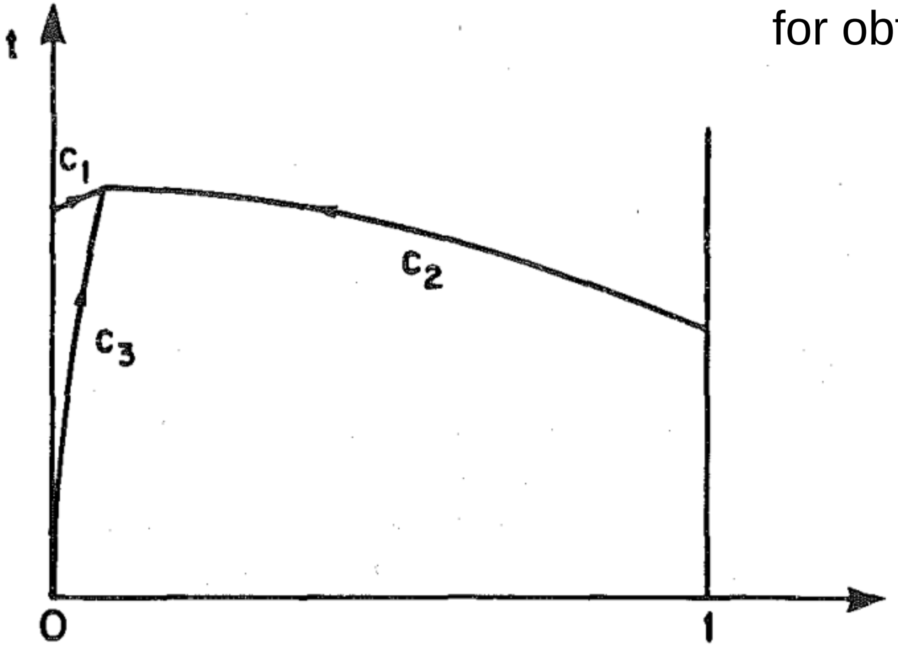
Lyn (1987)

c_1, c_2 : Flow celerities
c_3 : Bed celerity



Boundary conditions

Saint-Venant - Exner

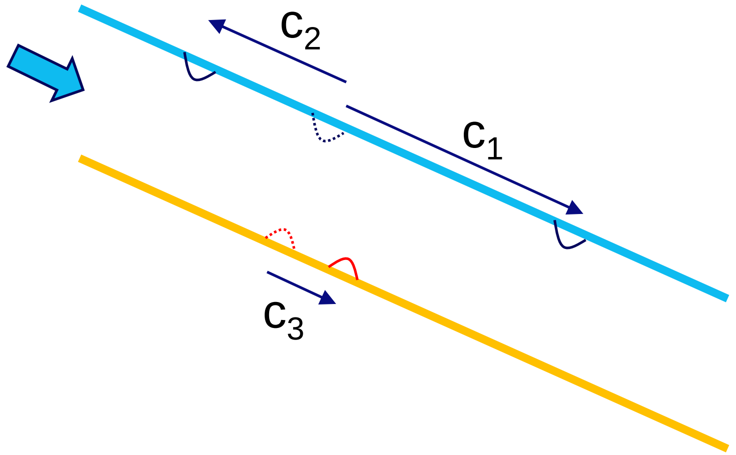


Lyn (1987)

A boundary condition is needed for each outgoing characteristic for obtaining a well-posed model.

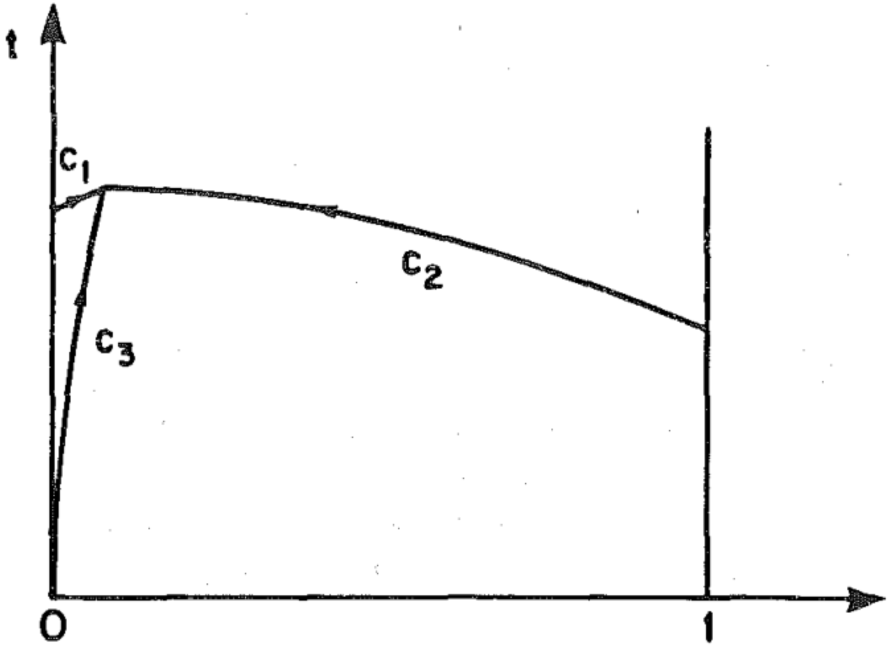
$$\mathbf{A}_0 = \begin{pmatrix} 0 & 1 & 0 \\ gh_0 - u_0^2 & 2u_0 & gh_0 \\ \left.\frac{\partial q_b}{\partial h}\right|_0 & \left.\frac{\partial q_b}{\partial q}\right|_0 & 0 \end{pmatrix}$$

c_1, c_2 : Flow celerities
c_3 : Bed celerity



Boundary conditions

Saint-Venant - Exner



Lyn (1987)

Under subcritical flow conditions:

- Flow upstream
- Flow downstream
- Morphodynamics upstream

With Delft3D you can model supercritical flow, but not at the boundaries.