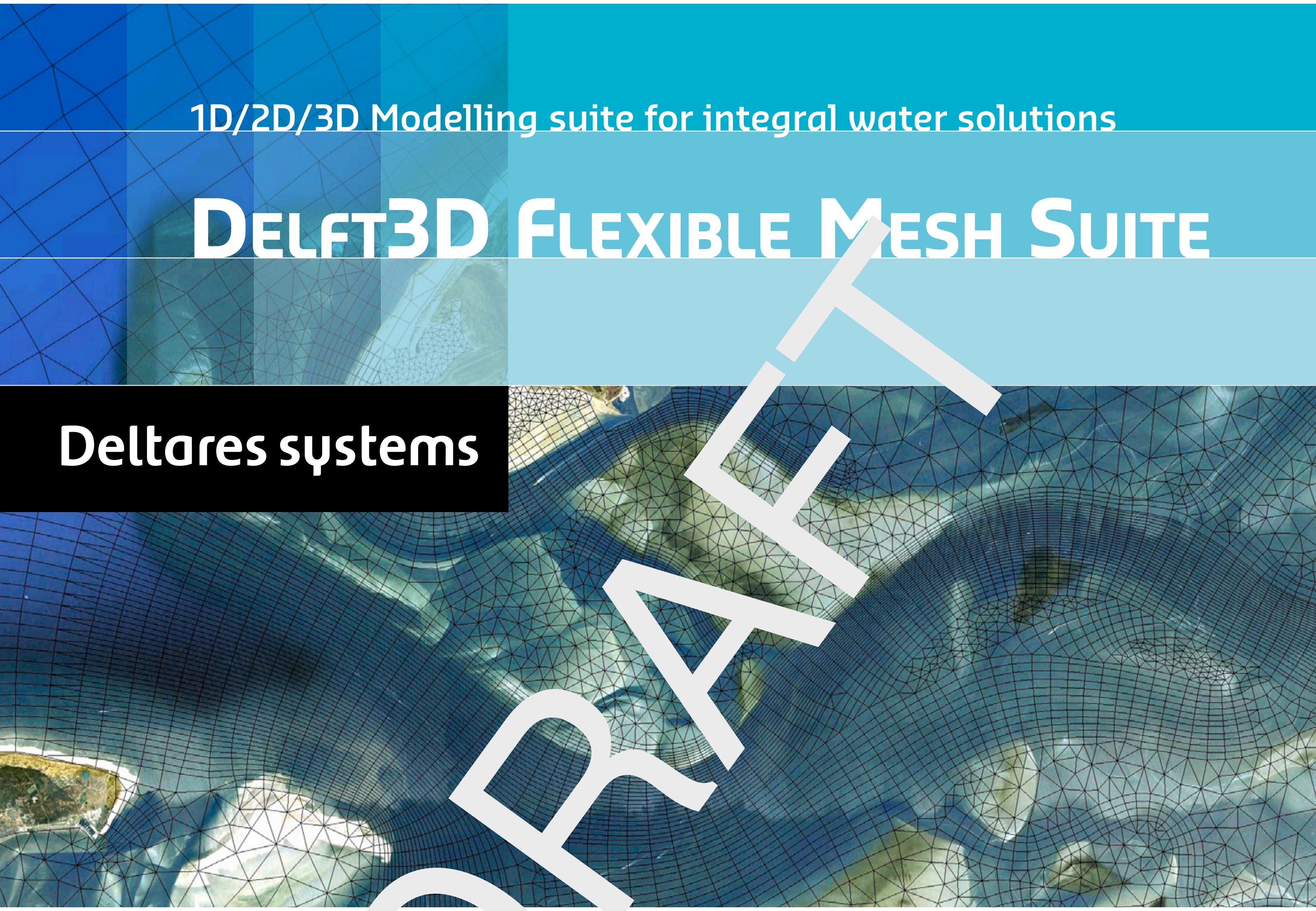
1D/2D/3D Modelling suite for integral water solutions

Delft3D Flexible Mesh Suite

Deltares systems



D-Flow Flexible Mesh

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Enabling Delta Life

Validation Document

D-Flow Flexible Mesh

Validation Document

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D-Flow Flexible Mesh, Validation Document

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1.1 Engelund-Hansen transport formula for total transport

Quality Assurance

Date	Author	Initials	Review	Initials	Approval	Initials
01 June 2018	Andries Paarlberg		Willem Ottevanger		Aukje Spruyt	

Version information

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Location : https://svn.oss.deltares.nl/repos/trunk/riverlab/f27_mor1d_tabulated_crosssections/c01_mc_sediment_transport_Engelund_Hansen
SVN revision : -

Purpose

D-Flow FM-1D-mor can use so-called tabulated cross-sections (from SOBEK3), where the flow width is specified as a function of the water level. The bed level is updated in the main channel only.
The purpose of this validation case is to prove that the calculated sediment transport with the Engelund, F. and E. Hansen (1967) formula is correct in D-Flow FM-1D, with tabulated cross sections. The formula is tested using several different parameter values, as outlined below.

Linked claims

◇ Water levels computed with D-Flow FM are comparable to water levels computed with SOBEK3.
◇ D-Flow FM accurately calculates sediment transport according to the formula of Engelund-Hansen.

Approach

We start from an existing SOBEK3-test model (/DSCTestbench/cases/e106_dflow1d/f13_morphology/c01_sediment_transport_Engelund_Hansen). That model consists of four (non-connected) branches, each with the same length, but different properties. The values of the Chézy roughness, and the bed slope i_b are varied. The test is carried out for several different discharge values (and downstream water levels). In this test case, we assume that the velocities as calculated by the flow module are correct; simulated water levels are compared with SOBEK3.

The total sediment transport S [kg/s] calculated by the Engelund-Hansen formula is given by:

$$S = B\rho_s s = B\rho_s(0.05\frac{\alpha u^5}{\sqrt{g}C^3\Delta^2 D_{50}}) \tag{1.1}$$

where

u	the magnitude of the flow velocity [m/s],
Δ	the relative density given by $\Delta = \frac{\rho_s-\rho_w}{\rho_w}$ [-],
C	the Chézy friction coefficient [m$^{1/2}$/s],
D_{50}	the median diameter of sediment [m],

α the user-defined calibration coefficient [-],
B the width of the main channel [m] and
ρ_s the sediment density [kg/m^3].

In this test, the sediment transport is calculated analytically based on the calculated velocity by the flow module. The analytically computed sediment transport is then compared to the sediment transport as calculated by D-Flow FM-1D.

Model description

The model domain, consisting of four (non-connected) straight branches, each with the same length of 10 km, but different properties is shown in Figure 1.1.

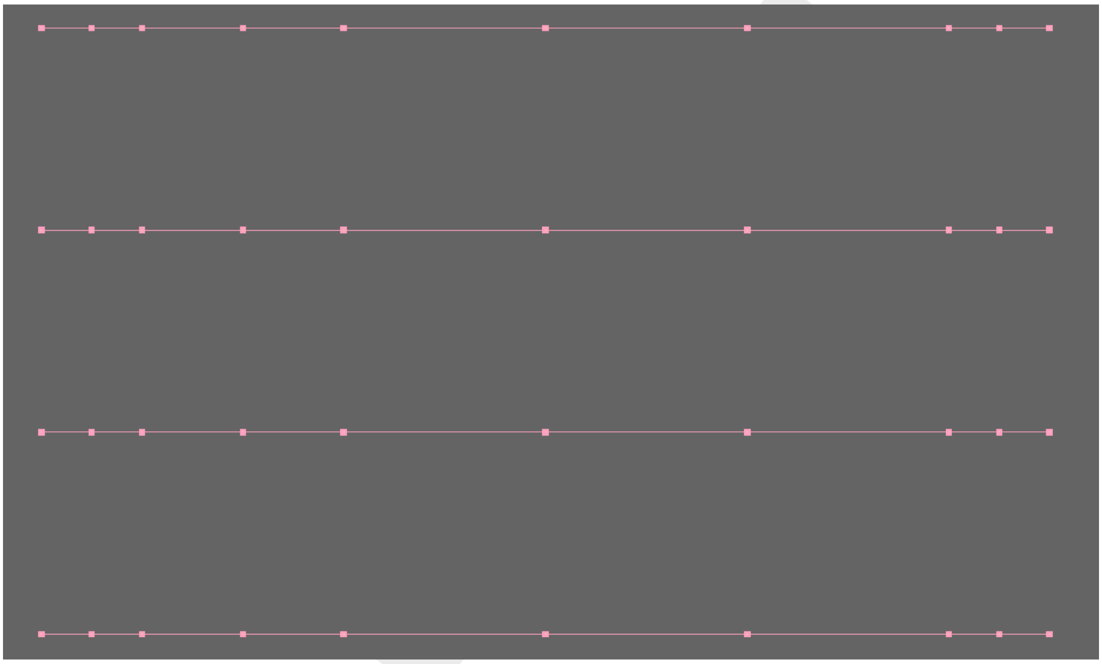

Figure 1.1: *Four (non-connected) branches, channels with equal length, but different properties.*

For this test case, each of the channels is straight with homogeneous cross-sections. The flow is stationary but non-homogeneous. The flow direction in the channel is oriented in the same direction as the computational grid. Upstream a discharge boundary is imposed (Figure 1.2), downstream a water level boundary (Figure 1.3). No further connection nodes are added. The channel contains rectangular cross-sections of 200 m in width throughout. See Figure 1.4. Computational nodes are placed at non-uniform distances. Calculations are done for four different testcases in which several parameter values are varied. An overview of these varied parameter values is shown in Table 1.1. Note that T1 and T3, two independent branches, have identical settings and should produce identical results. Other model settings for all cases are given in Table 1.4.

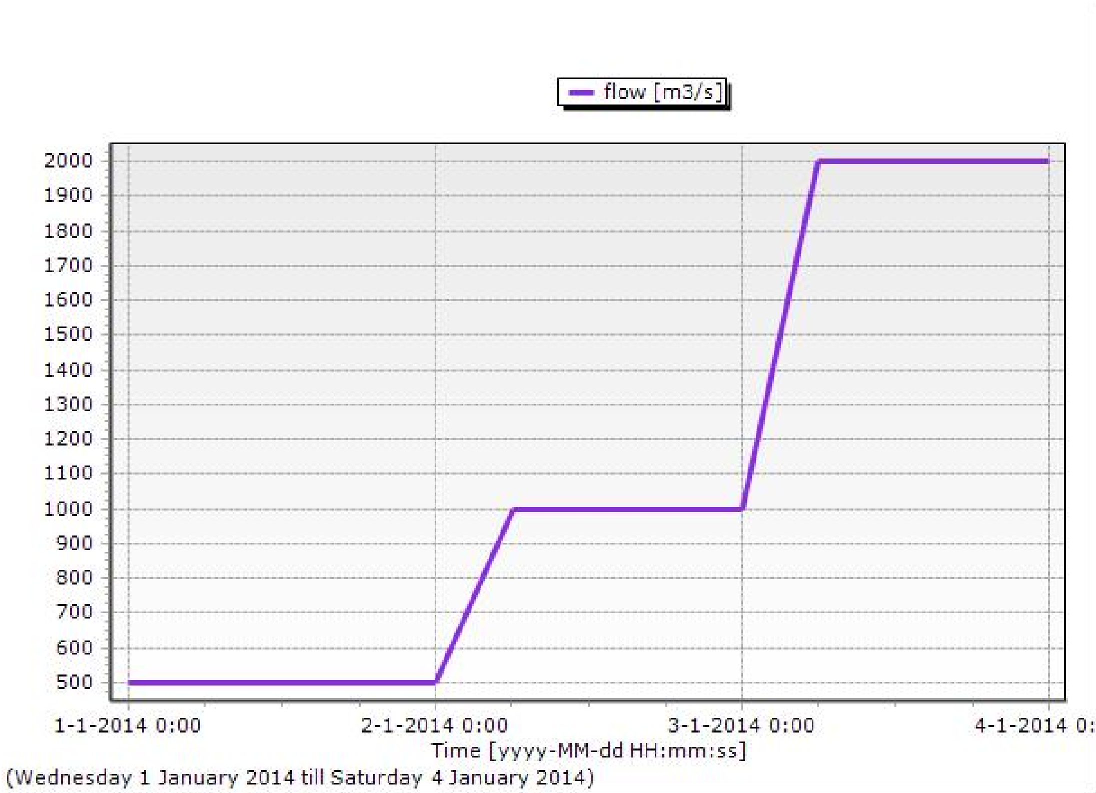

Figure 1.2: *Upstream discharge boundary condition.*

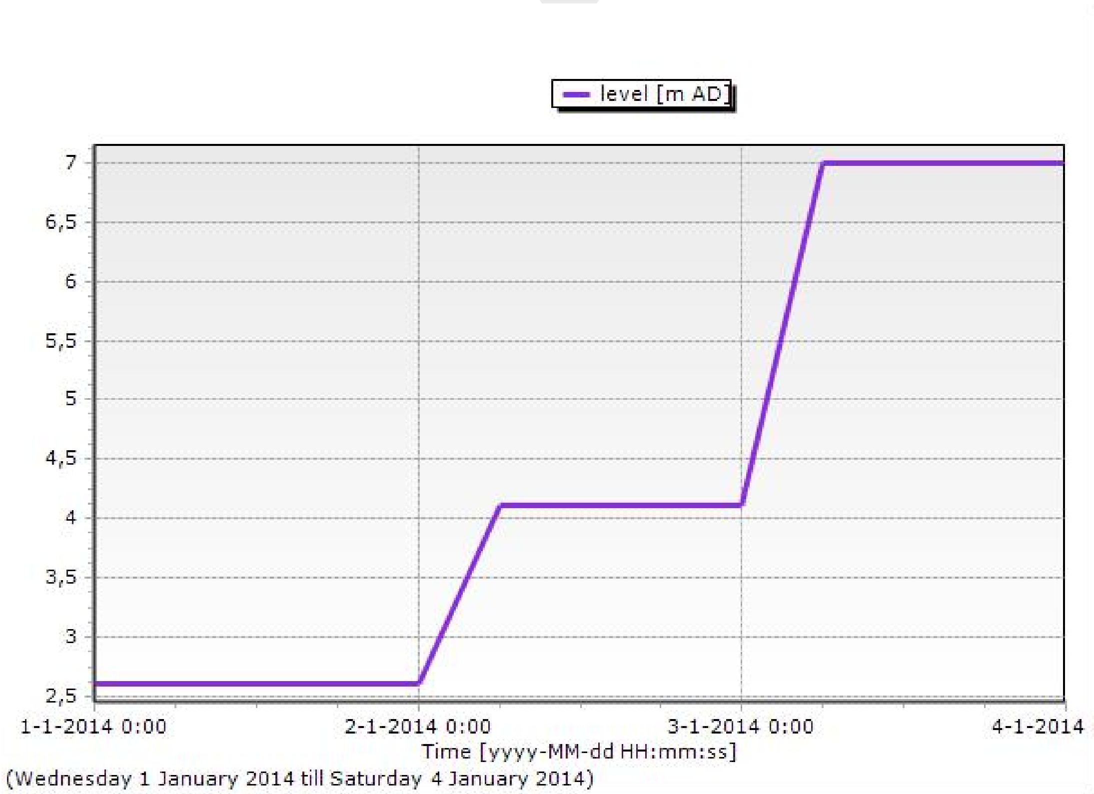

Figure 1.3: *Downstream water level boundary condition.*

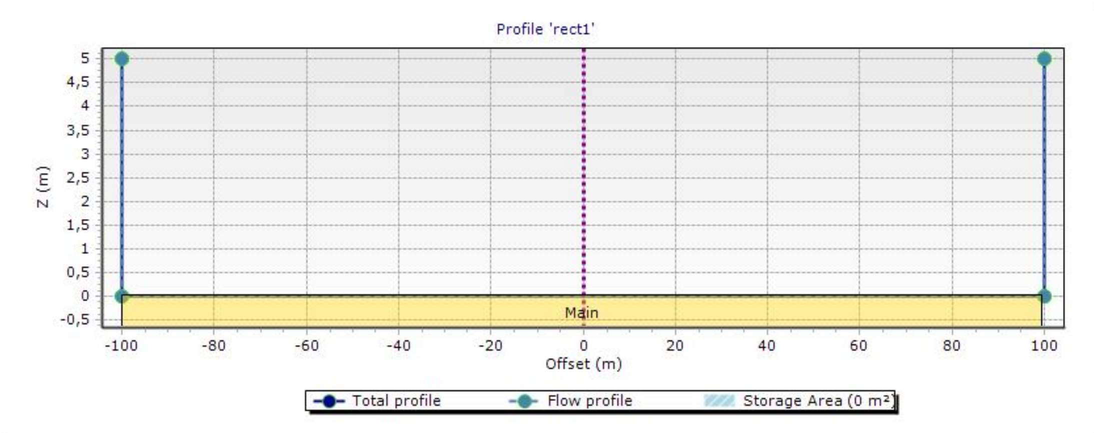

Figure 1.4: *Cross-section of test case.*

The basis model we use is set-up in SOBEK3. The geometry (tabulated cross-sections, roughness and some other properties), are directly imported into D-Flow FM using a specific keyword in the MDU-file:

```
OneDNetworkFile = dflow1d\water flow 1d.md1d
```

Some settings have to be set manually though:

- ◇ A SOBEK3 import only works if a (dummy) Network file is present. We advise to use a 2D network, to ensure that it doesn't conflict with the 1D network (as imported from SOBEK3).
- ◇ Timings such as refdate, start/end time and map-output intervals need to be converted manually to the MDU-file.
- ◇ The boundary conditions (locations and values) are not yet imported from SOBEK3. They have to be manually created. We defined 4 polylines at the upstream boundary for imposing the discharge, and 4 polylines at the downstream boundary to impose the water levels. Note that the boundary lines must be just *outside* the model. Also note that for the boundary definition when using morphology, each branch must have *its own* polyline, otherwise the morphological boundary condition is invalid.
- ◇ Recall that in SOBEK3 the water level at the downstream boundary holds at the last pressure point in the grid, while in D-Flow FM it gets mirrored half a grid cell outside the control volume around each grid point. Effectively, this means that the water level has to be specified as if it is Δx further downstream, considering the bed slope. For this case, at the downstream boundary, $\Delta x = 500m$. For a bed level slope of 1×10^{-4} this implies a 5 cm lower water level compared to SOBEK3.
- ◇ In the MOR input file, the boundaries need to be imposed at the polylines specified in one of the steps above.
- ◇ For the upstream (us) and downstream (ds) bed boundary condition we specify
  `IBedCond_us=1`
  `IBedCond_ds=0`
  Note that, since morphological updating is switched off, this is not relevant for this case though.

Results - hydraulics, comparison SOBEK3 vs D-Flow FM

Remember that for this case, we have 3 distinct discharges, all run for 1 day (to a stationairy condition).
The figures below compare some hydraulic output between SOBEK3 and D-Flow FM.

***Table 1.1:** Parameter values for the different test cases.*

	T1	T2	T3	T4
Sediment size D_{50} (mm)	0.6	0.6	0.6	0.6
Chézy roughness C (m$^{1/2}$/s)	50	70	50	50
Bed slope i_b (m/m)	0.0001	0.0001	0.0001	0.0002

***Table 1.2:** Model Settings*

Input description	Symbol	Value	Unit
flow			
gravitational acceleration	g	9.81	ms^{-2}
branch length	s_{tot}	10000	m
height upstream crosssection	z_{offset}	1	m
bed level slope	i	0.0001 / 0.0002	m/m
cross section width	B	200	m
upstream discharge boundary	Q	Q(t)	m^{3}s^{-1}
downstream water level boundary	h	Q-h	m
Chezy roughness coefficient	C	50 / 70	m$^{1/2}$s^{-1}
initial water depth	h_{ini}	4.71	m
water density	ρ_w	1000	kg m^{-3}
morphology parameters			
sediment diameter	D_{50}	0.0006	m
sediment density	ρ_s	2650	kg m^{-3}
relative density	Δ	1.65	
porosity	ϵ_p	0.4	
engelund-hansen calibration parameter	α	1	
model parameters			
computational grid size	Δx	500-2000	m
computational time step	Δt	60	s
output time step		24	h

- Figure 1.5: Apart from some "initial condition effects" the upstream water level for branch T1 compares very well between SOBEK3 and D-Flow FM.
- Figure 1.6: Differences in water level just a couple of cm.
- Figure 1.7: Also along the channels only small differences in water level.
- Figure 1.8: Differences in water level small.
- Figure 1.9: Some strange differences near the boundaries of the model.

Results - sediment transport D-Flow FM

The differences in the sediment transport between results of D-Flow FM and analytical values are shown in Figure 1.10 for Q1, in Figure 1.11 for Q2 and in Figure 1.12 (Q3). Each line represents a branch, T1 being the most southern branch, T4 the most northern branch. Both absolute differences [kg/s] as relative differences [[-]] are shown.

The differences in sediment transport (FM1D compared to analytical results) are larger than for SOBEK3 (where the max difference was 0.001662% for branch T2), but are acceptable small (max 2%) and there is no structural difference.

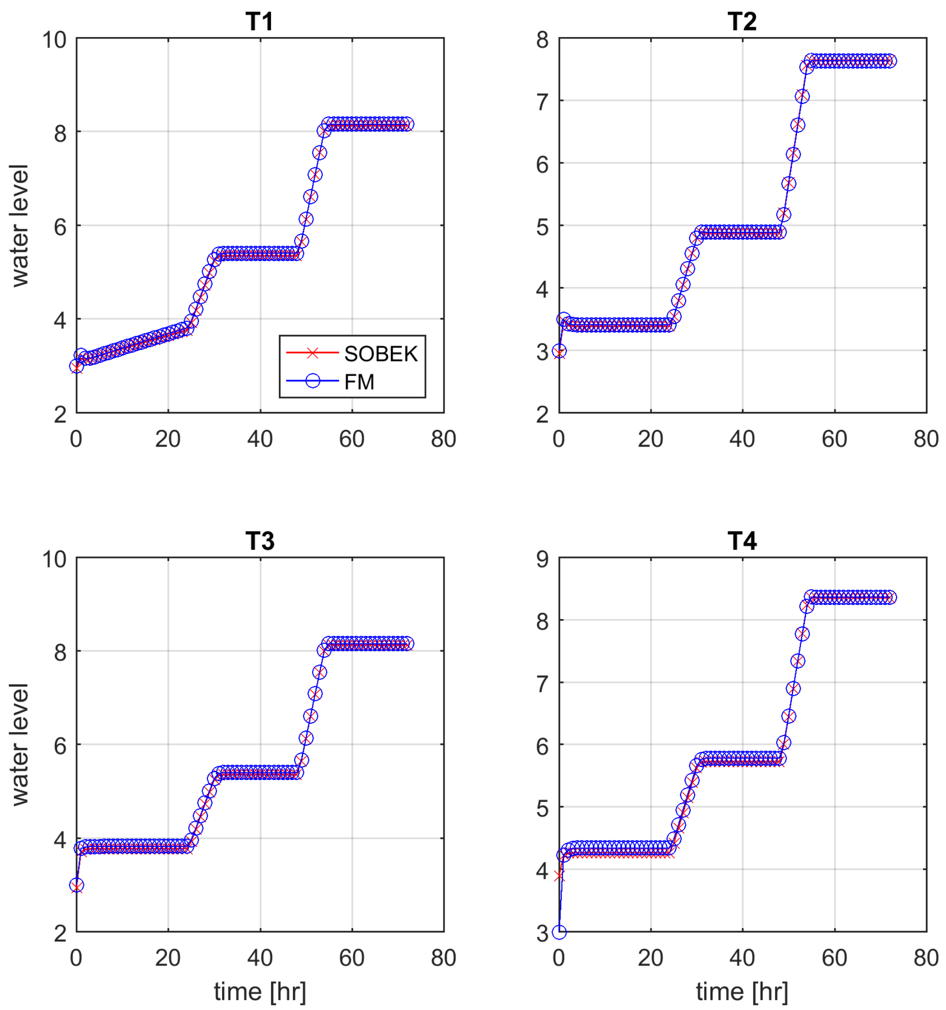

Figure 1.5: *Time series of water level at the second computational node at branch T1 (lowest).*

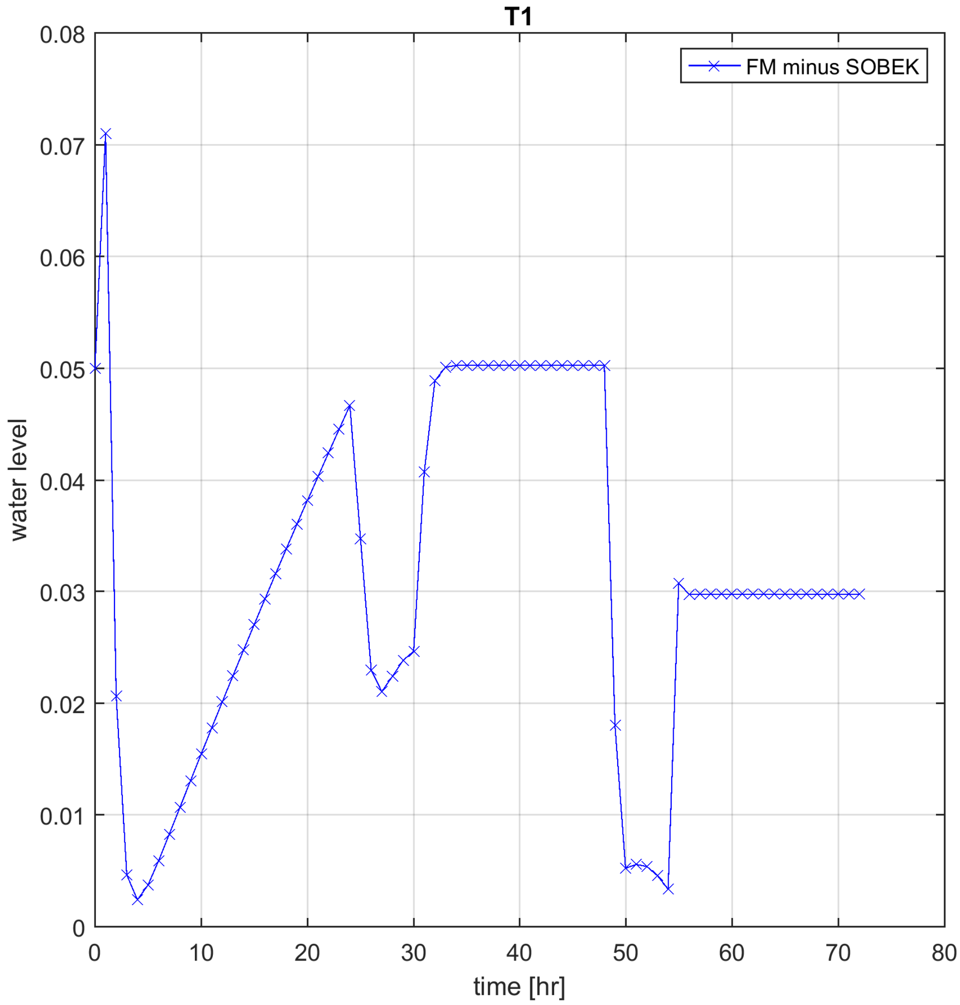

Figure 1.6: *Time series of difference in water level at the second computational node at branch T1 (lowest).*

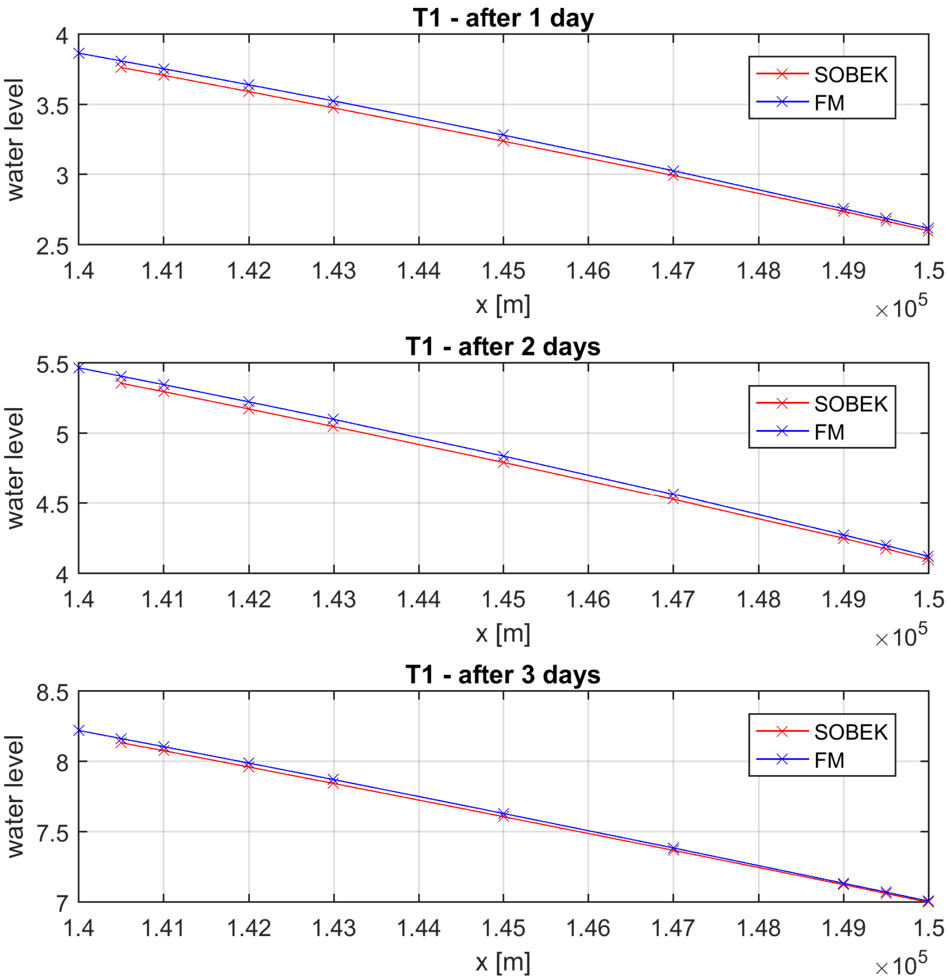

Figure 1.7: *Water level along the channel for branch T1 (top: Q1, center: Q2, bottom: Q3).*

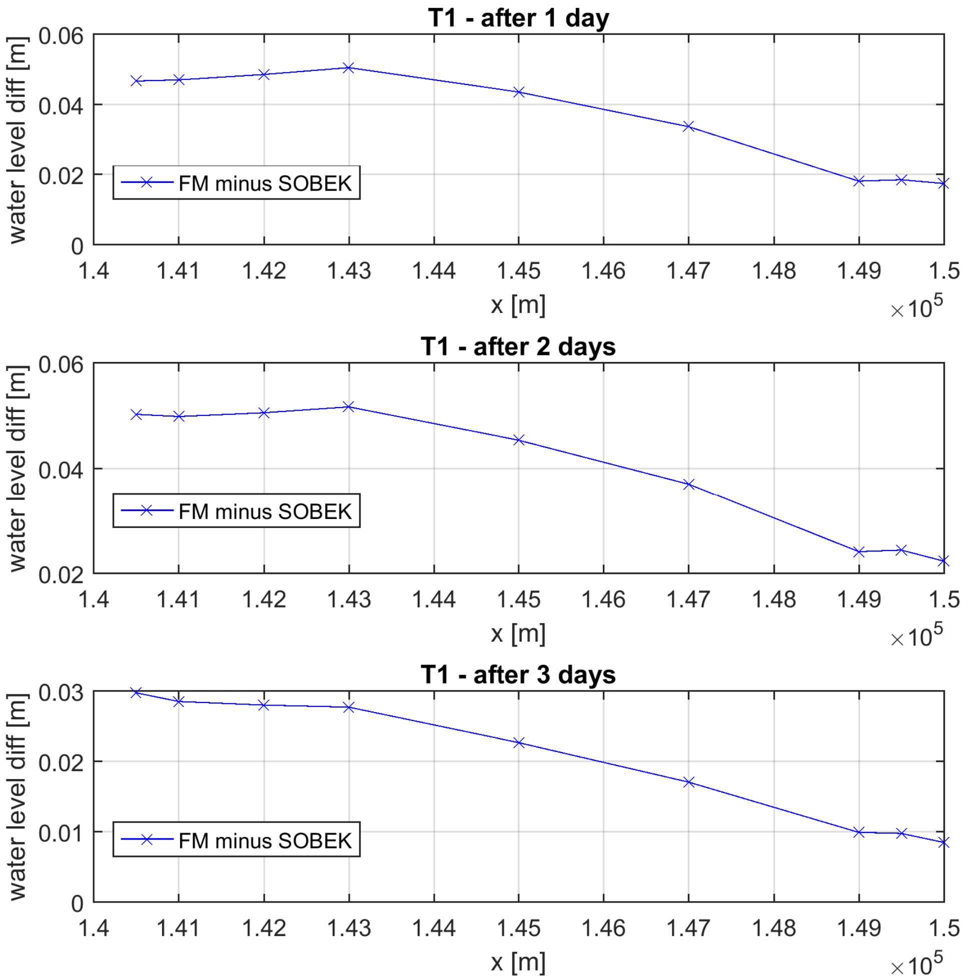

Figure 1.8: *Water level difference along the channel for branch T1 (top: Q1, center: Q2, bottom: Q3).*

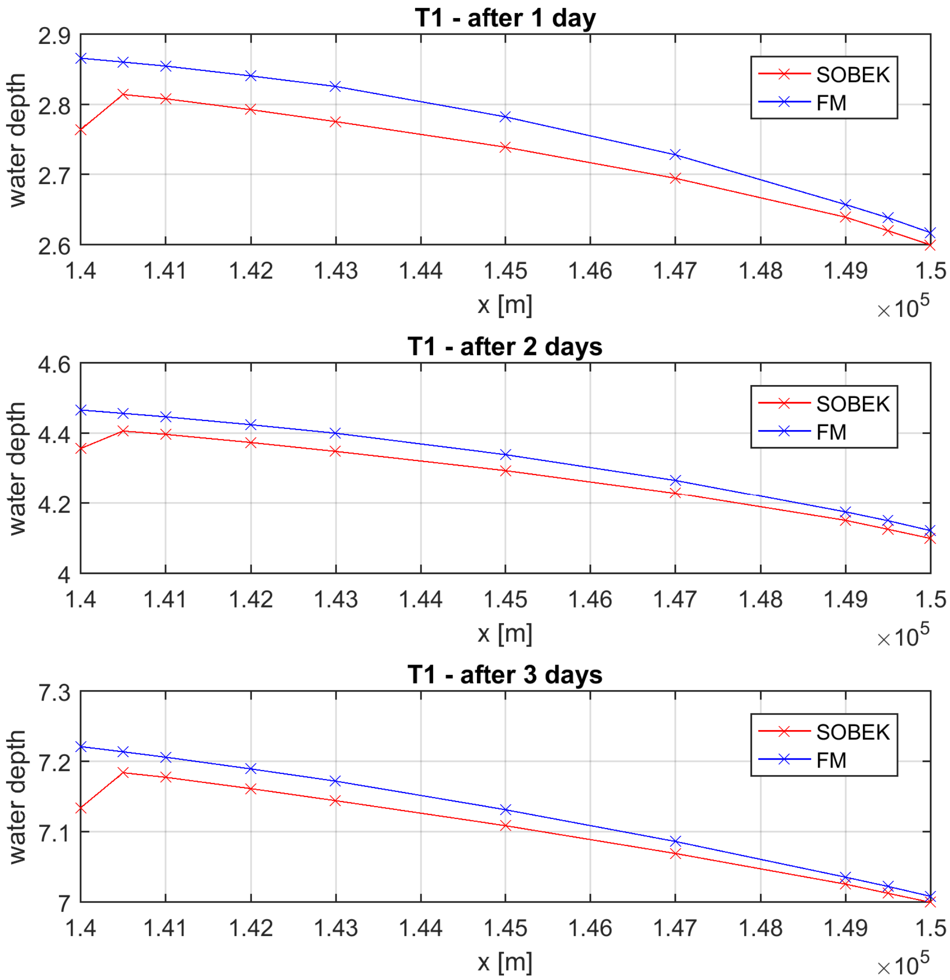

Figure 1.9: *Water depth along the channel for branch T1 (top: Q1, center: Q2, bottom: Q3).*

	Q1	Sed.tr. FM				[kg/s]				
x	140000	140500	141000	142000	143000	145000	147000	149000	149500	150000
T1	51,35	68,76	68,98	69,12	69,89	70,68	74,66	81,04	92,35	71,15
T2	42,88	52,94	52,48	51,52	50,48	48,25	45,69	42,79	41,94	32,98
T3	16,75	22,61	22,90	23,17	23,86	24,52	26,40	29,06	33,68	26,09
T4	123,20	165,73	164,77	162,64	160,01	153,69	144,83	132,89	128,79	91,97
	Q1	Sed.tr. Analytic				[kg/s]				
T1	24,65	68,95	69,18	69,49	70,30	71,54	75,79	82,62	93,00	33,95
T2	19,01	52,94	52,48	51,52	50,48	48,26	45,69	42,79	41,94	14,44
T3	8,04	22,67	22,96	23,29	23,99	24,82	26,83	29,68	33,95	12,46
T4	59,15	165,84	164,88	162,74	160,12	153,79	144,92	132,98	128,87	43,05
	Q1	DIFF, FM minus analytic				[kg/s]				
T1	26,70	-0,19	-0,20	-0,37	-0,41	-0,86	-1,13	-1,58	-0,65	37,20
T2	23,87	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	18,55
T3	8,71	-0,06	-0,06	-0,12	-0,14	-0,31	-0,43	-0,62	-0,26	13,63
T4	64,05	-0,11	-0,11	-0,11	-0,11	-0,10	-0,10	-0,09	-0,08	48,93
	Q1	DIFF relative, FM minus analytic				[-]				
T1	1,08	0,00	0,00	-0,01	-0,01	-0,01	-0,01	-0,02	-0,01	1,10
T2	1,26	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	1,28
T3	1,08	0,00	0,00	-0,01	-0,01	-0,01	-0,02	-0,02	-0,01	1,09
T4	1,08	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	1,14

Figure 1.10: *Sediment transport from D-Flow FM and analytical values in kg/s for Q1.*

	Q2	Sed.tr. FM				[kg/s]				
x	140000	140500	141000	142000	143000	145000	147000	149000	149500	150000
T1	174,40	235,32	238,38	241,12	248,08	254,56	272,27	295,25	330,80	252,77
T2	125,88	155,58	154,45	152,13	149,71	144,69	139,23	133,32	131,66	104,42
T3	58,13	78,44	79,46	80,37	82,69	84,85	90,76	98,42	110,27	84,26
T4	363,93	488,68	485,01	477,22	468,45	449,04	425,40	397,19	388,52	280,59
	Q2	Sed.tr. Analytic				[kg/s]				
T1	83,73	235,95	239,04	242,35	249,44	257,44	275,96	300,11	332,66	120,43
T2	55,80	155,58	154,45	152,14	149,71	144,69	139,23	133,32	131,67	45,71
T3	27,91	78,65	79,68	80,78	83,15	85,81	91,99	100,04	110,89	40,14
T4	174,74	489,00	485,33	477,53	468,75	449,34	425,68	397,46	388,78	131,33
	Q2	DIFF, FM minus analytic				[kg/s]				
T1	90,66	-0,62	-0,66	-1,22	-1,36	-2,88	-3,68	-4,86	-1,86	132,34
T2	70,08	-0,01	-0,01	-0,01	-0,01	0,00	0,00	0,00	0,00	58,71
T3	30,22	-0,21	-0,22	-0,41	-0,45	-0,96	-1,23	-1,62	-0,62	44,11
T4	189,20	-0,32	-0,32	-0,31	-0,31	-0,30	-0,28	-0,26	-0,26	149,26
	Q2	DIFF relative, FM minus analytic				[-]				
T1	1,08	0,00	0,00	-0,01	-0,01	-0,01	-0,01	-0,02	-0,01	1,10
T2	1,26	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	1,28
T3	1,08	0,00	0,00	-0,01	-0,01	-0,01	-0,01	-0,02	-0,01	1,10
T4	1,08	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	1,14

Figure 1.11: *Sediment transport from D-Flow FM and analytical values in kg/s for Q2.*

	Q3	Sed.tr. FM				[kg/s]				
x	140000	140500	141000	142000	143000	145000	147000	149000	149500	150000
T1	487,33	658,31	662,15	665,53	673,82	681,22	700,02	721,50	749,53	559,85
T2	281,04	346,35	342,88	335,94	328,94	315,07	301,04	286,89	283,20	224,55
T3	162,44	219,44	220,72	221,84	224,61	227,07	233,34	240,50	249,84	186,62
T4	865,39	1153,29	1135,92	1100,80	1064,51	991,47	915,29	837,05	816,07	587,88
	Q3	Sed.tr. Analytic				[kg/s]				
T1	233,99	659,33	663,20	667,24	675,62	684,55	703,77	725,76	751,14	265,82
T2	124,57	346,36	342,89	335,95	328,96	315,08	301,05	286,90	283,21	98,29
T3	78,00	219,78	221,07	222,41	225,21	228,18	234,59	241,92	250,38	88,61
T4	415,51	1154,05	1136,67	1101,52	1065,21	992,12	915,89	837,60	816,61	275,15
	Q3	DIFF, FM minus analytic				[kg/s]				
T1	253,35	-1,02	-1,05	-1,71	-1,80	-3,33	-3,75	-4,27	-1,61	294,04
T2	156,46	-0,01	-0,01	-0,01	-0,01	-0,01	-0,01	-0,01	-0,01	126,25
T3	84,45	-0,34	-0,35	-0,57	-0,60	-1,11	-1,25	-1,42	-0,54	98,01
T4	449,89	-0,76	-0,75	-0,72	-0,70	-0,65	-0,60	-0,55	-0,54	312,73
	Q3	DIFF relative, FM minus analytic				[-]				
T1	1,08	0,00	0,00	0,00	0,00	0,00	-0,01	-0,01	0,00	1,11
T2	1,26	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	1,28
T3	1,08	0,00	0,00	0,00	0,00	0,00	-0,01	-0,01	0,00	1,11
T4	1,08	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	1,14

Figure 1.12: *Sediment transport from D-Flow FM and analytical values in kg/s for Q3.*

Conclusion

Hydraulics almost equal between SOBEK3 and D-Flow FM with tabulated cross sections. These tests show that D-Flow FM with tabulated cross sections is able to accurately calculate sediment formulation according to Engelund-Hansen.

References

Engelund, F. and E. Hansen (1967). *A monograph on Sediment Transport in Alluvial Streams*. Teknisk Forlag, Copenhagen.

1.2 Meyer-Peter-Muller transport formula for total transport

Quality Assurance

Date	Author	Initials	Review	Initials	Approval	Initials
01 June 2018	Andries Paarlberg		Willem Ottevanger		Aukje Spruyt	

Version information

Date of study : 01 June 2018
Executable : D-Flow FM Version 1.2.0.55920M, May 31 2018, 20:05:27
Location : https://svn.oss.deltares.nl/repos/trunk/riverlab/f27_mor1d_tabulated_crosssections/c02_mc_sediment_transport_MPM
SVN revision : -

Purpose

D-Flow FM-1D-mor can use so-called tabulated cross-sections (from SOBEK3), where the flow width is specified as a function of the water level. The bed level is updated in the main channel only.
The purpose of this validation case is to prove that the calculated sediment transport with the Meyer-Peter, E. and R. Müller (1948) formula is correct in D-Flow FM-1D, with tabulated cross sections. The formula is tested using several different parameter values, as outlined below.

Linked claims

- ◇ Water levels computed with D-Flow FM are comparable to water levels computed with SOBEK3.
- ◇ D-Flow FM accurately calculates sediment transport according to the formula of Meyer-Peter-Muller.

Approach

We start from an existing SOBEK3-model (/DSCTestbench/cases/e106_dflow1d/f13_morphology/c02_sediment_transport_Meyer-Peter-Muller). The values of the Chézy roughness, and the bed slope i_b are varied. The test is carried out for several different discharge values (and downstream water levels). In this test case, we assume that the velocities as calculated by the flow module are correct; simulated water levels are compared with SOBEK3.

The total sediment transport S [kg/s] calculated by the Engelund-Hansen formula is given by:

$$S = B\rho_s s = B\rho_s(0.05\frac{\alpha u^5}{\sqrt{g}C^3\Delta^2 D_{50}}) \tag{1.2}$$

where

u	the magnitude of the flow velocity [m/s],
Δ	the relative density given by $\Delta = \frac{\rho_s - \rho_w}{\rho_w}$ [-],
C	the Chézy friction coefficient [m$^{1/2}$/s],
D_{50}	the median diameter of sediment [m],
α	the user-defined calibration coefficient [-],
B	the width of the main channel [m] and
ρ_s	the sediment density [kg/m^3].

In this test, the sediment transport is calculated analytically based on the calculated velocity by the flow module. The analytically computed sediment transport is then compared to the sediment transport as calculated by D-Flow FM-1D.

Model description

The model domain, consisting of four (non-connected) straight branches, each with the same length of 10 km, but different properties is shown in Figure 1.13.

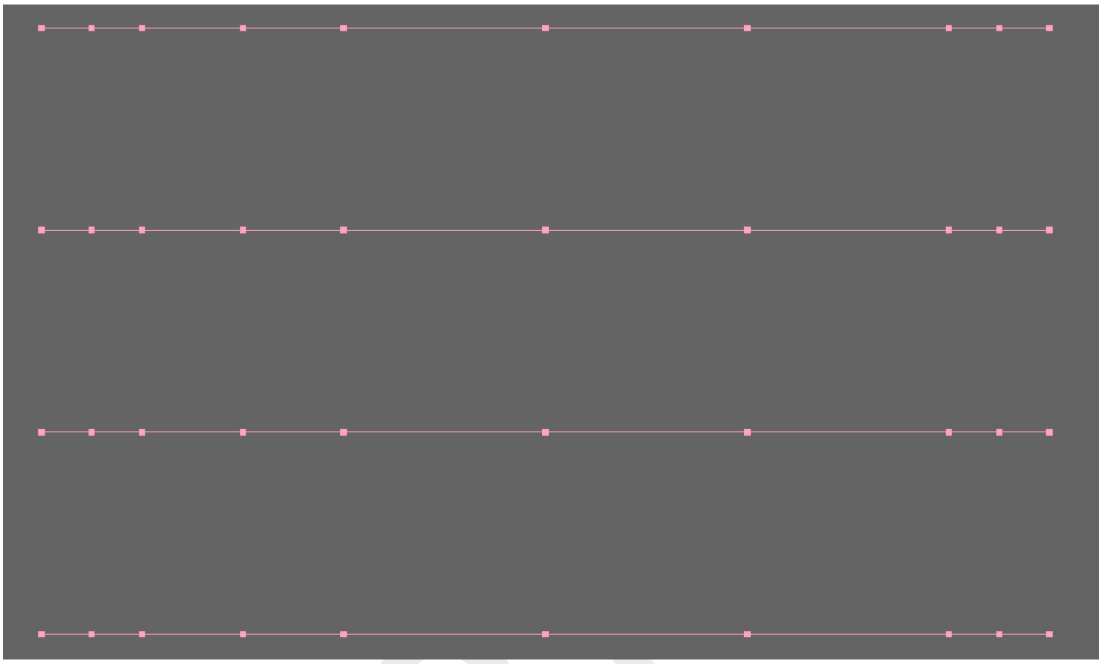

Figure 1.13: *Four (non-connected) branches, channels with equal length, but different properties.*

For this test case, each of the channels is straight with homogeneous cross-sections. The flow is stationary but non-homogeneous. The flow direction in the channel is oriented in the same direction as the computational grid. Upstream a discharge boundary is imposed (Figure 1.14), downstream a water level boundary (Figure 1.15). No further connection nodes are added. The channel contains rectangular cross-sections of 200 m in width throughout. See Figure 1.16. Computational nodes are placed at non-uniform distances. Calculations are done for four different testcases in which several parameter values are varied. An overview of these varied parameter values is shown in Table 1.3. Note that T1 and T3, two independent branches, have identical settings and should produce identical results. Other model settings for all cases are given in Table 1.4.

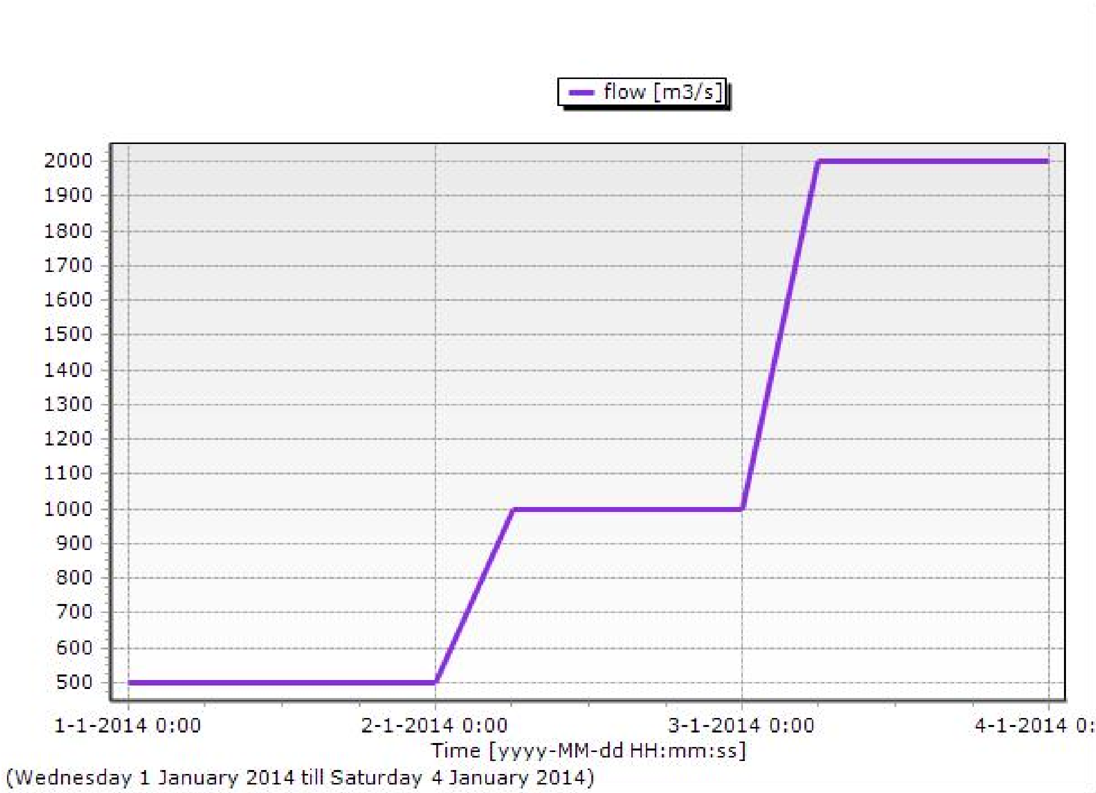

Figure 1.14: *Upstream discharge boundary condition.*

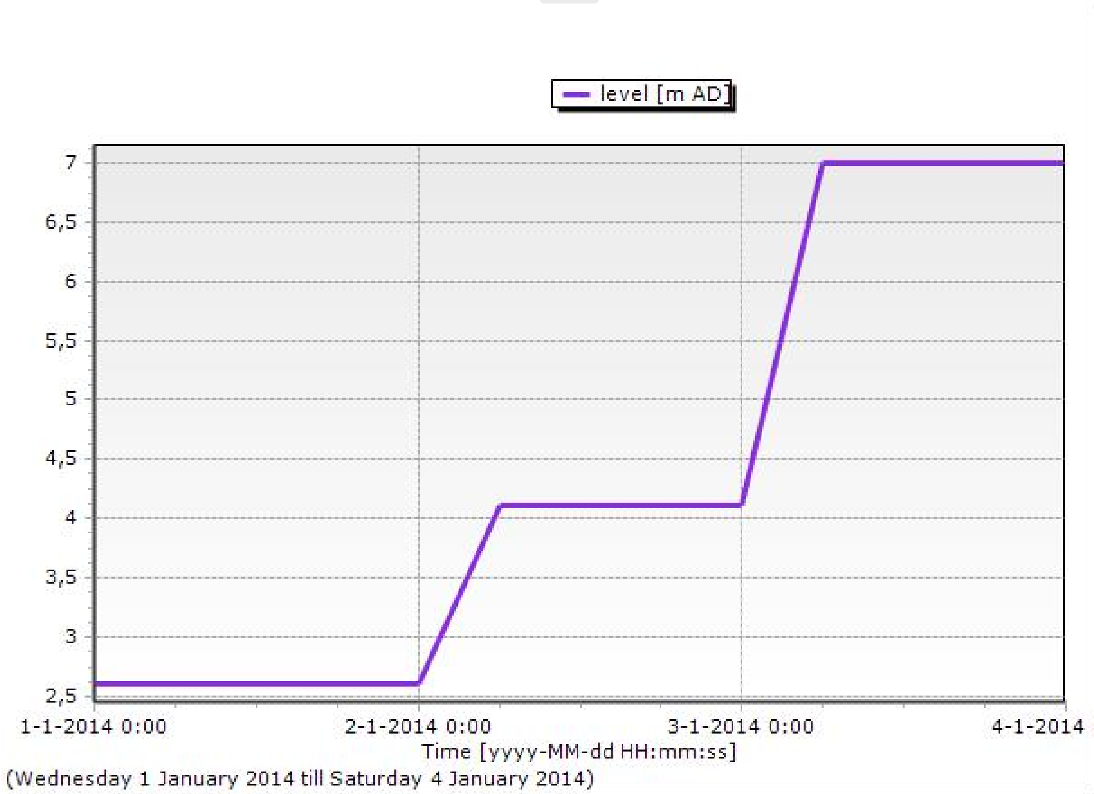

Figure 1.15: *Downstream water level boundary condition.*

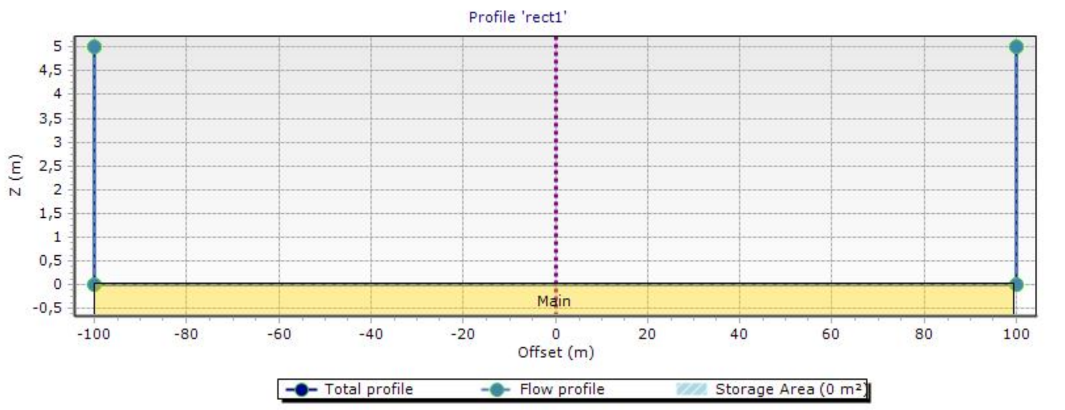

Figure 1.16: *Cross-section of test case.*

The basis model we use is set-up in SOBEK3. The geometry (tabulated cross-sections, roughness and some other properties), are directly imported into D-Flow FM using a specific keyword in the MDU-file:

```
OneDNetworkFile = dflow1d\water flow 1d.md1d
```

Some settings have to be set manually though:

- A SOBEK3 import only works if a (dummy) Network file is present. We advise to use a 2D network, to ensure that it doesn't conflict with the 1D network (as imported from SOBEK3).
- Timings such as refdate, start/end time and map-output intervals need to be converted manually to the MDU-file.
- The boundary conditions (locations and values) are not yet imported from SOBEK3. They have to be manually created. We defined 4 polylines at the upstream boundary for imposing the discharge, and 4 polylines at the downstream boundary to impose the water levels. Note that the boundary lines must be just *outside* the model. Also note that for the boundary definition when using morphology, each branch must have *its own* polyline, otherwise the morphological boundary condition is invalid.
- Recall that in SOBEK3 the water level at the downstream boundary holds at the last pressure point in the grid, while in D-Flow FM it gets mirrored half a grid cell outside the control volume around each grid point. Effectively, this means that the water level has to be specified as if it is Δx further downstream, considering the bed slope. For this case, at the downstream boundary, $\Delta x = 500m$. For a bed level slope of 1×10^{-4} this implies a 5 cm lower water level compared to SOBEK3.
- In the MOR input file, the boundaries need to be imposed at the polylines specified in one of the steps above.
- For the upstream (us) and downstream (ds) bed boundary condition we specify
  `IBedCond_us=1`
  `IBedCond_ds=0`
  Note that, since morphological updating is switched off, this is not relevant for this case though.

Results - hydraulics, comparison SOBEK3 vs D-Flow FM

Remember that for this case, we have 3 distinct discharges, all run for 1 day (to a stationairy condition).
The figures below compare some hydraulic output between SOBEK3 and D-Flow FM.

Table 1.3: *Parameter values for the different test cases.*

	T1	T2	T3	T4
Sediment size D_{50} (mm)	0.6	0.6	0.6	0.6
Chézy roughness C ($m^{1/2}$/s)	50	70	50	50
Bed slope i_b (m/m)	0.0001	0.0001	0.0001	0.0002

Table 1.4: *Model Settings*

Input description	Symbol	Value	Unit
flow			
gravitational acceleration	g	9.81	ms^{-2}
branch length	s_{tot}	10000	m
height upstream crosssection	z_{offset}	1	m
bed level slope	i	0.0001 / 0.0002	m/m
cross section width	B	200	m
upstream discharge boundary	Q	Q(t)	m^3s^{-1}
downstream water level boundary	h	Q-h	m
Chezy roughness coefficient	C	50 / 70	$m^{1/2}s^{-1}$
initial water depth	h_{ini}	4.71	m
water density	ρ_w	1000	kg m^{-3}
morphology parameters			
sediment diameter	D_{50}	0.0006	m
sediment density	ρ_s	2650	kg m^{-3}
relative density	Δ	1.65	
porosity	ϵ_p	0.4	
engelund-hansen calibration parameter	α	1	
model parameters			
computational grid size	Δx	500-2000	m
computational time step	Δt	60	s
output time step		24	h

- Figure 1.17: Apart from some "initial condition effects" the upstream water level for branch T1 compares very well between SOBEK3 and D-Flow FM.
- Figure 1.18: Differences in water level just a couple of cm.
- Figure 1.19: Also along the channels only small differences in water level.
- Figure 1.20: Differences in water level small.
- Figure 1.21: Some strange differences near the boundaries of the model.

Results - sediment transport D-Flow FM

The differences in the sediment transport between results of D-Flow FM and analytical values are shown in Figure 1.22 for Q1, in Figure 1.23 for Q2 and in Figure 1.24 (Q3). Each line represents a branch, T1 being the most southern branch, T4 the most northern branch. Both absolute differences [kg/s] as relative differences [[-]] are shown.

The differences in sediment transport (FM1D compared to analytical results) are larger than for SOBEK3 (where the max difference was 0.000023% for branch T2), but are acceptable small (max 1%) and there is no structural difference.

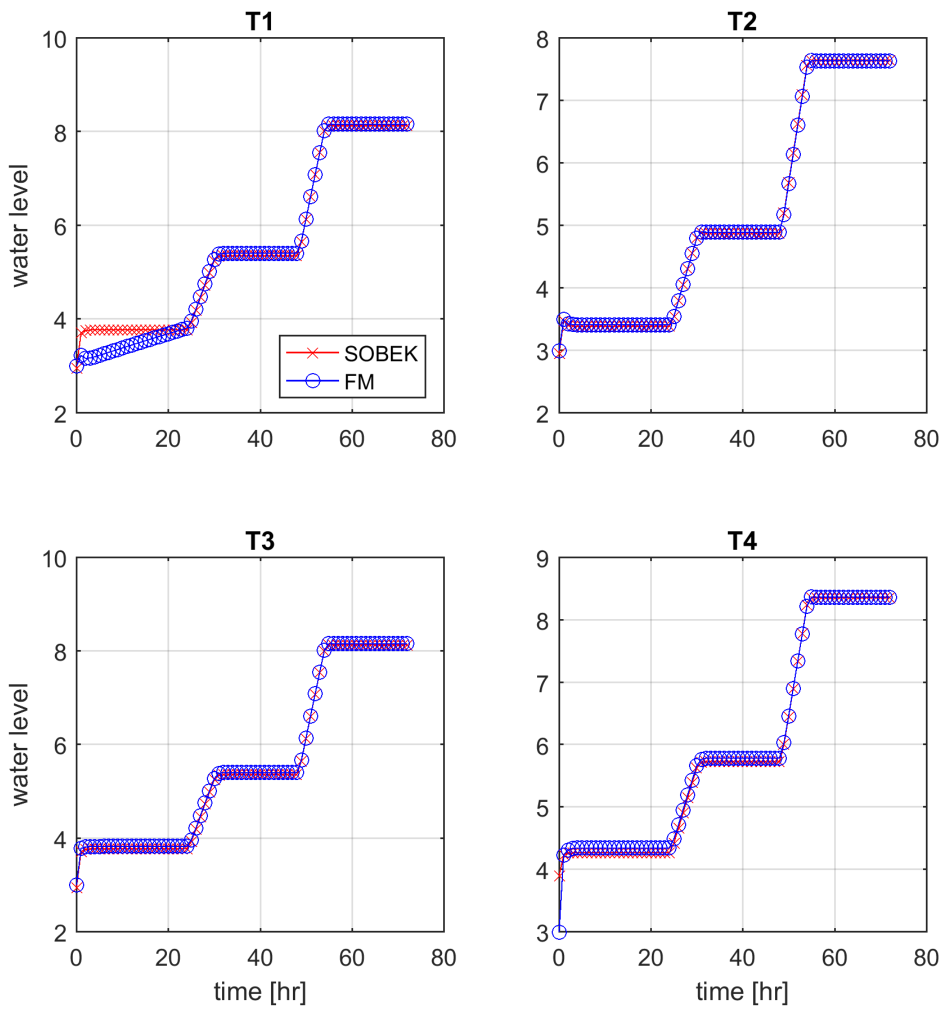

Figure 1.17: *Time series of water level at the second computational node at branch T1 (lowest).*

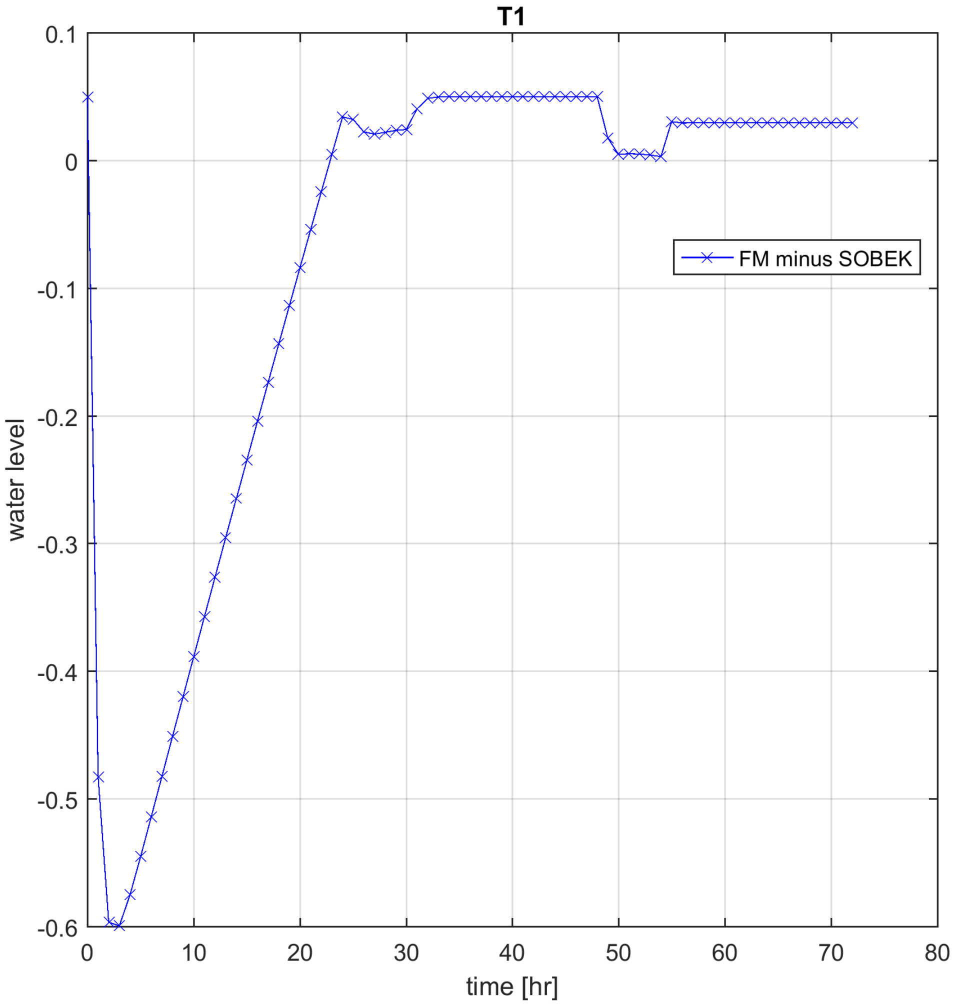

Figure 1.18: *Time series of difference in water level at the second computational node at branch T1 (lowest).*

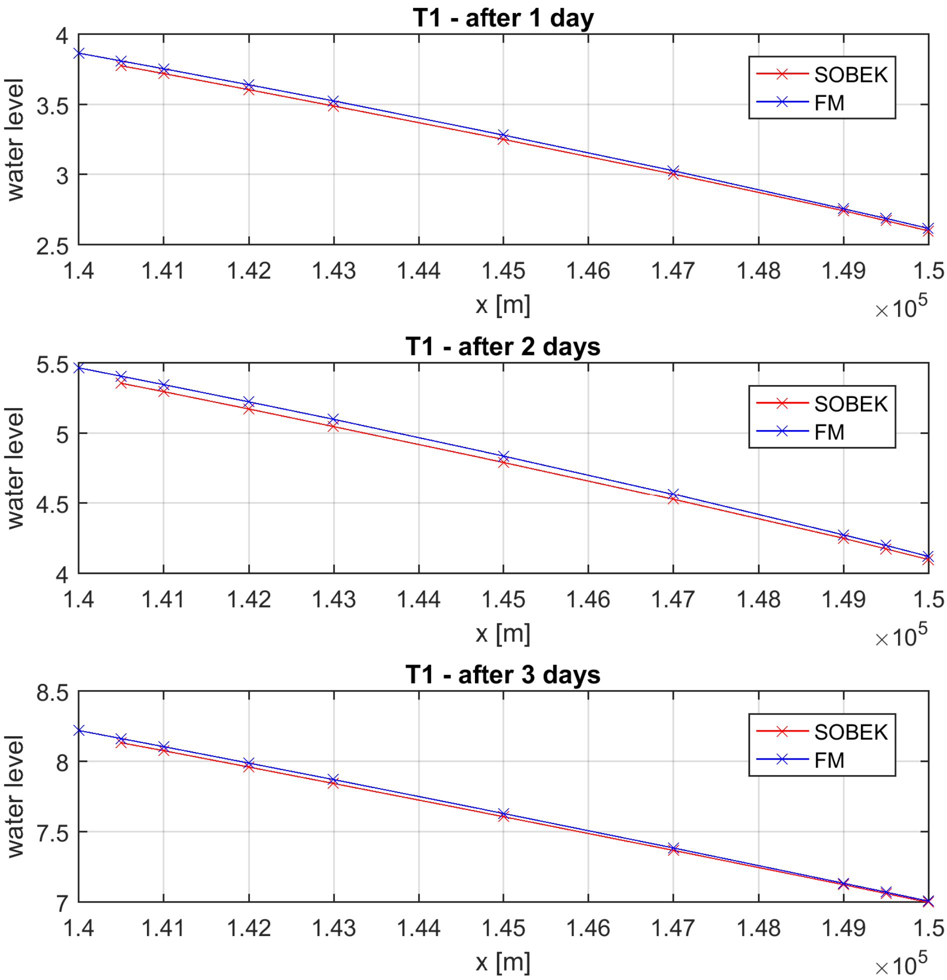

Figure 1.19: *Water level along the channel for branch T1 (top: Q1, center: Q2, bottom: Q3).*

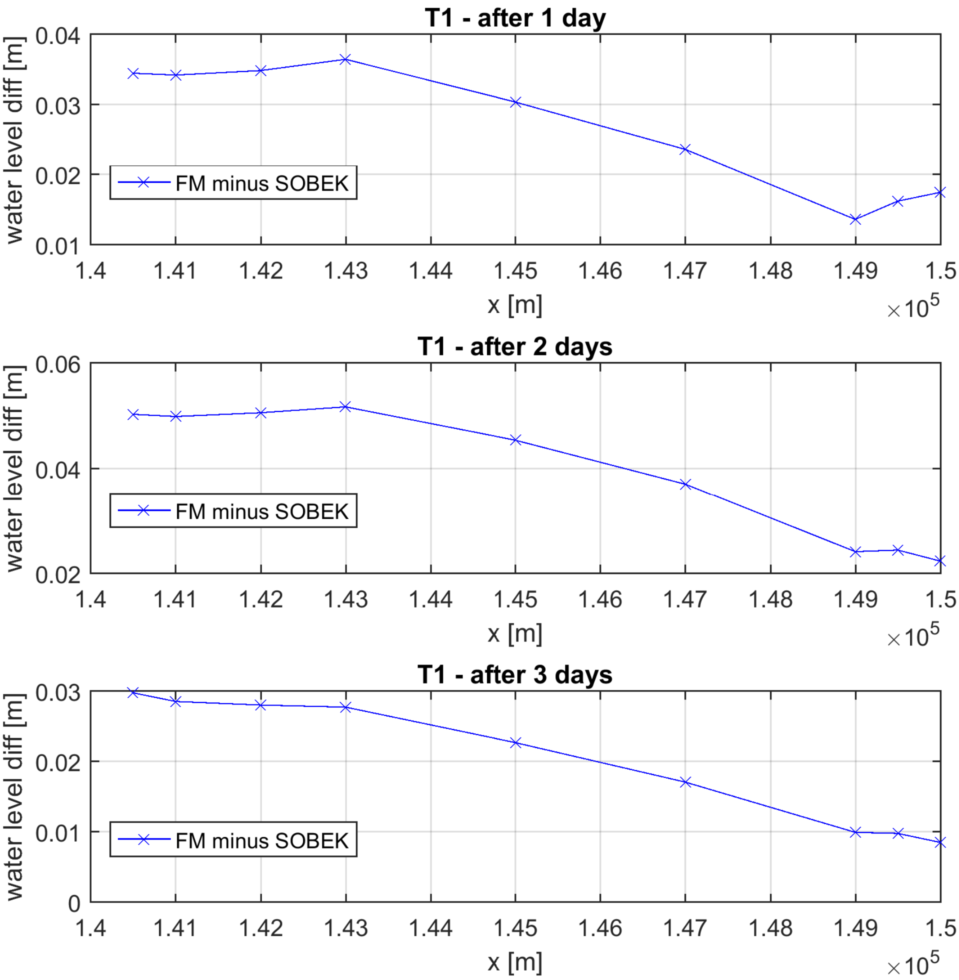

Figure 1.20: *Water level difference along the channel for branch T1 (top: Q1, center: Q2, bottom: Q3).*

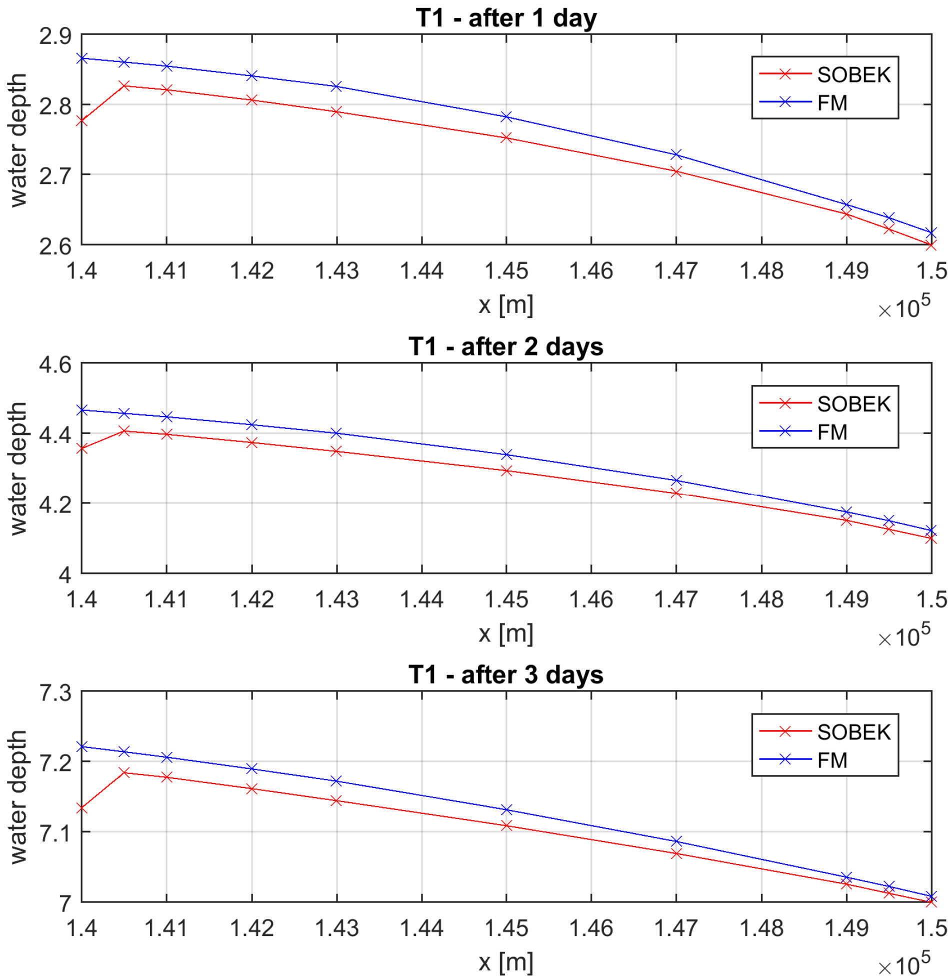

Figure 1.21: *Water depth along the channel for branch T1 (top: Q1, center: Q2, bottom: Q3).*

Q1	Sed.tr. FM				[kg/s]					
x	140000	140500	141000	142000	143000	145000	147000	149000	149500	150000
T1	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
T2	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
T3	6,88	6,87	6,93	6,98	7,15	7,30	7,88	8,71	10,08	10,47
T4	15,99	15,76	15,52	15,16	14,73	14,54	14,24	13,77	13,35	12,89
Q1	Sed.tr. Analytic				[kg/s]					
T1	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
T2	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
T3	6,88	6,88	6,94	7,01	7,17	7,39	8,00	8,89	10,14	10,53
T4	15,99	15,77	15,52	15,16	14,73	14,54	14,24	13,78	13,36	12,89
Q1	DIFF, FM minus analytic				[kg/s]					
T1	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
T2	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
T3	0,00	-0,01	-0,01	-0,02	-0,03	-0,08	-0,12	-0,18	-0,06	-0,07
T4	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Q1	DIFF relative, FM minus analytic				[-]					
T1	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
T2	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
T3	0,00	0,00	0,00	0,00	0,00	-0,01	-0,01	-0,02	-0,01	-0,01
T4	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00

Figure 1.22: *Sediment transport from D-Flow FM and analytical values in kg/s for Q1.*

Q2	Sed.tr. FM				[kg/s]					
x	140000	140500	141000	142000	143000	145000	147000	149000	149500	150000
T1	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
T2	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
T3	18,14	18,13	18,29	18,45	18,84	19,22	20,35	21,80	23,92	24,50
T4	32,48	32,20	31,91	31,41	30,86	30,17	29,28	28,14	27,61	27,04
Q2	Sed.tr. Analytic				[kg/s]					
T1	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
T2	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
T3	18,14	18,16	18,32	18,51	18,90	19,39	20,56	22,08	24,00	24,60
T4	32,48	32,21	31,91	31,42	30,86	30,17	29,29	28,14	27,62	27,04
Q2	DIFF, FM minus analytic				[kg/s]					
T1	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
T2	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
T3	0,00	-0,03	-0,03	-0,06	-0,07	-0,16	-0,21	-0,28	-0,09	-0,10
T4	-0,01	-0,01	-0,01	-0,01	-0,01	-0,01	-0,01	-0,01	-0,01	-0,01
Q2	DIFF relative, FM minus analytic				[-]					
T1	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
T2	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
T3	0,00	0,00	0,00	0,00	0,00	-0,01	-0,01	-0,01	0,00	0,00
T4	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00

Figure 1.23: *Sediment transport from D-Flow FM and analytical values in kg/s for Q2.*

Q3	Sed.tr. FM				[kg/s]					
x	140000	140500	141000	142000	143000	145000	147000	149000	149500	150000
T1	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
T2	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
T3	35,73	35,72	35,86	35,99	36,31	36,61	37,41	38,32	39,44	39,72
T4	54,14	53,56	52,95	51,77	50,53	48,19	45,66	42,92	42,10	41,25

Q3	Sed.tr. Analytic				[kg/s]					
T1	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
T2	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
T3	35,74	35,75	35,89	36,05	36,37	36,74	37,55	38,48	39,49	39,77
T4	54,15	53,57	52,96	51,78	50,54	48,20	45,67	42,93	42,11	41,25

Q3	DIFF, FM minus analytic				[kg/s]					
T1	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
T2	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
T3	-0,01	-0,03	-0,03	-0,05	-0,06	-0,12	-0,14	-0,16	-0,05	-0,05
T4	-0,01	-0,01	-0,01	-0,01	-0,01	-0,01	-0,01	-0,01	-0,01	-0,01

Q3	DIFF relative, FM minus analytic				[-]					
T1	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
T2	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
T3	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
T4	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00

Figure 1.24: *Sediment transport from D-Flow FM and analytical values in kg/s for Q3.*

Conclusion

Hydraulics almost equal between SOBEK3 and D-Flow FM with tabulated cross sections. These tests show that D-Flow FM with tabulated cross sections is able to accurately calculate sediment formulation according to Meyer-Peter-Muller.

References

Meyer-Peter, E. and R. Müller (1948). “Formulas for bed load transport”. In: *Proceedings of the 2nd Congress IAHR, Stockholm*. Vol. 2, pp. 39–64.

1.3 Cross-section with floodplain: Umain

Quality Assurance

Date	Author	Initials	Review	Initials	Approval	Initials
08 Dec 2017	Andries Paarlberg		Bert Jagers		Aukje Spruyt	

Version information

Date of study : 22 Dec 2017
Executable : Deltares, D-Flow FM Version 1.1.261.53873M, Dec 19 2017, 23:18:32
Location : `https://repos.deltares.nl/repos/DSCTestbench/trunk/cases/e02_dflowfm/f27_mor1d_tabulated_crosssections/c07_fp_sediment_transport_Umain`
SVN revision : -

Purpose

D-Flow FM-1D (mor) can use so-called tabulated cross-sections (from SOBEK3), where the flow width is specified as a function of the water level. The bed level is updated in the main channel only.
SOBEK3 (and thus D-Flow FM 1D-mor) allows the user to define compound channels by defining multiple sections ('Main', 'FloodPlain1' and 'FloodPlain2'). For Morphology and Sediment Transport, D-Flow FM uses only the 'Main' channel for the calculation of sediment transport and morphological updating. The purpose of this validation case is to analyze whether D-Flow FM and SOBEK3 compute comparable water levels and to prove that D-Flow FM uses the velocity of the main channel for the calculation of sediment transport.

Linked claims

◇ Water levels computed with D-Flow FM are comparable to water levels computed with SOBEK3.
◇ D-Flow FM accurately uses the flow velocity of the 'main' section in a compound cross-section.
◇ D-Flow FM accurately calculates sediment transport according to the formula of Engelund-Hansen.

Approach

We start from an existing SOBEK3-model (`/DSCTestbench/cases/e106_dflow1d/f13_morphology/c07_sediment_transport_main_channel`). That model is converted to D-Flow FM and run with the same properties. Then, we calculate, given the wet area of the compound channel, the velocity in the main channel:

$$u = \frac{Q_{main,sobek}}{d_{main} W_{main}} \tag{1.3}$$

where

$Q_{main,sobek}$ is the discharge in the main channel as calculated by D-Flow FM,
d_{main} is the water depth in the main channel and
W_{main} is the width of the main channel.

Subsequently, we calculate the sediment transport according to Engelund Hansen and compare with D-Flow FM results (see also case 1.1).

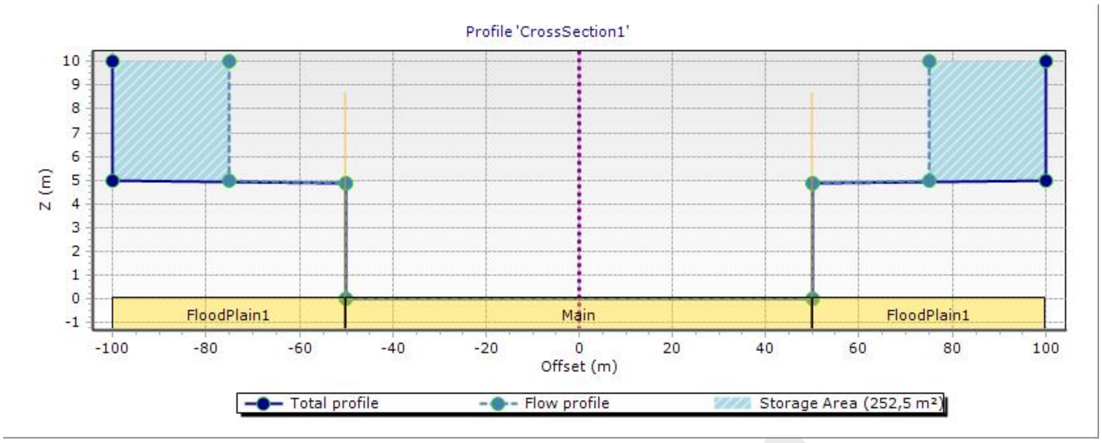

Figure 1.26: *Cross-section of test case*

Model description

The model consists of a single branch with an approximate length of 11 km, unevenly spaced computational points as shown in shown in Figure 1.25.

Figure 1.25: *One branch of 11 km.*

The single branch has one cross-section which consist of a main channel and a floodplain on either side, see Figure 1.26. Table 1.5 gives an overview of the model settings. The upstream boundary condition is given by a discharge timeseries: Q1=250, Q2=500, Q3=1000, Q4=2000; each discharge level has a duration of 1 days, before it steps to the next discharge in 6 hours time. The downstream boundary condition is given by a water level time series (2.0, 4.5, 7.0, 8.0 m w.r.t. a certain reference). Together the boundary conditions describe a quasi-stationary computation with four distinct stationary situations. For the first two discharge, the water remains in the main channel, for the third discharge the floodplains just start to flood and for the fourth discharge the floodplains convey quite some water.

The basis model we use is set-up in SOBEK3. The geometry (tabulated cross-sections, roughness and some other properties), are directly imported into D-Flow FM using a specific keyword in the MDU-file:

```
OneDNetworkFile = dflow1d\water flow 1d.md1d
```

Some settings have to be set manually though:

- A SOBEK3 import only works if a (dummy) Network file is present. We advise to use a 2D network, to ensure that it doesn't conflict with the 1D network (as imported from SOBEK3).
- Timings such as refdate, start/end time and map-output intervals need to be converted manually to the MDU-file.
- The boundary conditions (locations and values) are not yet imported from SOBEK3. They have to be manually created. We defined one polyline at the upstream boundary for imposing the discharge, and one polyline at the downstream boundary to impose the water level. Note that the boundary lines must be just *outside* the model.

Table 1.5: *Model settings*

Input description	Symbol	Value	unit
flow			
gravitational acceleration	g	9.81	ms^{-2}
branch length	s_{tot}	11000	m
height upstream crosssection	z_{offset}	1	m
bed level slope	i	0.0001	m/m
cross section width	B	100	m
upstream discharge boundary	Q at 2-1-2014	250	m^3s^{-1}
upstream discharge boundary	Q at 3-1-2014	500	m^3s^{-1}
upstream discharge boundary	Q at 4-1-2014	1000	m^3s^{-1}
upstream discharge boundary	Q at 5-1-2014	2000	m^3s^{-1}
downstream water level boundary	h	Q-h	m
Chézy roughness coefficient	C	50	$m^{1/2}s^{-1}$
initial water depth	$h_i ni$	4.71	m
water density	ρ_w	1000	kg m^{-3}
morphology parameters			
sediment diameter	D_{50}	0.0002	m
sediment density	ρ_s	2650	kg/m3
relative density	Δ	1.65	
porosity	ϵ_p	0.4	
engelund-hansen calibration parameter	α	1	
model parameters			
computational grid size	Δx	500-2000	m
computational time step	Δt	60	s
output time step		24	h

- ◇ Recall that in SOBEK3 the water level at the downstream boundary holds at the last pressure point in the grid, while in D-Flow FM it gets mirrored half a grid cell outside the control volume around each grid point. Effectively, this means that the water level has to be specified as if it is Δx further downstream, considering the bed slope. For this case, at the downstream boundary, $\Delta x = 1000m$. For a bed level slope of 1×10^{-4} this implies a 10 cm lower water level compared to SOBEK3.
- ◇ No morphological boundary conditions are specified for this case (so default "free boundaries" are used). Since bed level updating is switched off, this is not relevant.
- ◇ For the sediment transport calculation, we use the Engelund, F. and E. Hansen (1967) formula, see case 1.1 for details.

Results - hydraulics, comparison SOBEK3 vs D-Flow FM

Remember: three discharges, all run for 1 day (to a stationairy condition).
The figures below compare some hydraulic output between SOBEK3 and D-Flow FM. For this case we have used:

```
NonLin1D = 1
```

(we are still investigating the exact effects of this settings, but it doesn't seem to have an effect for straight channels with uniform cross-sections).

- ◇ Figure 1.27: Water level ok when flow in main channel, too high when in floodplain (compared to SOBEK3).
- ◇ Figure 1.28: See above.
- ◇ Figure 1.29: See above.
- ◇ Figure 1.30: See above.
- ◇ Figure 1.31: See above.

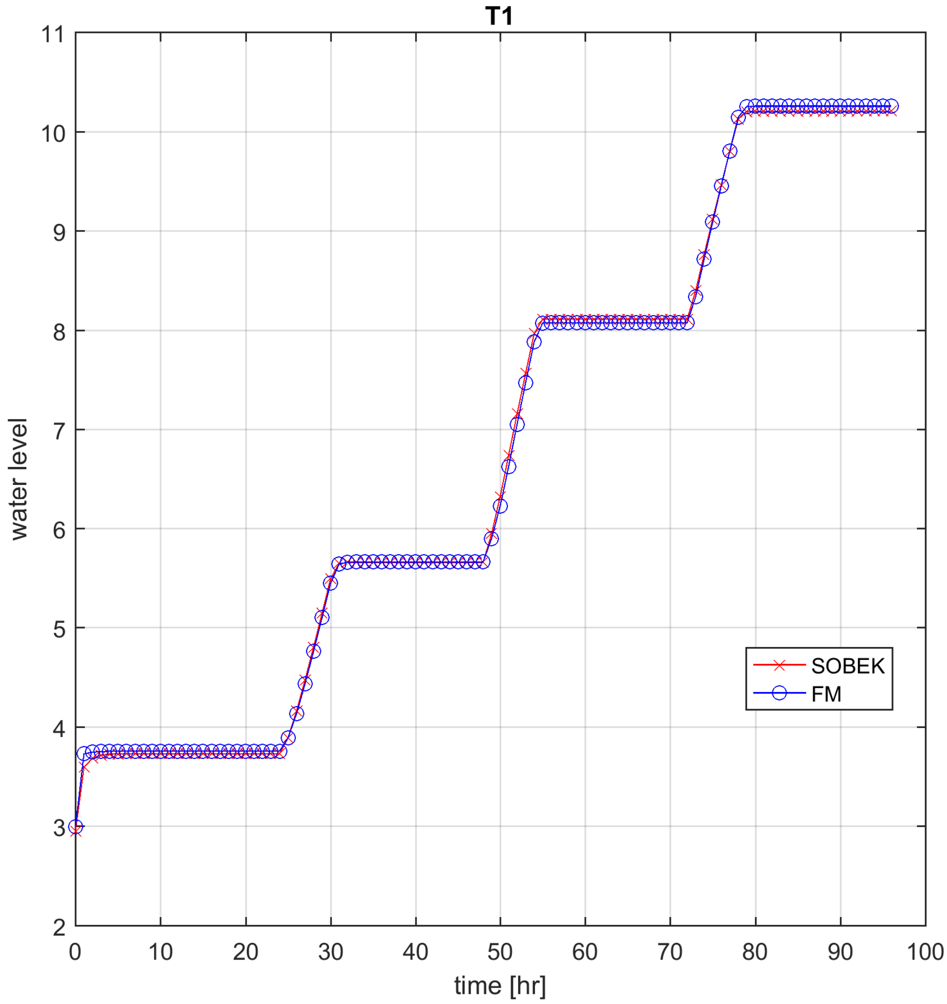

Figure 1.27: *Time series of water level at the second computational node of the channel.*

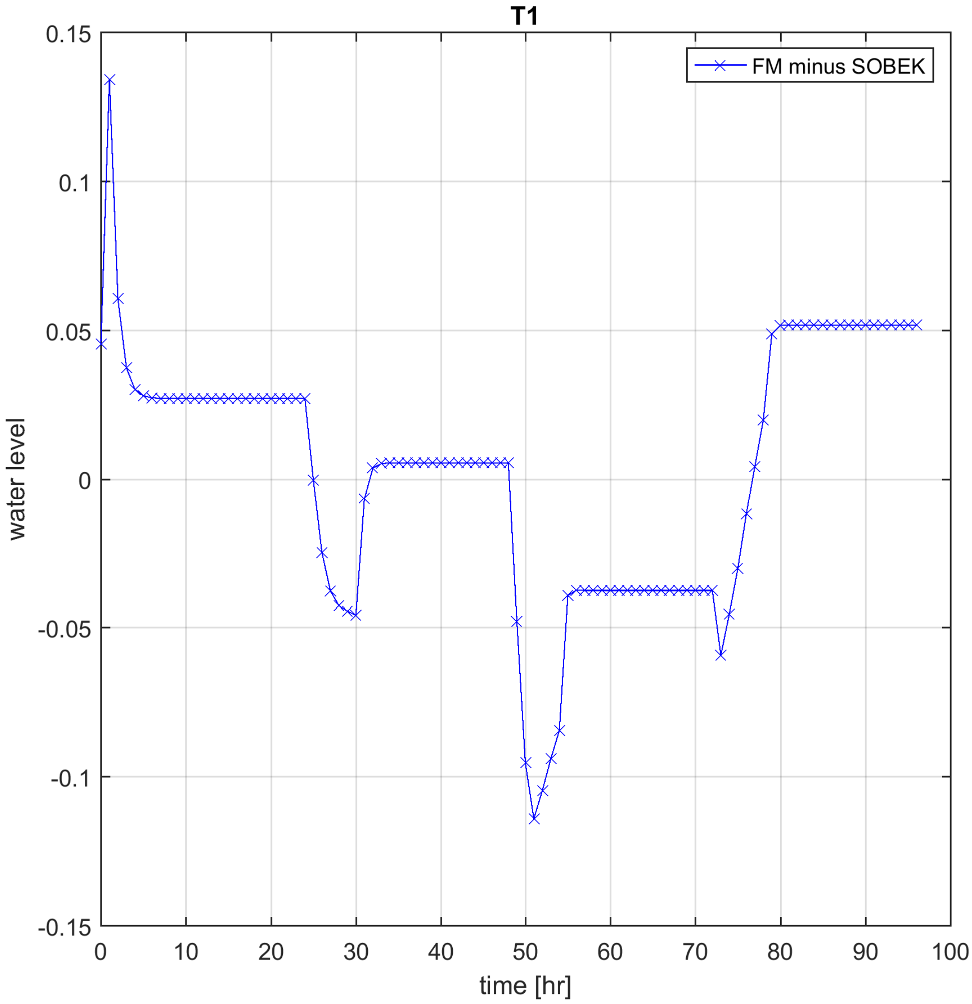

Figure 1.28: *Time series of difference in water level at the second computational node of the channel.*

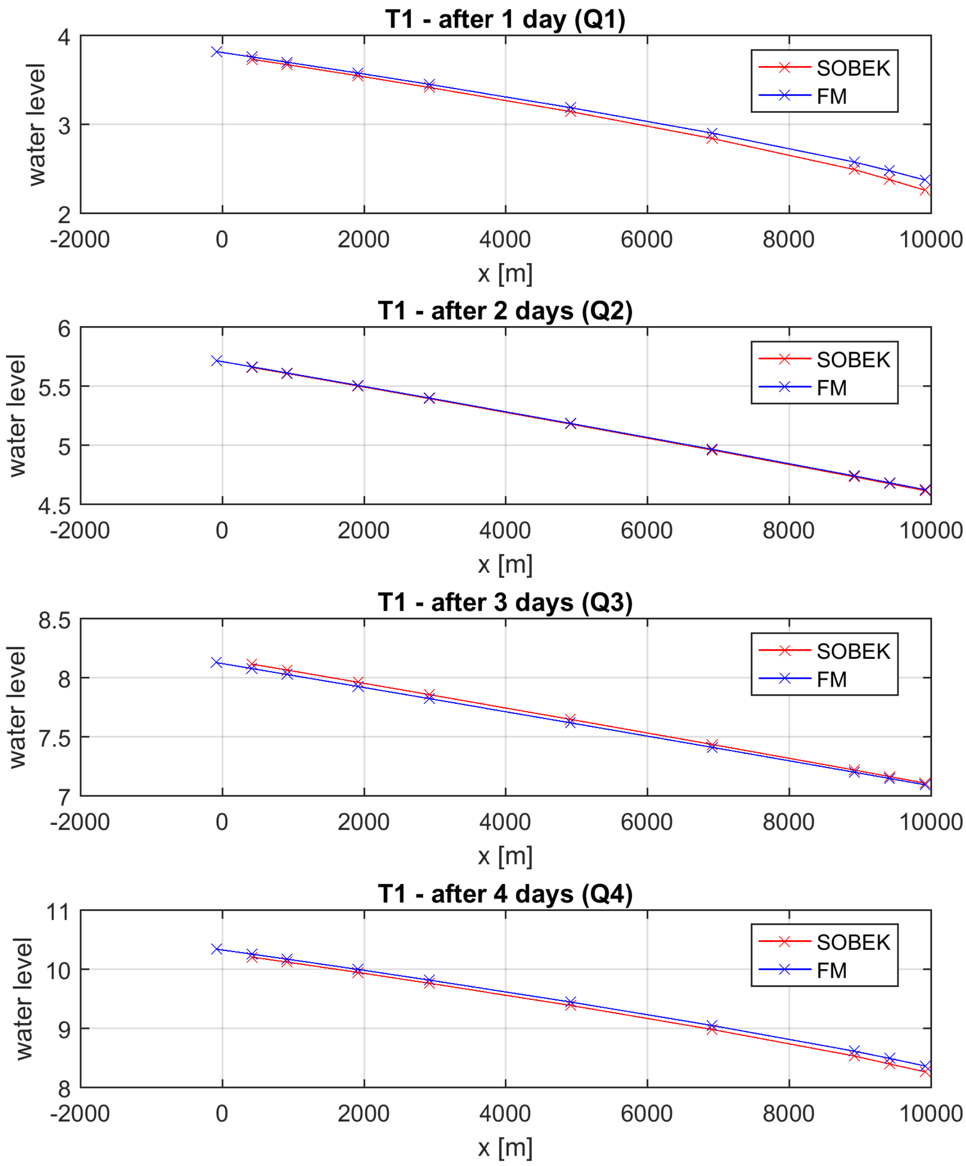

Figure 1.29: *Water level along the channel.*

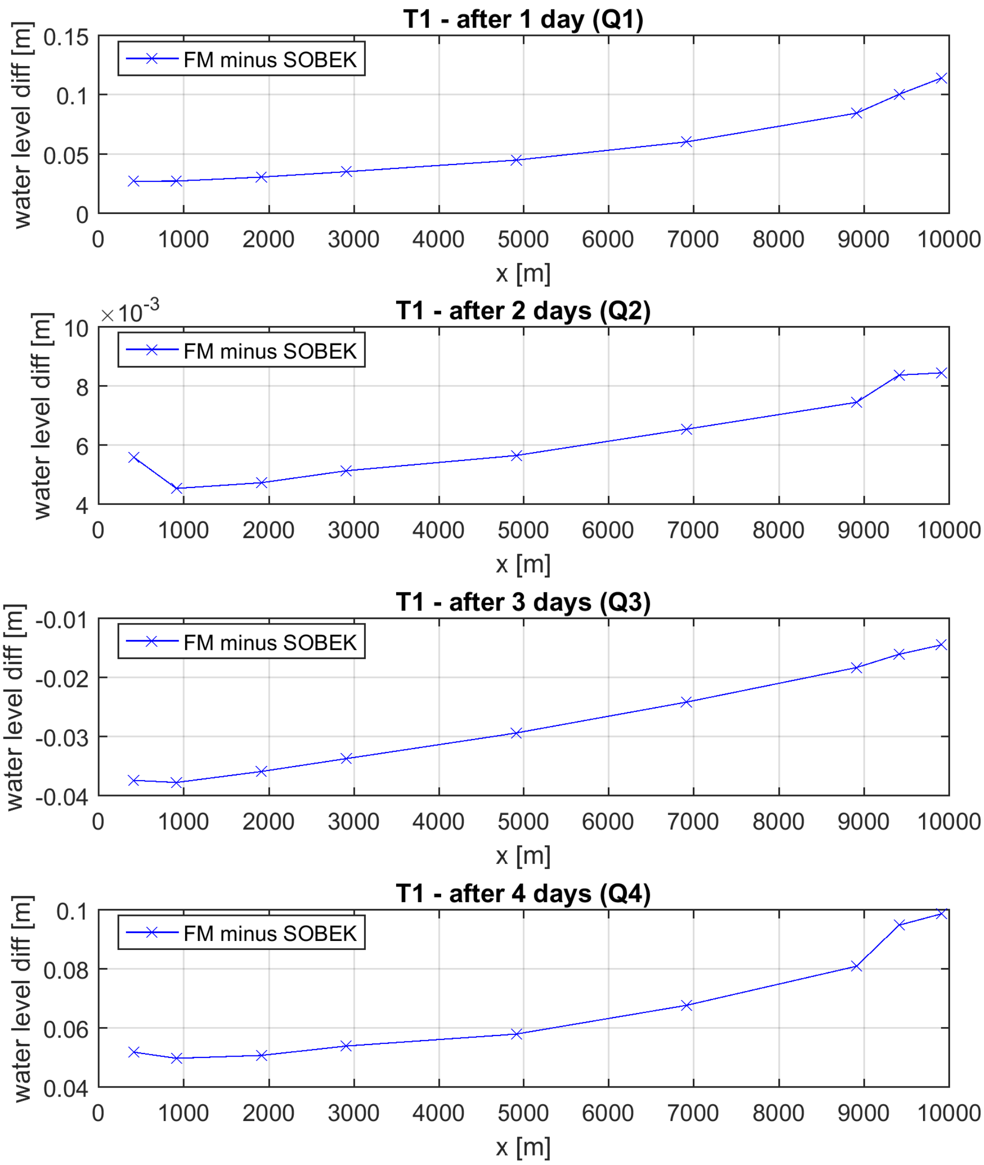

Figure 1.30: *Water level difference along the channel.*

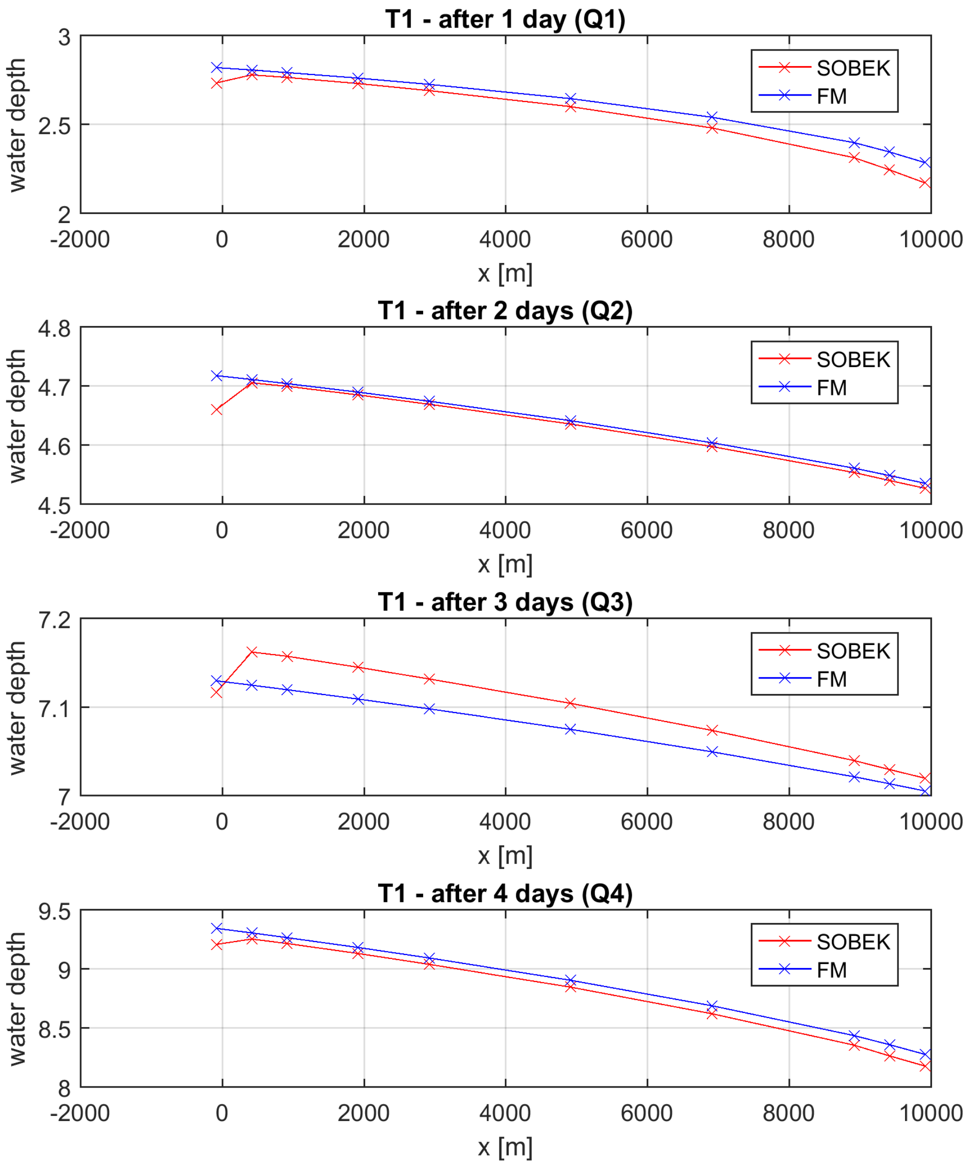

Figure 1.31: *Water depth along the channel.*

Results - sediment transport D-Flow FM

[TODO (Umain not yet implemented).]

NOTE: sediment transport not yet computed in D-Flow FM for this case (since first Umain needs to be available).

Conclusion

Hydraulics main channel OK, floodplain NOT OK, but for now acceptable.

TODO: implement Umain.

References

Engelund, F. and E. Hansen (1967). *A monograph on Sediment Transport in Alluvial Streams*. Teknisk Forlag, Copenhagen.

In **??** this test case is described as test case T3.

1.4 Shoal propagation

Quality Assurance

Date	Author	Initials	Review	Initials	Approval	Initials
13 Dec 2018	Andries Paarlberg Lieke Lokin		Bert Jagers		Aukje Spruyt	

Version information

Date of study : 23 Aug 2018
Executable : Deltares, D-Flow FM Version 1.1.294.57585M, Aug 23 2018, 11:09:09
Location : https://repos.deltares.nl/repos/DSCTestbench/trunk/cases/e02_dflowfm/f27_mor1d_tabulated_crosssections/c31_shoal_ds_IBedCond0_us_IBedCond1
SVN revision : -

Purpose

D-Flow FM-1D (mor) can use so-called tabulated cross-sections (cf SOBEK3), where the flow width is specified as a function of the water level. The bed level is updated in the main channel only.
The purpose of this validation case is to prove that the propagation speed of bed disturbances in D-Flow FM-1D is correct.

Linked claims

- ◇ The propagation speed of bed disturbances in D-Flow FM-1D is identical to SOBEK3.
- ◇ The propagation speed of bed disturbances in D-Flow FM-1D is in line with an analytical approximation based on the method of characteristics.

Approach

We start from an existing SOBEK3-model (/DSCTestbench/cases/e106_dflow1d/f13_morphology/c31_shoal_ds_IBedCond0_us_IBedCond0), and set-up the equivalent model in D-Flow FM-1D. The propagation speed of bed disturbances c_{bed} [m/s] can be approximated by the following formula (Equation 1.4) which is based on the method of characteristics. The formula is valid for small Froude numbers (Fr $\ll$ 1).

$$c_{bed} = \left(\frac{u \cdot n \frac{S}{Q}}{1 - Fr^2} \right). \tag{1.4}$$

Table 1.6: Symbol definitions

Symbol	Definition	Unit
u	flow velocity in main channel	ms^{-1}
n	power in sediment transport equation, for Engelund-Hansen: n=5	$-$
S	sediment transport (volume rate of bed material)	m^3s^{-1}
Q	discharge in main channel	m^3s^{-1}
Fr	Froude number, $Fr = u/\sqrt{gh}$	$-$
h	water depth	m
g	gravitational acceleration	m^2s^{-1}

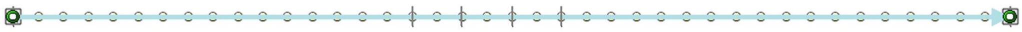

Figure 1.32: *Computational grid for T1 and T2.*

To prove that the computed propagation speed of bed disturbances in D-Flow FM is correct, the simulated propagation of a shoal is compared with the analytical approximation (and with SOBEK3). A local shoal is included in the initial bed level of the test case. This local shoal is on top of the equilibrium bed level.

Model description

The model domain, consists of a straight channel with a length of 10 km. The (equilibrium) bed level slope is 1×10^{-4}. The shoal is initially located halfway the channel. The initial maximum height of the shoal is 0.4 m above the equilibrium bed level. The cross-section is a rectangular profile with a width of 200 m. For this case, the width of the main channel is equal to the total width of the cross-section.

The model is forced with a constant upstream total discharge of 1000 m^3/s. The downstream water level has a fixed value of 4.64 m AD such that the water depth equal is to the equilibrium water depth. The hydraulic roughness of the channel (Chézy) is 50 $m^{1/2}$/s.

The median sediment diameter is 0.2 mm. The sediment transport is computed with the formula of Engelund-Hansen. As upstream boundary conditions, a fixed bed level is applied. At the downstream boundary, no bed level constraints are applied (i.e. Neumann boundary condition for sediment transport).

The model has a uniform computational grid size of 250 m. The computational grid of the test case is visualized in Figure 1.32. The time step has a value of 2 minutes.

The basis model we use is set-up in SOBEK3. The geometry (tabulated cross-sections, roughness and some other properties), are directly imported into D-Flow FM using a specific keyword in the MDU-file:

```
OneDNetworkFile = dflow1d\water flow 1d.md1d
```

Some settings have to be set manually though:

- ◇ A SOBEK3 import only works if a (dummy) Network file is present. We advise to use a 2D network, to ensure that it doesn't conflict with the 1D network (as imported from SOBEK3.
- ◇ Timings such as refdate, start/end time and map-output intervals need to be converted manually to the MDU-file.
- ◇ The boundary conditions (locations and values) are not yet imported from SOBEK3. They have to be manually created. We defined one polyline at the upstream boundary for imposing the discharge, and one polyline at the downstream boundary to impose the water level. Note that the boundary lines must be just *outside* the model.
- ◇ Recall that in SOBEK3 the water level at the downstream boundary holds at the last pressure point in the grid, while in D-Flow FM it gets mirrored half a grid cell outside the control volume around each grid point. Effectively, this means that the water level has to be specified as if it is Δx further downstream, considering the bed slope. For this case, at the

downstream boundary, $\Delta x = 250m$. For a bed level slope of 1×10^{-4} this implies a 2.5 cm lower water level compared to SOBEK3.
NOTE: IT IS NOW SPECIFIED AS 1.25 cm, but will not make a big difference.
- In the MOR input file, the boundaries need to be imposed at the polylines specified in one of the steps above.
- For the upstream (us) and downstream (ds) bed boundary condition we specify
`IBedCond_us=1`
`IBedCond_ds=0`
Note that in the SOBEK3 test case it was both 0.

Results

Figure 1.33 shows the initial bed level for this test case.

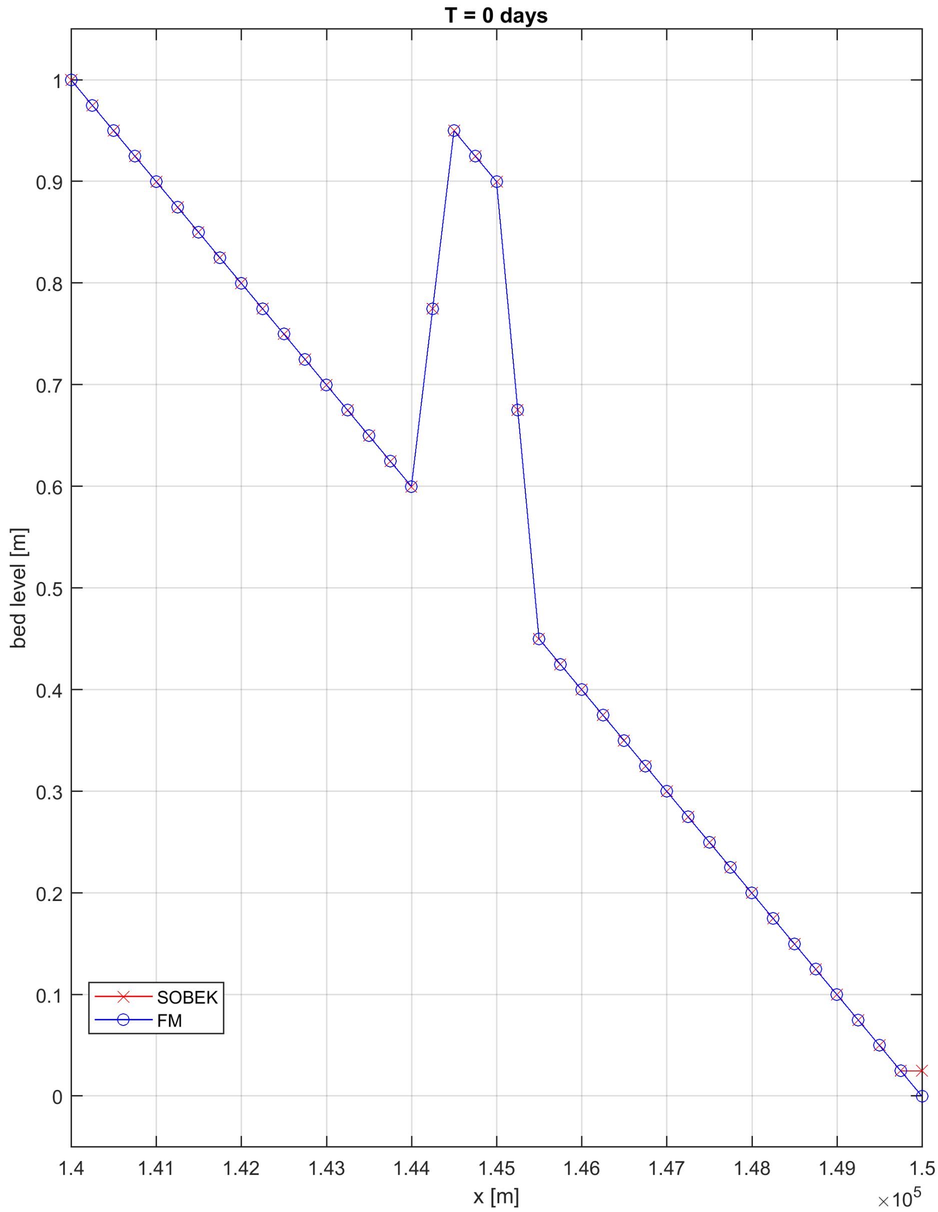

Figure 1.33: *Initial bed level.*

Figure 1.34 shows that the water level as a function at the upstream and downstream boundaries of the model compares very well between SOBEK3 and D-Flow FM.

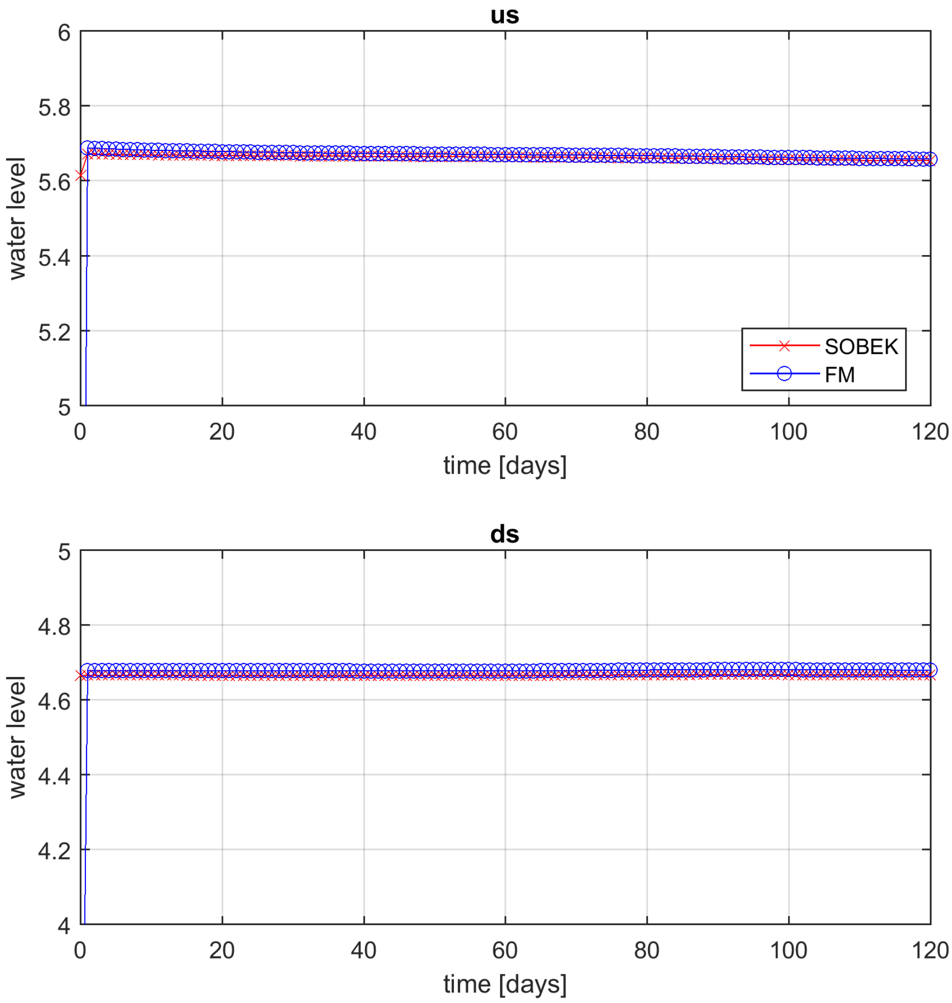

Figure 1.34: *Water level in SOBEK3 and D-Flow FM.*

Figure 1.35 to Figure 1.37 visualize the propagation of the shoal for test case in different ways for a total period of 120 days. Figure 1.35 shows the longitudinal profile of the bed level with an interval of 10 days. Figure 1.36 compares SOBEK3 and D-Flow FM by plotting the bed level in one figure, with an interval of 20 days. Figure 1.37 just gives another representation, with an interval of 30 days.

The propagation speed (and evolution of bed level shape) of the shoal is equal in SOBEK3 and D-Flow FM. These figures shows that the shoal leaves the model domain after about 3 months.

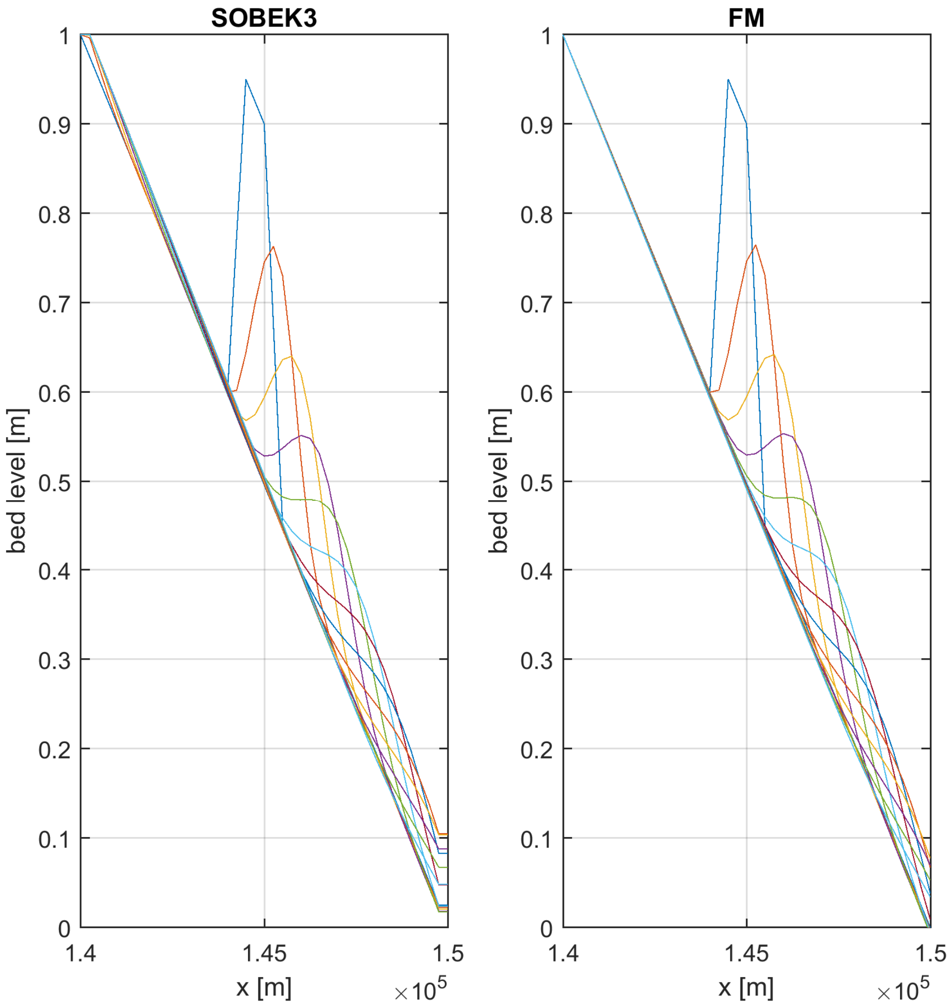

Figure 1.35: *Shoal propagation in SOBEK3 and D-Flow FM 1D.*

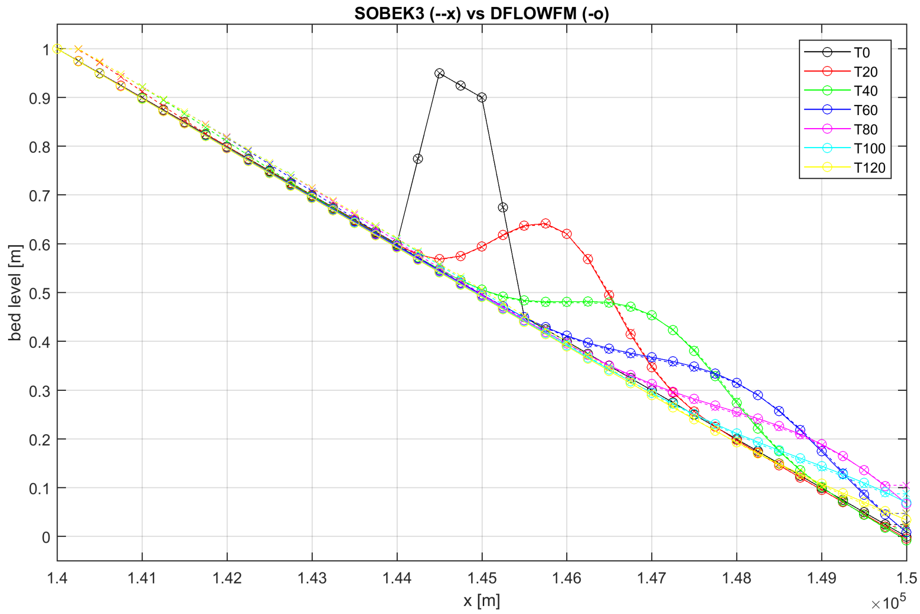

Figure 1.36: *Shoal propagation in SOBEK3 and D-Flow FM 1D.*

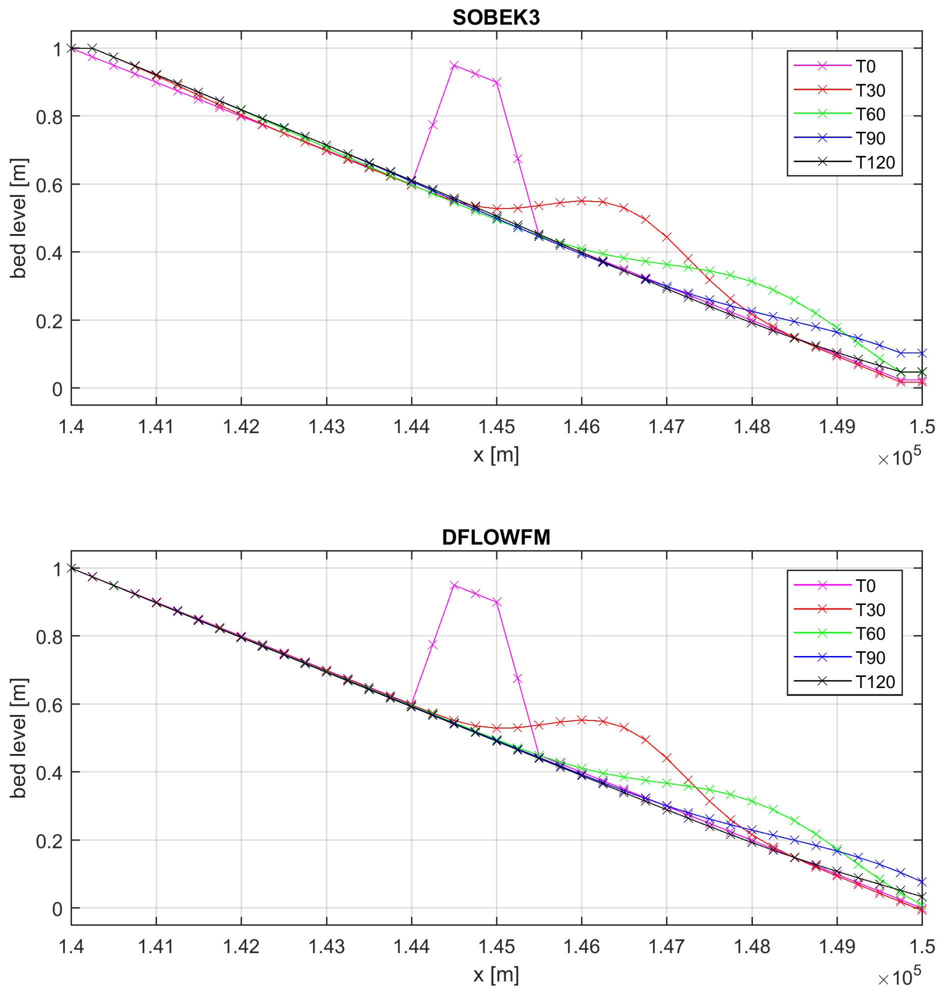

Figure 1.37: *Shoal propagation in SOBEK3 and D-Flow FM 1D.*

[INFO BELOW COPIED FROM SOBEK3 TEST CASE, SINCE SOBEK3 and D-Flow FM COMPARE WELL.]

For SOBEK3 the propagation was calculated from the horizontal shift of the maximum of the shoal during time. Figure 1.38 shows the location of the maximum of the shoal with the symbol: $*$. In this figure, the bed level relative to equilibrium bed level is indicated with the color range.

A comparison of the simulated propagation speed of the shoal with the analytical approximation of the propagation speed is included in Table 1.7. Both absolute differences [m/s] as relative differences [%] are shown.

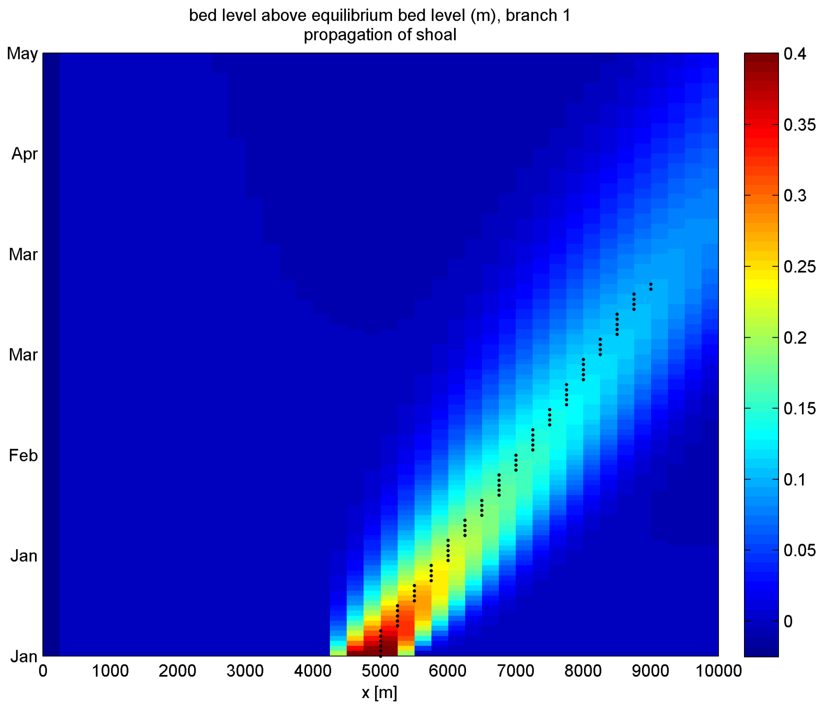

Figure 1.38: *Longitudinal profile of bed level relative to equilibrium bed level (horizontal axis) over time (vertical axis) for T1. [NOTE: COPIED FROM SOBEK3 TEST CASE*

Table 1.7: *Comparison of simulated propagation speed of bed disturbance c_{bed} with analytical propagation speed for the different test cases.*

	test case
Difference [m/s]	0.000003
Relative difference [%]	0.89

Conclusion

The propagation of a shoal is simulated accurately in D-Flow FM 1D. It compares well to SOBEK3 and an analytical approximation.

1.5 Case idealized Waal

Quality Assurance

Date	Author	Initials	Review	Initials	Approval	Initials
08 Dec 2017	Andries Paarlberg		Bert Jagers		Aukje Spruyt	

Version information

Date of study : 22 Dec 2017
Executable : Deltares, D-Flow FM Version 1.1.261.53873M, Dec 19 2017, 23:18:32
Location : https://repos.deltares.nl/repos/DSCTestbench/trunk/cases/e02_dflowfm/f27_mor1d_tabulated_crosssections/c51_fp_IdealizedWaal
SVN revision : -

Purpose

D-Flow FM-1D (mor) can use so-called tabulated cross-sections (cf SOBEK3), where the flow width is specified as a function of the water level. The bed level is updated in the main channel only.
The purpose of this test case is to provide a simple test case with dimensions similar to the Waal River. We compare model results (hydraulics only) with SOBEK3.

Linked claims

◇ Simulated water levels in SOBEK3 and D-Flow FM-1D, where the schematization of D-Flow FM is read from SOBEK3, are identical.

Approach

We schematize a very simple channel in SOBEK3, and D-Flow FM-1D. The water levels are compared between SOBEK3 and D-Flow FM-1D for 4 discharge levels.

Model description

The model consists of a single branch with a length of 100 km and a bed level slope of 1×10^{-4} (Figure 1.25). Grid points are evenly spaced at a distance of 500 m.

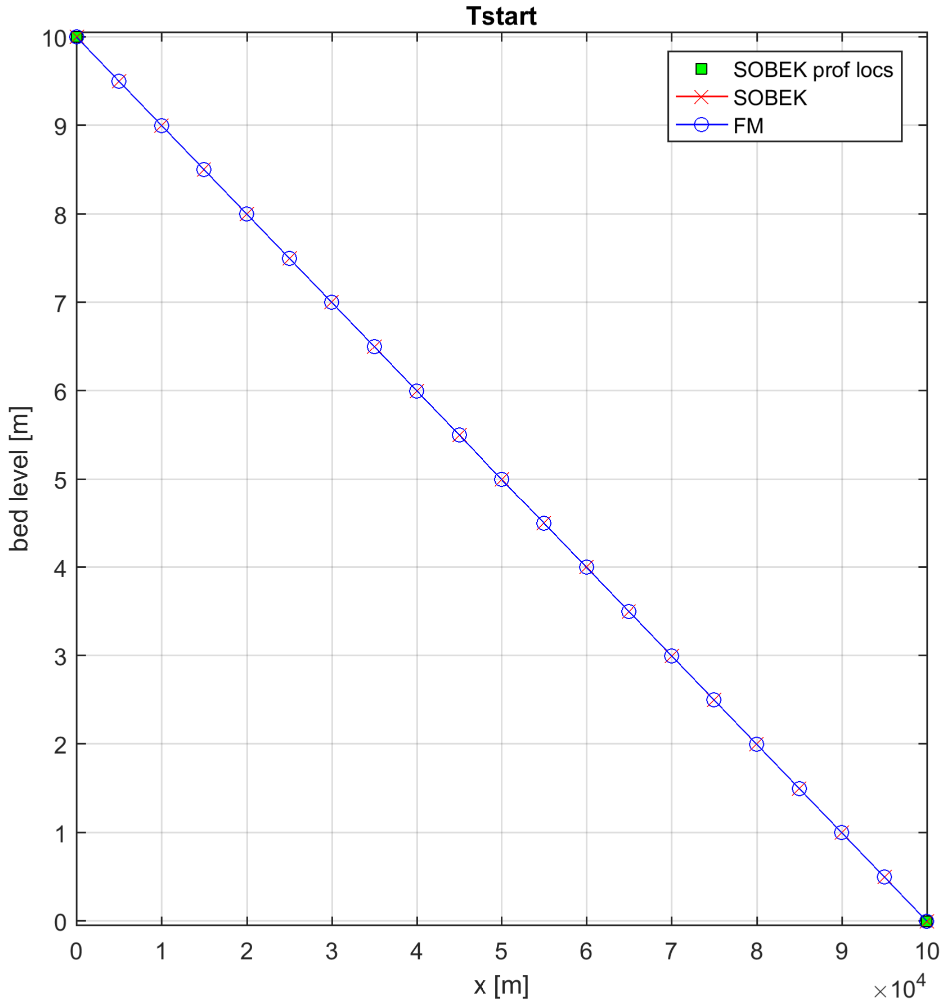

Figure 1.39: *One branch of 100 km.*

The single branch has one cross-section which consist of a main channel and a floodplain on either side (cross-section only specified at start and end node). The main channel is 100 m wide, the floodplains 500 m in total (250 m each side). The hydraulic roughness of the main channel (Chézy) is 50 m$^{1/2}$/s and for the floodplain we use $C = 35$ m$^{1/2}$/s. The upstream boundary condition is given by a discharge timeseries: Q1=250, Q2=500, Q3=1000, Q4=2000, each run for 1 day. The downstream boundary condition is given by a water level timeseries (2.0, 4.5, 7.0, 8.0 m w.r.t. a certain reference. Together the boundary conditions describe a quasi-stationary computation with four distinct stationary situations. For the first two discharge, the water remains in the main channel, for the third discharge the floodplains just start to flood and for the fourth discharge the floodplains convey quite some water.

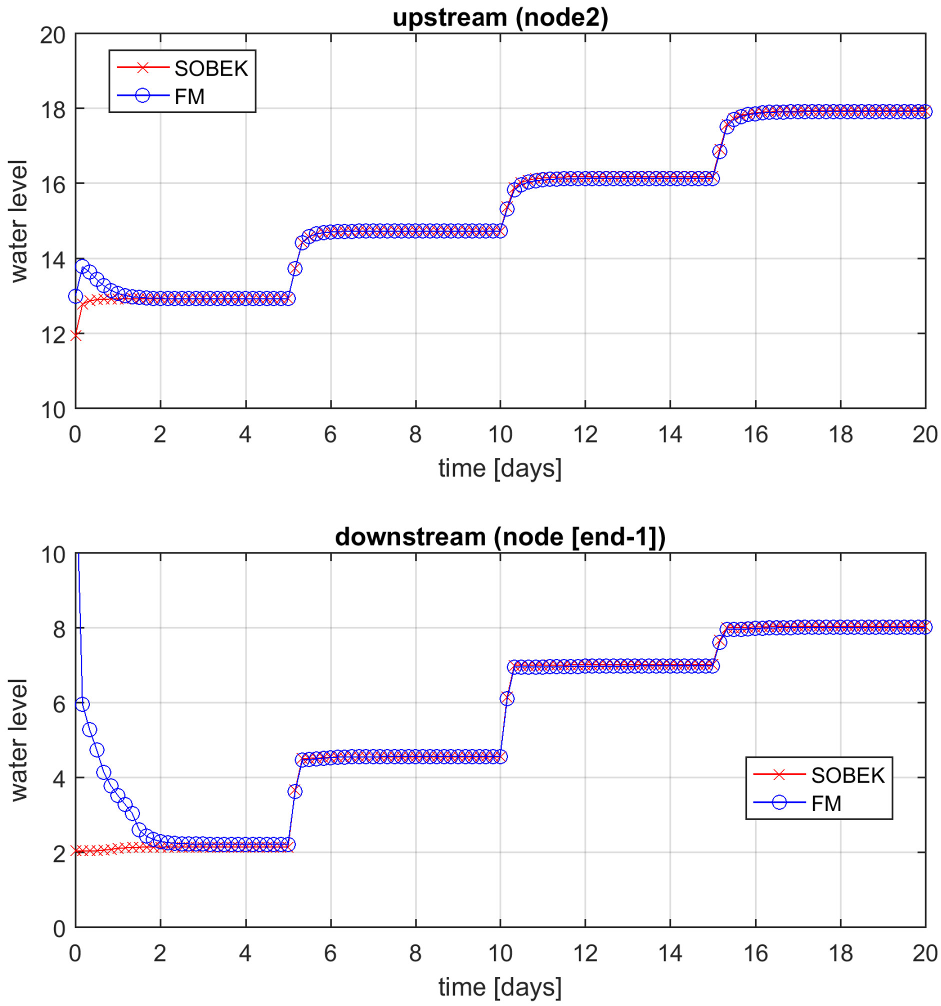

Figure 1.40: *Comparison of water levels.*

Results

Figure 1.40 shows the water level for the 4 discharge levels in SOBEK3 and D-Flow FM-1D. Comparison is well in main channel. Deviations when flow in floodplain.

The following four figures show the model behaviour in some more detail:

◇ Figure 1.41: largest difference for Q3 when water is just in the floodplain.
◇ Figure 1.42: water level along the channel in D-Flow FM has similar shape as in SOBEK3.
◇ Figure 1.43: water level difference along the channel. For flow IN main channel (Q1) a relatively arge difference at the downstream boundary; for flow in the floodplain the difference builds up along the domain, which might be related to e.g. differences in how the flow equations are solved, the computation of the Chézy coefficient, or the computation of the hydraulic radius in D-Flow FM. Since this might be / is related to the issues with U_{main}, this is STILL UNDER INVESTIGATION.
◇ Figure 1.44: Water level differences logically also show up in the water *depth* differences.

Conclusion

Flow in main channel:OK. In floodplain quite so differences. Probably this has to do with computation of hydraulic radius when water in the flood plain.

SOME ASPECTS OF THIS CASE STILL UNDER INVESTIGATION.

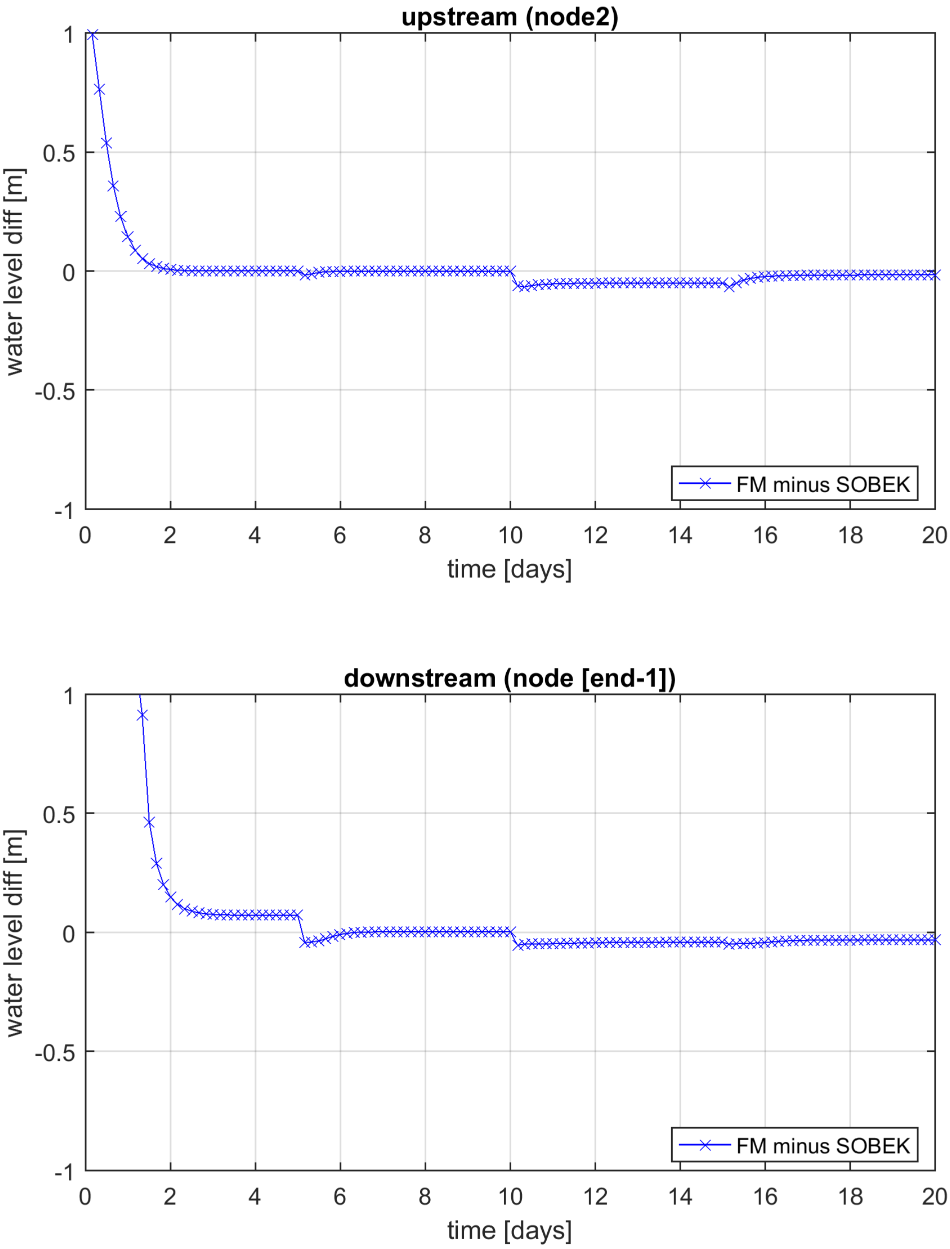

Figure 1.41: *Water level differences upstream (top) and downstream (bottom).*

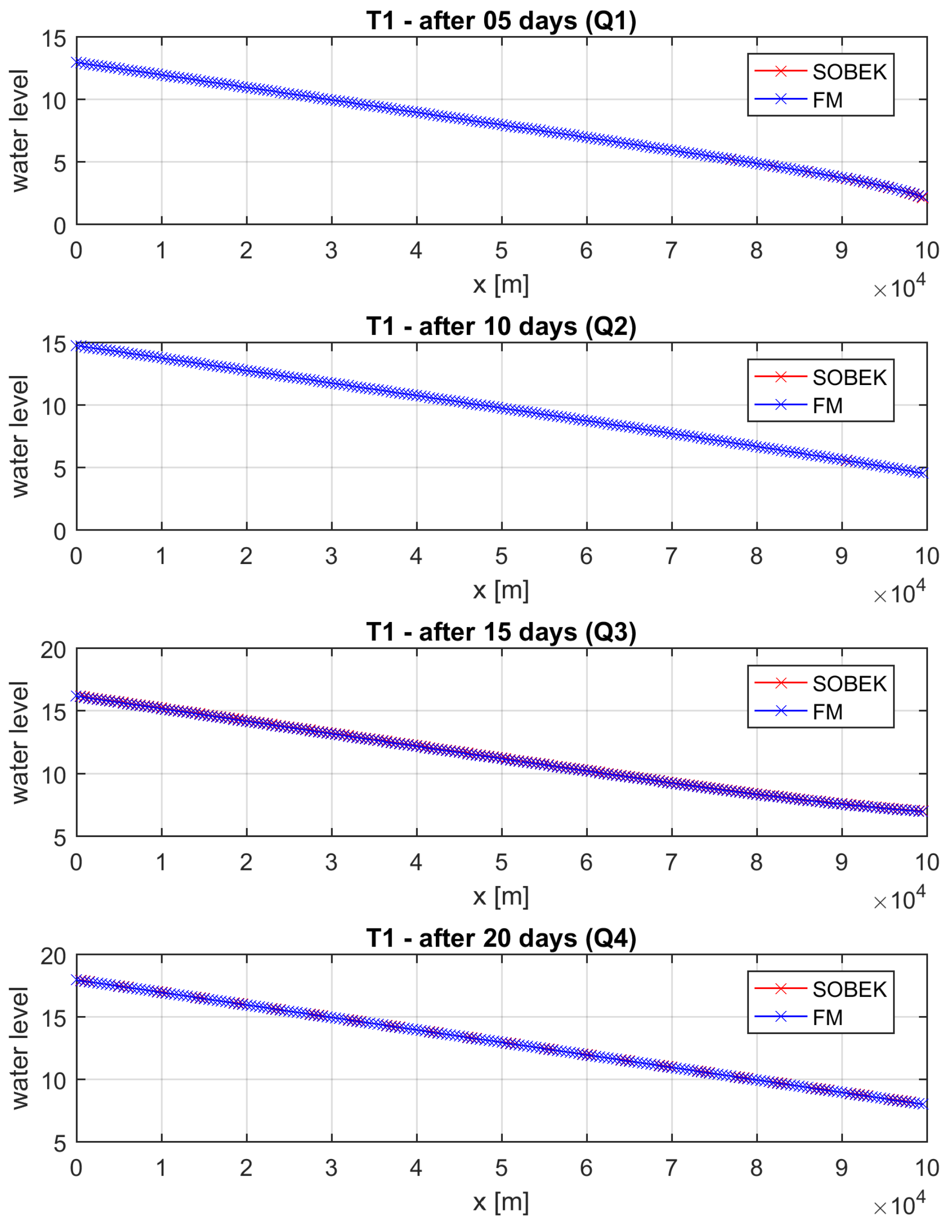

Figure 1.42: *Water level along model domain for 4 discharges.*

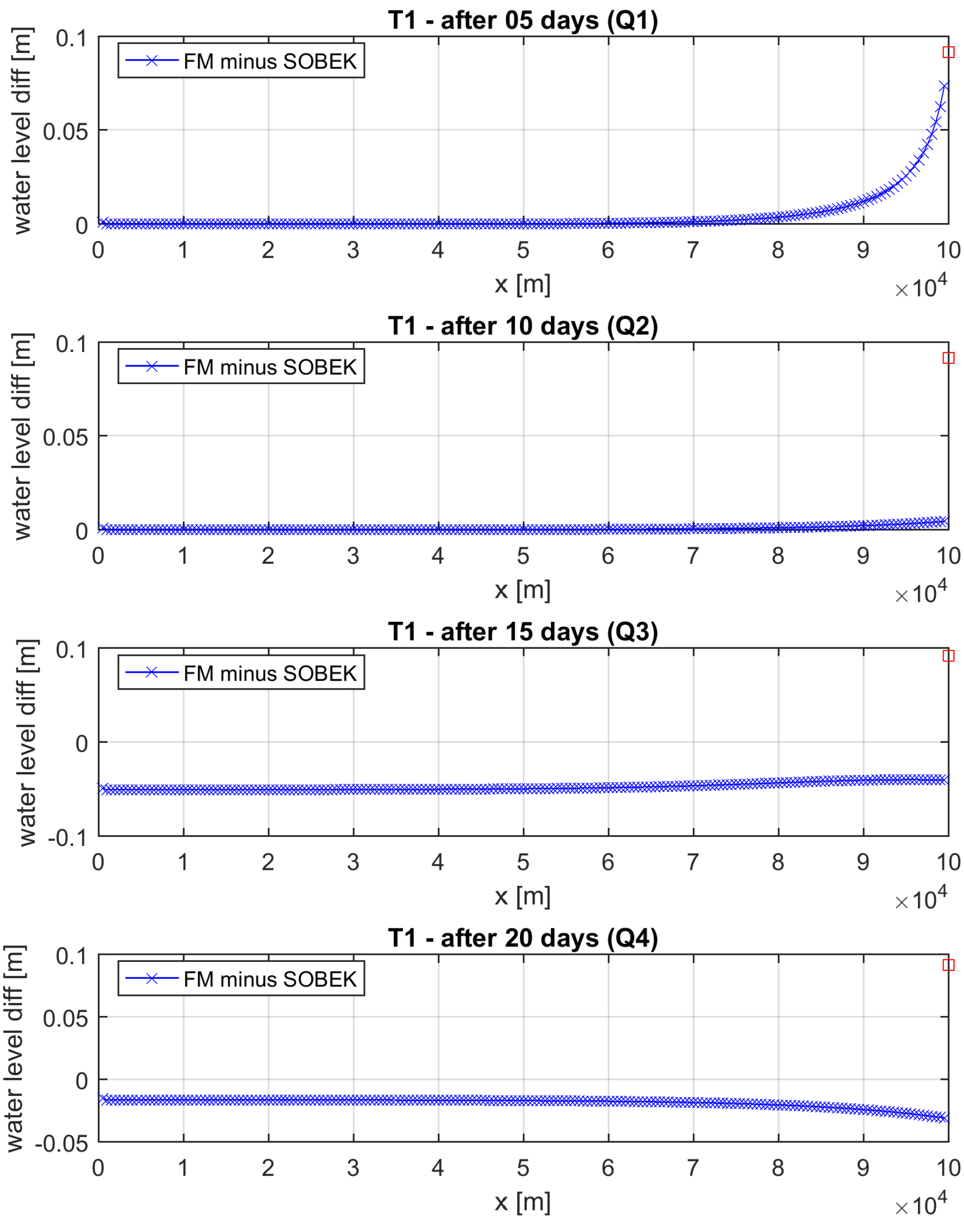

Figure 1.43: *Water level differences along model domain for 4 discharges (the square gives the difference at the boundary).*

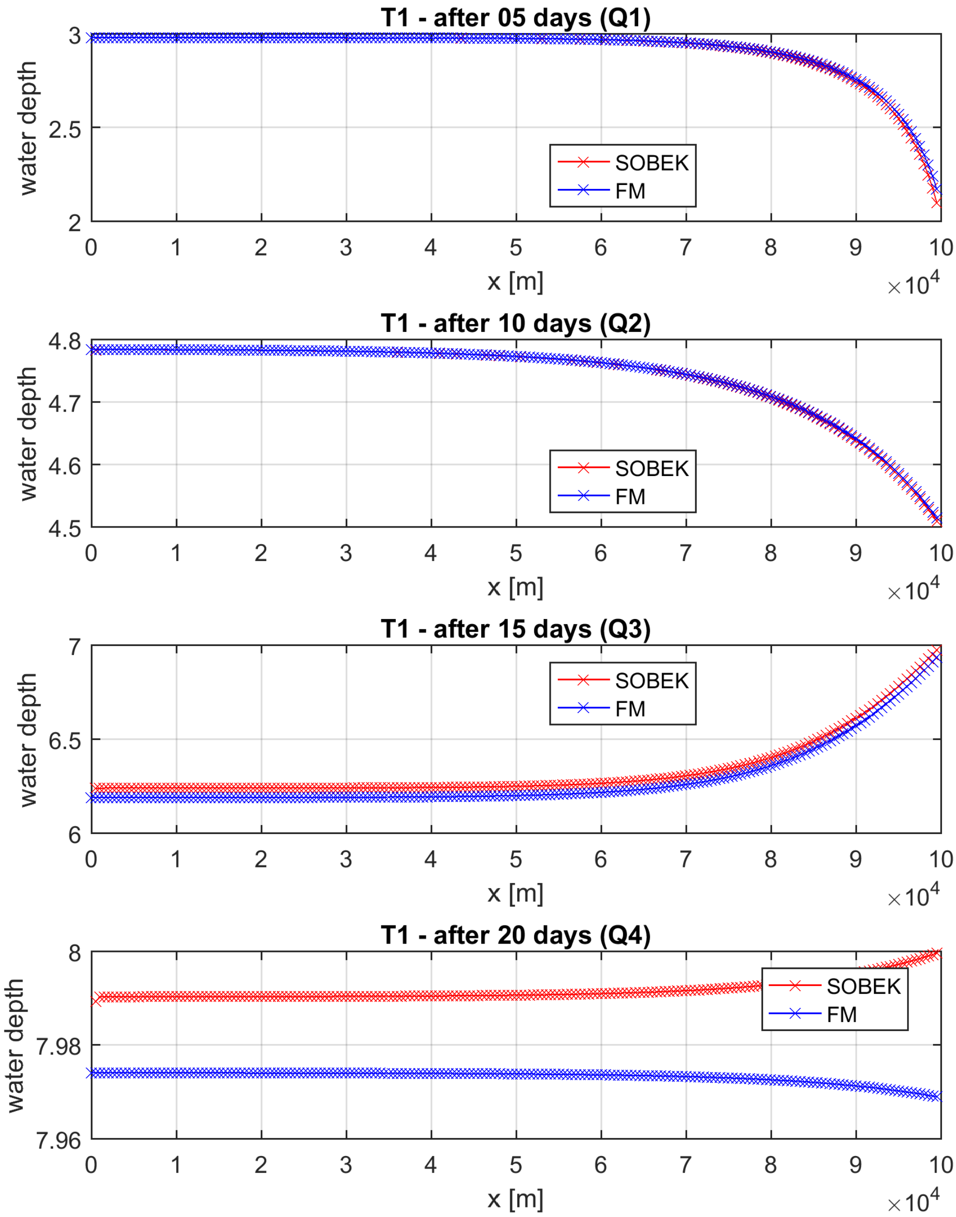

Figure 1.44: *Water* depth *differences along model domain for 4 discharges.*

1.6 Water level and discharge-dependent roughness

Quality Assurance

Date	Author	Initials	Review	Initials	Approval	Initials
17 May 2018	Andries Paarlberg		Willem Ottevanger		Aukje Spruyt	

Version information

Date of study : 17 May 2018
Executable : Deltares, D-Flow FM Version 1.1.294.57223M, Aug 04 2018, 22:27:06
Location : https://svn.oss.deltares.nl/repos/trunk/riverlab/f27_mor1d_tabulated_crosssections/c61_wl_q_dependent_roughness
SVN revision : -

Purpose

D-Flow FM-1D (mor) can use so-called tabulated cross-sections (cf SOBEK3), where the flow width is specified as a function of the water level. The bed level is updated in the main channel only.
The purpose of this test case is to provide a test case to with dimensions similar to the Waal River. We compare model results (hydraulics only) with SOBEK3.

Linked claims

◇ Simulated water levels in SOBEK3 and D-Flow FM-1D, where the schematization of D-Flow FM is read from SOBEK3, are identical.

Approach

We schematize a very simple channel in SOBEK3, and D-Flow FM-1D. The computed water levels are compared between SOBEK3 and D-Flow FM-1D for 6 boundary condition sets.

Model description

The test comprises of six sub-models **T1** to **T6**, each containing different boundary conditions and/or roughness conditions (see Figure 1.47). The computational grid, the boundary conditions, the cross-sectional profiles and the hydraulic roughness of each sub-model are given in Table 1.8 to **??**.

Flow is driven by specifying a water level as function of time at the upstream and downstream boundary, see , respectively. Every 3 hours, the water level increase by 0.3 m, both on the upstream and downstream boundary. The water surface slope equals the bed slope which is 0.25 m / 1000 m.

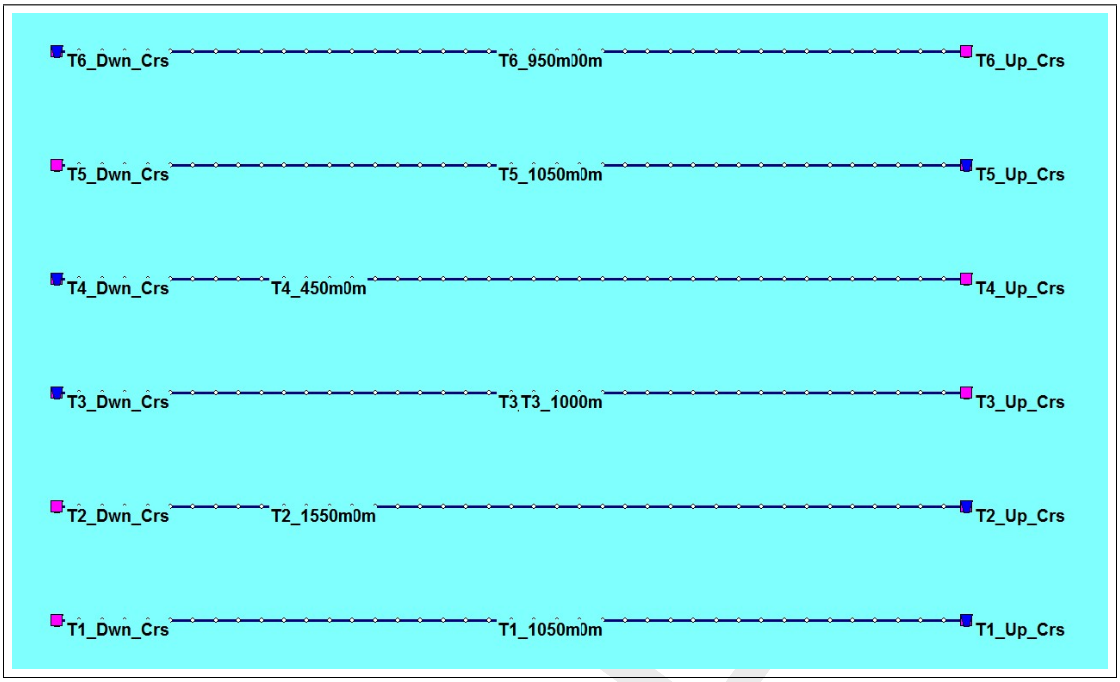

Figure 1.45: *Model lay-out. Blue = x = 0 m, purple = x = 2000 m.*

Table 1.8: *Computational grids applied in sub-models **T1** to **T6** (E $\rightarrow$ W means from East to West*

	T1	**T2**	**T3**	**T4**	**T5**	**T6**
B1: Direction x-axis	E $\rightarrow$ W	E $\rightarrow$ W	E $\rightarrow$ W	E $\rightarrow$ W	E $\rightarrow$ W	E $\rightarrow$ W
B1: Length $[m]$	2100.00	2100.00	2100.00	2100.00	2100.00	2100.00
B1: Equidistant Δx $[m]$	100.00	100.00	100.00	100.00	100.00	100.00

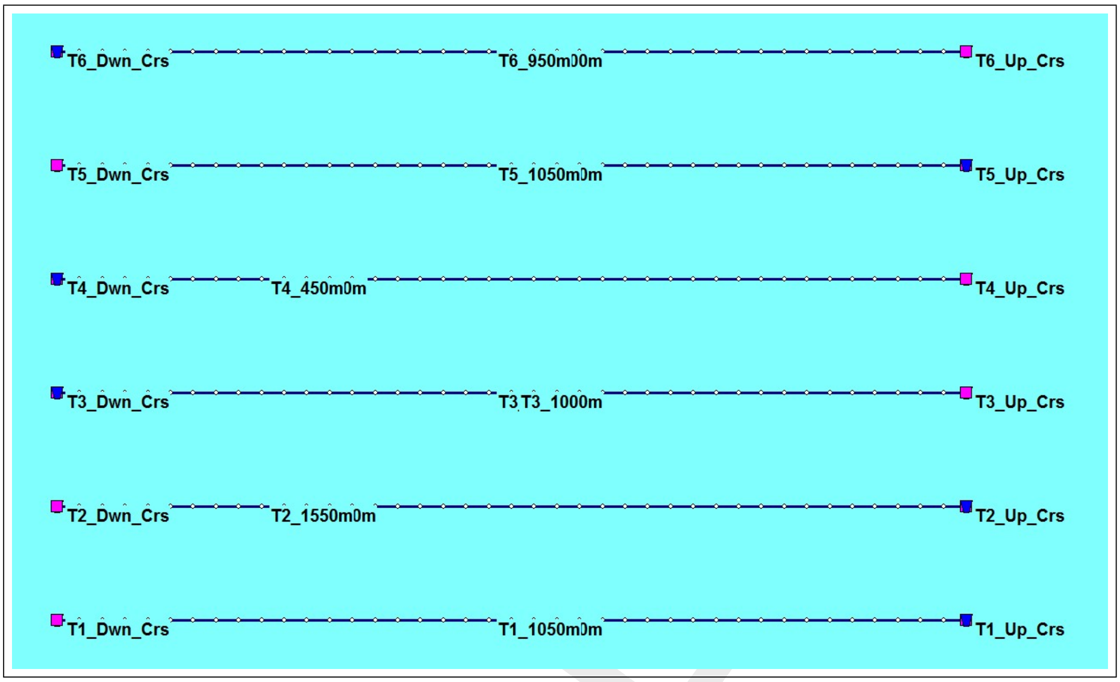

Figure 1.46: *Model lay-out. Blue = x = 0 m, purple = x = 2000 m.*

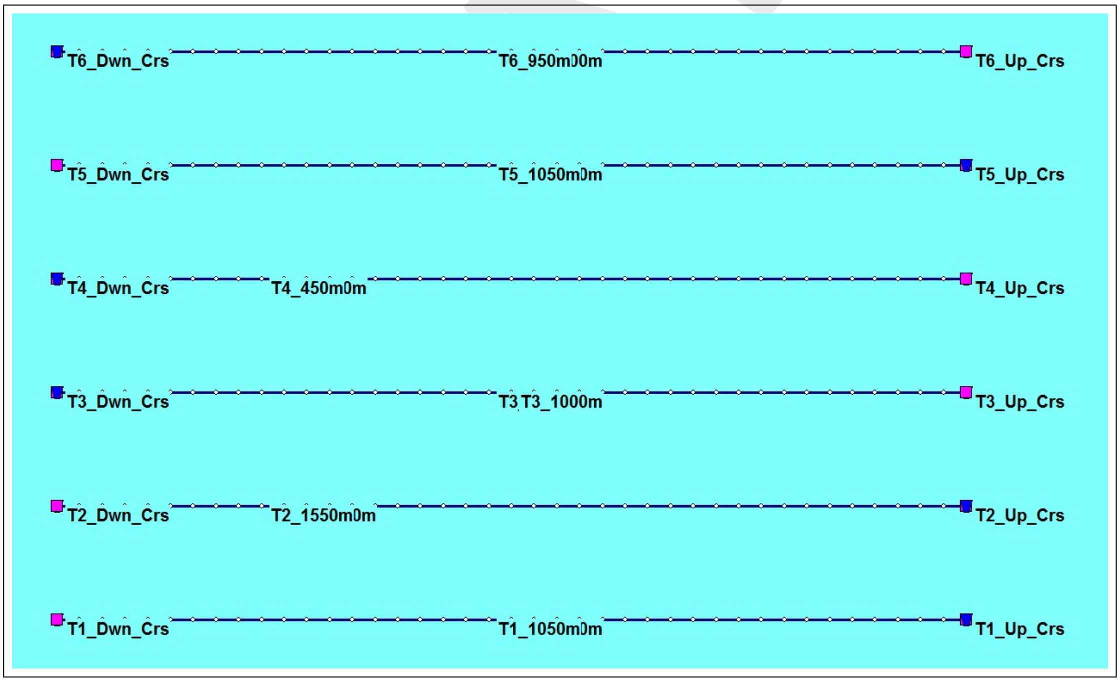

Figure 1.47: *Model lay-out. Blue = x = 0 m, purple = x = 2000 m.*

Results

shows the water level for the 4 discharge levels in SOBEK3 and D-Flow FM-1D. Comparison is well in main channel. Deviations when flow in floodplain.

Conclusion

References

Engelund, F. and E. Hansen (1967). *A monograph on Sediment Transport in Alluvial Streams*. Teknisk Forlag, Copenhagen.

Meyer-Peter, E. and R. Müller (1948). “Formulas for bed load transport”. In: *Proceedings of the 2nd Congress IAHR, Stockholm*. Vol. 2, pp. 39–64.

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