1 1D uniform sediment

Quality Assurance

Date	Author	Initials	Review	Initials	Approval	Initials
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Version information

Date of study : 05 Dec 2017
Executable : Deltares, D-Flow FM Version 1.2.0.55840, May 25 2018, 20:10:47
Location : https://repos.deltares.nl/repos/DSCTestbench/trunk/cases/e02_dflowfm/f29_mor1d2d_morfologie/c01_uniform_sediment
SVN revision : -

Purpose

The purpose of this validation case is to examine the performance of the Engelund-Hansen sediment transport formation in a 1D, also called, line model. The performance of the 1D model is compared with a validated 2D model. Furthermore, the 1D hydrodynamics have been tested in the previous chapter, see Chapter **??**. Here, a schematised straight channel is modelled. The test case reference number is C01 till C04.

Linked claims

Claims that are related to the current test case are:

- The Engelund-Hansen sediment transport formulation in a 1D model is correctly programmed, according to a comparison with a 2D model.
- The differences in the sediment transport result from small differences in hydrodynamics between 1D and 2D grids.
- The differences in equilibrium bed slope are sufficiently small from a physical point of view.

Approach

Three different grids are designed and combined with two bathymetries. Each of the grids models a straight channel but the first grid has a width of 5 cells, the second a width of 1 cell and the third is a 1D grid, see Figure 1. The bathymetries are a flat channel and a channel with a trench, see Figure 2. These schematisations are combined to verify the claims.

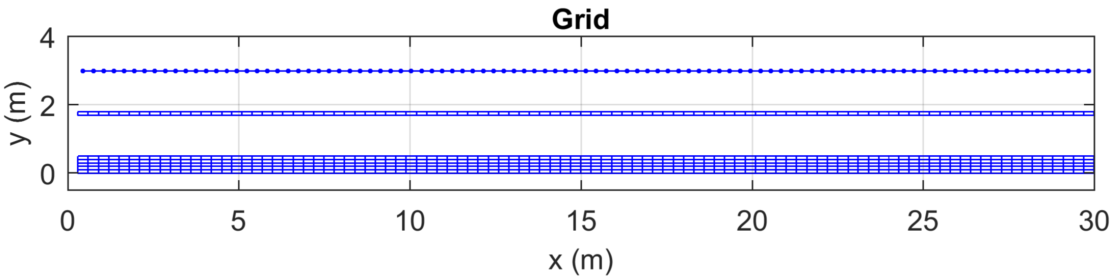

Figure 1: Figure of the different grids. The top grid shows the 1D grid, the middle a quasi-2D grid and the bottom the full 2D grid.

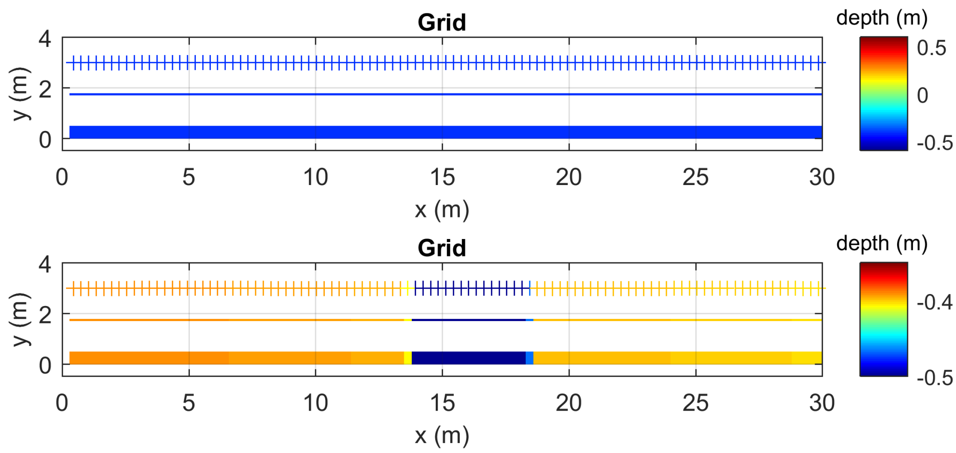

Figure 2: The two bathymetries used for these cases. The top bathymetry represents the flat channel and the bottom bathymetry shows the trench. The plotmarks indicate the 1D bathymetry and the patches the 2D grids.

Conclusion

The results show that the sediment transport in 1D gives equal results as in the 2D case. Tiny differences can be related to the accepted differences in the hydraulics between a 1D and 2D schematisation. The induced morphological changes show a larger difference between the 1D and 2D case. The inequality is in the order of 1% for the bottom slope. From a physical point of view this difference is acceptable but from a numerical point of view improvements are most likely possible.

Model description

In this test case we use a network composed of 3 straight channels in a single schematisation. The schematisation consists of 3 flat channels or 3 channels with each a trench. For the flat channel the bottom is kept at a constant depth of -0.4 m. For the trench a longitudinal bottom slope i_b is prescribed to be $4 \cdot 10^{-4}$ and the channel starts at a depth of -0.39 m. Each channel has a length of 30 m. The width of the 2D channel is set to 0.5 m. The line model and the quasi-2D model have a width of 0.1 m. In the 2D model a discharge Q of 0.09945 m^3/s is prescribed as an upstream boundary condition. In the 1D and quasi-2D the discharge is reduced according to the width to 0.0199 m^3/s. The Nikuradse roughness height is set to 0.025 m and evaluated using the White-Colebrook formula. For the downstream boundary condition a water level is set to 0 m.

In this test-case a uniform sediment grain size $D_{50} = 1.4 \cdot 10^{-4}$ is used.

The default parameters in the morphological setup are mainly used. Nevertheless, in the following section important related setup of morphology and sediment files used are described as follows:

- Sediment file $< *.sed >$:

```
[Sediment]
Name                 = #Sediment_sand#                  Name of sediment fraction
SedTyp               = sand                             Must be "sand", "mud" or "bedload"
RhoSol               =  2.6500000e+003        [kg/m3]   Specific density
SedDia               =  1.4000000e-004        [m]       Median sediment diameter (D50)
CDryB                =  1.6000000e+003        [kg/m3]   Dry bed density
IniSedThick          =  5.0000000e-001        [m]       Initial sediment thickness layer-bed
FacDSS               =  1.0000000e+000        [-]       FacDss * SedDia = Initial SS dia
TraFrm               = 1
ACAL                 = 1.0
```

Sediment transport equation is the transport relation by Engelund, F. and E. Hansen (1967).

The morphological update $MorUpd$ and bed composition update $CmpUpd$ are switched off to check the total transport. Then it is switched on to check the bed level change. Consequently, it results in 4 scenarios with each 3 channels, see Table 1. $MorFac$ is equal to 18 and the spin-up interval from the start time until the start of morphological changes $MorStt$ is 5.0 minutes.

Scenarios	Bathymetry	Morphological changes
1	Flat Channel	Unable
2	Flat Channel	Able
3	Trench	Unable
4	Trench	Able

Table 1: Overview of the different scenarios.

Results

The results for scenarios 1 are visualized in Figure 3 and Figure 4. The velocity differences between the different grids are of the order 10^{-4} m/s between the two 2D grids and of the order 10^{-5} m/s between the 1D and quasi-2D grid. Similar results were found in Chapter **??** and were excepted. The inequality between the 1D and quasi-2D grid in total sediment transport is in the order of 0.1 % of the total transport. Similar as for the velocity, the difference between the 1D and quasi-2D case is one order of magnitude smaller than between the 2D grids. The disparity can be related to the difference in flow velocity between the different grids and is therefore accepted.

The effects of the morphological developments are shown in Figure 5, Figure 6, Figure 7 and Figure 8. Here, the results for Scenario 2 after 300 min are used. The morphological changes have become zero and the bed has reached a slope of $-3.6 \cdot 10^{-4}$. A minor difference between the 1D and quasi-2D grid can be observed and is in the order of 1% of the slope. The difference in slope also explains the difference in flow velocity and consequently in total sediment transport.

In Scenario 3 and 4 a constant bedslope combined with a trench is simulated. The steady state flow conditions and total sediment transport are visualised in Figure 9 and Figure 10 for Scenario 3. The difference in flow velocity between the 1D and quasi-2D grid is of the order 10^{-5} m/s. This is one order of magnitude smaller than the inequality between the quasi-2D and full 2D grid and therefore acceptable. For the total sediment transport similar differences are found.

The morphology changes due to the spatial variation in total sediment transport, see Figure 11. At t=30 minutes the system has not reached a morphological steady state and the trench is still migrating in the current direction. The differences between the different grids are of similar order of magnitude as found in Scenario 2. Hence the same conclusions can be made: still a small inequality exist between the 1D and 2D grid. This difference results in a 1% inequality in bedlevel. It is acceptable from a physical point of view but from a numerical perspective improvements can me made. The difference in morphology also effects the current velocity and thereby the total sediment transport, see Figure 12 and Figure 13.

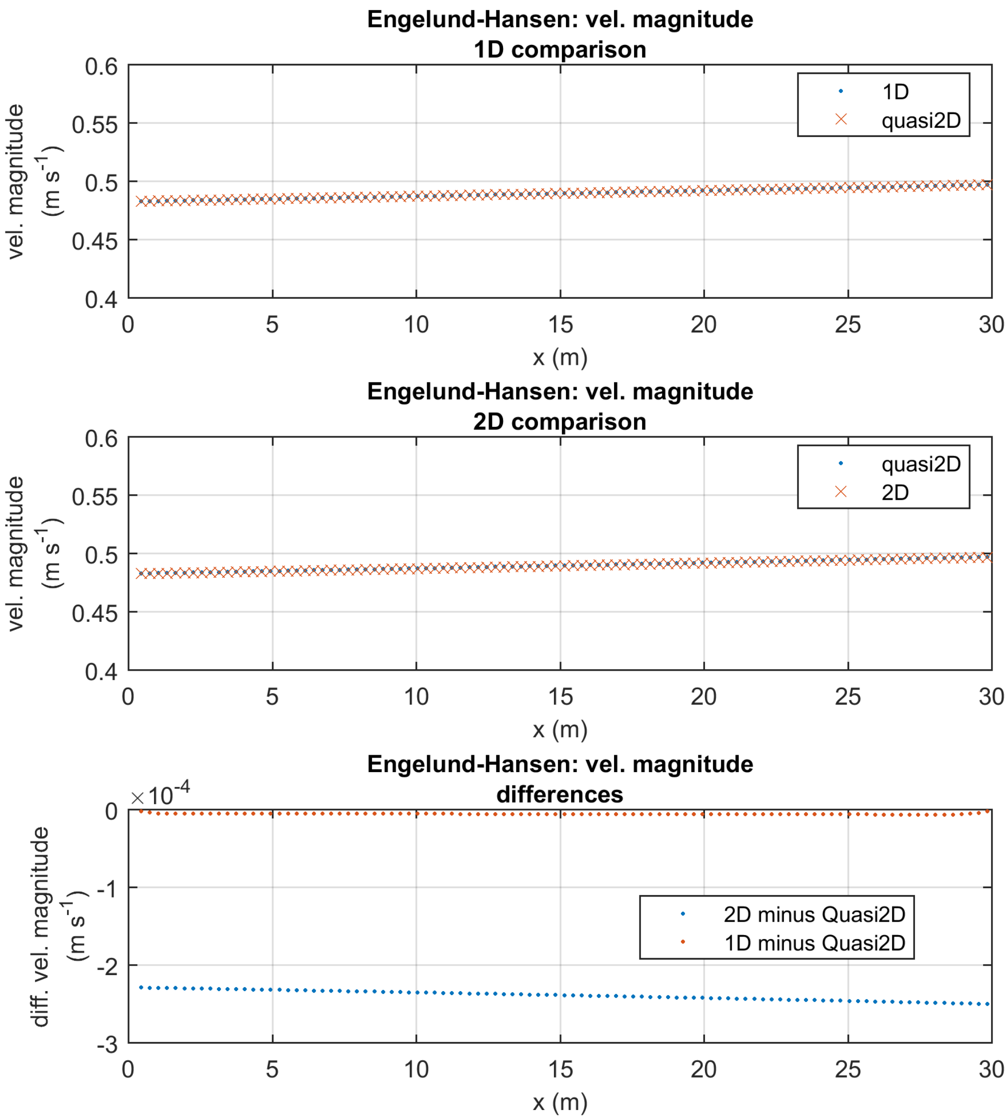

Figure 3: The velocity magnitude for Scenario 1.

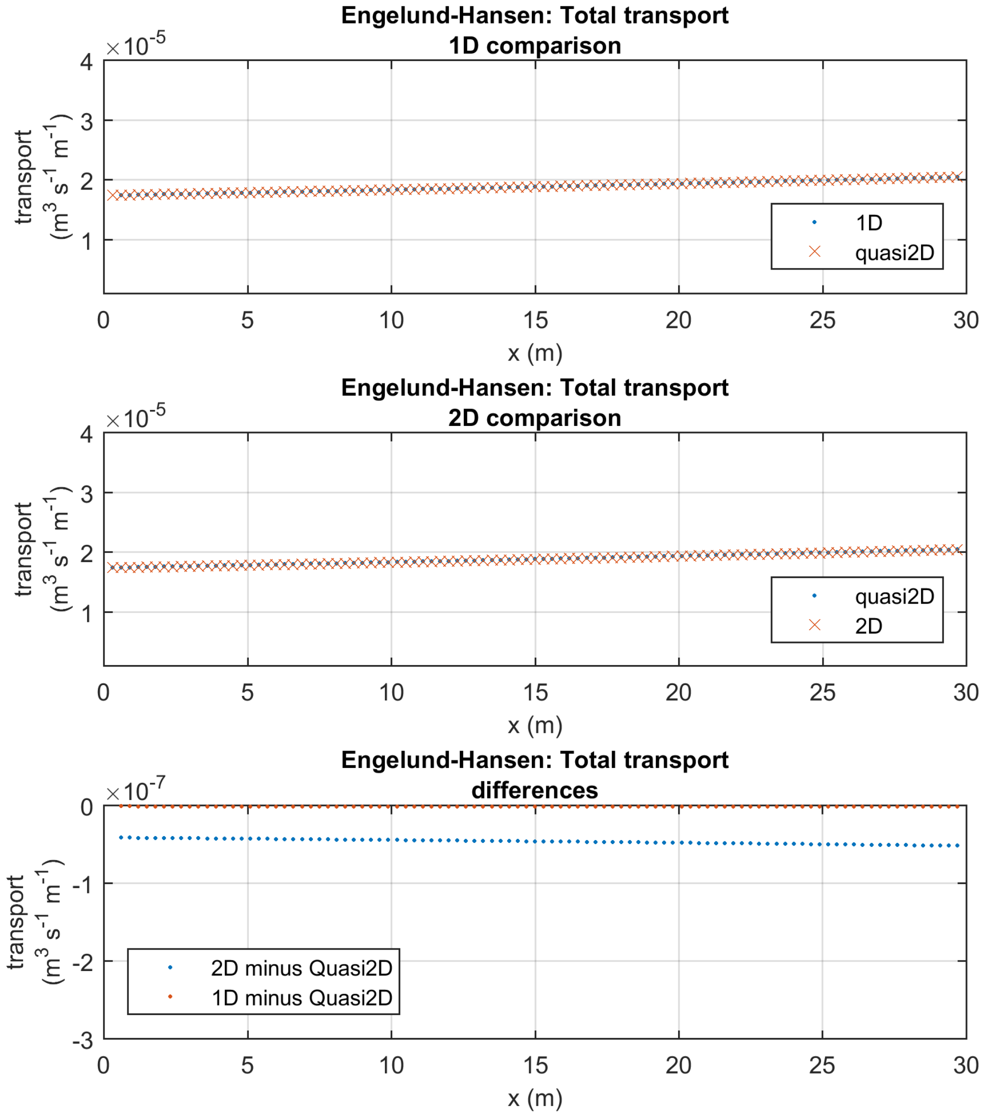

Figure 4: The total sediment transport for Scenario 1.

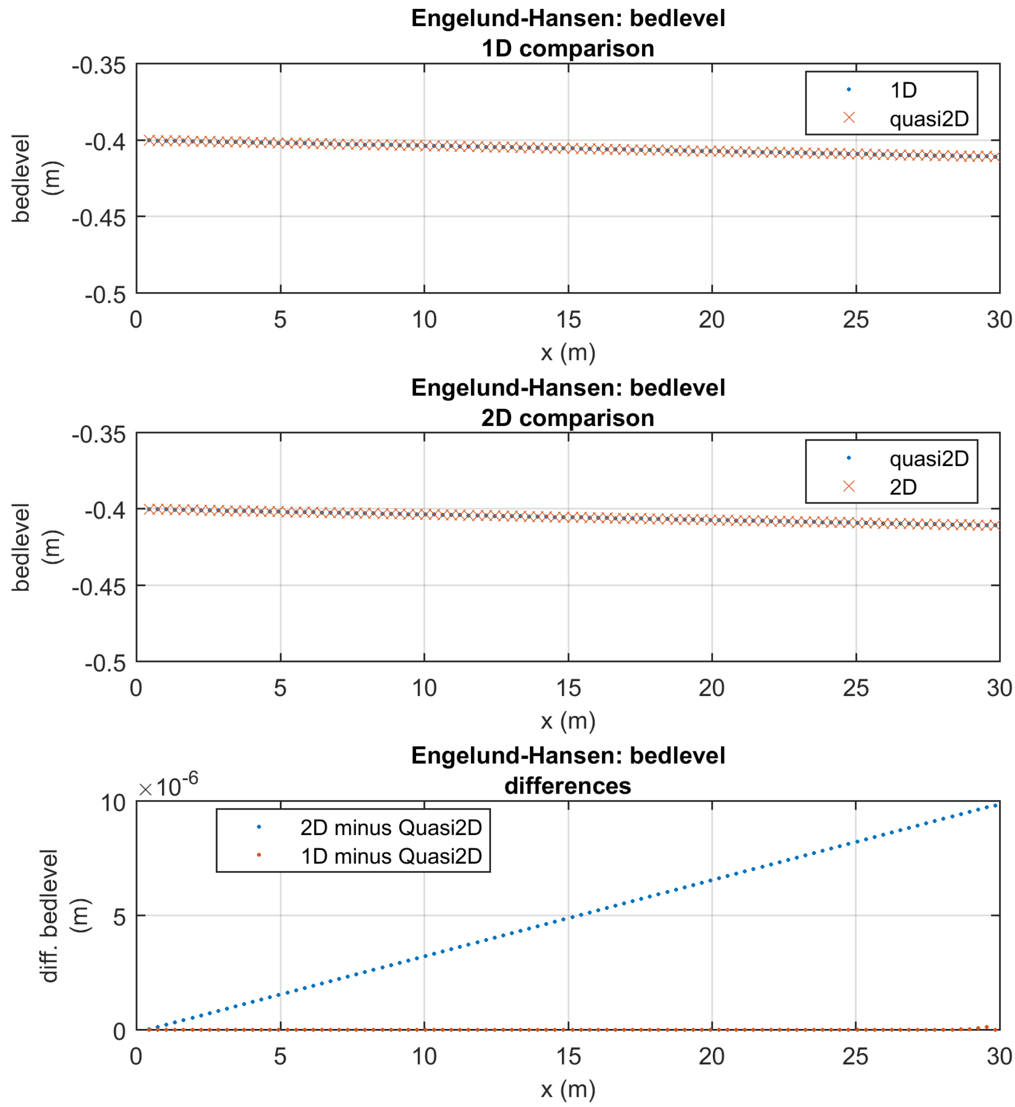

Figure 5: The bathymetry for Scenario 2 after 300 min. The bathymetry is no longer changing.

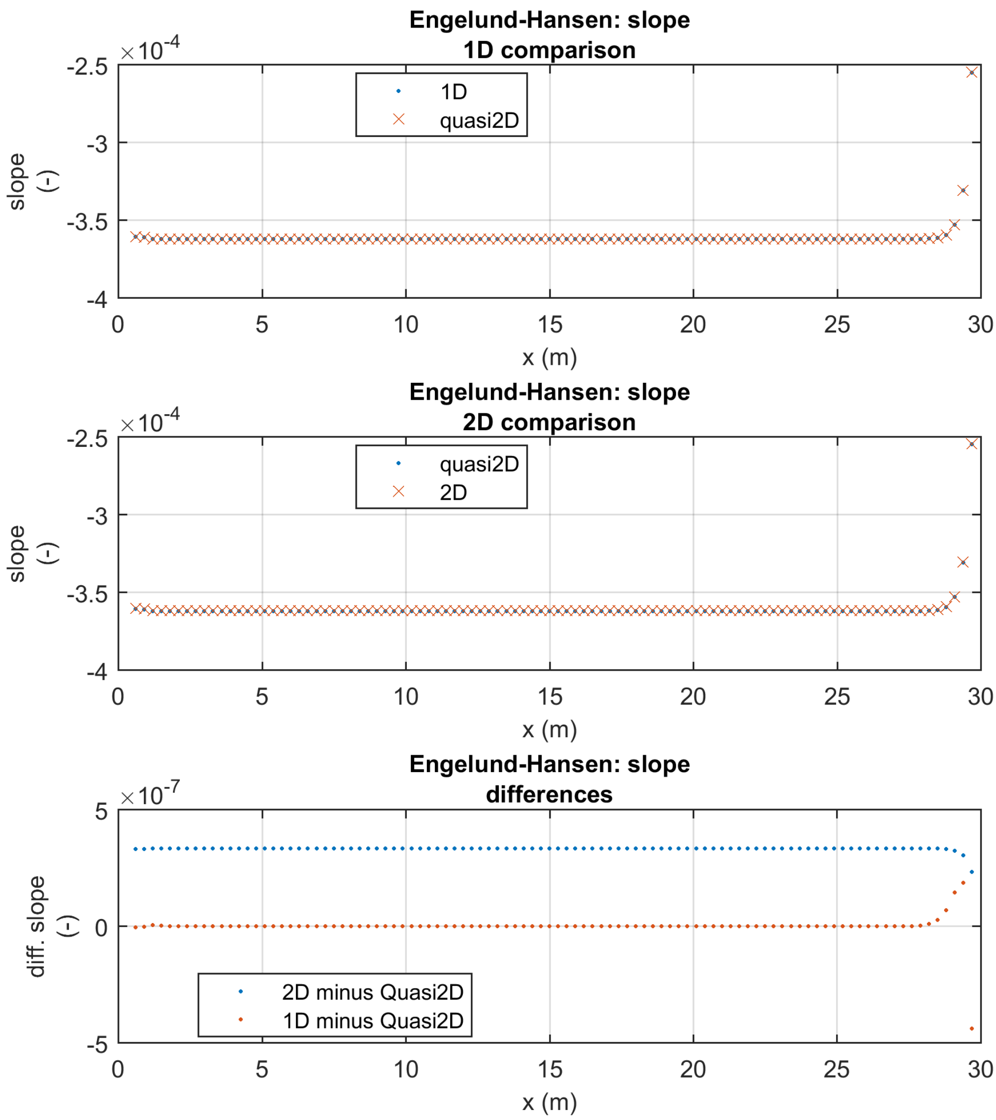

Figure 6: The slope of the bed for Scenario 2 after 300 min. The bathymetry is no longer changing in time.

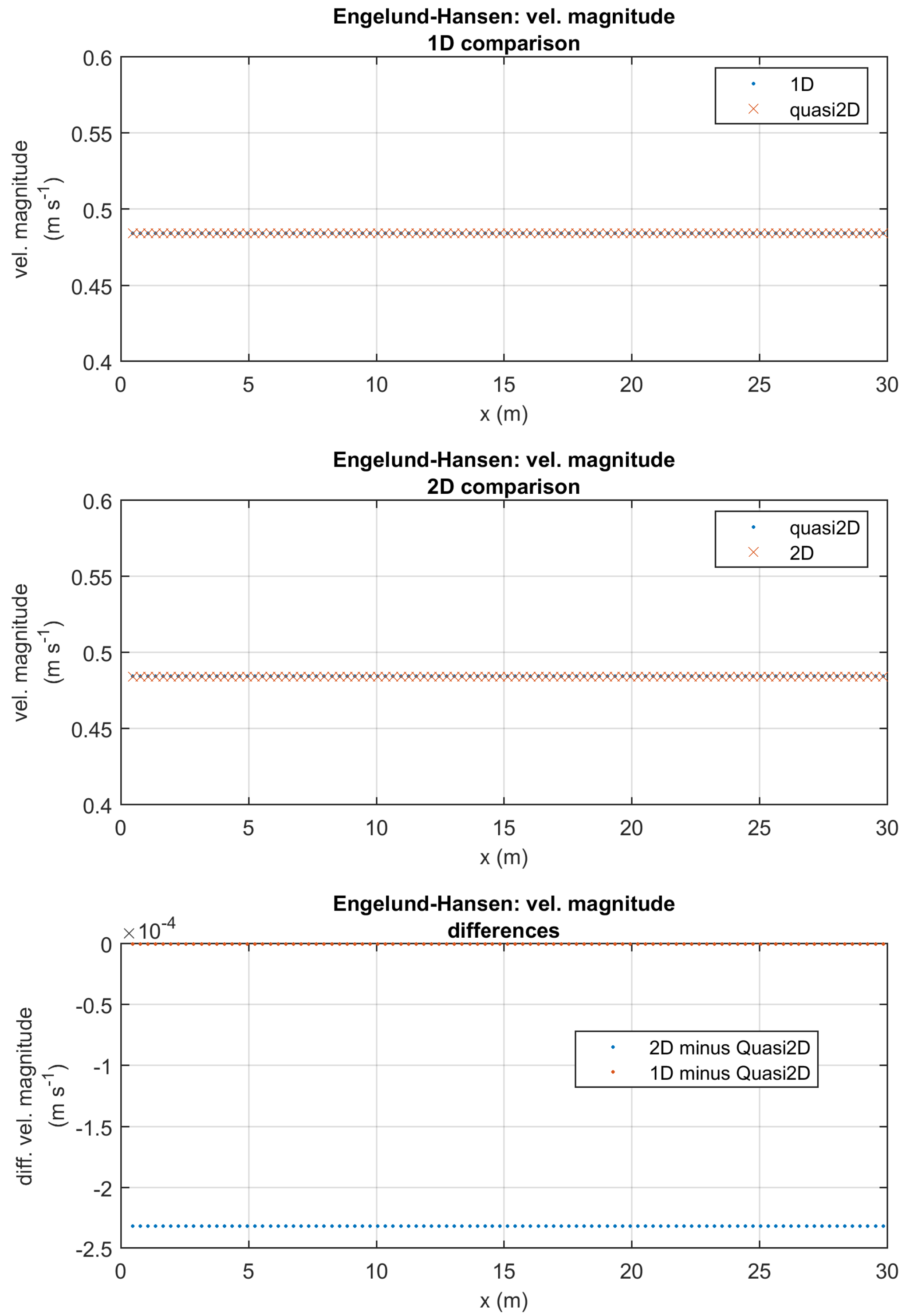

Figure 7: The velocity after 300 min for Scenario 2. The velocity is no longer changing in time.

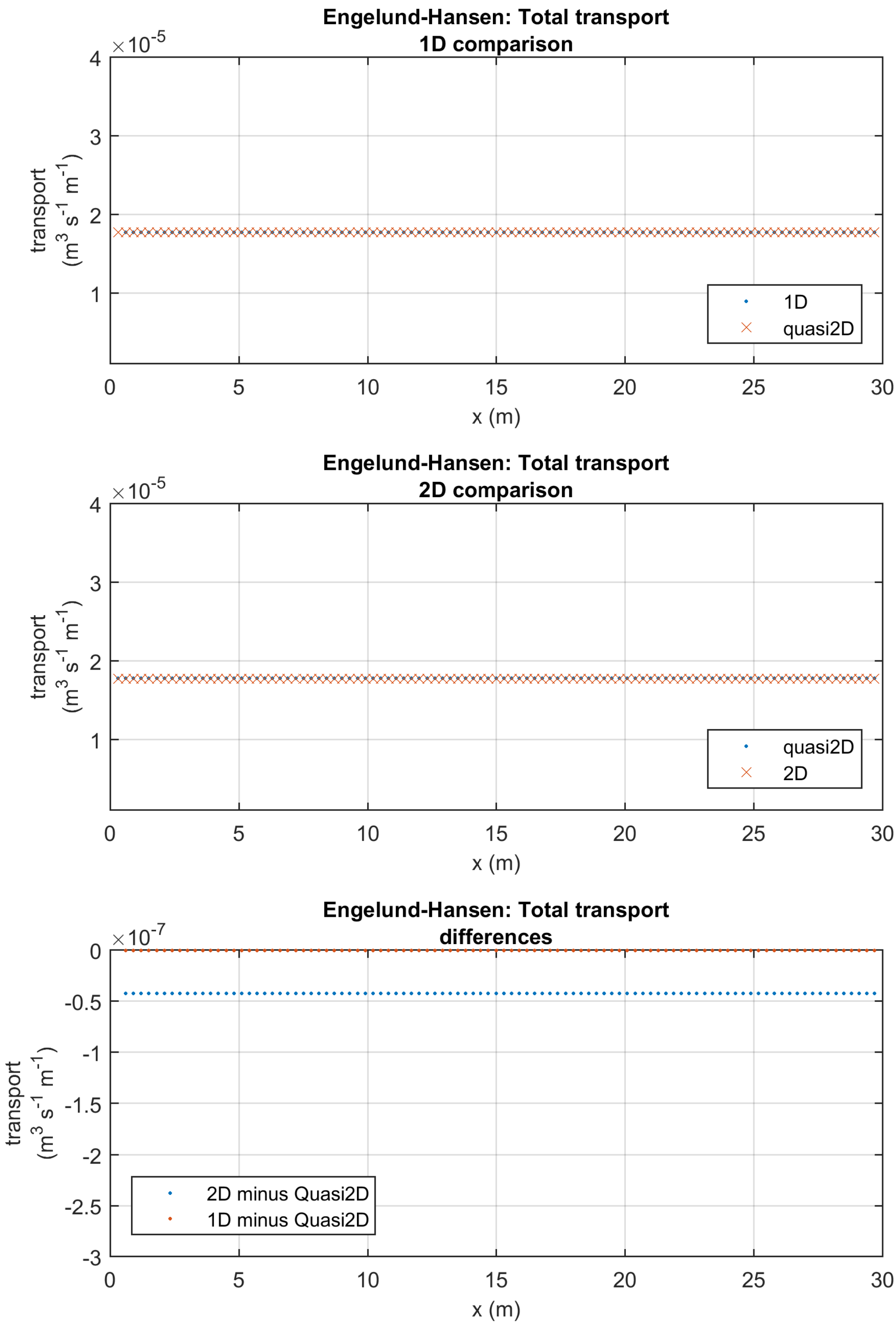

Figure 8: The total sediment transport after 300 min for Scenario 2. The total sediment transport is no longer changing in time.

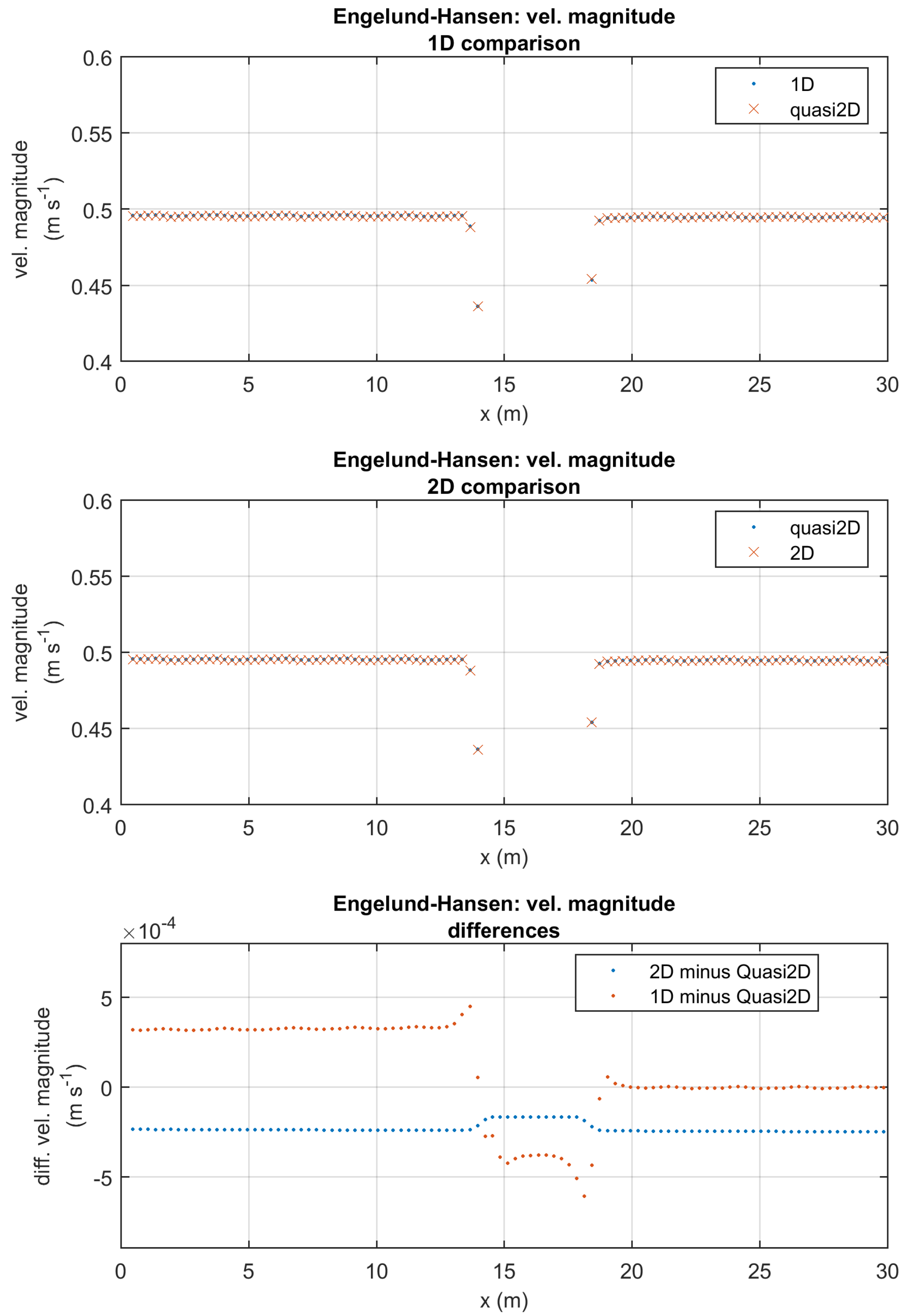

Figure 9: The steady state flow velocity for Scenario 3.

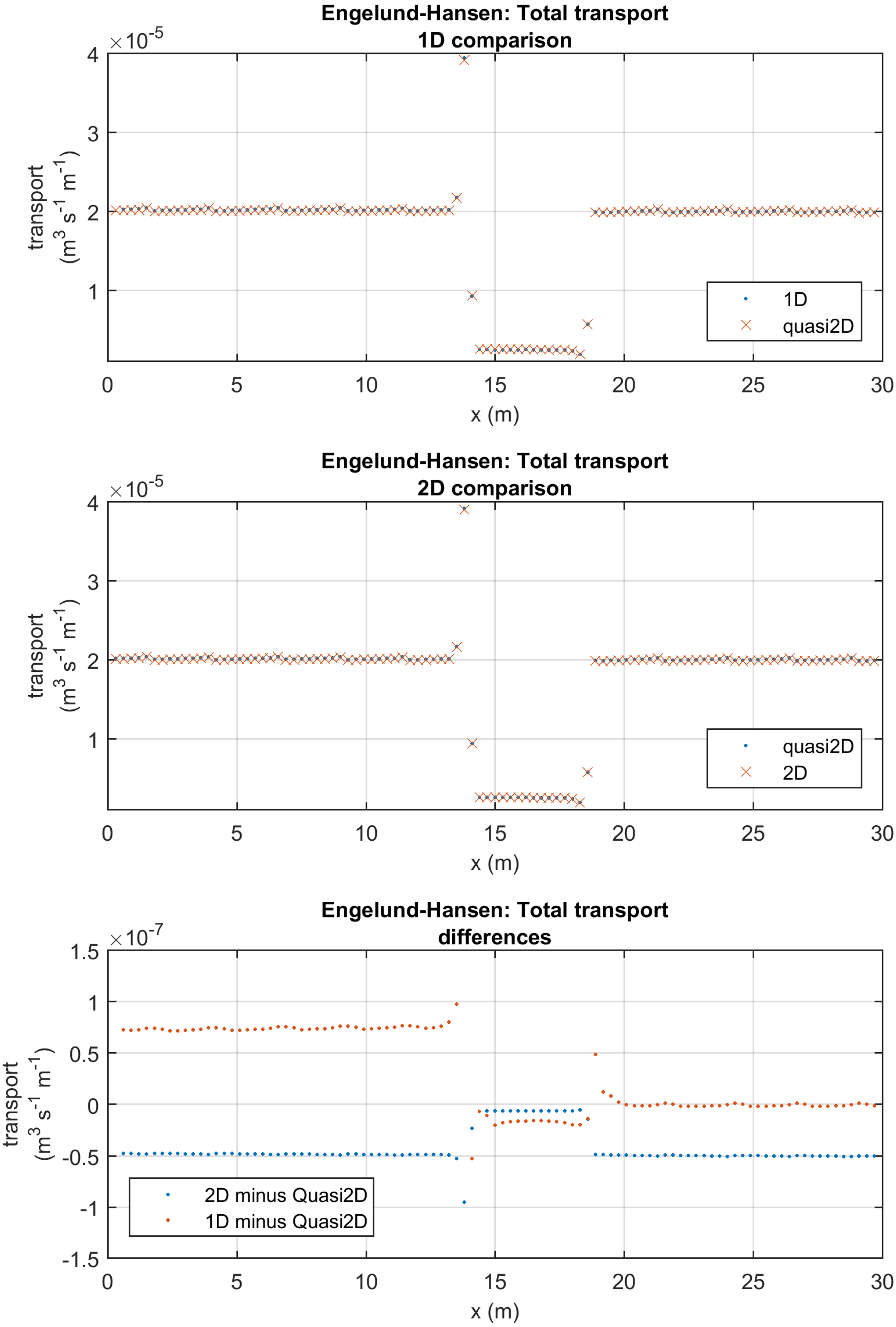

Figure 10: The steady state total sediment transport for Scenario 3.

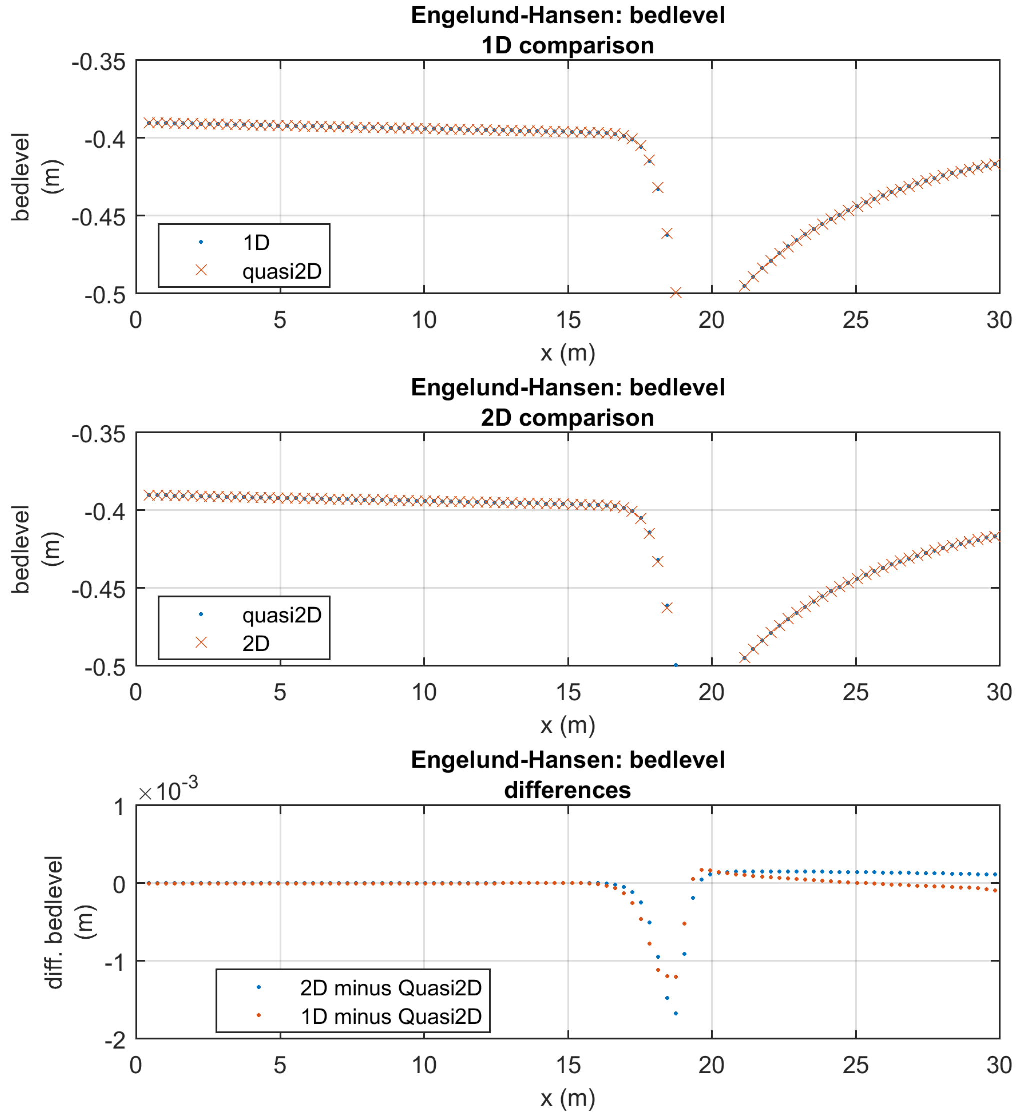

Figure 11: The bathymetry for Scenario 4 after 30 min. The trench is still migrating in the current direction.

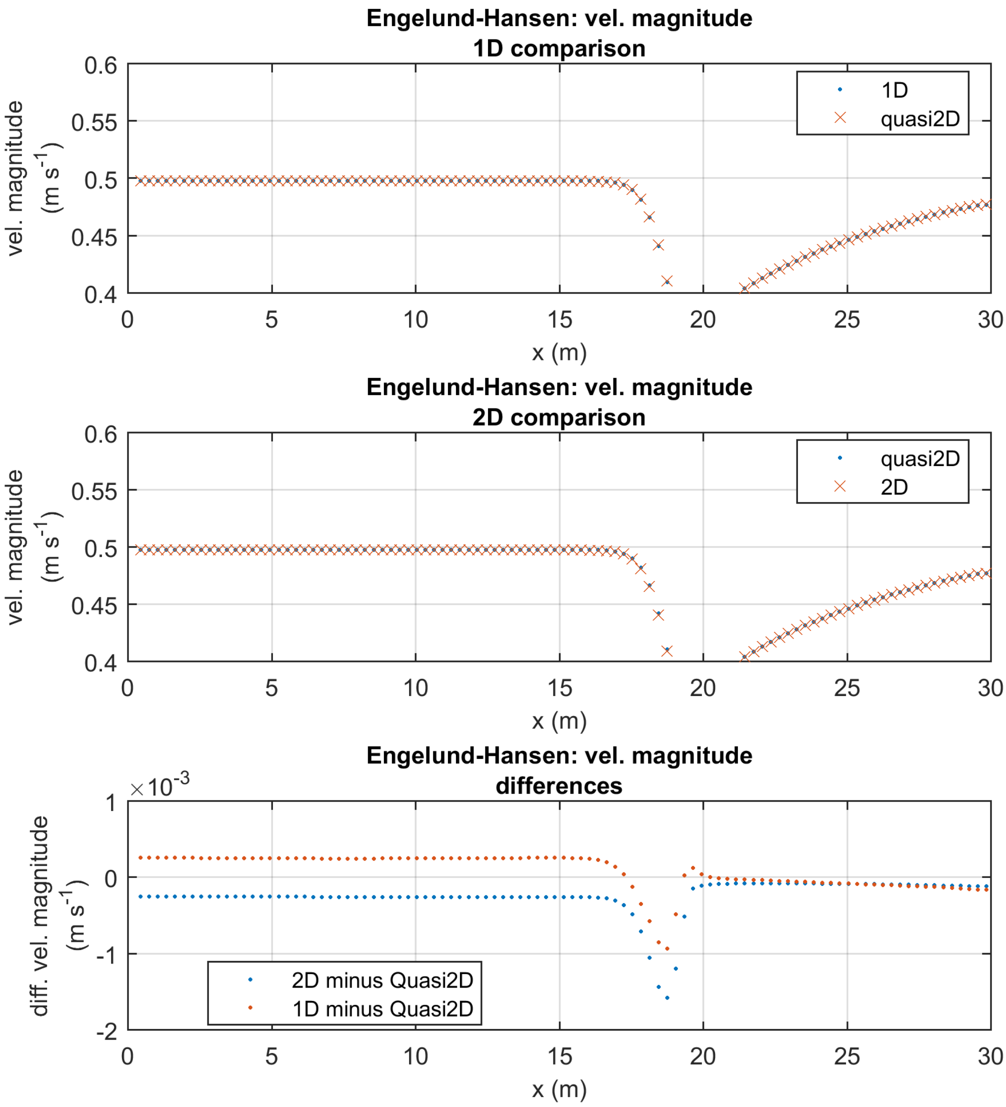

Figure 12: The flow velocity for Scenario 4 after 30 min. The trench is still migrating in the current direction.

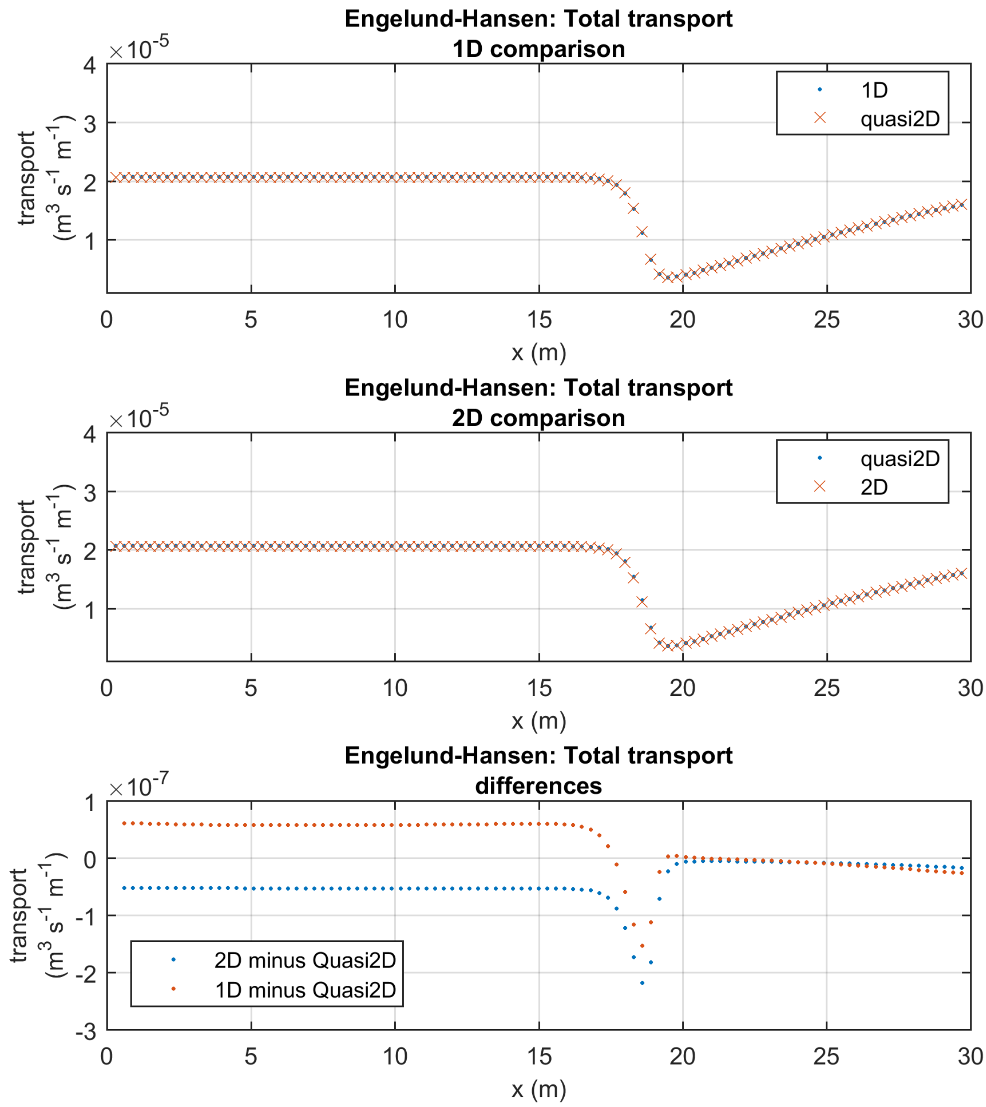

Figure 13: The total sediment transport for Scenario 4 after 30 min. The trench is still migrating in the current direction.

Conclusion

The results show that the sediment transport in 1D gives equal results as in the 2D case. Tiny differences can be related to the accepted differences in the hydraulics between a 1D and 2D schematisation. The induced morphological changes show a larger difference between the 1D and 2D case. The inequality is in the order of 1% for the bottom slope. From a physical point of view this difference is acceptable but from a numerical point of view improvements are most likely possible.

References

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