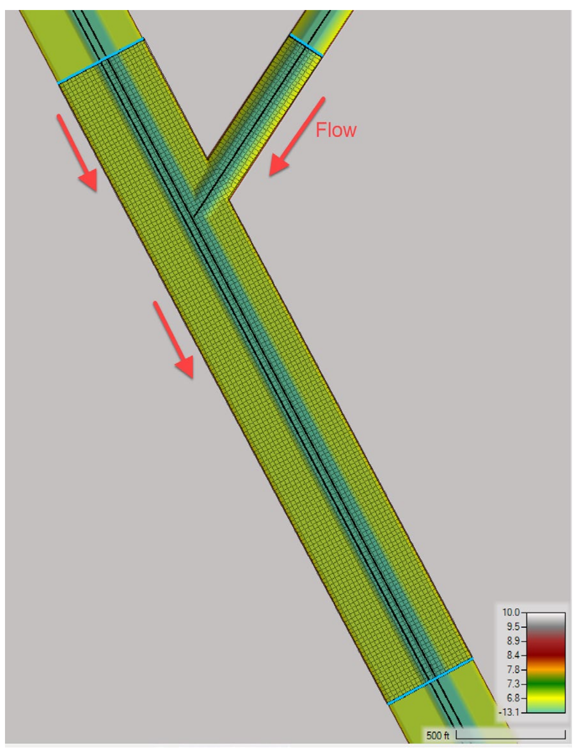
Sediment Transport Processes
Workshop

1 Objective

The goal of this workshop is to gain an understanding of basic sediment transport processes such as advection, diffusion, erosion, deposition, hysteresis, and equilibrium vs non-equilibrium transport. The workshop does not require specific knowledge of how these processes are computed or setup in HEC-RAS. It only guides the reader through different examples illustrating and highlighting the effect of specific processes using idealized models. The models utilized are based on a simple river confluence with idealized boundary and initial conditions. The reason for using an idealized dataset is to isolate specific processes as much as possible and to avoid distractions with complicated terrains. However, the examples are complicated enough to be interesting and relevant to field applications.

2 Introduction

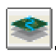
The terrain consists of a straight river with an incised channel and a confluence with a smaller stream (see figure below). The mesh has a resolution of 20 ft and is aligned mostly with the direction of flow

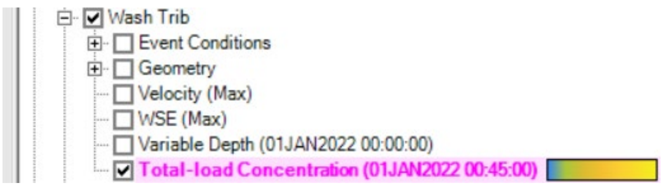


The model has flow boundary conditions upstream and a constant stage boundary condition downstream. The flow hydrographs vary for different plans depending on the specific processes being analyzed.

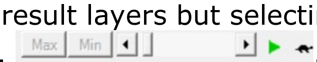
3 Wash Load Analysis

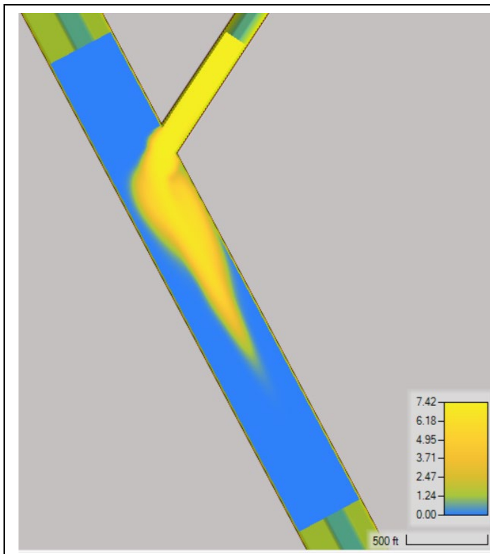
To understand the processes of advection and diffusion, it is useful to remove as many other processes as possible. This can be done by analyzing how wash load from a tributary is advected and mixed in the mainstem. The sediment bed is assumed to be cohesive and with critical shears above the bed shear stresses and therefore there is no erosion. In addition, the sediment is assumed to be very fine with a critical shear for deposition above the actual bed shear stresses and therefore there is no deposition. The wash load is essentially being modelled as a passive tracer. The task is analyze and compare two results: "Wash Trib" and "Wash Trib Diff". Both plans have advection, but only the second plan has diffusion.

1. **Start HEC-RAS**.
2. Open the HEC-RAS project names "Confluence.prj"
3. Launch **RAS Mapper** .
4. Expand the Result layers called "Wash Trib" and "Wash Trib Diff" and select the "Total-load Concentration" layer as shown below

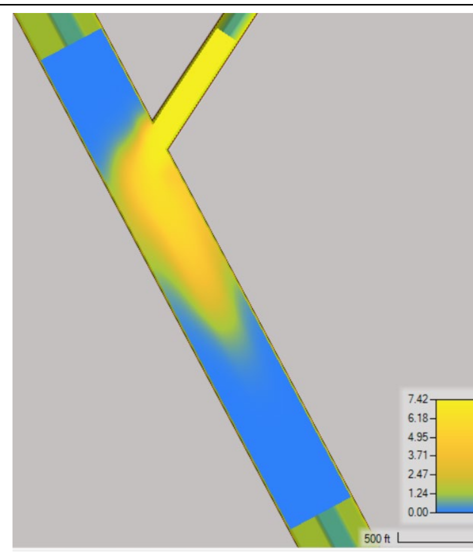


The Total-load Concentration represents the concentration of the clay wash load.

5. Animate the concentrations using the toolbar 
.
6. Now compare the two plans results with the plan called "Wash Trib Diff". This plan has both advection and diffusion. Note that it's possible to synchronize the times of result layers but selecting the base "Results" node and moving the time bar. 
. Compare the concentration fields at different locations and times. Below are a few examples.



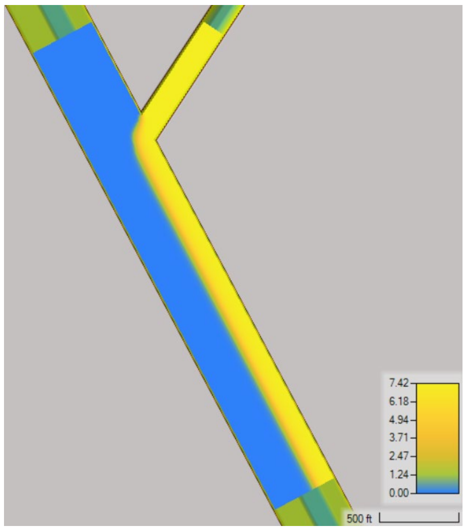
Without Diffusion



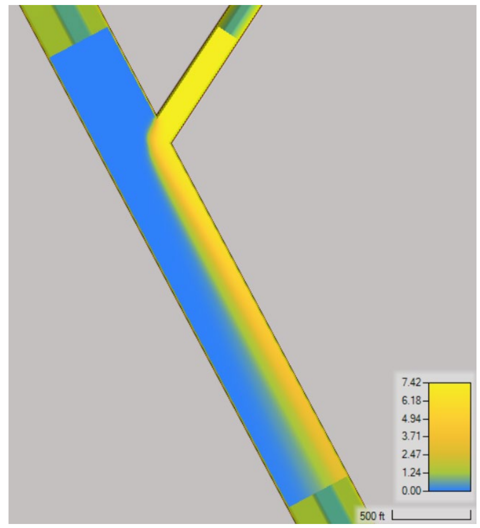
With Diffusion

Question: How do advection and diffusion affect the concentration field?

7. Compare the concentration fields at the end of the simulation.



Without Sediment Diffusion



With Sediment Diffusion

Question: In the case with diffusion, what would happen further downstream of this model extent? Would the transverse concentration profile change any further?

4 Sand Erosion Downstream of a Confluence

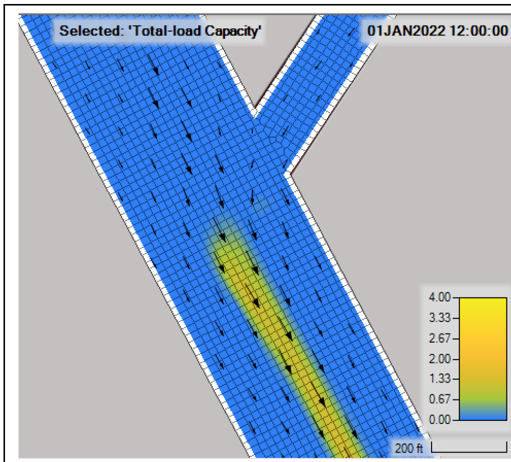
A common situation found in natural rivers is channel erosion or degradation downstream of confluences. This situation can be oversimplified with Lane's equation as $Qw \cdot S \propto Qs \cdot Ds$ where Qw and Qs are the water and sediment discharge, S is the channel slope, and Ds is the sediment diameter. At a confluence, the water discharge increases and therefore the sediment discharge must increase, since there is less sediment discharge upstream of the confluence, these produces a region of erosion downstream of the confluence.

4.1 Equilibrium vs Non-Equilibrium Transport

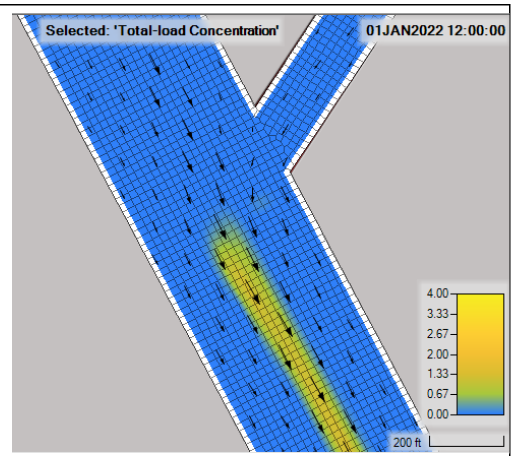
This section analyzes the differences between equilibrium and non-equilibrium sediment transport. Even though HEC-RAS is a non-equilibrium sediment transport model, it can approximately simulate equilibrium transport by forcing the concentrations to be equal to the capacities. The upstream flow is constant for the tributary and linearly increases to a constant value for the mainstem. The runs have a single sand grain class with clear-water upstream boundary conditions for both the mainstem and tributary. The flow conditions are such that the initial flow is a clear water condition but the flow in the mainstem increases until sediment transport occurs downstream of the confluence. The remaining details of the model setup are not as important. The main purpose of this section is to understand the difference in equilibrium vs non-equilibrium transport.

8. In **RAS Mapper**, select the plans called "Sand Eq". This run represents equilibrium sediment transport.

9. Toggle between the "Total-load Capacity" and "Total-load Concentration" and compare the two fields. Below is an example at the end of the simulation.



Total-load Capacity

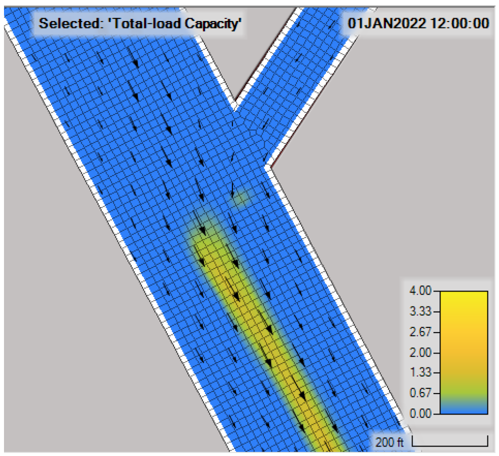


Total-load Concentration

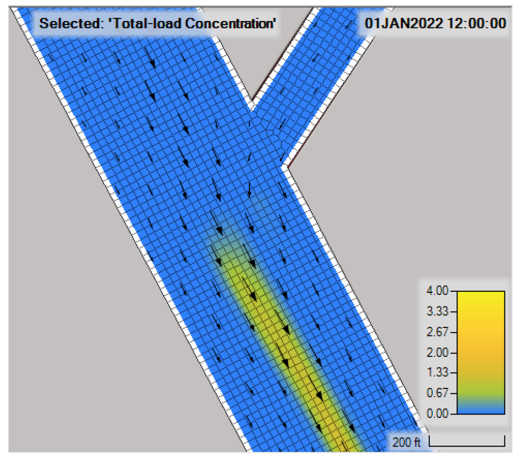
From the image above it is clear that for equilibrium transport, the sediment concentration is assumed to be equal to the equilibrium value (i.e. concentration capacity).

Question: If the sediment concentration is assumed to be at equilibrium, does the model still need to solve an advection-diffusion equation?

10. Now inspect the non-equilibrium sediment transport results. Select the plan called "Sand".
11. Toggle between the sediment concentration and capacity and compare the two fields. Below is an example at the end of the simulation.



Total-load Capacity



Total-load Concentration

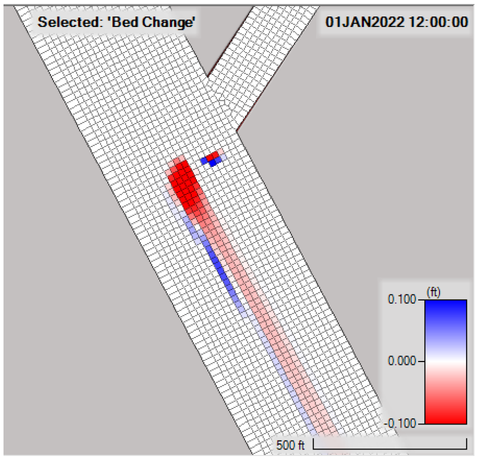
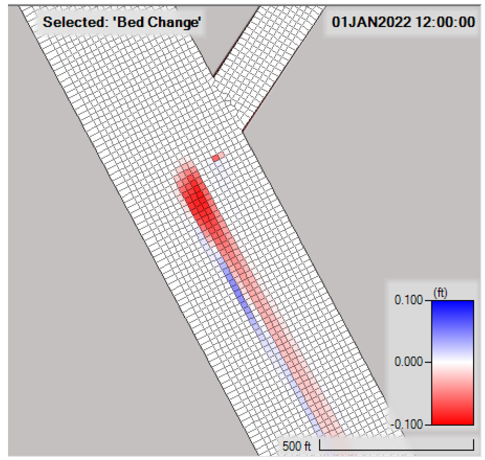
Question: How can you explain the differences between the actual concentrations and capacities near the confluence?

Question: What happens to the actual sediment concentrations downstream of the confluence? (Hint: compare to equilibrium values)

Question: What is the main difference between equilibrium and non-equilibrium sediment models?

Question: When spatially averaging over larger and larger scales, does the sediment transport tend towards an equilibrium model?

12. Take a minute to compare the "Bed change" between the equilibrium and non-equilibrium runs.

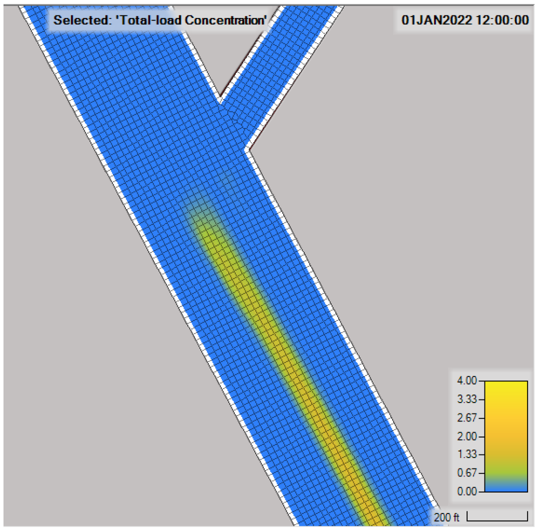
 Equilibrium Sediment	 Non-Equilibrium Sediment

Question: How can you explain some of the differences between the equilibrium and non-equilibrium bed change results?

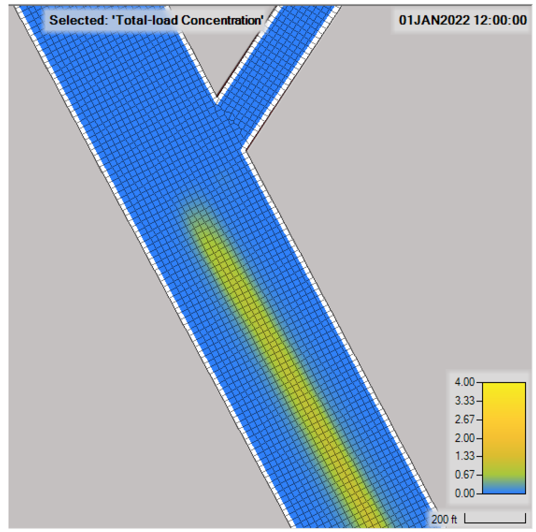
4.2 Sediment Horizontal Mixing

The section of the workshop revisits the topic of sediment mixing/diffusion from the first section. Here however, the diffusion is analyzed for the bed-material load, instead of the wash load. Diffusion is added to the non-equilibrium run from the previous section and the results are compared.

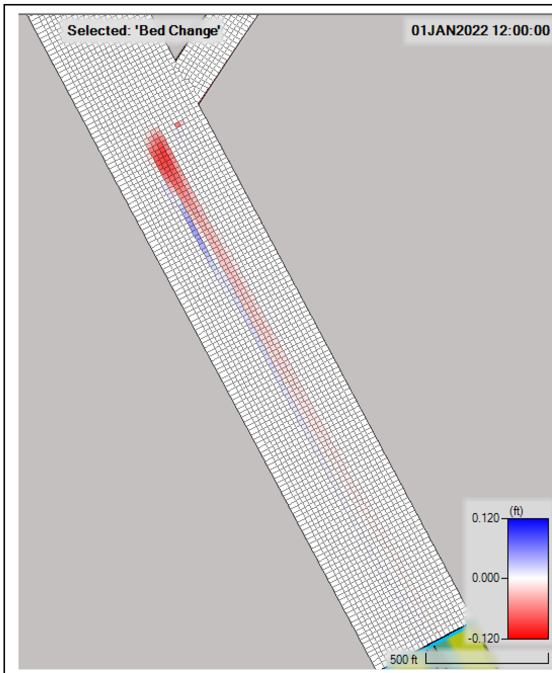
13. In **RAS Mapper** select the plans called "Sand" and "Sand Diff" and compare the sediment concentration, capacities and bed change



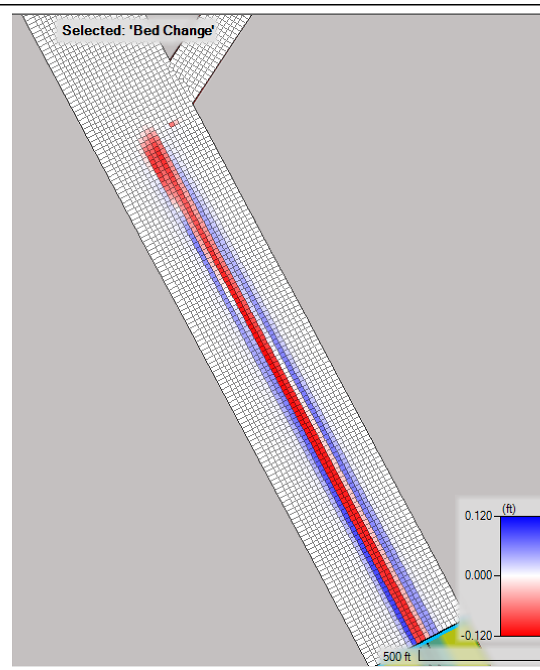
Without Sediment Diffusion



With Sediment Diffusion



Without Sediment Diffusion



With Sediment Diffusion

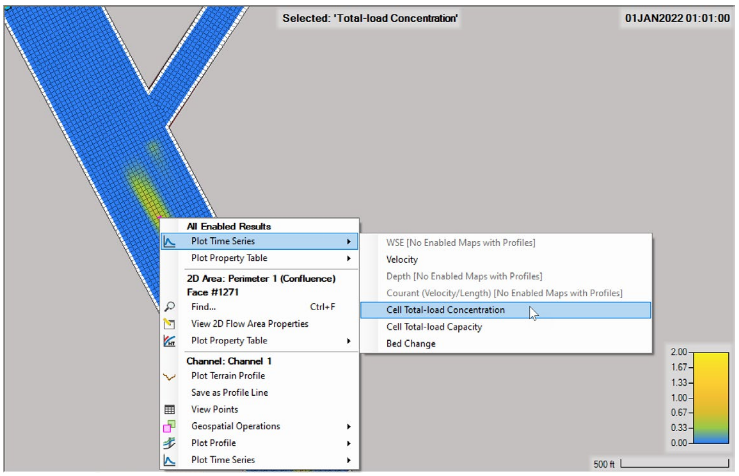
Question: Explain the differences in the bed change results with and without diffusion based on the sediment concentrations.

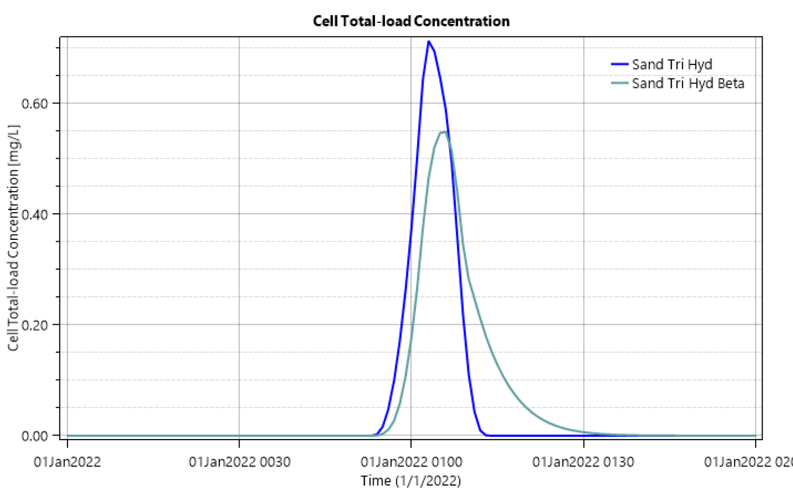
4.3 Sediment Hysteresis

This section analyzes the effect of sediment hysteresis. Sediment hysteresis is the lag between flow and sediment transport. Two plans are compared with and without the load-correction factor in the temporal term which accounts for the non-uniform vertical profiles of the current velocity and sediment concentration. The two plans have a simple triangular hydrograph with a very short duration.

14. In **RAS Mapper**, select the plans "Sand Tri Hyd" and "Sand Tri Hyd Beta".

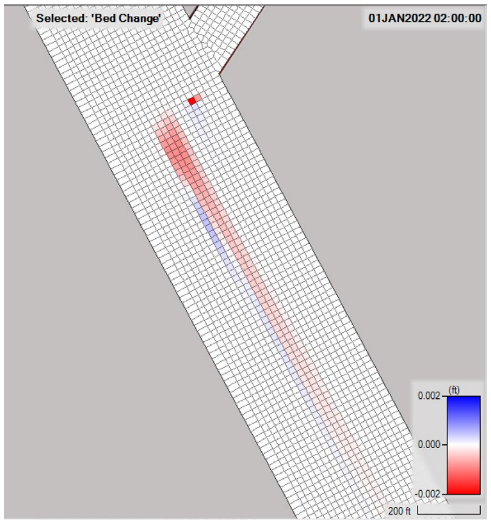
15. Compare time-series of the sediment concentrations at different locations.



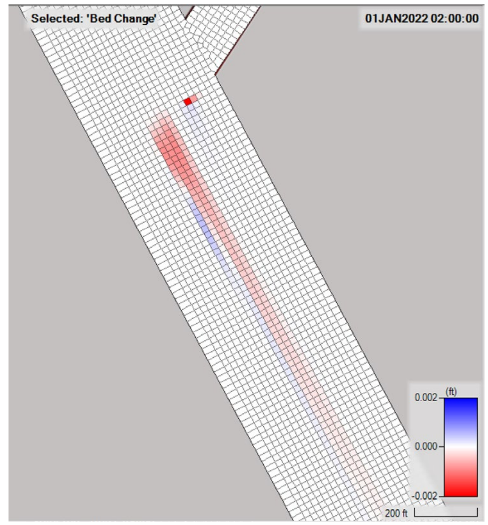


Question: Explain the differences between the concentration time-series with and without the total-load correction factor (i.e. beta)

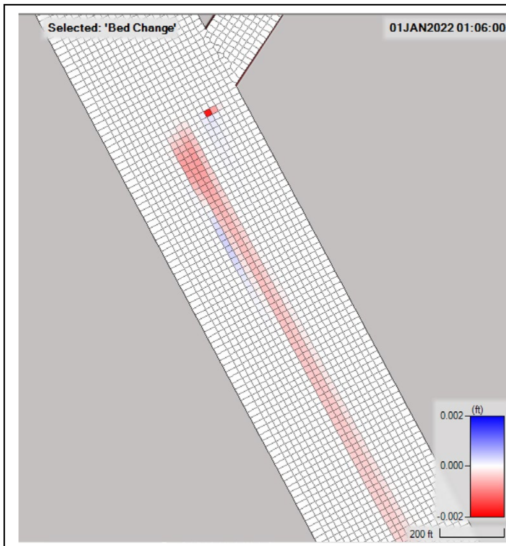
16. Compare the bed change with and without the total-load correction factor at the end of the simulation and at 01:06 as shown below.



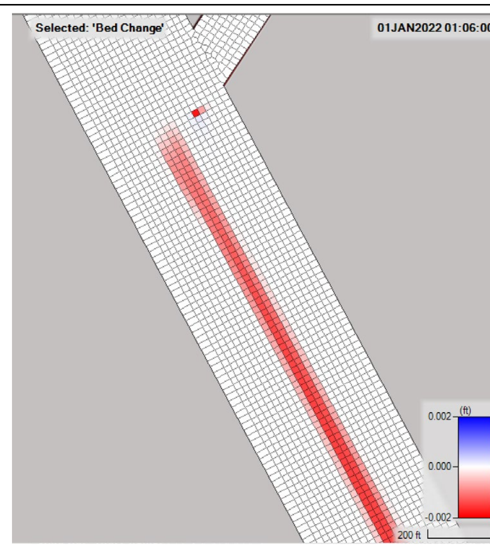
Without Beta



With Beta

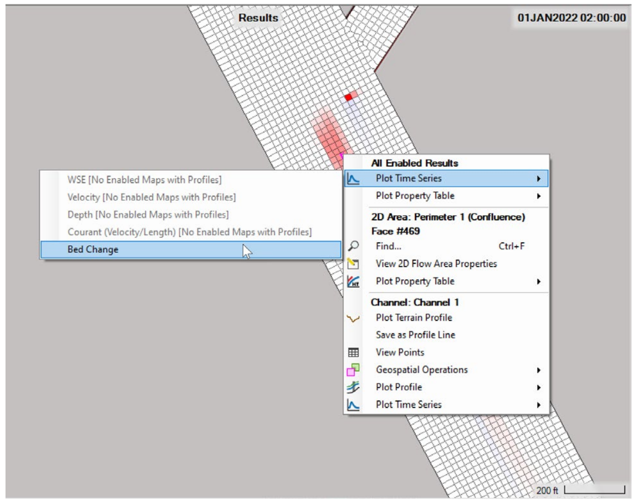


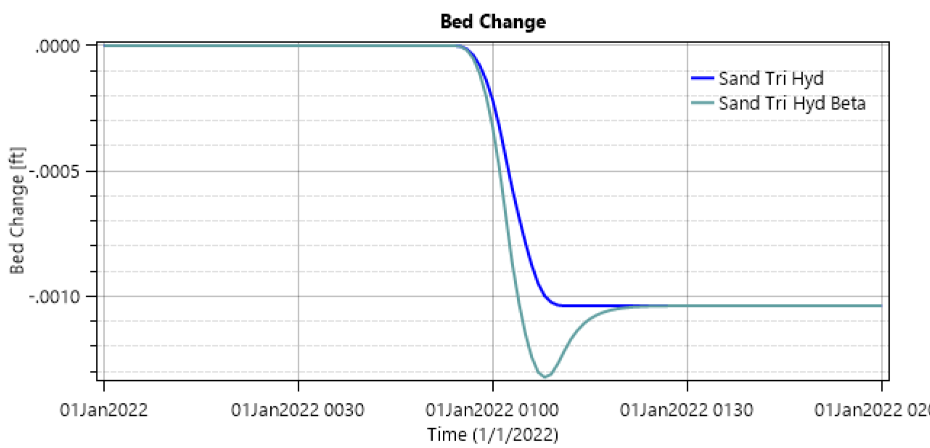
Without Beta



With Beta

17. Plot a time-series of bed change near the confluence for both plans as shown below.





Question: Explain the differences and similarities in the bed change time-series.