# INTRODUCTION

This training worksheet is designed to familiarize the user with the "Module for flow discharge and sediment load relation in a river" and its use. It is highly recommended to read through the provided document "theory.pdf" to understand the underlying physics of sediment transport. Here sediment load refers to bed material load, which is defined in "theory.pdf" document.

# TRAININGS

Please go through following questions to get hands-on exercise and familiarize yourself to the module.

## 1. General behavior of the module

Q1a) How does the sediment load respond to the increase of flow rate?

A1a)

Q1b) Does the general behavior of the relation change if input parameters (slope, channel width, grain size, and channel resistance) are changed?

A1b)

Q1c) Explain why the model behaves this way.

A1c)

## 2. Effect of channel slope

Q2a) What is the effect of the increase in channel slope on the relation between sediment load and flow discharge? Higher slope causes more sediment transport capacity or less?

A2a)

Q2b) Explain why the channel slope affects the relation this way.

A2b)

## 3. Effect of channel width

Q3a) What is the effect of the increase in channel width on the relation between sediment load and flow discharge? Wider channel has higher or lower capacity of sediment transport?

A3a)

Q3b) Explain why the channel slope affects the relation this way.

A3b)

* Also remember that when the channel is narrow, the wall effect can be significant, adding resistance to the channel hence reduce the bed shear stress (compared to the wide channel).

## 4. Effect of grain size

Q4a) What is the effect of the increase in grain size on the relation between sediment load and flow discharge? Coarser grain yields more or less sediment load?

A4a)

Q4b) Explain why the grain size affects the relation this way. Obviously, coarser sediment is more difficult to be moved by flow. What is the theoretical perspective of this behavior?

A4b)

## 5. Effect of channel resistance

Q5a) What is the effect of the increase in channel resistance on the relation between sediment load and flow discharge? Higher resistance leads to more or less sediment load?

A5a)

Q5b) Explain why the channel resistance affects the relation this way.

A5b)

## 6. Advanced

Open the module source file “module_ discharge_sediment.py” to make changes in the source code. Please make sure to save changes before run the module.

Q6a) Go to line 27, where the range of flow discharge (Qw) can be defined. Change the values and then run the module. See if the change is reflected.

Q6b) Go to lines from 32 to 35, where minimum and maximum values of channel slope (Smin, Smax), channel width (Bmin, Bmax), grain size (Dmin, Dmax) and channel resistance (Cfmin, Cfmax) can be modified. Change the values and then run the module to see if the change is reflected.

Q6c) Sometime, especially when the module predicts the small value of sediment load, it is hard to read the plot. To overcome this problem, the user can change the scale of the y-axix by changing values in line 36 (ymin, ymax). Change the values and see if the result is reflected.

# CASE STUDY

## 1. Minnesota River near Jordan, MN, USA

The Minnesota River near Jordan (MN, USA) is approximately 100 m wide ($B$ = 100 m), 0.0002 or 0.02% steep ($S$ = 0.0002 or 0.02%), the roughly estimated channel resistance coefficient is 0.0045 ($C_f$ = 0.0045) and characteristic bed surface sediment size is 0.3 mm ($D$ = 0.3 mm).

Q1a) According to the record made by U.S Geological Survey (USGS), the daily average flow discharge on the 24th of July 2014 was approximately 200 m$^3$/s ($Q_w$ = 200 m$^3$/s). Estimate the daily average sediment load on that day, either using the plot of the module, or the Eq. (1.7) in the "theory.pdf" document. If you are to solve this manually, it is recommended to assume that the hydraulic radius is equal to the flow depth ($R_h = H$) since it involves solving the nonlinear relation between flow depth, channel resistance and channel width.

A1a)

Q1b) Suppose probability distribution of the annual discharge is as follows: 25% of the time the flow is at 100 m$^3$/s, 25% of the time the flow is at 400 m$^3$/s, 25% of the time the flow is at 600 m$^3$/s, 20 % of the time the flow is at 800 m$^3$/s and 5% of the time the flow is at 1000 m$^3$/s. Estimate the annual sediment load? Use either the plot of the module or the Eq. (1.7) in the "theory.pdf" document. The answer should be given in the unit tons/year.

A1b)

## 2. Finding your own problem site

Go to USGS National Water Information System website (https://waterdata.usgs.gov/nwis). Click "Current Conditions" tab on the left side of the page, then click the state of your interest in the map. Click one of the circles (indicating gaging sites) to go to the specific site that you would like to investigate. If you know the name of the river and the location of the gaging station, you can simply search the name in the searching window. Obtain daily discharge data (either graph or table form) of the site, either on specific day or specific period of time.

Q2a) The data provided here is expressed with ft$^3$/s. Firstly the unit needs to be converted from US unit to SI unit (ft$^3$/s to m$^3$/s).

A2a)

Q2b) Estimate the sediment load of the day (or time period) of your interest.

A2b)

# ANSWERS

## TRAININGS

A1a) Sediment load increases with increasing flow discharge

A1b) General behavior does not change with changing input values. The sediment load always increases with increasing flow rate.

A1c) The increase in flow rate yields increase in flow depth and flow velocity, hence increase in bed shear stress. Higher bed shear stress yields higher rate of sediment load.

A2a) As the channel slope increases, sediment load for given flow discharge increases, making the plot steeper. This indicates that the steeper channel has higher capacity of sediment transport.

A2b) For a given discharge, steeper channel yields higher bed shear stress, according to Eqs. (1.4) and (1.5).

A3a) Wider channel leads to lower sediment transport capacity, making the plot milder.

A3b) Wider channel makes the hydraulic radius smaller, causing the reduction in the bed shear stress, according to Eqs. (1.3) and (1.4). Although wider channel has more space to transport the sediment, the energy to move the sediment decreases. Therefore, the transport capacity decreases.

A4a) Coarser grain size leads to lower sediment load, making the plot milder.

A4b) Bed shear stress is normalized with the bed grain size. In other words, bed shear stress is evaluated in terms of the ratio of force induced by flow to force required to move the sediment (Eq. (1.5)). As the grain size increases, greater force is required to be mobilized. Thus, coarser grains are less transported by a given flow, compared to fine grains.

A5a) Higher channel resistance leads to lower sediment load, making the plot milder.

A5b) Higher channel resistance causes the flow to slow down, according to Eq. (1.2). Moreover, the energy of the flow is dissipated to overcome the resistance, making less energy to be available to transport the sediment. *This may not be apparent in the provided document.*

A6a) NA

A6b) NA

## CASE STUDY

A1a) ~4000 tons/day. If the module is used to compute, the change in the y-scale of the plot is required. If it is calculated manually, it is recommended to assume the hydraulic radius being equal to the flow depth.

A1b) ~8000000 tons/year. First, compute sediment load for each discharge. Then sediment load for each discharge is multiplied by the corresponding time fraction. Finally, the products are summed up.

A2a) NA

A2b) NA