Colloid transport in a one-dimensional saturated soil column under steady flow condition

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In this example we show the creation of a simple model of multi-disperse particle transport and filtration in a one-dimensional column under steady-state flow condition using GIFMod. The column will be assumed to have $50cm$ lenght and an area of $100cm^2$ and it which is descretized into 10 layers. A dummy reservoir will also be added a the bottom of the column to ease imposition of downstream boundary condition through prescribed flow feature.

1. **Create the first block and assign the properties:** Add a Darcy block from the top menu. Set the following properties:
   - **Bottom Area:** $0.01m^2$
   - **Bulk Density:** $1600kg/m^3$
   - **Depth:** $0.05m$
   - **Initial moisture content:** 0.4
   - **Saturated moisture content:** 0.4
   - **Storitivity:** $1m^{-1}$

2. **Create a vertical array:** Right-click on the block that was just created and then click on "Make array of blocks" item. Select "Vertical 2D array" and then change the number of rows to 10. Click "Ok".
   - **Note:** When a vertical grid is made the bottom area of the original block will be copied as the interface area of the connectors.

3. **Introducing particles:** We will model three different particle types with three different sticking rate coefficients $alpha_p$ values. In order to introduce the particles, from the **Project Explorer** window right-click on **Water Quality→Particles** and then select "Add Particles" from the drop-down menu.

4. **Setting particle properties:** Set the following properties for the particle:
   - **Name:** *Particle I*
   - **Model:** *Dual Phase*
   - **Attachment Efficiency:** *1*
   - **Collection Efficiency:** *1e-6*
   - **Specific Surface Area:** *$10000m^-1$*

   Add two more particle types with the following properties:
   - **Name:** *Particle II*
   - **Model:** *Dual Phase*
   - **Attachment Efficiency:** *1*

- **Collection Efficiency:** *1e-5*
- **Specific Surface Area:** *$10000m^{-}1$*

- **Name:** *Particle III*
- **Model:** *Dual Phase*
- **Attachment Efficiency:** *1*
- **Collection Efficiency:** *1e-4*
- **Specific Surface Area:** *$10000m^{-}1$*

5. **Save:** It is now a good time to save the work.

6. **Inflow file:** Here we create the inflow file. It is assumed that the flow rate is constant and equal to $0.01m^3/day$ which results in a velocity of $2.5m/day$ over the entire experiment which takes 1 day and the particle concentration for all three types of particles in $10mg/L$ for a period of 1hr and which is followed by no particles in the inflow. The inflow file will look like figure 1. Create or download "in-
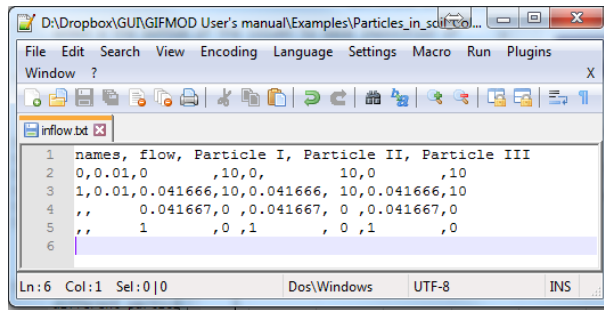

Figure 1: Inflow file for particle transport in soil example

flow.txt" from the example folder. Click on block **Darcy (1)** and from the **Properties** window double-click the Inflow time series value and then select the inflow.txt file from **User/Documents/GIFMod Projects/Examples/Particles in soil Column/**
Right-click on the **Darcy (1)** block and visualize the time series using **Plot Inflow Properties** menu item. The inflow concentration for particle I for example should look like Figure 2

7. **Outflow:** In order to impose the outflow boundary condition a dummy reservoir will be added to the bottom of the soil column. The type of the block used for this reservoir is not important because we
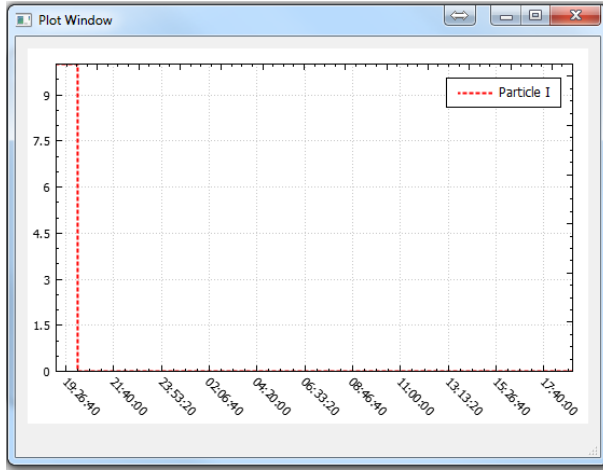
Figure 2: Concentration of Particle I in the inflow

will use the **prescribed flow** feature to control the outflow. Let's use a storage block to create the dummy outflow reservoir:

- Add a storage by clicking on the storage icon 🔲 on the top tool bar. Move the newly added storage block to the bottom of the column and connect it to the block named **Darcy (10)**.
- Enter a non-zero **Length** and **Interface** for the newly added connector.
- For the newly added storage block add a non-zero **Bottom area** and **Depth** for the newly added storage block. These two values are required for the model to run.
- Also to prevent the storage block from becoming over-saturated enter a value of zero in the **Head-Storage relationship** property.
- Set the **Bulk density** to *1600kg/m³*. **Note:** that if the value of **Medium Bulk Density** is entered in particle properties of a particle type, it will be used as the media density when performing the mass-balance for that particle class.

8. **Outflow rate time-series:** We want the outflow rate to be equal to the inflow rate. This can be accomplished in two ways. One is to turn on the "Steady State Hydraulics" in the **Setting→Project Settings** or by assigning a **prescribed flow** to the bottom connector. We are

going to use the second approach here:
- Click on the **Darcy (10)-Pond (1)** connector
- Set **Type** value to "Prescribed Flow".
- For the **Prescribed flow time series** value choose "outflow.txt" from **User/Documents/GIFMod Projects/Examples/Particles in soil Column/**
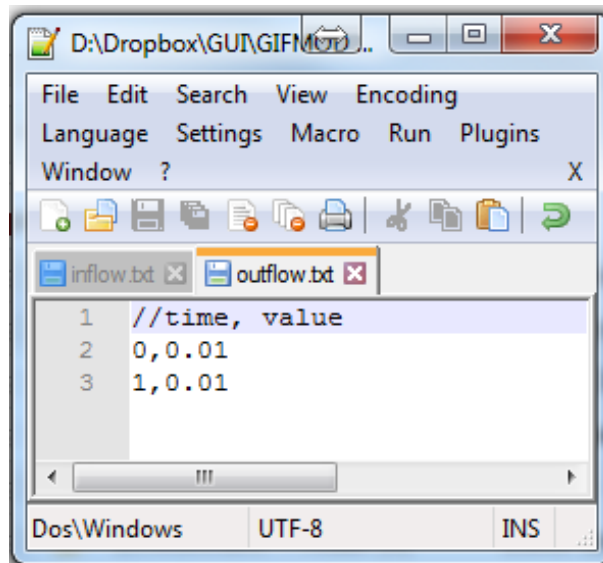 The flow time series that should be prescribed to the **Darcy (10)-**

Figure 3: Outflow file

Pond (1) connector should look like Figure 3. Please note that the heading file in Figure 3 is ignored by the program and is only necessary for user documentation.
- Save the project.
- Now the model is ready to run. Click on the run icon on the left side tool bar and wait for the simulation to end.
- Right-click on the block named **Darcy (10)** and choose **Water Quality Results→ Particles I→ Mobile** to see the breakthrough curve for particle type I
- Do the same thing for **Particle II** and **Particle III**. Right-click on the graph containing particle II results and right-click on the graph and select the **Copy Curve** item, then click on the graph containing

particle type I results, right-click and select the **Paste** item.
- Do the same with particle III to see the three breakthrough curves for the three particle types in a single graph. You can change the format of each curve by right-clicking on the graph and selecting the name of each curve (Figure 4).
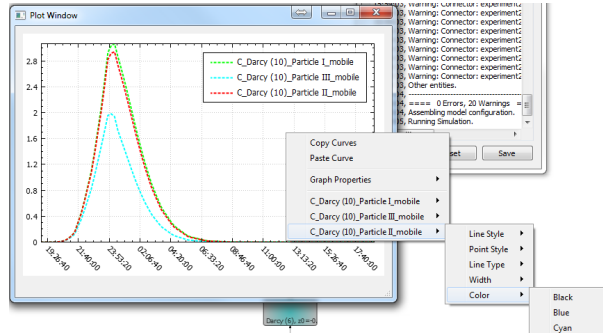

Figure 4: Particle breakthrough curves for the three particle classes