**The Challenge**

1. Read the paper that summarizes the stream flow packages in Modflow and look at the [flopy documentation](https://flopy.readthedocs.io/en/3.3.5/source/flopy.modflow.mfstr.html) for the str package to understand how we have implemented this in our code. Write a short explanation for how the str package works and what assumptions it is making.
   * Flow in the stream is specified by discharge in the first part of the river that enters the model boundary. Discharge downstream is computed as the difference between the discharge in the previous section and the seepage through the bottom sediment layer.
   * Surface water level is calculated using Manning’s Equation: A picture containing text, watch

     Description automatically generated

Q = discharge [m3/s]

n = Manning’s roughness coefficient [-]

A = cross-sectional area of stream [m2]

R = hydraulic radius [m]

S = hydraulic gradient slope [m/m]

* + STR assumptions: flow from previous reaches is instantaneously available at the next reach in flow direction

1. The code is provided to produce the first set of 'correct' figures. Use these figures to describe the nature (direction/magnitude) of stream/aquifer exchange along the stream. In particular, explain why the leakage changes magnitude or direction where these values change.
   * Chart, histogram

     Description automatically generated
   * At row 21 or 22 there is a jump in our flow and it increases at a faster rate than before. Then at row 30 our flow begins to decrease and our head values level off. Around row 45 flow ceases and our head drops.
   * Part of the reason is because we have a sink at the bottom right of our domain where water from our stream is being pulled towards it.
   * Another part of the reason is how our river bed conductance changes from low to high going down our domain. This lowers the head values and our hydraulic gradient decreases, reducing flow values.
2. Use the head distribution to describe the movement of water across the boundaries and into/out of the stream.
   * Chart, diagram

     Description automatically generated
   * Water is moving into our domain from the entire left side and the top right corner of our domain. This is because of our high constant head boundaries we have set (9 and 10). On the right side of our boundary we have a constant head boundary, but it changes from 10 to 3m from the top of the domain to the bottom. Water from the entire system is moving toward the bottom right corner toward the lower head.
3. Choose two things to explore (e.g. impact of streambed K or inflow into the river or recharge rate). Produce a plot for each to compare to the base plots and use the plots to explain the impact of the hydrologic change.
   * I changed the right boundary condition to be constant head of 9 for the entire column
   * Chart, line chart

     Description automatically generated
   * Our flow continually increases from top to bottom of the domain.
   * Around row 23, our flow rate jumps and increases. This is in part because of our high conductance at the lower reaches of our stream.
   * I’m not entirely sure what it means to have a head higher than the stage head of the stream. Is there some type of pressure causing the head to be greater at the top of our stream…?
   * Our flow increases at the bottom of our domain because our K increases massively even though our head gradient nearly stops changing.
   * Chart

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   * Our head contour map shows the higher conductance layer of our stream which has lower head and draws water toward it.
   * Alternate Scenario 2- Here I decreased the hydraulic conductivity of the river bottom by 2 orders of magnitude (from 1 to 0.01 f/d). I kept the constant head value of 9 for the right domain.
   * Chart, line chart

     Description automatically generated
   * With low conductance everywhere there is nearly no flow in the stream for the top half of the domain. Then, once we get to a higher conductance area of our stream our flow increases quickly.
   * Our head is above the stage height for the entirety of the domain, which I want to talk about what this means in the real world during discussions.
   * Chart

     Description automatically generated
   * The low K has made It so no flow is going into the stream from our upper rows.