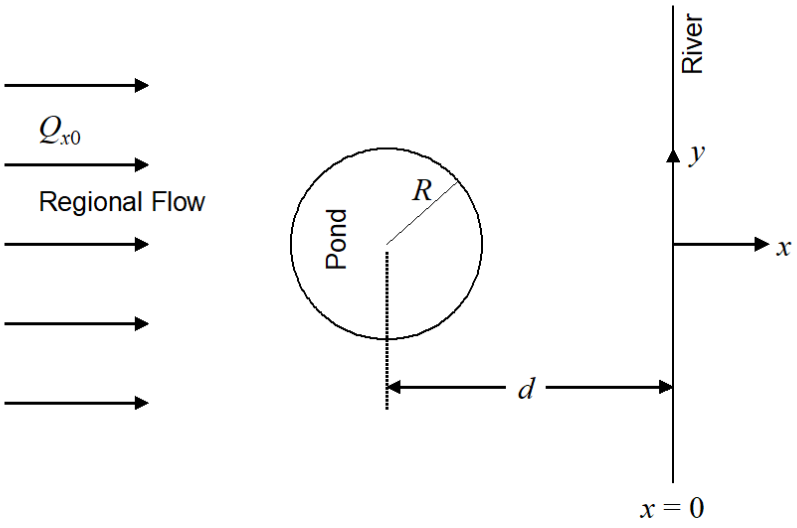
CGN 6933 Groundwater Engineering

Homework #5 Fall 2019

Due Tues., Oct. 15, 2019 Prof. J. A. Cunningham

This assignment will be collected and graded.
Complete this assignment in a team of 2 or 3 students.

Suppose that you are a private consultant who specializes in problems of groundwater flow. You have been hired by the U.S. Environmental Protection Agency (EPA) for the following problem. A certain company operates a waste disposal pond in the vicinity of a river. The disposal pond is not lined on the bottom, so the wastewater in the pond can infiltrate down into the groundwater. The regional groundwater flow is towards the river. The EPA has hired you because they are concerned that perhaps the river is becoming contaminated by wastewater. A diagram of the situation is provided below. The discharge rate of the regional flow is Q_{x0}, the radius of the disposal pond is R, the distance from the center of the pond to the river is d, and the infiltration rate through the bottom of the pond is N. The aquifer is unconfined.



(1) Write the expression for the discharge potential, $\Phi(x, y)$, of the groundwater. The hydraulic head at the river is $h = 10$ m. (The river is a constant-head boundary.)

(2) The EPA informs you that $R = 20$ m, $d = 500$ m, $N = 10$ cm/d $= 0.10$ m/d, and $Q_{x0} = 0.5$ m^2/d. The hydraulic conductivity in the aquifer is $K = 3 \times 10^{-4}$ cm/s and the porosity of the aquifer is $n = 0.33$. The company's records show that the pond has been operating for about 10 years. Has any wastewater reached the river by now? Hint: in order to determine the shortest travel time from the pond to the river, you will need to find the groundwater velocity along the fastest flow path. Also, a spreadsheet will probably be helpful.

(3) The company is going to continue operating its disposal pond in the future. Therefore, the EPA wants you to design a hydraulic containment system (i.e., using wells) to ensure that no wastewater reaches the river. You can use injection wells and/or extraction wells. Assume that the radius of the wells is 10 cm, i.e., 0.10 m. Specify the location(s) and the pumping rate(s) of the well(s). Like most design problems, there is no unique answer to this problem. However, some designs are better than others. Your design should do the following:

(i) Ensure that no contaminated water reaches the river from the pond.
(ii) Capture the contaminated water that is already present in the aquifer from the 10 years of operation so far. (From problem (2), you know how far the contamination has made it so far.)
(iii) Make sure that you do not draw down the aquifer all the way to the bottom, i.e., h cannot be less than zero anywhere in the aquifer.
(iv) Use as few wells as possible, because installing wells costs money.
(v) Pump at low flow rates, because pumping requires electricity.
(vi) Extract as little water as possible (though you do want a little margin of safety).
(vii) Avoid pumping water out of the river.

For your final design, show a figure with the equipotentials and streamlines, verifying that no wastewater reaches the river. Also calculate the head at each of your extraction wells to verify that you have not drawn down the aquifer too far. You will probably want to write a program in MatLab.

Although this problem is fictional and has some over-simplifications, it also has some very realistic aspects to it. Problems often do not have a "right" answer; engineering is art as well as science. This problem has constraints, but it is also open-ended. (An unrealistic part of this problem is that you are given reliable estimates of the hydrogeologic properties such as K, the hydraulic conductivity. In real problems, the values of those parameters are often unknown, and must be estimated somehow.)