

Modeling drains



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Introduction

The objective of this example is to illustrate how do simulate internal drains within a soil region using SEEP/W. Drains are often used in engineering design, as well as in agricultural practices. The purposes of the underground drains are extensive, but can include decreasing the risk of flooding, de-saturating near-surface soils, preventing salinization of soils, etc. The example will discuss the addition of a drain under the toe of a slope where water would typically exit, which may lead to salinization of the soil over time. There are two methods that can be used to simulate drains in SEEP/W. Both of these methods will be presented and discussed in this example.

Numerical Simulation

The two-dimensional domain used in this example consists of an embankment with a reservoir of 13 m and a river on the right side of the domain (Figure 1). The slope and soil surface between the reservoir and the river experiences seepage along the toe of the embankment, leading to potential salinization of the ground and poor productivity. The addition of a drainage canal will be simulated to determine the influence of the drain on the overall flow regime.

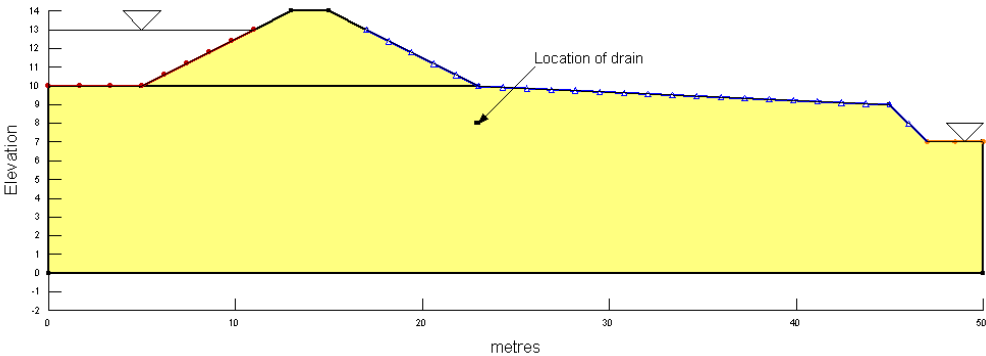


Figure 1. Problem configuration.

The initial steady-state analysis simply shows the flow regime of the domain without the drain present. The upper reservoir is simulated using a total head boundary condition set to 13 m. The river water level is simulated using a head boundary condition of 7 m. A potential seepage face boundary condition is applied along the lower slope near the toe, along the soil surface and along the river bank. This means that the node will be reviewed by the internal solver to determine if the phreatic surface reaches the node. If the phreatic surface reaches the surface node, then the boundary condition will be changed to a pressure head equals zero boundary condition and flow will pass out of the domain along that node.

The saturated/unsaturated material model was used to simulate the homogeneous material representing the embankment and soil. The steady-state analyses do not require the volumetric water content function, as there will be no change in the storage of water within the domain. The volumetric water content function was still defined, however, for use in the estimation of the hydraulic conductivity function. A volumetric water content function was added with a saturated water content of 0.5 and a coefficient of volume compressibility of $1 \times 10^{-3} \text{ 1/kPa}$ (Figure 2). The saturated hydraulic conductivity of the material was set to $1 \times 10^{-5} \text{ m/sec}$ in the hydraulic conductivity function (Figure 3).

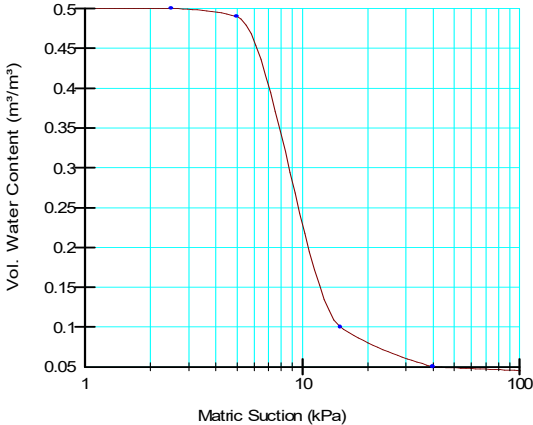


Figure 2. Volumetric water content function of the soil material.

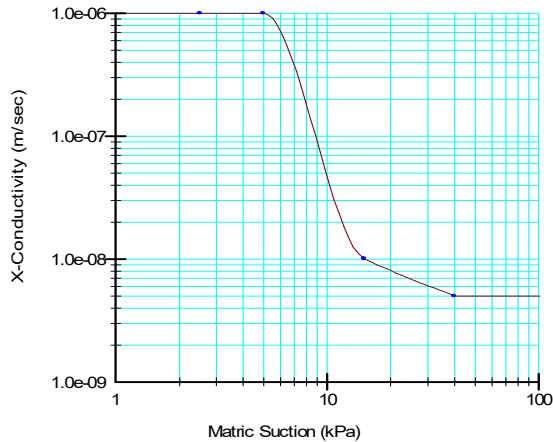


Figure 3. Hydraulic conductivity function of the soil material.

A geometry point was added to the domain in the location of the drain. There are two methods that can be used in SEEP/W to simulate a drain within the soil domain. One way is to model the drain using a physical opening in the finite element mesh. In this method, the Circular Opening option is selected in the Draw Regions window (Figure 4). The first step is to click at the centre of the circle and then to click somewhere along the perimeter of the circle. This creates two Points, which can be refined if necessary with the Define Points command. The x-y coordinate for the centre of the circle is 23, 8 and the point on the perimeter is 22.9, 8. This makes the radius of the circle to be 0.1 m (10 cm or about 4 inches) or a diameter of 20 cm or 8 inches.

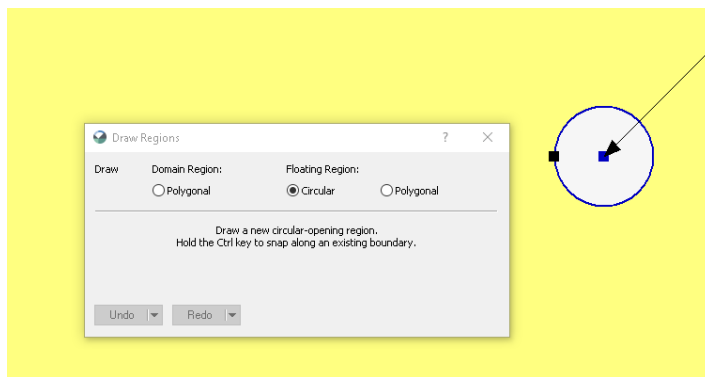


Figure 4. Creating a circular opening in the finite element mesh.

For the analysis that does not include the effects of a drain, the circular opening can simply have the soil material assigned to it. By not including any boundary conditions on the perimeter of the opening, this will treat the domain as a homogeneous soil. For the analysis including the drain, the perimeter of the circular opening must have a boundary condition applied. In this case, the conditions along the perimeter are unknown; neither the water pressure or flow rate into the drain is known at each of the nodes along the perimeter. This needs to be determined as part of the SEEP/W solution. This can be done by making the perimeter a potential seepage face review boundary condition.

A second way of simulating the effect of a drain on a model domain is to simply specify a pressure or head-type boundary condition at the location of the drain. Assuming that the drain can handle the inflow, an appropriate boundary condition is to make the pressure head equal to zero.

The global element mesh size was set to 1 m using the Quads & Triangles mesh pattern. The automatic meshing pattern ensures that a finer discretization exists around the drain location (Figure 5). Elements have also been included within the circular opening in this case, as the first and third analyses require that a material is assigned within the opening.

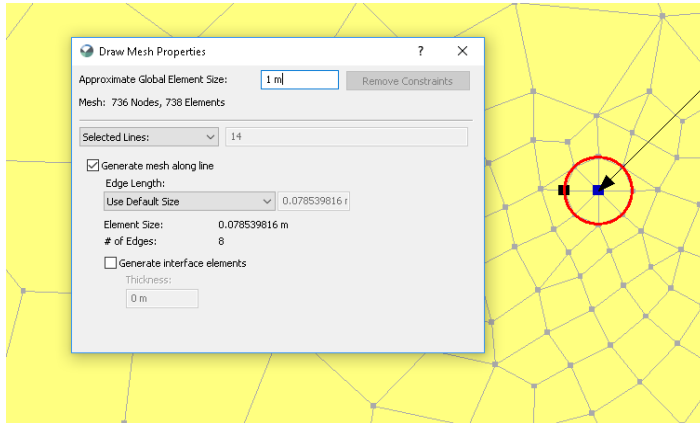


Figure 5. Mesh pattern around the circular opening.

Results and Discussion

The initial analysis without the drain present results in the total head contours and flow paths shown in Figure 6. The phreatic surface (blue dashed line), as well as the top flow path, indicate that water is moving from the reservoir, through the embankment and out of the toe of the slope. Deeper into the soil, the flow paths indicate that there is deeper flow that goes directly from the reservoir to the river bank.

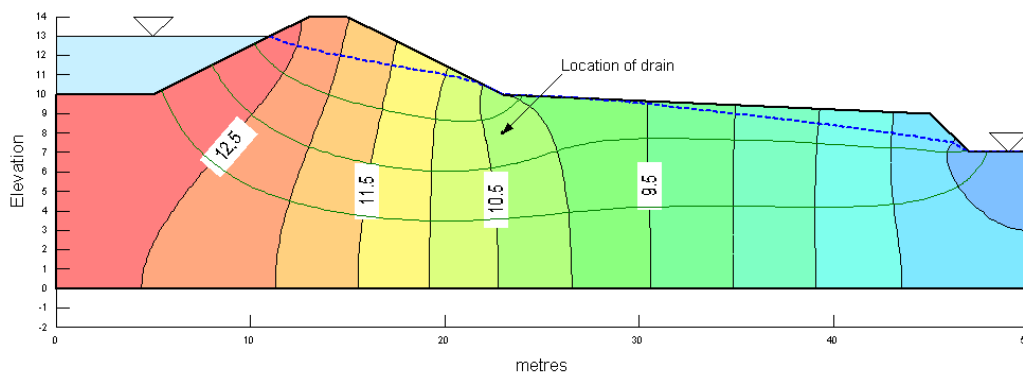


Figure 6. Resulting total head contours and flow paths of the initial condition with no drain present.

In the second analysis, the potential seepage face along the perimeter of the circular opening is effective in preventing the canal leakage from exiting onto the outside ground surface (Figure 7). A

closer look at the drain reveals that the zero pressure contour (phreatic zone) does not reach down to the drain (Figure 8). Using the View Results Information command also reveals that the water pressure along the entire perimeter is zero. This indicates that the drain is within a saturated zone, but it does not mean that the drain is running full of water. This simply indicates that the water is dripping into the drain along the entire perimeter of the circular opening.

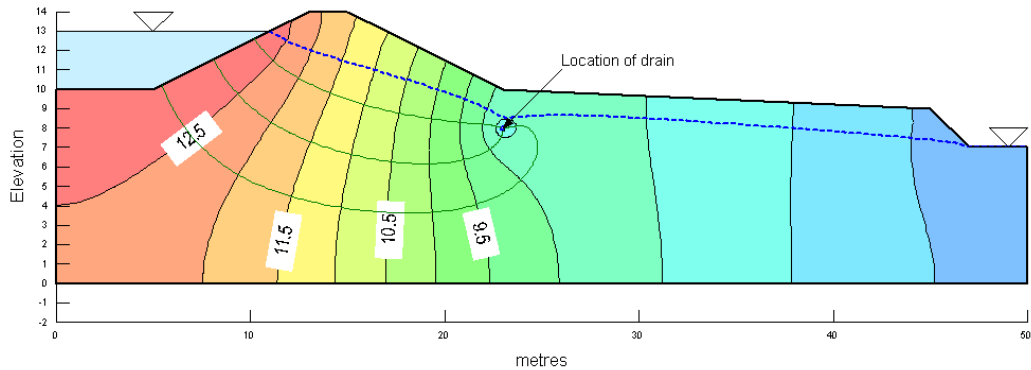


Figure 7. Resulting total head contours and flow paths with the drain present using the circular opening.

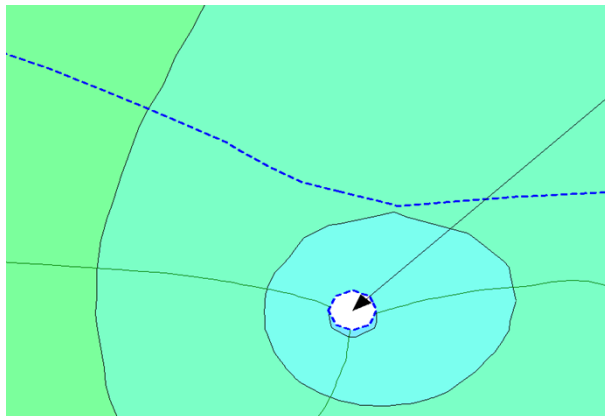


Figure 8. Details of the results around the drain represented by the circular opening.

The amount of water that is dripping into the drain can be determined with the Draw Graph function. The graph parameters need to be set as shown in Figure 9. The subdomain must be a group of complete elements that surround the drain, with the node location set to the drain perimeter (Figure 10). In this case, the total amount of water leaving the domain through the drain is approximately $-2.10 \times 10^{-6} \text{ m}^3/\text{sec}$ (/m in the out-of-plane direction). The negative sign here indicates that water is flowing out of the mesh domain.

The total inflow rate from the reservoir is approximately $2.74 \times 10^{-6} \text{ m}^3/\text{sec}$, indicating that the drain is effective in preventing the seepage from flowing onto the ground surface, with most of the water flowing out of the drain. Only $-6.45 \times 10^{-7} \text{ m}^3/\text{sec}$ of water is flowing out of the river bank location.

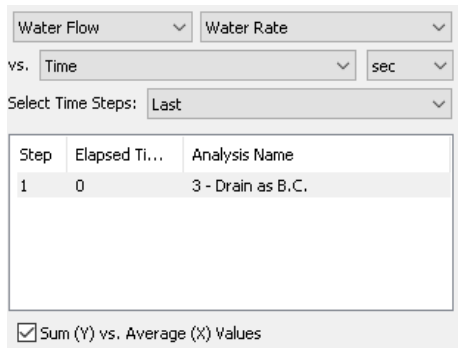


Figure 9. Graphing parameters for the water rate into the drain.

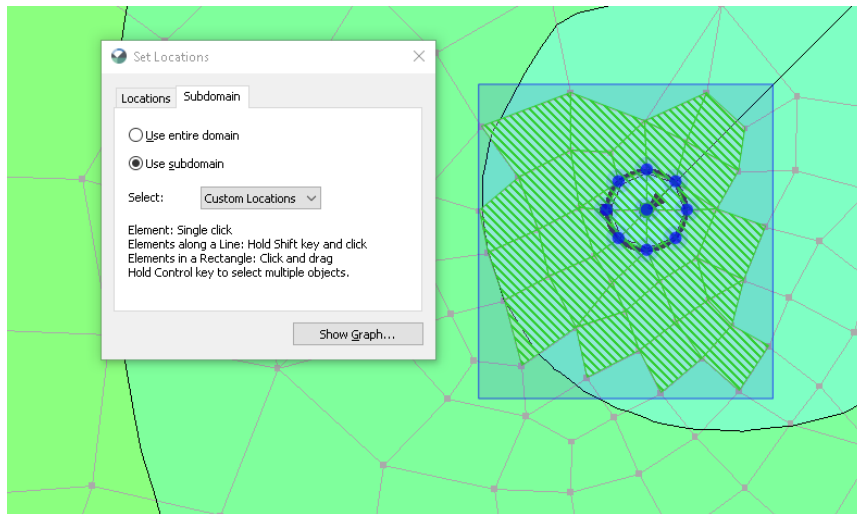


Figure 10. Subdomain and node locations used for the water rate graph.

Figure 11 shows the situation when the drain is simulated with a specified boundary condition at a single node. The result is similar to the above case with the circular opening. The phreatic surface, however, is not drawn down quite as far in this case. The amount of water flowing out of the drain in this third analysis is $-1.77 \times 10^{-6} \text{ m}^3/\text{sec}$, which is slightly less than the circular opening analysis.

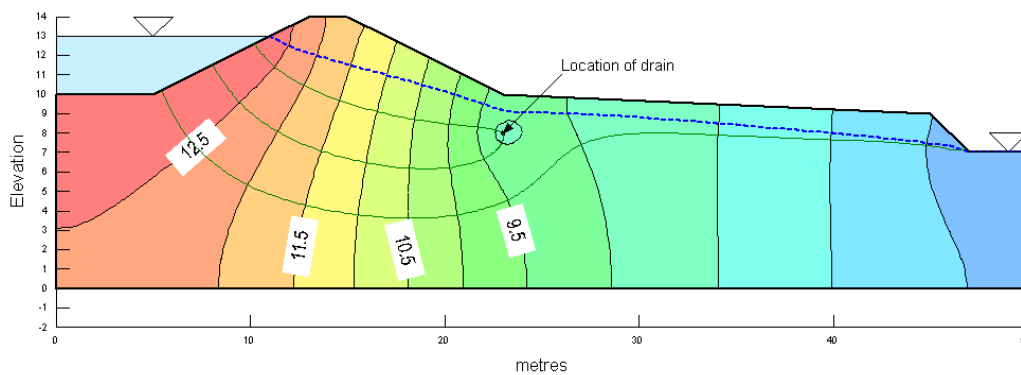


Figure 11. Resulting total head contours and flow paths with the drain present using the boundary condition.

Re-call that the basic finite element equation for steady-state conditions is:

$$[K]\{h\} = \{Q\}$$

Equation 1

where K is the hydraulic conductivity, h is the total head and Q is the total flow rate. When h is specified, the solution gives Q at each node. If Q is specified, the solution gives h at each node.

In the drain problem here, h is specified at the drain location and, therefore, the solution provides Q , even though there is no physical opening. This is one of the beautiful things amount numerical modeling; the effect of a physical object can be simulated with a boundary condition.

Summary and Conclusions

While modeling the drain as a physical opening is perhaps more realistic, the effort and complexity is considerably higher than simply using a boundary condition. The drain simulated in this example is 20 cm in diameter, which is a large drain pipe for this application. Often, the perforated flexible pipes for this type of application are 10 cm in diameter. Including openings of this size becomes increasingly more cumbersome and significantly increases the mesh size.

As the opening becomes smaller, the result tends to be closer to the specified boundary condition solution. So, for small drain diameters, it becomes a question as to whether the added complexity of simulating them as a physical opening is warranted. In light of the accuracy with which the hydraulic conductivity can be defined, the conclusion usually is that the added complexity is not warranted.

Including a small physical opening is particularly difficult in large domains with a very large number of elements. Adding small openings further increases the number of elements required, and thereby further increases the numerical complexity and data management.

It is always useful to start with the boundary condition approach, particularly for small-sized drains. It provides a reference point which can be used to decide whether the added effort and complexity of including physical openings is warranted.