GeoStudio Example File
Foundation with anisotropy

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Introduction

The objective of this example is to illustrate the ability of SEEP/W to simulate groundwater flow in anisotropic porous media in which properties are defined in a rotated Cartesian coordinate system. A gravity dam is simulated with a cutoff wall extending into the foundation material below the upstream side of the dam. Two scenarios are considered, each with a different foundation material. The first foundation consists of an isotropic material while the second consists of an anisotropic material with hydraulic conductivity greater in one direction than in other directions.

Numerical Simulation

Figure 1 shows the problem configuration in which a gravity dam retains water on the left-hand side of the domain while a twenty-foot-long cutoff wall reduces seepage and uplift pressure at the base of the retaining structure.

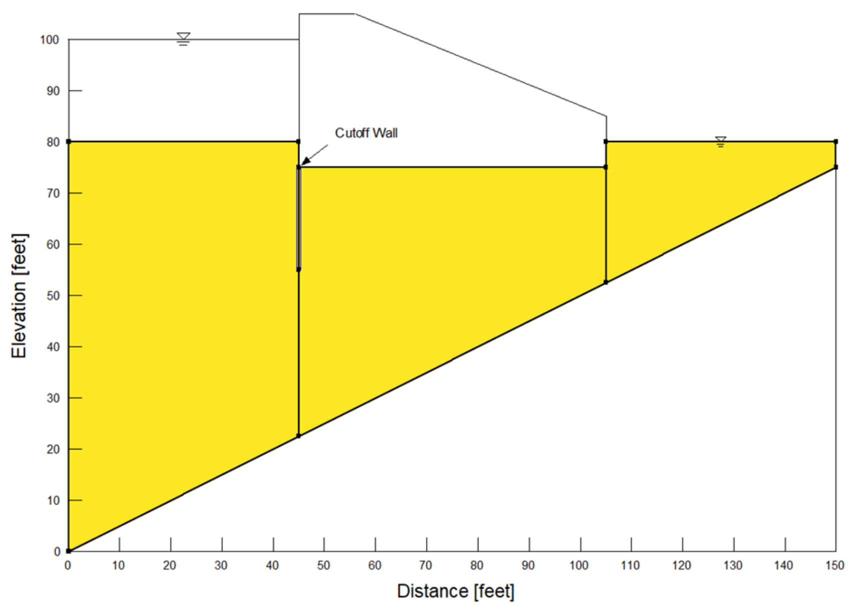

Figure 1. Problem configuration.

The dam is partially embedded in the foundation, which lies on an inclined impervious rock mass. The foundation material is represented by the Saturated Only material model. Figure 2 shows the material definition of the anisotropic foundation material in which the hydraulic conductivity parallel to the stratification is ten times greater than the hydraulic conductivity perpendicular to the stratification The hydraulic conductivity along the x'-axis ($K_{x'}$) is specified while that along the y'-axis ($K_{y'}$) is calculated from the input anisotropy ratio ($K_{y'}/K_{x'}$). The dip direction and dip angle of the stratification are equal to 270° and 26.57°, respectively.

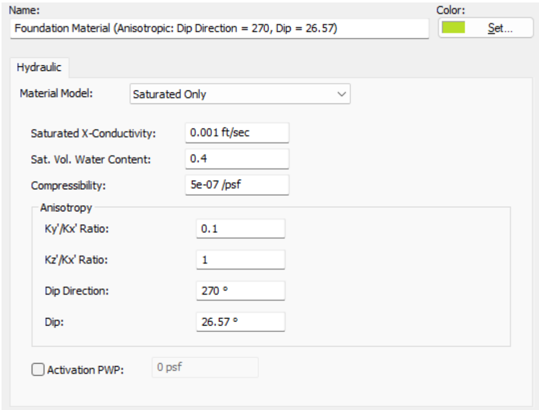

Figure 2. Saturated material properties for the anisotropic foundation material.

As shown in Figure 3, the dip direction is the azimuth of the dip line of the stratification, and the dip angle is the steepest angle of descent of the stratification relative to a horizontal plane. The dip direction is clockwise positive from North, and more specifically, the negative z-axis. The dip angle is always positive and lies between zero and ninety degrees.

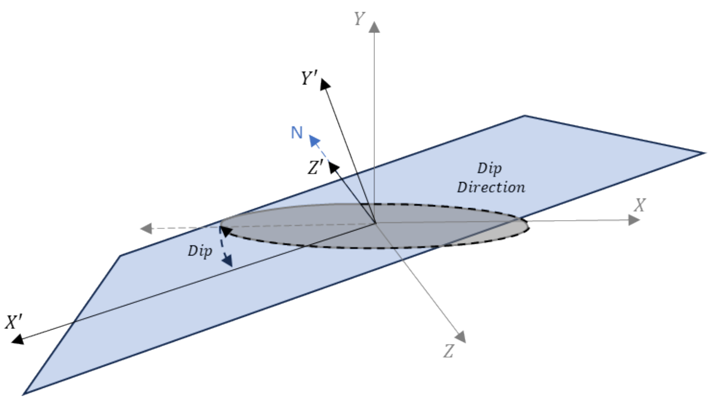

Figure 3. Rotation of the principal conductivity axes.

The cutoff wall is simulated using an impervious barrier, which effectively creates a zero-thickness discontinuity in the mesh. The water in the reservoir is simulated using a total head boundary condition of 100 ft while the tailwater on the downstream side of the dam is simulated using a total head boundary condition of 80 ft. Although not shown here, the file also contains a mirrored domain in which the dip direction and dip angle of the stratification is set equal to 90° and 26.57°, respectively.

Results and Discussion

Anisotropy can sometimes make it difficult to interpret the results of a groundwater flow analysis. A good practice is to start with an isotropic scenario prior to moving on to the anisotropic flow scenario. Figure 4 shows the total head contours and flow paths for the isotropic scenario. The results seem logical and appear to follow the anticipated behavior for homogeneous and isotropic conditions in which flow paths cross the equipotential (or constant total head) lines at right angles.

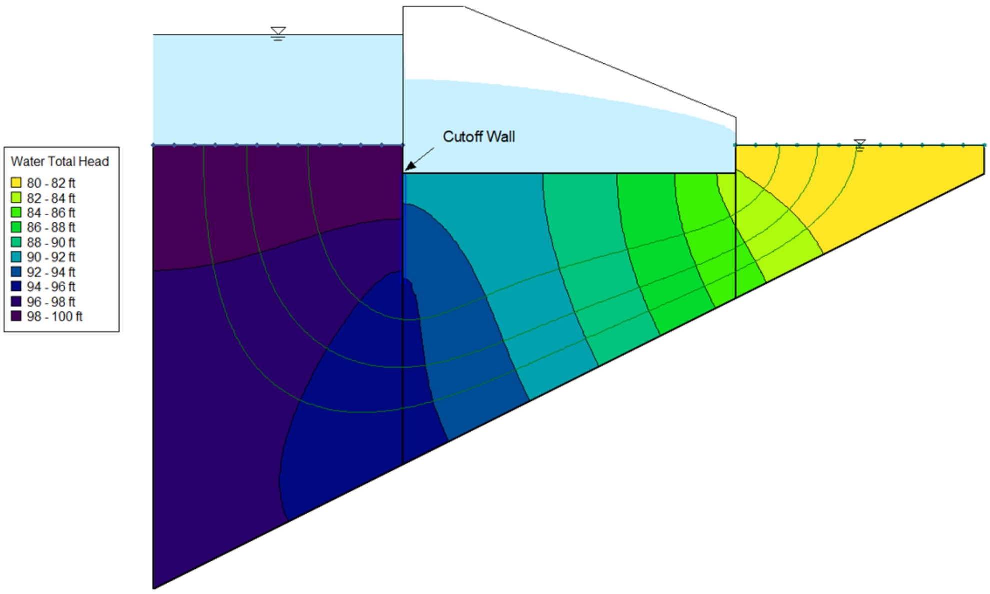

Figure 4. Flow regime for isotropic homogeneous conditions.

Figure 5 shows the total head contours and flow paths for the anisotropic scenario. In this case, the flow paths do not cross the equipotential lines at right angles due to the difference in horizontal and vertical hydraulic conductivity. The location of the total head contours also changes as water moves deeper into the foundation material before flowing laterally towards the ground surface on the downstream side of the dam. In general, the stratification tends to compress the flow net in the direction of lesser hydraulic conductivity and pull or stretch the flow net in the direction of greater hydraulic conductivity. Figure 6 shows the water flux vectors under anisotropic conditions.

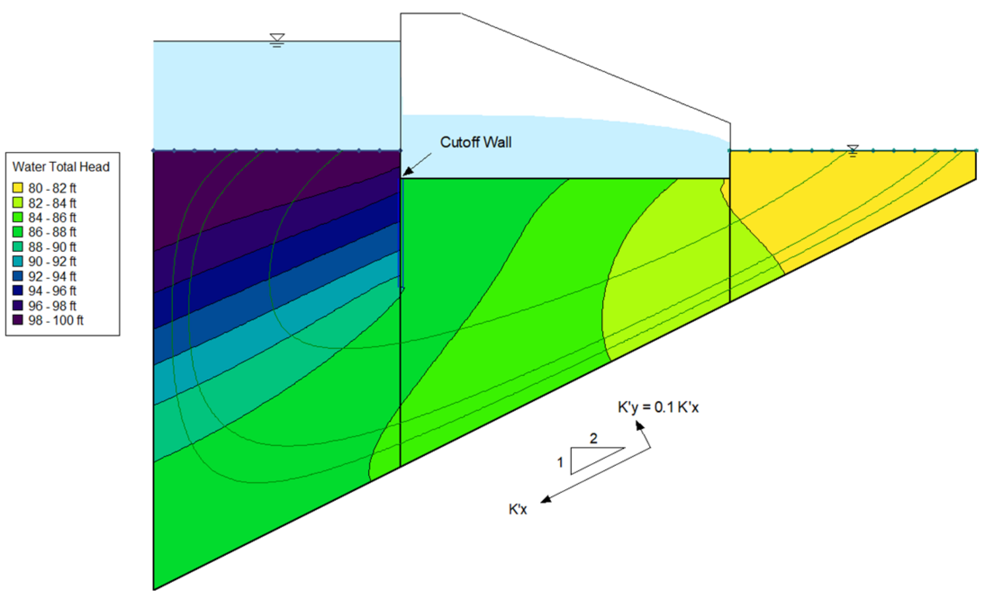

Figure 5. Flow regime for anisotropic homogeneous conditions.

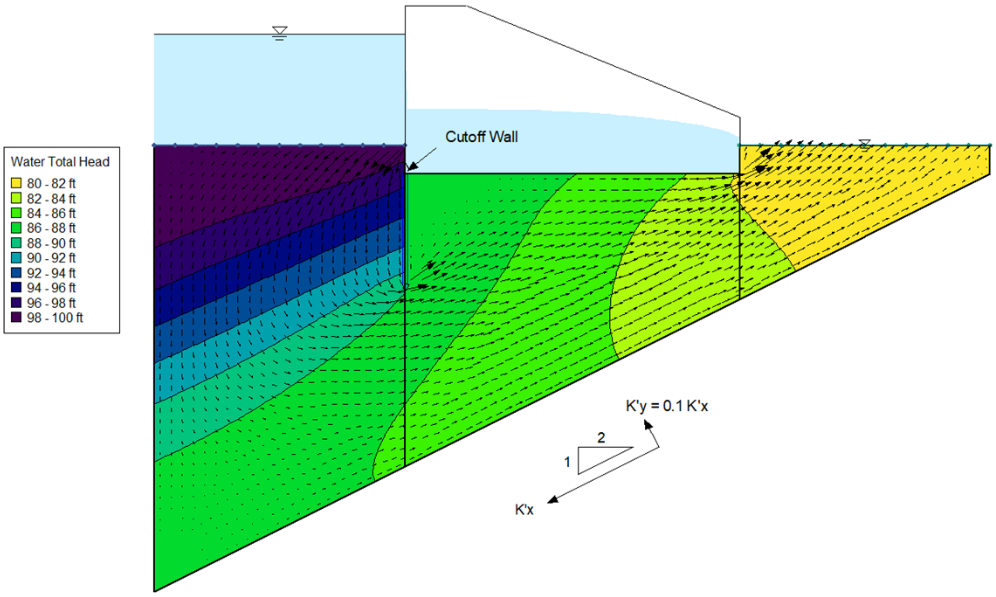

Figure 6. Water flux vectors for anisotropic conditions.

The cumulative water rate graphs indicate that flow under the cutoff wall is lower under anisotropic conditions. As shown in Figure 7, the subdomain was defined along the geometry line below the cutoff wall. The cumulative water rate, which matches the inflow/outflow rates since the analysis is steady-state, was equal to -5.23×10^{-3} and -1.86×10^{-3} m^3/sec for the isotropic and anisotropic conditions, respectively. The negative sign indicates that water is exiting the subdomain as it moves from the reservoir, under the cutoff wall, into the subdomain (and out the node locations) over to the ground surface on the downstream side of the dam.

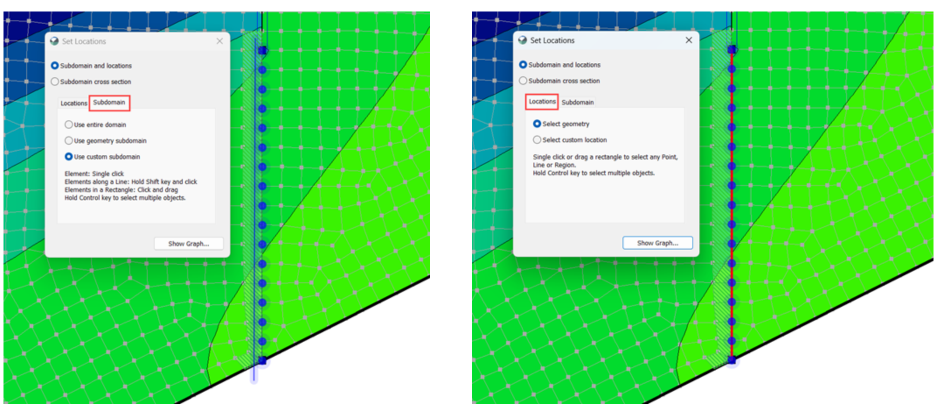

Figure 7. Subdomain and node locations below the cutoff wall.

Figure 8 compares the uplift pressure at the base of the foundation for the isotopic and anisotropic scenarios. The reduced hydraulic conductivity along the y'-axis ($K_{y'}$) causes a greater dissipation of hydraulic head as water flows downwards on the upstream side of the cutoff wall. As a result, the uplift pressures are greatly reduced under the foundation on the downstream side of the cutoff.

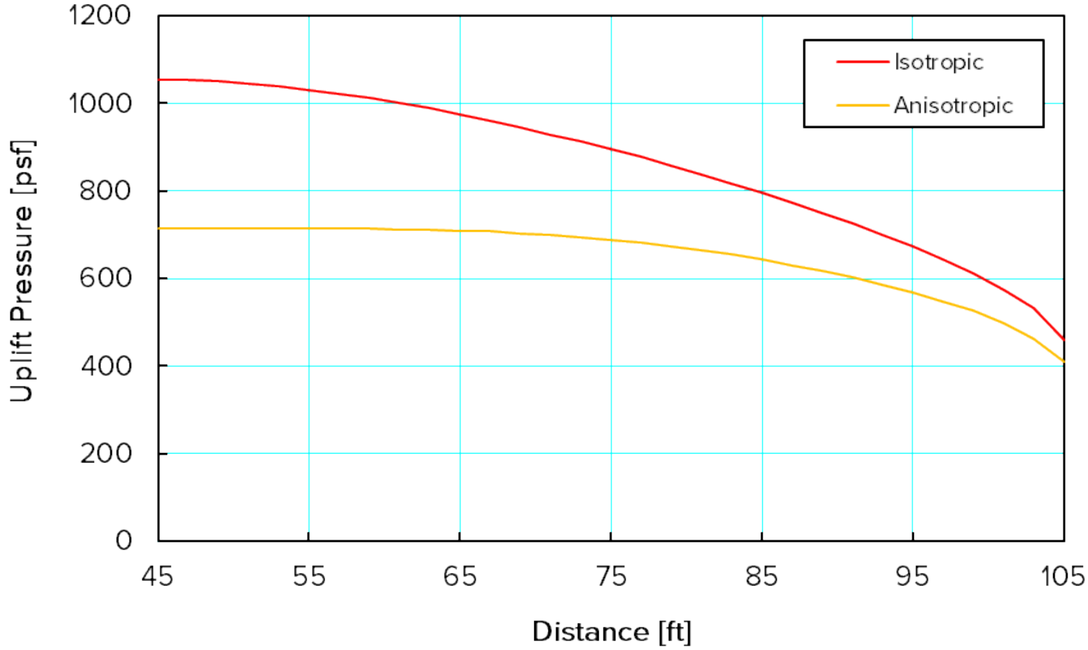

Figure 8. Comparison of the uplift pressures at the base of the foundation for the isotropic and anisotropic scenarios.

Summary and Conclusions

The objective of this example was to illustrate the ability of SEEP/W to simulate groundwater flow in anisotropic porous media. Anisotropy was shown to have a significant effect on groundwater flow. Interpretation of the results is made easier by adopting the best practice of first simulating the isotropic scenario and then introducing anisotropy.