Comparisons of Estimates of Hydraulic Conductivity in the Unsaturated Zone

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Abstract

The main objectives of this research are to assess the effectiveness of ground penetrating radar (GPR) techniques for estimating hydraulic conductivity at multiple depths at the field scale and to determine the infiltration parameters needed to implement this technique. UWEC researchers have recently shown that GPR techniques can be used to estimate hydraulic conductivity and that hydraulic conductivity estimates from GPR data appear to vary with depth. Additional data acquisition using conventional methods for measuring hydraulic conductivity at different depths is needed to evaluate the variations in hydraulic conductivity indicated by the GPR data. Another important aspect of this research is to determine the infiltration parameters needed to provide the constant rate of infiltration. Additionally, accurate estimation of hydraulic conductivity using GPR techniques requires constant (steady state) infiltration over the test interval being investigated; this research seeks to determine the duration and interval of infiltration needed to establish constant infiltration for a range of sampling depths and soil types using numerical simulation and laboratory column experiments. The results of this research can be used to generate practical guidelines for estimation of hydraulic conductivity in the unsaturated zone that would be of great interest to the agricultural and geological communities.

Methods

Sieve Tests

The samples were sieved for a few reasons. Any soil that was sieved gave data on the percentages of sand and fines in the soil. The sieves were used with approximately 500 grams of soil that was crushed beforehand to separate any particles that would stick together. Another reason that the soils were sieved was to obtain fines. The soils are added to the top sieve, shaken on their way down and fall through a series of screens. The fines were anything that fell below the screen diameter of 200 micrometers.

Hydrometer Analysis

The hydrometer analyses were done on the 14 soil samples collected from Spooner, Wi., in the 0-6 in range. Each of the soils were sieved beforehand and the fines were separated out. These fines were then combined with a deflocating agent and water. The hydrometer tests ran for 48 hours during which time data was recorded fifteen times. These times were specifically meant to show the speed at which the fines sank to the bottom changing the density of the water. Based on the amount of time and the readings on the hydrometer, the percentages of silt and clay in each of the soils were determined, giving a more accurate picture of the soil texture.

Falling Head Permeameter

The falling head tests were used to determine the hydraulic conductivity of available soils between 0-6 and 6-12 inches to find similarities. Only eight of the fourteen soils were available to test for both depths and thus able to be compared. The falling head tests are a common laboratory method used to determine hydraulic conductivity. The tests used in this study were shown to show how long it would take for the water to pass through saturated samples of soil.

With all of the data collected from different tests, the next step was to compare all of the data. This was done using the Microsoft Office Excel program.

Results

In general, Ground Penetrating Radar data resulted in higher hydraulic conductivity values than those obtained from infiltration measurements. This is due to the delays tested. The Ground Penetrating Radar data was tested at a shallower depth than the double ring infiltrometer data. Shallow depths have more permeability than deeper soils resulting in higher hydraulic conductivity values related to Ground Penetrating Radar.

The average percentages of sand, silt, and clay within the soil was found to be approximately 87%, 10%, and 2% respectively. This was at a depth of 1 to 6 inches. The average hydraulic conductivity of the soil overall was 0.1 to 0.25 cm/sec.

Figure 1: This graph shows the percentages of clay found in each soil sample, at a depth of 1 to 6 inches, compared to the hydraulic conductivity measurements from the same depth.

Figure 2: This graph shows the percentages of silt found in each soil sample, at a depth of 1 to 6 inches, compared to the hydraulic conductivity measurements from the same depth.

Figure 3: This graph shows the percentages of sand found in each soil sample, at a depth of 1 to 6 inches, compared to the hydraulic conductivity measurements from the same depth.

Figure 4: The following graphs show comparisons between all of the methods used for estimating hydraulic conductivity. Each has a correlation added showing R values. The R values can be used to understand how well the data is correlated. A higher R value means the better the data is correlated. In the top graph, the Double Ring INFIL and GPR are seen to be the best estimates. In the bottom graph, the data from GPR and Hazen’s method are seen to be the best estimates.

Conclusion

In conclusion, Ground Penetrating Radar data provided the highest values of hydraulic conductivity followed by falling head permeameter tests, double ring infiltrometer tests, and Hazen’s method. It was assumed that the ground was fully saturated in order to obtain accurate data from the ground penetrating radar. Both the GPR and double ring infiltrometer methods for calculating hydraulic conductivity occur in situ, or in the field. This allows for the calculations to be completed when the structure of the soil is preserved. The other methods, falling head permeameter tests and Hazen’s method, do not account for the original structure of the soil. Through the various methods of estimating hydraulic conductivity as well as obtaining the percentages of sand, silt, and clay, the soil of Spooner field can be characterized as a well-sorted sand with a relatively high hydraulic conductivity. Throughout the area though, the soil shows heterogeneity in the soil composition. This results in various degrees of hydraulic conductivity and shows the importance of the structure of the soil which makes in-situ tests such as GPR and Double Ring INFIL more important.

Future research around this topic would be to continue to test more data points to increase the accuracy of each of the tests and improve upon the initial comparison. In addition to collecting data from more locations, other testing techniques such as the Guelph permeameter could be used to estimate hydraulic conductivity. The Guelph permeameter would provide estimates at depths of 6 to 18 inches. This would help to further characterize the hydraulic conductivity of the soil. It would be beneficial to complete the falling head tests that were started by collecting more samples of unsieved soil from each field location as well.

References

- ASTM International, Standard Test Method for Infiltration Rate of Soils in Field Using Double-Ring Infiltrometer, West Conshohocken, PA.
- Holman, which provided access to the site and equipment for double-ring infiltrometer tests.
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