ceNEWS.com

Rock, water, and wells

ASSESSING GROUNDWATER RESOURCES IN FRACTURED ROCK AQUIFERS

By Chuck Houser, CHG, CEG

Multiple fracture orientations are visible in this outcrop. Note two major sets are near vertical and dipping toward the right of the photo. A well drilled through rock with dipping fractures may encounter multiple fractures and provide abundant groundwater supply.
Photo: Chuck Houser/SCS Engineers

Accessing groundwater is a viable alternative when obtaining water as a water resource. However, properly drilling a groundwater supply well is a multi-faceted endeavor that involves considering basic water quality trends, assessing aquifer characteristics, estimating water production, evaluating impacts groundwater supply wells have on each other within a particular basin, and recognizing cultural and political allotments. Hydrogeology can be applied to accurately assess groundwater quantity and quality, and in fractured rock aquifers a "fractured trace analysis" can yield valuable information to evaluate potential water supply.

Typical aquifers are composed of porous sedimentary geologic materials, with variable grain size, porosity, and groundwater flow characteristics that are relatively consistent. This consistency makes it slightly easier to calculate an aquifer's transmissivity and storage, assess quality, and estimate quantity. Once a water supply well is installed, estimates may be close to actual quality and quantity of water obtained.

Fractured rock aquifers require a different approach because groundwater flow is controlled by fractures in the subsurface. When assessing a fractured rock aquifer, several aspects of the aquifer must be evaluated. The characteristics of the fractures containing groundwater impact water quality, quantity, and sustainability. Fracture characteristics affecting groundwater flow include frequency, orientation, interconnectedness, width (aperture), and openness or filling of fracture. For example, a fractured rock aquifer with discrete fractures of similar orientation and mineral-filled may result in low water production. Conversely, an aquifer with many variable, interconnecting, and open fractures may yield high water production. Evaluating a fractured rock aquifer as a groundwater resource begins with completing a hydrogeological study that includes researching existing information about the hydrogeology for a site, and completing a fracture trace analysis for the site area.

Fracture trace analysis

Initially, a fracture trace analysis involves an evaluation of photolineaments visible in aerial photographs. Photolineaments provide clues about the nature of fractures in an aquifer. Evaluating photolineaments in aerial photographs can identify fractures in rock outcroppings, topographic lineaments, lines of vegetation, or other features indicating possible fractures. Combining information from a photolineament study with research into existing wells that includes locations, quality, and quantity can provide valuable insight into a fractured rock aquifer.

After completing the photolineament study, field mapping is performed, which requires a decent pair of boots, sunscreen, and a good compass. Field mapping is performed to collect data on the locations and orientations of fractures, and to help confirm whether observed photolineaments may represent fractures or other relevant structural features in the site vicinity. Data collection efforts may be optimized by focusing on readily available rock outcroppings visible from roads and clearly defined trails. Because unlimited data cannot be collected from all outcrops, focus on obtaining fracture measurements and descriptions without giving much consideration to preferred fracture orientations or fracture sets inferred from the photolineament study. Attempting to evaluate fracture data relative to the photolineament study in the field might bias the data collection efforts.

A groundwater supply well is drilled at a golf course in fractured rock terrain in central San Diego County. Abundant groundwater flowed from the well bore during drilling. *Photo: Chuck Houser/SCS Engineers*

Data collected in the field is used to plot fracture attitudes on a stereonet, which can be created manually or by using a plotting program such as Stereo 32 to plot the points of the fracture planes and generate a contour of the fracture measurements. A hydrogeologist will use a contour plot to differentiate between outcrops, observing distinct areas of a site and site vicinity, and selecting preferred fracture orientations.

Interpretation

Once field mapping is completed and evaluated, it is compared with the photolineament study interpretations, and similarities may be noted. Photolineaments and field mapping are also evaluated with respect to regional structural features such as faults. Hydrogeology research, interpretations from the photolineament study, and field mapping are integrated into a hydrogeologic study to develop a structural picture of the site.

During one such hydrogeologic study, the photolineament study revealed two preferred orientations of photolineaments. A majority of observed lineaments were relatively short and trended roughly northeast-southwest. Another preferred orientation was roughly west-northwest and were long, relatively continuous lineaments through the site vicinity. Based on the fracture measurements, just over 50 percent of the measurements were oriented generally northeast-southwest, and were interpreted to be the primary fracture set for the site vicinity. The secondary set, comprised of approximately 20 percent of the measurements, was west-northwest trending, and over half the fractures in the secondary set were described in the field as shear zones in the rock.

In this case, a major regional northwest-trending strike-slip fault was located within approximately 2,000 feet of the site. The west-northwest through-going photolineaments and the northwest-trending fracture sets with apparent shearing are consistent with the regional faulting near the site. In addition, other research previously conducted in the vicinity regarding primary and secondary fractures was remarkably consistent with the findings of the assessment. This consistency between vicinity research and fracture trace analysis provided strong support for the conclusions presented in the hydrogeologic study for the site.

Summary

Random fractures in fractured rock aquifers add an additional layer of difficulty when completing hydrogeologic studies in these environments. Even when a relatively well ordered fracture system exists, the spacing, orientations, and overall characteristics of the fractures tend to be random. The practice of hydrogeology in such environments involves assessment of several aspects of the aquifer to effectively evaluate potential water resources. Even so, when the assessment is complete and all data taken into account, there will still be that sense of anticipation when the drill bit begins turning and the test borings progress: Will we find water today?

Chuck Houser, CHG, CEG*, senior project hydrogeologist with SCS Engineers, has more than 27 years of experience in the earth science industry. Working in a variety of geological conditions around San Diego County, he has conducted environmental site assessments, groundwater monitoring, fault and landslide investigations, groundwater resource studies, geological mapping, and geotechnical investigations.*