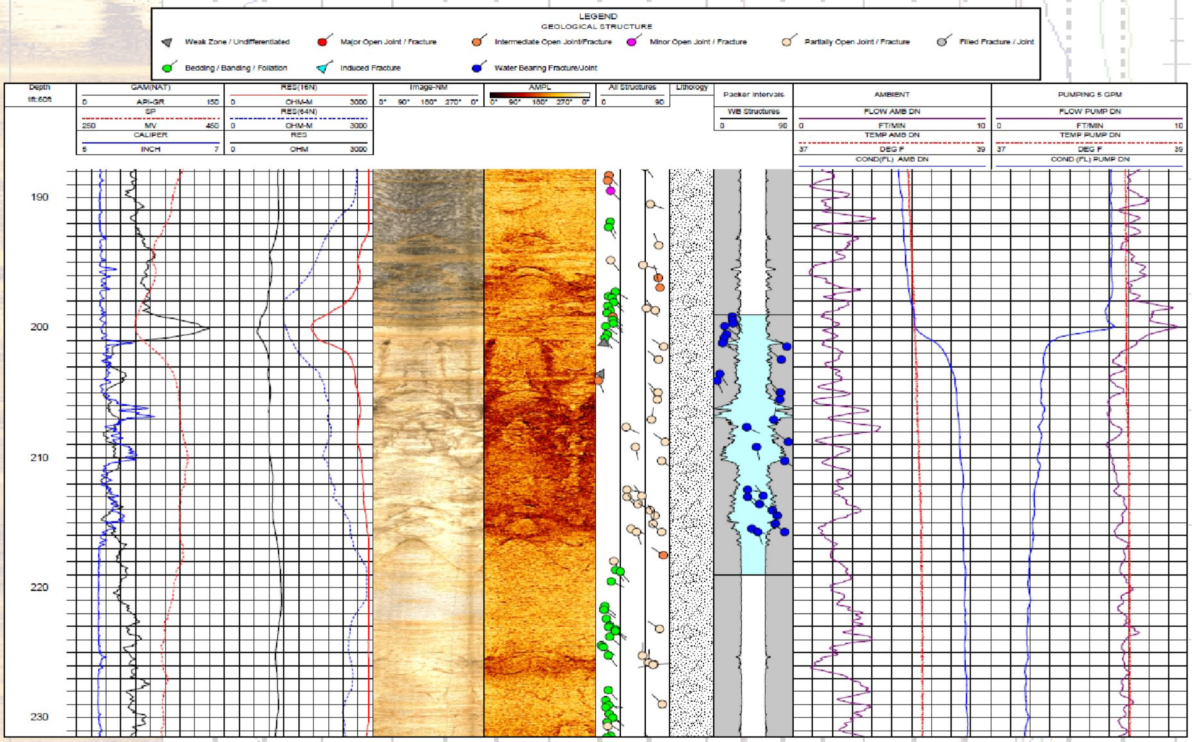
Using Borehole Logs to Understand PFAS Contamination (Fate and Transport) in Aquifers

Accurately characterizing PFAS[1] in aquifers is a challenging proposition. Extremely low detection and minimum concentration limits for PFAS require downhole tools and testing equipment to be 100% PFAS-free. To comply with these requirements, RAS recently developed and modified borehole geophysical, hydrophysical and straddle packer testing equipment to be remove any potential PFAS contributing components. After verification of the PFAS-free equipment, RAS applied this equipment at an active site investigation near Bennington, Vermont.

The site hydrogeology was a fractured bedrock aquifer and extremely difficult to drill. Due to hole stability issues, both open-holes and completed wellbores were evaluated. RAS's tools proved to be applicable in both screened and open wellbores in the PFAS setting.The downhole equipment included, 3-arm caliper, natural gamma, normal and single point resistivities, fluid temperature and fluid electrical conductivity, electromagnetic flowmeter, hydrophysical logging, straddle packer testing, groundwater sampling, discrete point sampler, borehole analog video, borehole optical and acoustic televiewers.These tools were applied as part of a large comprehensive site investigation in four newly drilled wells to fully characterize the fractured aquifer groundwater flow system. Specifically, these tools were deployed to evaluate the extent and orientation of the fracture network, evaluate the water bearing fractures, the associated geology and to determine the vertical extent of the PFAS contamination.



The results of the study showed that: 1) water bearing fractures were a small percentage of the total number of fractures observed in the borehole; 2) the water bearing fractures were present among all the major geologic units; 3) the water bearing fractures displayed high hydraulic conductivity; and 4) the PFAS contamination appeared widely dispersed vertically, as the deepest water bearing zones (at 300 feet) were contaminated.

Our investigation suggested that the conductive fracture network was vertically connected and that PFAS at this site was widely dispersed spatially; similar concentrations were observed vertically in the conductive fractures in the tested wellbores. This information was critical in developing an accurate site conceptual model and preliminary considerations for the design of a more effective remedial approach.

[1]Perfluoroalkyl compounds (PFAS). EPA recommends no more than 70 parts per trillion in drinking water, California is considering allowing no more than 27 ppt.

REALtime Aquifer Services

http://www.rasinc.org
bpedler@rasinc.org
Phone: 303.517.0509

1634 W. Alpine Ave.
Stockton, CA 95204

Summary Description of Geophysical and Flow Measurements Deployed

Tool Name (Abbreviation)	Description
Three-arm caliper	Continuously measures diameter of well casing and open hole.
Natural gamma (NG)	Measures natural radioactivity of geologic materials, commonly used to identify lithology.
Downhole camera (DHC)	Provides visual inspection of casing and open borehole. Affected by water clarity in the fluid column.
Full wave sonic (FWS) and cement bond log (CBL)	Detects the degree of cement bonding to the steel casing. Limited to the fluid filled portion of the cased interval. FWS useful in open hole section of wellbore to locate changes in lithology and structure.
Compensated gamma-gamma density (GGD)	Measures natural bulk density, directly detects voids and openings in annular material behind steel and PVC casing.
Neutron	Detects hydrogen content, saturated porosity and moisture content of geologic materials. Typically, a complementary log to GGD logs in well integrity studies.
Fluid Resistivity and Temperature	Measures the temperature and resistivity of the fluid column.
16-64 Normal, Single Point Resistance (SPR) and Spontaneous Potential (SP)	Measures the electrical properties (primarily resistivity) of the formation.
Acoustic Televiewer (ATV)	Provides high resolution information on the location and character of secondary permeability, such as fracture and solution openings as well as strike and dip of planar features such as fractures and bedding planes. Requires fluid in hole.
Optical Televiewer (OTV)	Provides high resolution, 360-degree image of the borehole wall, both above and below the water table, and location and character of secondary permeability, such as fracture and solution openings. The oriented image provides strike and dip of planar features such as fractures and bedding planes.
Electromagnetic Flowmeter (EMFM) and Hydrophysical Logging (HPEM)	The electromagnetic flowmeter consists of an electromagnet and two electrodes with no moving parts that operates according to Faraday's Law of Induction and is deployed to identify water bearing, or hydraulically conductive intervals. A recent upgrade to this tool included installation of a high-resolution fluid electrical conductivity sensor. HPEM is an advanced version of the EM flowmeter incorporates a high resolution FEC sensor (and temperature). This upgrade optimizes advancements of both the EM and hydrophysical logging approaches, typically involving profiling of the wellbore fluid column for extremely high resolution evaluation of water bearing intervals and associated flow rates. The upgraded FEC/T sensor affords better, less obstructed flow through the EM sensor, better flow by the FEC/T sensor and improved FEC response. The upgrade has resulted in better identification and quantification of water bearing intervals in the borehole of interest.
Straddle Packer Testing and Sampling	Based on the results of the borehole geophysical and flow evaluation surveys, the identified water bearing intervals are selected for application of the straddle/single packer sampling system. The straddle packer system has been developed for challenging site specific conditions and is designed to collect isolated groundwater samples and interval specific hydrogeologic information. Packer elements can be deployed at varying intervals of separation, depending on well conditions with varying pumping systems and sampling approaches, including a bladder system for low discharge rates and an electric submersible for higher pumping rates.

REALtime Aquifer Services

http://www.rasinc.org
bpedler@rasinc.org
Phone: 303.517.0509

1634 W. Alpine Ave.
Stockton, CA 95204