Appendix B. Borehole USGS 136 Geophysical Logs (480–1,048 ft BLS)

Geophysical Logs

Wireline geophysical logs were run after completion of coring and during construction of borehole USGS 136; geophysical data were presented for the interval 480 to 1,048 ft below land surface (BLS). Geophysical data were collected using Century™ logging equipment, and data files were processed using WellCAD™ analytical software. A composite geophysical log (fig. B1) is provided in appendix B; a summary of log measurements, tool specifications, property measured, and log application is given in table B1. Additional information on the interpretation of geophysical logs in groundwater studies can be obtained from some of the suggested publications: Keys (1990), Hearst and Nelson (1985), and Paillet (1994).

A synergistic approach was used to view all geophysical logs, side-by-side, to determine information about the aquifer flow and stratigraphy. Borehole logs indicate specific features that were verified in core and are associated with changes in permeability and (or) areas of inflow and outflow from the borehole under ambient hydraulic head conditions. Additionally, marker features such as sediment layers, fractured basalt, and dense basalt can be related to areas of vertical borehole flow and (or) changes in groundwater chemistry within the eastern Snake River Plain (ESRP) aquifer.

The natural gamma log trace depicts a sediment layer (about 5 ft in thickness) near 723 ft BLS, described as silt and clay in the core log descriptions (appendix A). Another sediment layer, not depicted in the natural gamma log, occurs near 503 ft BLS and was described in the core log descriptions (appendix A).

Caliper logs were collected over 2 days, starting May 11, 2011, then merged into a continuous trace. Caliper log traces were displayed as left and right (mirror image) and depict slight variations in borehole diameter. The borehole size changes from 3.8 to 4.8-in. diameter near 563 ft BLS, where PQ-size coring stopped and HQ-size coring was started. The log trace helps confirm the presence of fractured basalt and sediment layers.

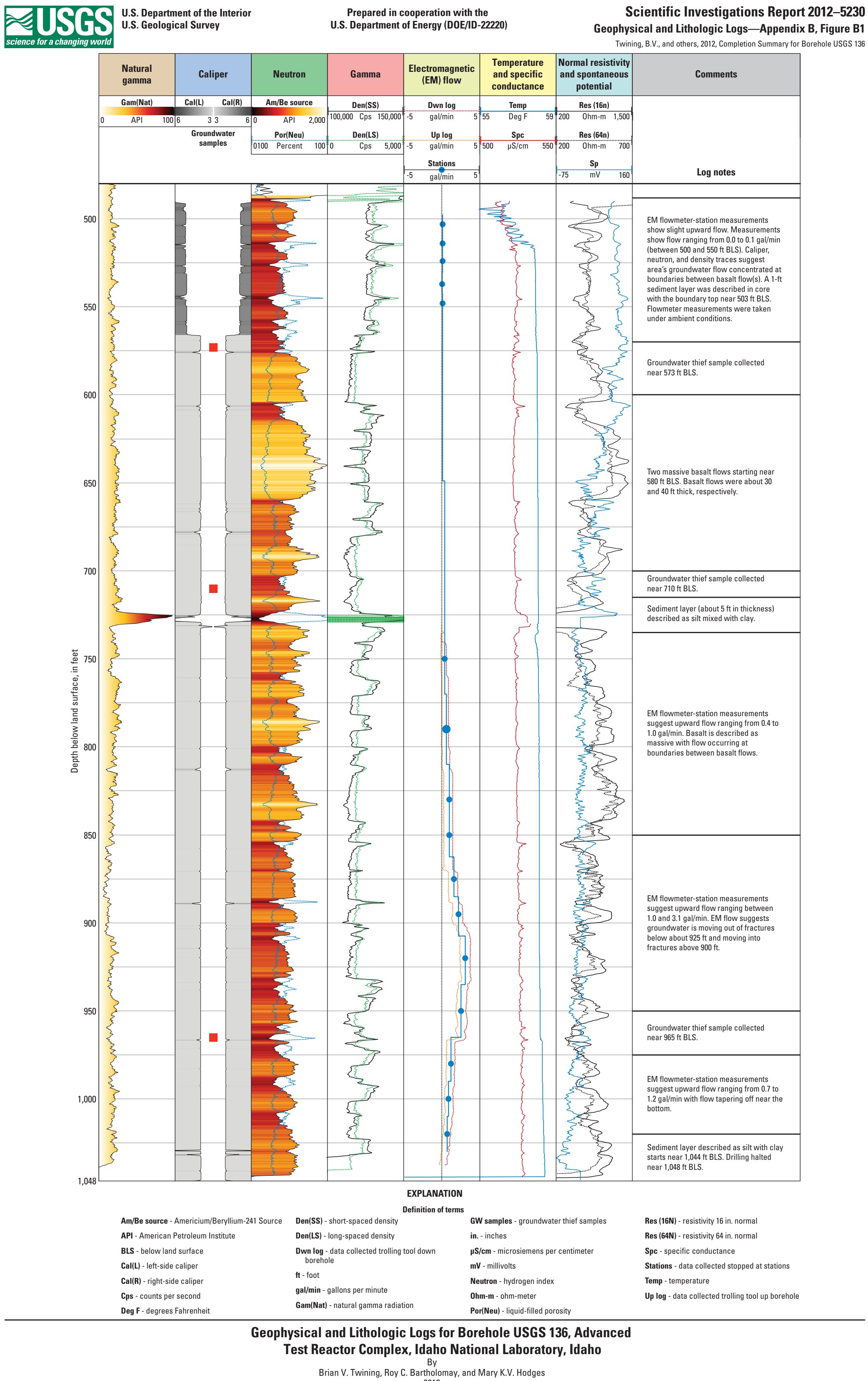
A single neutron log was run through drill steel and used to estimate areas of increased hydrogen content and approximate porosity. A vertical gradient, ranging from red (higher hydrogen content) to white (lower hydrogen content), was applied using WellCAD™ software; these areas correlate with fractured and dense basalt, respectively.

Gamma-gamma density logs were run through drill steel and were used to estimate bulk formation density in the vicinity of the borehole. The short-spaced (DEN(SS)) and long-spaced (DEN(LS)) density logs show good agreement with changes in rock density when compared to neutron logs and visual inspection of core logs (appendix A).

Electromagnetic (EM) flowmeter data (trolling (10 ft/min) and stationary measurements) were collected under ambient conditions after the borehole was allowed to settle for 7 days, post-drilling. Continous trolling flowmeter measurements were collected from about 490 to 550 ft BLS and from 740 to 1,040 ft BLS; stationary measurements were collected after continuous trolling measurements and displayed in figure B1. Measureable upward groundwater flow was detected in borehole USGS 136 during logging runs. Groundwater flow between 490 and 550 ft BLS and from 740 to 1,040 ft BLS ranged from 0.0 to 0.1 gal/min and from 0.4 to 3.1 gal/min, respectively. The flow regime for the uppermost open-hole interval (490 to 550 ft BLS) consisted of only a slight change in vertical groundwater flow, suggesting subtle hydraulic head differences and predominantly horizontal groundwater movement. The flow regime for the lowermost open-hole interval (740–1,040 ft BLS) consisted of groundwater moving upward out of fractures from below about 925 ft BLS and moving into fractures above about 900 ft BLS, suggesting measureable hydraulic head differences between permeable fractures within this interval.

Measurements of temperature and specific conductance were collected between 490 and 550 ft BLS and from 740 to 1,040 ft BLS and merged into a continuous trace. Groundwater temperature ranged from 55 to 58 °F; specific conductance ranged from 510 to 530 µS/cm. No attempts were made to evaluate a temperature gradient for borehole USGS 136 because detailed temperature profiles in boreholes require several weeks of undisturbed conditions to allow fluid temperatures to stabilize and equilibrate with the surrounding aquifer. Drilling schedules prohibited leaving the borehole undisturbed for this amount of time.

Normal resistivity and spontaneous potential logs were collected between 490 and 550 ft BLS and from 740 to 1,040 ft BLS and merged into a continuous trace. The normal resistivity log (16 normal and 64 normal) shows good agreement with changes in basalt (fractured and dense) when compared to neutron measurements and visual inspection of core (appendix A). The spontaneous potential logs show good agreement with changes in porosity when compared to neutron porosity measurements.



Page-size example of composite geophysical log. A full-size composite geophysical log is available for download as a PDF at http://pubs.usgs.gov/sir/2012/5230/.

Table B1. Summary of geophysical equipment used to log borehole USGS 136.

[Summary of geophysical logs assembled in figure B1. **Abbreviations:** API, American Petroleum Institute; CPS, counts per second; mV, millivolts; µS/cm, micosiemens per centimeter at 25 degrees Celsius; gal/min, gallons per minute]

Log type	Specifications	Property measured	Application(s)
Natural gamma (API)	Sodium iodide (NaI) scintillation detector	Changes in background gamma activity	Stratigraphy and lithology
Caliper (inch) and thief samples	Three-arm caliper Groundwater thief samples taken using electronic thief sampling tool at discrete depths of 573, 710, and 965 feet below land surface	Borehole diameter Groundwater quality	Fracture identification Electronically controlled probe valve enables collection of depth discrete groundwater samples
Neutron (API) and porosity (percent)	Helium-3 detector 1.0 Curie, americium-241/ beryllium source	Neutron flux attenuation	Stratigraphy and lithology
Gamma-gamma (CPS)	NaI scintillation detector 200 millicurie, cesium-137 source	Omi-directional, non-focused density	Apparent density changes
Flowmeter (gal/min)	Electromagnetic (EM) flowmeter	Vertical borehole flow	Entry and exit points for flow
Temperature (degrees Fahrenheit) and specific conductance (SpC) (µS/cm)	Fluid column measurement	Borehole fluid temperature and fluid specific conductance	Borehole flow and changes in water quality
Normal resistivity (RES) (ohm-meters) and spontaneous potential (SP) (mV)	16- and 64-inch spacing Electric potential	Formation resistivity Electric potential, in millivolts, between borehole and grounded surface voltage	Lithology and porosity Changes in rock properties