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April 16, 2009

Neal Farmer
Special Projects Coordinator
Idaho Department of Water Resources
322 E. Front Street
P.O. Box 83720
Boise, ID 83720-0098

Re: Hagerman Fish Culture Experiment Station – Exploratory Borehole No. 1

Dear Neil:

Hydro Logic, Inc. (HLI) was called upon to run a suite of borehole geophysical logs in the Hagerman Fish Culture Experiment Station Exploratory Borehole No.1 on August 13th, 2008. Kurt Newbry of HLI met Neal Farmer on site to run the geophysical logs and later to inspect the drill-cuttings from the bore for comparison to the geophysics. We were also able to run a down hole underwater camera survey to 225 feet below ground after clearing the well by adding water from another on site well. Therefore we were able to directly visually inspect the upper 225-feet of basalt volcanics. Finally, HLI was asked to interpret the geophysical logs with respect to the drilled geologic section and to provide a short synopsis of our observations.

1) **DRILLED GEOLOGIC SECTION:**
   a. A nominal 6-inch diameter air-rotary drilled bore was advanced to 703 feet below ground level (bgl) by Eaton Drilling and Pump Service, Inc.

   b. The sampled cuttings, as is often the case in air-rotary drilled wells, are not considered highly representative and our lithologic log (Figure 1) is "adjusted" by using the geophysical logs as a comparison. The composition of the lowermost 352 feet of the bore remains uncertain.

   c. The drilled section consists, generally, of three distinct geologic reaches.
      i. <u>Surficial basalt flows from land surface to ~ 217 feet bgl.</u>
         1. The upper ~ 40 feet of basalt is highly fractured reddish brown-to-dark gray flows.
         2. The fractures appear to be predominantly horizontal.
         3. The basalt, itself, is highly vesicular.
         4. From ~40 feet-to-~80 feet the basalts appear more massive and competent with a predominantly vertical joint/fracture pattern where the fractures appear to be moderately "healed" (infilled with precipitate).
         5. Below ~80 feet, the basalt becomes highly fractured and characterized by an irregular blocky bore.

ii. Interbedded sediments from 217-to 400 feet bgl

1. These interlayered sediments are comprised of approximately 50% low-permeability silts and clays and 50% fine-to-course-grained sands.
2. The sediments are all oxidized in the upper portion (217-to-~300 feet bgl) turning gray-to-dark gray in the lower section (~300-to-400 feet bgl).
3. The lowermost 100 feet showed some weak cementation.

iii. Volcanic basalt flows from 400-to-703 feet bgl.

1. Below ~400 feet, the drilled section reportedly (driller) consists of black-colored lava flows.
2. From the driller's observations, the individual flow units are well defined interflow zones of soft broken lava.
3. The cuttings from this interval, however, are at least 70% sediments (sand and gravel) with lesser percentage of volcanic rocks suggesting that the cuttings may be cavings from above or that the lower section is also comprised of sediments.

2) DOWN HOLE CAMERA INSPECTION:

a. HLI's small diameter (1½") axial (no side view) was used to inspect the 6-inch diameter air-rotary-drilled bore to a depth of ~225 feet bgl (essentially the base of the upper basalt section).

b. The bore was open to 351 feet bgl but the cloudy water column would not permit inspection below 225 feet bgl.

c. The upper ~ 40 feet of basalt is highly fractured reddish brown-to-dark gray flows.

d. The fractures appear to be predominantly horizontal.

e. The basalt, itself, is highly vesicular.

f. From ~40 feet-to-~80 feet the basalts appear more massive and competent with a predominantly vertical joint/fracture pattern where the fractures appear to be moderately "healed" (infilled with precipitate).

g. Oversized portions of the bore are shown on Figure 1 and on the videotape supplied to IDWR.

h. Ground water begins to seep into the open bore at about 32 feet bgl with approximately ½ gallon per minute flowing at the top of the standing column of water in the well.

i. Non-pumping water level in the well at the time of inspection was ~90 feet bgl.

j. The surface of the water was bubbling profusely from a constant stream of gas rising through the water column in the well.

k. The rising bubbles served to somewhat obscure the camera view down to 173 feet bgl which was the lowermost entry point for gas into the bore. In other words, no gas was entering the well below 173 feet.

l. We believe the "gas" entering and rising through the water column is air from the air-rotary drilling that was forced out into fractures and caverns in the basalt during drilling and is slowly coming back out of the formation.

m. The water column was extremely clear from the water level to 225 feet as a result of the rising air and relatively fast ground water flow through the basalts.

n. The lowermost 100 feet of the basalt section is characterized by several sections of irregular diameter bore with many ledges and some voids (see 159½ feet bgl).

3) **BOREHOLE GEOPHYSICAL LOGGING:**

a. A suite of standard borehole geophysical logs were run in the open bore on August 13, 2009 (Figure 1).

b. The individual logs include: 1) natural gamma-ray, 2) single-point resistance, 3) caliper, 4) 16"/64" normal resistivity , and 5) fluid temperature. These are discussed individually below:

i. <u>Natural gamma-ray:</u>

1. This log measures the low-level natural radioactivity in the geologic section. The extremely low gamma "counts" (~10-to-15) from land surface to ~218 feet bgl are typical of basalt lava formations owing to the inherent low levels of radioactive elements in mafic lavas.
2. The few obvious "spikes in this interval (110', 145', and 165') are likely due to soil horizons and/or clays interbeds between the individual basalt flows.
3. The base of the upper basalt is shown clearly at ~218 feet).
4. Below 218 feet, the gamma-ray log shows increased radioactivity within the sedimentary section. Gamma counts in the 70-to-80 counts per second (cps) range indicate sand strata and counts in the 90-to-100 cps range indicate finer-grained siltstone and clay.

5. Notice that the low cps log excursions to the left are coincident with voids in the formation (where there is less rock within the radius of influence of the probe).

ii. Single-point resistance:

1. The single-point resistance log measures the electrical resistance between the probe and a surface electrode. It is the best indicator of the precise top and bottom of individual strata.
2. Within the basalt section (above 218 feet bgl) the high resistance responses (higher than about 200 ohms) indicate massive unfractured sections of the basalt while the lower resistances (below 200 ohms) are indicative of fractures and/or oxidized portions of the basalts.
3. Below the base of the basalt, higher single-point excursions to the right are typical of permeable sand layers and lower log excursions to the left indicate lower permeability strata.

iii. Normal resistivity:

1. Normal resistivity logs, like all electrically based logs are designed for mud-rotary drilled bores and not necessarily for air and water-filled bores. None the less, the logs do "read" in water filled bores but are somewhat more subjective.
2. In general, the log response in the basalt section is similar to that described in the single-point resistance log section (above).
3. Within the sedimentary section, the normal resistivity logs, and especially the "spread" between the two logs, generally suggests permeability.
4. The somewhat erratic nature of this couplet of logs is representative of a highly interbedded sequence of sands and clays with some siltstone lenses.
5. In general the response is very low resistivity suggesting the water in the aquifer is somewhat conductive (saline) with elevated TDS.

iv. Caliper:

1. The caliper log measures borehole diameter. As such, it is a very valuable log for interpretation of the other geophysical logs owing to the fact the individual sondes have a limited radius of influence. In other words, in a void, there is less rock matrix in the vicinity of the instrument so it would measure air or water-filled void space.

2. The expanding arms of the caliper retract in tight spots in the borehole and expand in the oversized portions.
3. The caliper trace in the Borehole #1 shows a fairly "tight" and uniform 6-inch nominal diameter bore from the base of the six-inch casing to the base of the basalt section.
4. Below the base of the upper basalt, there are at least seven areas within the sediments where the bore is oversized ranging between a couple of inches over size (8-inch) to an enlarged bore of 42-inches (see Figure 1). The borehole diameter between these spalled zones (which appear to be coincident with sand strata.) is pretty consistent with the bit size

v. Temperature:
1. The temperature log is not particularly helpful or meaningful because of the addition of water to the bore for the camera survey prior to logging and and owing to the degassing bubbles from the drilling moving upwards through the water column above 173 feet and disturbing the temperature equilibrium in the bore. Furthermore, the 67.2 degrees F measured at the top of the infill was not a "bottom hole temperature" that can be diagnostic; even in air rotary drilled holes.

4) HYDROGEOLOGY:

a. Standing (non-pumping) water level in the well was measured at 91 feet bgl.

b. **Three distinct hydrogeologic settings were drilled including:**
   i. A 218-foot thick upper basalt unit that is highly fractured and saturated over the lowermost ~130 feet. This aquifer is likely closely connected to, and in hydraulic connection to, the area surface water bodies.
   ii. A central sedimentary section from 218-to-400 feet bgl that appears to be highly interbedded sands and clays with siltstone lenses. This section is likely permeable and should be considered an aquifer. Sufficient stratification and low-permeability units are present such that this aquifer would have natural protection from surface land use activities.
   iii. A lower basalt section of black lava flows from 400-to-total depth at 703 feet bgl. Owing to poor quality drill cuttings, and the lack of geophysical logs below 351 feet (see Figure 1) little is known about the hydrogeology of the lowermost 300 feet of drilled section. Although the driller reported the entire 300-feet to be black lava, the drill cuttings from this section are comprised of sands and gravels?

5) **CONCLUSIONS:**

a. This well still has potential for being constructed and sealed as a good long-term designated water-level and water quality monitoring well.

b. The well is likely not infilled from 351 feet down but, rather, only "bridged" near the top of the fine-grained sand unit at 351 feet bgl.

c. The voids in the bore hole created within the sedimentary section will require some additional design and effort to fill and seal if a monitoring well is constructed.

d. The measured non-pumping water level in the well is really a "composite" head from the three hydrogeologic settings pierced by this bore.

e. While this open bore is sitting idle, ground waters under differing head, and carrying different geochemistries, may be exchanging between the units that will require more time to pump out when the well is properly sealed.

f. In its current open condition, the bore poses a threat to the ground water resources of the area.

g. The cost to complete the well as a multi-level piezometer nest is estimated to be low and is offset by the costs of abandonment anyway.

h. Ground water development potential beneath the site is considered high.

i. Owing to a poor agreement between the driller's observations and a lack of conformational geophysical logs, the nature and composition of the lowermost 352 feet of the geologic section is inconclusive.

6) **RECOMMENDATIONS:**

a. Re-enter the well and obtain borehole geophysical logs to full depth.

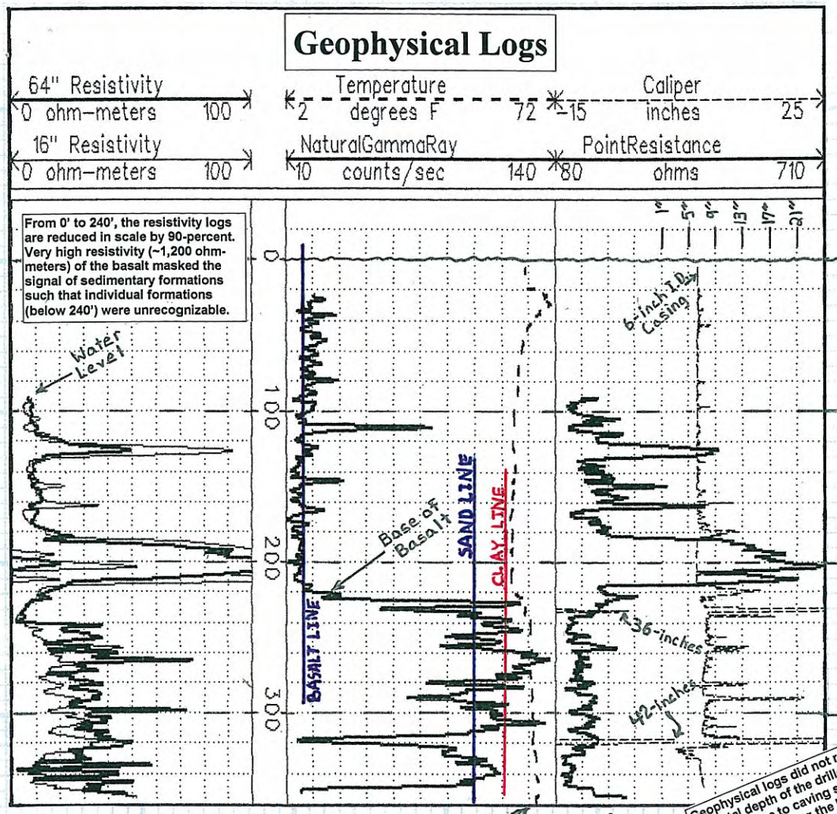
b. Construct a 3-tube multi-level piezometer nest for long-term monitoring.

c. If the well is not intended to become a monitoring well, it should be properly abandoned as soon as possible.

University of Idaho

Hagerman Fish Culture Experiment Station
Exploratory Borehole #1
T. 8 S., R. 14 E., Section 6, SE¼, NW¼, SE¼
Latitude 42° 45' 29.684" Longitude 114° 51' 21.978"
Well drilled August 2008

Geophysical Logs



Geophysics conducted by:
Hydro Logic, Inc. on August 13, 2008
in a water-filled hole

Depth

(feet below ground level)

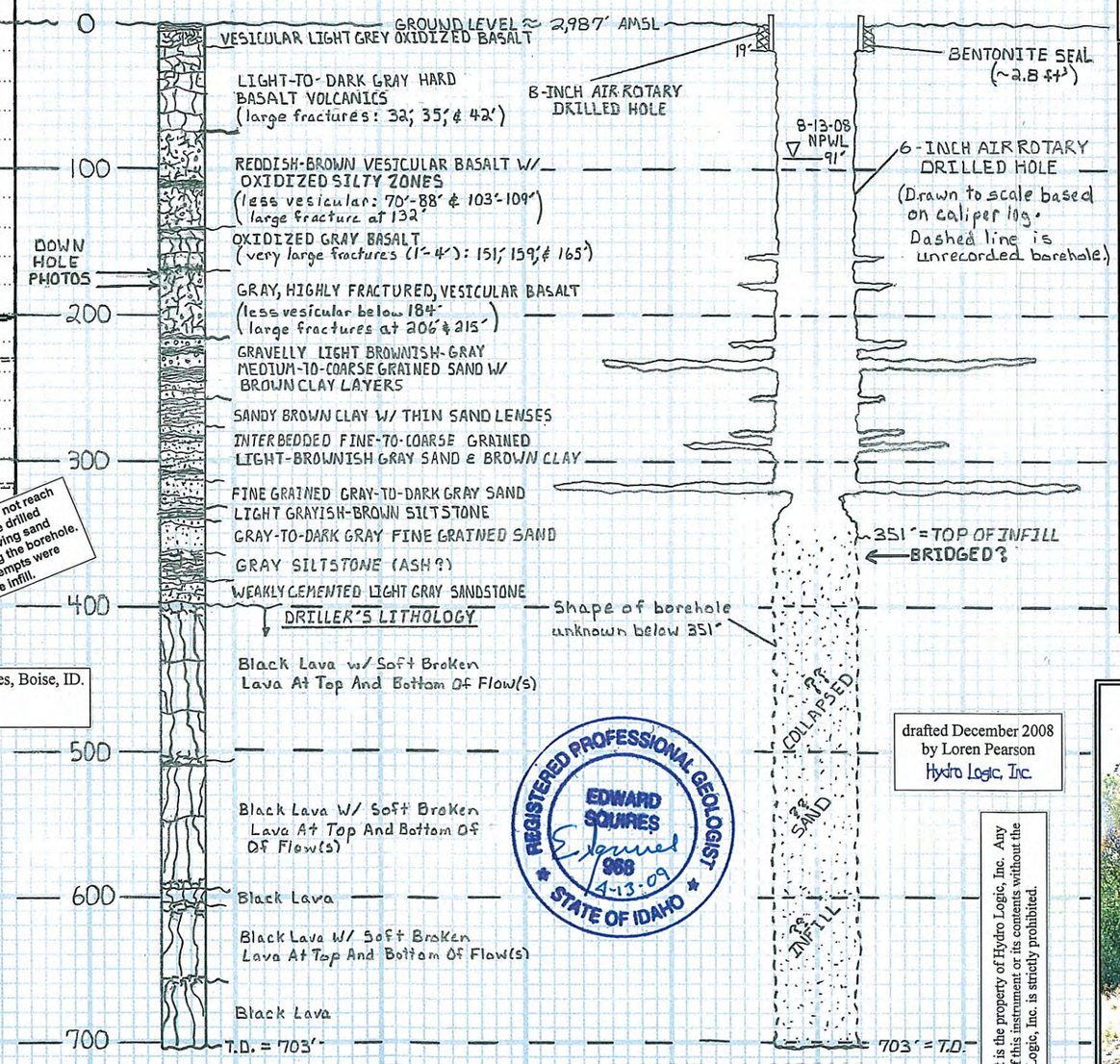
Lithology

Hydro Logic, Inc. lithologic log (0' to 396') is interpreted and drawn from geophysical logs, downhole camera survey, and analysis of drilled cuttings from the borehole.
(The lower portion of the lithology (396' to 703') is drawn from the IDWR Driller's Report due to the irregularity of cuttings from the borehole.)

Hydro Logic, Inc.
Boise, Idaho

Details of Well Construction

(As of August 14, 2008)
(horizontal scale 0.1"=1.0")
(vertical scale 1"=100')

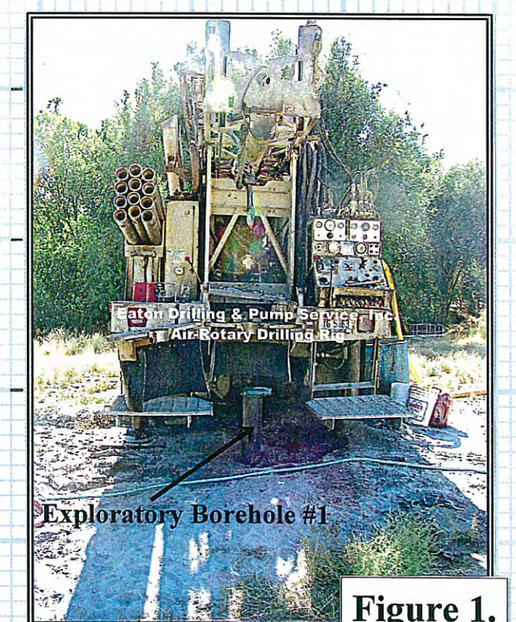


REGISTERED PROFESSIONAL GEOLOGIST
EDWARD SQUIRES
Expired
968
4-13-09
STATE OF IDAHO

drafted December 2008
by Loren Pearson
Hydro Logic, Inc.

Camera Survey Photos

by: Hydro Logic, Inc. August 13, 2008



On site supervision and well design by: Neil Farmer, Special Projects Coordinator, Idaho Department of Water Resources, Boise, ID.
Funding for this project made possible by: Idaho Water Resource Board.
Air-rotary drilling and well construction by: Eaton Drilling and Pump Service, Inc., Wendell, ID

Well Site Location

NOTE: *Analysis of cuttings below 396 feet revealed that the samples appear to be contaminated with sand and gravels from the upper portion of the borehole and without corresponding geophysical logs, an accurate representation of the lithology below 396 feet is not possible. The Driller's Report indicates that the formations below 396 feet are hard or soft broken black lava flows, but only ¼ -to- ½ of the material in each sample bag is lava. The remaining material in the bags consists of granitic gravels, polished rounded mafic gravels, dark gray sand, and weakly cemented siltstone. The majority of all samples take below 396' contain about 70% grey sand. A slight increase in lava cuttings occurs in the 540'-to-545' and the 550'-to-555' samples. Several sample intervals were sieved to attempt to determine a representative lithology for the lower portion of the borehole. Analysis of the sample portion remaining after being sieved showed that the majority of the cuttings left over after removing the dark gray sand are gravels, not lava, leading to the conclusion that the samples are cavings.*

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Figure 1.