REPORT
INDEPENDENT HYDROLOGIST REVIEW
ALTAROCK ENERGY
EGS DEMONSTRATION PROJECT
NEWBERRY, OREGON

February 24, 2011

9200 SW Nimbus Ave., Suite A, Portland, OR 97008 **p** | 503.644.9447 **f** | 503.643.1905

February 24, 2011
Project No. 116075

Will Osborn
AltaRock Energy, Inc.
2320 Marinship Way, Suite 300
Sausalito, CA 94965

Subject: **Independent Hydrologist Review Report**
AltaRock Energy
EGS Demonstration Project
Newberry, Oregon

Dear Mr. Osborn:

AltaRock Energy retained the services of Kleinfelder West (Kleinfelder) to provide an independent review of hydrology information for the EGS Demonstration Project proposed for Newberry, Oregon. The following report provides a summary of our opinions.
Kleinfelder appreciates the opportunity to be of service on this project. Should you require additional information or have any questions regarding this report, please contact this office at your convenience.

Sincerely,
KLEINFELDER WEST, INC.

Peter L. Stroud, C.E.G.
Principal Engineering Geologist
Kleinfelder West, Inc.

R. Scott Wallace, R.G., C.W.R.E.
Principal Geologist
Wallace Group, Inc.

Remi Allard, M. Eng., P. Eng.
Principal Hydrogeologist/Groundwater Engineer
Sustainable Subsurface Solutions

Jim Bailey, L.HG. P.G.
Senior Hydrogeologist
Well Services Director

TABLE OF CONTENTS

Section **Page**

FIGURES

TABLES

9200 SW Nimbus Ave., Suite A, Portland, OR 97008 **p** | 503.644.9447 **f** | 503.643.1905

1.0 INTRODUCTION

AltaRock Energy retained the services of Kleinfelder West (Kleinfelder) to provide an independent review of hydrology information for the EGS Demonstration Project proposed for Newberry, Oregon. Kleinfelder reviewed a number of technical documents provided by AltaRock Energy as well as several professional papers prepared by others. The documents reviewed are listed in the References section of this memorandum. In addition to our review, we also responded to a number of questions posed by the BLM and the public stakeholders.

2.0 BLM INDEPENDENT CONSULTING REPORT REQUIREMENTS

2.1 EXISTING CONDITION OF THE RESOURCE AND AFFECTED ENVIRONMENT

The hydrologic system (resource) at Newberry volcano is part of the upper Deschutes Basin which encompasses approximately 4,500 square miles within the larger, Deschutes River drainage basin of central Oregon. The system represents a dynamic equilibrium between recharge, surface water outflows via the Deschutes River and its tributaries, groundwater outflow, consumptive use, and evapotranspiration.

The primary hydrologic features subject to potential affect by the EGS Demonstration Project include:

- Two (2) Newberry caldera lakes (East and Paulina);
- Thermal spring discharge to the caldera lakes;
- The regional and local groundwater systems;
- Surface outflow from Paulina Lake to Paulina Creek; and
- Surface outflow from the Little Deschutes River.

2.1.1 Caldera Lakes

The caldera lakes have been subject to much study in an effort to document baseline conditions within the Newberry National Volcanic Monument, which was established in 1990. Based upon these studies, it is well-documented that East and Paulina Lakes recharge, almost exclusively, by precipitation and infiltration, with approximately 35 inches falling into the caldera annually (Sammel, 1983, and Phillips, 1968). This equates to approximately 31,900 acre-feet/year (Dames and Moore, 1994). East Lake does not have a surface water outlet and Paulina Lake discharges through an outlet structure to Paulina Creek. For irrigation purposes, the level of Paulina Lake and outflow volume to Paulina Creek have been controlled and managed since the early 1900s. Lake levels fluctuate seasonally dependent upon precipitation; however, the elevation of East Lake is generally 40 to 50 feet higher than Paulina Lake. The resulting hydraulic gradient from East Lake toward Paulina Lake and the relative stability of Paulina Lake and nearby groundwater levels relative to East Lake levels during below normal precipitation years, indicates appreciable groundwater flow from East Lake into Paulina Lake. This flow has been estimated at 2.3 cubic feet-per-second (cfs) through the permeable pumice and ash deposits separating the lakes (Morgan and others, 1997).

The groundwater system within the caldera appears to be structurally-controlled by faulting associated with Basin and Range extension and a series of ring-fractures from at least two periods of caldera collapse (Dames and Moore, 1994). These structures represent groundwater flow boundaries that impede the vertical and/or horizontal flow of groundwater from the caldera. Groundwater flow from the caldera to regional and local aquifer systems does occur however, and the U.S. Geological Survey has estimated the volume at 2,500 to 6,500 acre-feet/year (Sammel and Craig, 1983).

2.1.2 Thermal Springs

Thermal springs discharge as diffuse seeps along the northeast shore of Paulina Lake and the southeast shore of East Lake. The thermal springs are not the result of deep geothermal fluid upwelling, but rather the recirculation of meteoric water heated by high conductive heat flow and/or by mixing with steam that migrates up through fractures from a deeper system within the caldera. The recharge volume from thermal springs to the caldera lakes has not been quantified, however the yield for hot springs at East and Paulina Lakes is described as many small diffuse flows (Sammel and Craig, 1983) and is relatively small compared to recharge from precipitation.

2.1.3 Groundwater Systems

Groundwater underlying the west flank of Newberry volcano and the La Pine sub-basin is divided into two systems (regional and local) based upon geology, aerial extent, and flow characteristics. The prolific regional aquifer is of wide aerial extent and hosted in basaltic lavas, volcaniclastic rocks, and sedimentary units of the Deschutes Formation that overlie low permeability basement rocks of the Clarno and John Day Formations. The depth to the top of the regional aquifer varies based upon elevation; however, it generally ranges from 100 to over 500 feet below the ground surface (bgs). The “local” aquifer is of lesser aerial extent and made up of unconsolidated, glaciofluvial sediments under water table (unconfined) conditions. These materials blanket most of the La Pine sub-basin and were deposited as outwash from glaciers emanating from the High Cascade Range to the west. The local aquifer is comprised of well-graded sand and gravel with minor interbeds of low permeability silt and clay that overlie clay-rich marsh and lacustrine deposits associated with the damming of the ancestral Deschutes River. Most domestic wells in the La Pine sub-basin are drilled into the "local" aquifer and depths are generally less than 50 feet bgs. Water levels from wells installed at various depths within the local system generally show similar water levels (5 to 15 feet bgs), which suggests there is no significant vertical movement of water in the local aquifer (Century West Engineering, 1982).

The groundwater system is recharged by infiltration of precipitation (rainfall and snowmelt), and to a less extent by canal leakage, infiltration of applied irrigation water, and stream loss. Precipitation is the primary means for recharge, and there is a strong correlation between recharge and elevation. Recharge from precipitation ranges from less than 1 inch/year in the lower elevations where precipitation is less than 12 inches, to more than 130 inches in the High Cascade Range to the west where precipitation exceeds 200 inches. The mean recharge to the upper Deschutes Basin between 1962 and 1997 has been estimated at 11.4 inches/year, which is equivalent to 896 billion gallons, or 2,750,000 acre-feet/year (Gannett and others, 2001). About 84 percent of recharge from precipitation infiltration occurs between November and April (Gannett and others, 2001). Recharge to the groundwater system from the west flank of Newberry volcano may approach 224,000 acre-feet/year (Dames and Moore, 1994). The Fort Rock Basin to the southeast also contributes approximately 36,200 acre-feet/year to the upper Deschutes Basin (Gannett and others, 2001).

Groundwater flows eastward from the High Cascade Range and west-northwest from Newberry volcano toward the La Pine sub-basin where it enters the regional and local aquifers. From the La Pine sub-basin, groundwater flow is generally to the north within basalt bedrock and overlying volcanic and sedimentary deposits of the Deschutes Formation. The Clarno and John Day Formations underlie the regional (Deschutes Formation) aquifer and include low permeability stratigraphic units that inhibit the horizontal and vertical flow of regional groundwater (King, 1991). The shallow, local aquifer extends north approximately 18 miles to the Benham Falls area where the ancestral Deschutes River was dammed by Newberry lava flows erupted from a cinder cone in the northwest rift zone (Lava Butte), approximately 7,100 years ago. There is an abrupt topographic gradient north of Benham Falls at the contact between Newberry lavas and those of the High Cascade Range with source areas to the west. Correspondingly, the Deschutes River gradient increases from approximately 2.6 feet per mile (ft./mi.) in the La Pine sub-basin to 50 ft./mi. between Benham Falls and Bend. The slope of the water table also increases north of Benham Falls. The depth to water near the river at Benham Falls ranges from approximately 5 to 25 feet bgs. Approximately 8 miles to the north beneath Bend, the depth to the regional aquifer increases to over 300 feet bgs (Sherrod and others, 2002).

The northward-increasing depth to groundwater has implications for the interaction of the groundwater system and surface water. Within the La Pine sub-basin south of Sunriver, the Deschutes River system experiences slight gains due to groundwater discharge and significant gains from several major spring complexes. North of Sunriver, the Deschutes system begins to lose water as groundwater levels drop far below stream levels. Between Sunriver and Bend, the Deschutes River loses an estimated 113 cfs as it flows through permeable volcanics of Lava Butte and the north rift zone (Gannett and others, 2001).

2.1.4 Paulina Creek

Paulina Creek begins at the southwest shore of Paulina Lake at an elevation of 6,330 feet and flows west over 13 miles to the confluence with the Little Deschutes River at an elevation of 4,180 feet. The flow of Paulina Creek is controlled by a concrete spillway that has been in-place since the early 1900s. Paulina Creek gauge records indicate seasonal flows between March and June of 15 to 25 cfs, when snowmelt is peaking and the lake reaches the spillway elevation. Outflows of 10 to 15 cfs are generally sustained through the irrigation season. There are six (6) senior water rights for Paulina Lake and Paulina Creek irrigation water dating back to 1911 and 1918. These senior water rights total approximately 8 cfs. Above the Paulina-East Lake Road (also known as County Highway 21 and U.S. Forest Service Road 21) crossing at river mile (RM) 5.2 (Figure 1), the stream loses approximately 0.75 cfs/mile to groundwater (Morgan and others, 1997). Below RM 5.2 Paulina Creek does not appear to lose flow to groundwater and may receive some minor recharge as the stream intersects groundwater levels of the near-surface, local aquifer.

2.1.5 Little Deschutes River

Paulina Creek joins the Little Deschutes River near Little Deschutes RM15. In this portion of the La Pine sub-basin, the water table elevation is near land surface. Stream gains and losses along most of the Little Deschutes River are small and related to local changes in stream bed morphology. There is relatively little net exchange between groundwater and surface water in the Little Deschutes River between RM15 and its confluence with the Deschutes River.

2.2 ENVIRONMENTAL EFFECTS TO THE RESOURCE BY ALTERNATIVE WHICH INCLUDES – DIRECT, INDIRECT, AND CUMULATIVE EFFECTS

One of the stakeholders' concerns is the potential environmental effects of the EGS Demonstration Project at Newberry volcano to groundwater. The demonstration project is estimated to require the use of up to 142 million gallons of water all of which is considered as consumptive use. The project will rely on groundwater from the shallow aquifer present beneath the western flank of Newberry volcano to meet its water supply demands. There are currently three existing water supply wells available to supply water and two of them, the Pad 29 water well (DESC 58395) and the Pad 16 water well (DESC 58649) are expected to supply all of the demand during the demonstration project.

The direct effects on the groundwater resource are the anticipated temporary drawdowns near the existing water supply wells. Previous pumping tests on the water supply well on Pad 29 have provided some preliminary information on aquifer properties and the direct effects that could occur during the project. This pumping test data indicates that the radius of influence around each wellhead will be relatively small due to the generally low to moderate transmissivity of the water-bearing formation in this area.

The indirect effects would be potential connection between the EGS reservoir and the local and regional aquifers, and impacts to surface water bodies. The planned EGS reservoir created through hydroshearing at the Pad 29 site will be a network of fractures extending approximately 1,500 feet radially. Even if these fractures extended upward from the top of the EGS reservoir zone, it would still be several thousand feet below the bottom of the local and regional aquifers. Given the very low permeability of the receptor rock throughout the length of the vertical borehole below the regional aquifer, there is little chance that fluids would be able to migrate vertically during the testing period.

The conceptual hydrogeologic model indicates that Paulina Creek is in direct connection with the shallow aquifer present beneath the western flank of Newberry volcano, but above the Paulina-East Lake Road crossing at RM 5.2 (Figure 1), the stream loses approximately 0.75 cfs/mile to groundwater (Morgan and others, 1997). Current aquifer testing in the project vicinity (Schwartz and others, 2010) indicates a relatively low transmissivity aquifer which would indicate a relative steep cone of depression around the water supply well and a small (less than 2,500 feet) radius of influence (amount of water level drawdown as one moves away from the well). These conditions further imply that the pumping of the water supply well on Pad 29 will not impact flows in Paulina Creek.

The only other surface water bodies that could see an indirect effect are Paulina and East Lakes. However, since the base of the caldera lakes is topographically higher than the shallow aquifer present beneath the western flank of Newberry volcano, they would not be impacted if the shallow aquifer system is not. In addition, the caldera's lakes are located hydrologically upgradient of the test site, making it that much more unlikely that a connection could occur.

The cumulative effects on the hydrologic environment from groundwater pumping or injection during the EGS Demonstration Project are not considered likely based on the reasons cited above.

2.3 ANY MITIGATION BEING PROPOSED TO ELIMINATE OR REDUCE THE EFFECTS OF THE PROJECT ON THE RESOURCE?

With regards to mitigations being proposed to eliminate or reduce the effects of the project on the groundwater resource, there is reference to defining appropriate buffers and exclusion zones in order to protect water resources (groundwater and surface). Monitoring of water levels during stimulation and circulation tests is proposed to determine the footprint and extent of impacts, if any, to shallow groundwater and surface water.

There is a statement made in the Plan of Exploration, Operations Plan and Drilling Program document (June, 2010) that mitigation measures will be implemented to minimize the possible impact of project activities on surface and groundwater resources in the area. Specific comments are made in regards to drilling wastes being contained in the drilling sump and potential runoff from the drill pad also being directed to the sump. The sumps are double lined, with HDPE liners and clay. Furthermore, all drilling fluids will be formulated from non-toxic components. All non-thermal groundwater and all lower-temperature (below desired productions temperature) geothermal water will be cemented and cased off. This will both protect groundwater resources and prevent degradation of the geothermal production fluid within the well bore.

There is considerable information provided regarding the chemical composition and degradation products of diverter materials, mud additives, and tracers to be used on the project. The intention is that all of these chemicals would be captured either in the sump on site or be isolated in the subsurface within the EGS target reservoir. Due to the potential for water quality impacts to the shallow aquifer present beneath the western flank of Newberry volcano and surface water systems being very low, the number of monitoring points in the shallow aquifer is limited to the wells that will be pumped and for field and laboratory indicators relating to tracers and major elements. In our opinion, there is limited value in the use of pumping wells for the identification of water quality impacts. This is due to the dilution of source water chemistry that results from drawing relatively large volumes of water over a large capture zone area. It is recommended that a purpose-dedicated, water quality and level monitoring well be constructed at a location down-gradient of any pad where pumping and/or stimulation occur. Such a well should be equipped with a transducer and be sampled using low flow or passive methods.

We do recommend that mitigation plans address the unlikely event of chemicals being detected in the project site aquifer. The potential mitigation could be to stop pumping so that the chemicals are not pushed or pulled due to continued pumping from within the aquifer.

3.0 WATER CONSUMPTION DOCUMENT REVIEW COMMENTS

From our review of the Water Usage document prepared by AltaRock Energy, we have the following comments:

- Based on the pumping test report for the water supply well on Pad 29, it is not clear what the sustainable pumping capacity is;
- Aquifer properties are not well defined due to the problems with water level monitoring during the test and especially the lack of recovery data;
- To verify there would be no impacts to surface water features and the shallow aquifer present beneath the western flank of Newberry volcano during either the 21-day stimulation testing or the 30- to 60-day circulation testing period, both water supply wells on Pad 29 and Pad 16 should be pumped together for as long a period as is feasible. The combined pumping rate should equal that anticipated for maintaining a sufficient supply during the dual circulation test;
- If it is not possible to pump at the highest sustainable rate due to water storage limitations, one can still collect useful data on aquifer properties if the wells are pumped at a lower rate for a longer period than the maximum rate for a short period; and
- Based on the existing data, it does not appear that the water supply wells on Pad 29 and Pad 16 can supply a combined yield of 1,600 gallons per minute (gpm) for more than 7 days.

4.0 PUBLIC SCOPING QUESTIONS

The following questions have been asked by stakeholders at public outreach meetings and/or been submitted during the scoping phase of the project.

What is the source and ultimate disposition of the water used for testing?

The source of water for the stimulation and connectivity testing is three existing water supply wells. Two of these wells are located on Pad 29 and Pad 16. A third water supply well, water well #2 (DESC 10060), is located about half way between the Pad 29 and Pad 16 wells. The entire EGS Demonstration Project is expected to require at most 142 million gallons (436 acre-ft).

Does the region's water demand dictate that regardless of the stimulation test outcome, it could not afford to supply water for a full scale facility?

The purpose of the demonstration project and testing is to garner enough reliable scientific data to determine if it is possible to develop a reservoir in the rock. Based on the current understanding of the local hydrologic system and the anticipated water demands, it does not appear that the EGS Demonstration Project will have an impact on the region's water supply resource.

The Newberry Project could impact the environment in many ways, including by lowering the water table, depleting groundwater supplies. Will the aquifer(s) be affected in this way?

In addition to the response given for the previous question above, one of the nearest local beneficial use aquifers is located in the La Pine sub-basin which is over 4-miles away. The other beneficial use aquifers are located around Paulina and East Lakes at campgrounds. These aquifers are not in hydraulic connection with the shallow aquifer present beneath the western flank of Newberry volcano at the Newberry EGS Demonstration site.

Discuss the effects of EGS on area groundwater quality, seismicity, and the recreational features of Newberry Volcano, including East Lake, Paulina Lake, and Paulina Peak.

The EGS stimulation process will create multiple hydraulic fracture network zones in the low permeability host rock. This network of micro fractures will allow for the circulation of groundwater pumped from the shallow aquifer present beneath the western flank of Newberry volcano through hot rock and back to the surface via an extraction well. There is currently no evidence of vertical fault or fractures that would connect the EGS reservoir with the regional aquifer almost 5,000 feet above. This separation will prevent the mixing of water and potential for impacts to regional aquifer water quality.

URS has addressed seismic issues in their report, Evaluations of Induced Seismicity/Seismic Hazards and Risk for the Newberry Volcano (Wong and others, 2010).

Address the location of water resources and pipeline routes, both long and short-term water usage and effects on area aquifers.

The closest beneficial use wells are located around Paulina and East Lakes at campgrounds. These wells tap shallow aquifers that are not in direct hydraulic connection with the water that will be used for the demonstration project. The other, nearby, local beneficial use aquifer is located in La Pine sub-basin which is over 4-miles away. These aquifers are not in hydraulic connection with the shallow aquifer present beneath the western flank of Newberry volcano at the Newberry EGS Demonstration site. Pipeline routes for the demonstration test are not determined at this point but will only be used to bring water from the well on Pad 16 to the surface sump on Pad 29. They will have no impact on the groundwater resources.

What direct and cumulative impacts may the project have upon area aquifers?

The entire demonstration project will only use approximately 142 million gallons (436 acre-ft) at most. Based on the current understanding of the hydrologic system in the La Pine sub-basin, the aquifer underlying the western flank of Newberry volcano is in direct continuity and recharges the regional aquifer of the Deschutes Formation. Groundwater withdrawal for the EGS Demonstration Project will not be from the La Pine sub-basin aquifer, which supplies water to shallow wells in La Pine.

What are the range of potential direct and cumulative affects to the Paulina Creek water system, water source aquifers, community wells, and affected area soil hydrology?

It is unlikely that the demonstration project will have direct effect on Paulina Creek due to the distance from the test site at Pad 29, and the assumed aquifer properties in the project vicinity that indicate a generally low transmissivity aquifer. Above the Paulina-East Lake Road crossing at RM 5.2 (Figure 1), the stream loses approximately 0.75 cfs/mile to groundwater (Morgan and others, 1997) indicating that in the vicinity of the project area Paulina Creek is not recharged by groundwater. There are no community wells within the radius of influence of either water supply wells on Pad 29 or Pad 16 so there would be no direct or cumulative impacts. The demonstration project will have no impact on either the permeability of or infiltration capacity of area soils.

What total quantities of water will the project require, including the range of potential depletion rates, replenishment, and additional water needs over time?

It is anticipated that the entire demonstration project (21-day stimulation test and 30- to 60-day circulation test), will use at most 142 million gallons of water (436 acre-ft). The water pumped from the project site aquifer is injected in one well then removed in one or more extraction wells. Some of the injected water (10%) may remain in the deep, micro-fractured rock and some will be lost back at the surface as steam vented to the atmosphere (17 to 54%). The remaining water is recycled back into the injection well with additional water as needed to make up for that lost. If we assume a 50% consumptive use of the water during the 60-day circulation testing, and a maximum of 142 million gallons (436 acre-ft) used, then a test will require less than 1,000 gallons per minute to meet the water demands of the test.

Paulina and East Lakes are polluted from the hot springs that feed into the lakes. East Lake now has the second highest rate of mercury poisoning in the State of Oregon. Can you guarantee that will not get worse, or the lakes dry up or the temperature of the water dramatically change?

It is not likely that the demonstration project will impact the water quality of the hot springs or the lakes. The hydrogeologic regime beneath Paulina and East Lakes is complex including the source areas for the hot springs. Based on the subsurface drilling that has occurred around both lakes since the 1990s only the upper couple thousand feet of rock is permeable enough to allow for the natural circulation of water that ultimately feeds the hot springs. The stimulation and circulation testing is to occur in rocks over 3,000 feet below the zone that is in connection with the hot springs. There is no way for the lakes to dry up as a result of the demonstration project based on the amount of water the will be used and the limited area of influence due to pumping in the project site aquifer.

Paulina Lake and hot springs, as well as Paulina Creek and the water supply well on Pad 29, all contain naturally elevated levels of arsenic. Mercury levels are generally low across the project area (Morgan and others, 1997), but relatively high concentrations have been found in fish in the lakes. These are pre-existing water quality issues, and the extraction of water from the project site aquifer followed by injection into the target EGS reservoir are not expected to influence ambient levels for these parameters. The demonstration project activities will also not impact the temperature of the hot springs.

Will this deplete local aquifers?

The demonstration project will not permanently deplete the local or regional aquifers. During the period of testing the water table will decline in the vicinity of the pumping wells. Once the stimulation or circulation testing is completed, the water levels will return to pre-test levels. The well pumping tests will provide information on aquifer properties that will be used to better answer the question of how long the recovery will take.

Will the Deschutes Basin Aquifer be polluted as the various wells are drilled and the drilling mud (with unknown chemicals) get into the flow?

The deep geothermal wells will be cased as they are completed to a depth of approximately 6,000 feet. This is over 5,000 feet below the bottom of the local and regional aquifers in the La Pine sub-basin. During the drilling only drilling fluids commonly used for drilling water wells are used.

Will the Oregon Scenic Waterway Act be at risk?

No. Groundwater withdrawal for the EGS Demonstration Project is not expected to adversely affect flows on the Wild and Scenic Upper Deschutes or Lower Deschutes River.

Likewise, will the Redband Trout be in danger since the Deschutes River is already over-allocated?

As stated in the response to the previous question above, groundwater withdrawal for the EGS Demonstration Project is not expected to adversely affect flows on the Wild and Scenic Upper Deschutes or Lower Deschutes River. Therefore, if surface water flows are not affected, Redband Trout should not be subject to additional risk, beyond current conditions, as a result of the EGS Demonstration Project.

Are the two lakes East Lake and Paulina Lake in danger?

Neither of these lakes is in danger of being impacted by the demonstration project. Paulina Lake is over 2 miles from the test Pad 29 location and East Lake is even farther away. The project site aquifer being used for water supply for the test is separated from the caldera lakes aquifer by geologic structures that impede the lateral and vertical flow of groundwater. The bottom of Paulina Lake is also over 2-miles horizontal distance and over 1-mile vertical distance from the EGS stimulation zone (Figure 1).

Will the hot springs survive?

The hot springs exist due to the circulation of groundwater into fractures of rock that migrate downward into high temperature zones beneath the caldera. The proposed stimulation and circulation testing will not alter the pathways that this water is taking so the springs would not be impacted. The demonstration project activities will also not impact the temperature of the hot springs.

We would like to be assured that any earth movement or operation of the wells will not adversely affect the flow (i.e., underground springs) of water into Paulina lake nor affect the water flow down the mountain to our properties.

The aquifer within Newberry Caldera is recharged from precipitation and snow melt. Paulina and East Lakes are situated on both a topographic and hydrologic high meaning that water flows from these areas down to surrounding areas including the water supply well on Pad 29. The withdrawal of water from the water supply wells on Pad 29 or Pad 16 cannot affect the flow of water from the lakes since the lakes are hydrologically upgradient of these wells (Figures 2, 3, and 4).

It does not appear from the data we have reviewed that the hydroshearing of the reservoir rocks could have an impact on the shallow hydrologic regime. The hydroshearing would not influence the flow of recharge water to aquifers down slope of the test area since it would not be possible to alter the topographic features that are controlling this flow (i.e., surface elevation and hydraulic head).

Discuss the water flows into Paulina Lake as well as monitoring the water where it crosses Hwy 21 before proceeding with any testing of this magnitude.

Paulina Creek, at the crossing of County Highway 21 (also known as Paulina-East Lake Road and U.S. Forest Service Road 21) at RM 5.2, has been monitored by the US Geological Survey (Morgan and others, 1997) (Figure 1). The hydrologic flow patterns into Paulina Lake and its connection to the project site aquifer have been discussed in several of the responses provided above. We do not believe there is a need for monitoring of water flow/quality downgradient of the site at surface water bodies.

The area is in a drought and there is possibility of future drought. How will these water issues be addressed?

The period of time when the demonstration project will be pumping water from the project site aquifer is not expected to exceed 108 days total for the entire two-year project length. This amount of water withdrawal will not have an impact on drought-related water supply issues. However, the project will seek to minimize the amount of water used by limiting the pumping of the supply wells to only what is needed to replace water lost to evaporation or infiltration in the rock.

How will this water usage impact existing Deschutes Basin water inventory?

The maximum water use proposed by the Newberry EGS Demonstration Project is 141,750,000 gallons or 435 acre-feet. This represents approximately three-tenths of one percent (0.003) of the estimated annual recharge (73 billion gallons or 224,000 acre-feet) to the Deschutes Basin from the west flank of Newberry volcano.

What is risk that injected water will migrate into the shallow aquifer?

It is our opinion that the risk of development of a hydraulic connection between the proposed EGS reservoir and the shallow (project site) aquifer is extremely low. The hydrologic overview document, <u>Memorandum, Newberry Water Monitoring</u> (Callahan,

2010) provides a summary of the hydrogeologic environment at the proposed test site (Figures 2, 3, and 4). This document along with several others we reviewed (see References section) show the base of the regional aquifer system is approximately 5,000 feet above the top of the proposed EGS reservoir zone. The estimated EGS reservoir created through hydraulic stimulation at the Pad 29 site will be a network of fractures extending approximately 1,500 feet radially. Even if these fractures extended upward from the top of the EGS reservoir zone, it would still be several thousand feet below the bottom of the project site aquifer. Given the very low permeability of the receptor rock throughout the length of the vertical borehole below the project site aquifer, it is unlikely that fluids would be able to migrate vertically during the testing period.

The only other possible avenue for fluid migration would be through vertical fault traces. The data we reviewed (see References section) did not indicate the presence of faults in the area of the proposed injection test.

What is the risk that injected water will migrate into crater lakes?

As discussed in the response to the previous question above, the existing hydrologic barriers at the proposed injection site would likely prevent a direct connection to the shallow aquifer system beneath the caldera. Since the base of the caldera lakes are above the aquifer system at the EGS Demonstration site, the lakes would not be impacted if the shallow groundwater system inside the caldera was not. In addition, the caldera lakes are located hydrologically upgradient of the test site, making it that much more unlikely that a connection could occur.

Develop monitoring and sampling program for project timeframe. What wells will be monitored? How will the crater lakes be monitored?

Please see the comments at the end of the memorandum for Hydrology Sampling Plan Review for a response to this question.

How will water use by the project impact stream flow in Paulina Creek?

The estimated horizontal distance from the water supply well at Pad 29 to Paulina Creek is 4,790 feet or just less than 1 mile. The conceptual hydrogeologic model for the shallow aquifer (Figures 2 and 4) indicates that Paulina Creek is in direct connection with the project site aquifer but is a losing stream (water is leaving the stream and recharging the aquifer). Current aquifer testing at the project site indicates a relatively low transmissivity aquifer which would indicate a relative steep cone of depression around the water supply well and a small radius of influence (amount of water level drawdown as one moves away from the well). These conditions imply that the pumping of the water supply well on Pad 29 is not likely to impact flows in Paulina Creek since the radius of influence will not reach out that far.

However to confirm this, the pumping test in the water supply well on Pad 16 planned for the Spring 2011 should be run for as long as feasible in order to identify boundary conditions and better define project site aquifer properties.

What cumulative impacts will the project have on the local aquifers and streams?

There do not appear to be potential cumulative impacts to the upper Deschutes Basin hydrologic system associated with the planned Newberry EGS Demonstration Project.

What is the likely impact on the quantity and quality of water in wells at Newberry Estates?

The domestic wells at Newberry Estates serve individual homes and draw water from the shallow, local (La Pine sub-basin) aquifer at depths of generally less than 50 feet bgs. The local aquifer is not the water source aquifer for the proposed production wells for the EGS Demonstration Project. The EGS wells are located on the opposite (north) side of Paulina Creek from Newberry Estates and the closest demonstration project water supply well (Pad 29) is approximately 6.5-miles northeast of the subdivision. Based on these hydrologic and geographic conditions, it is unlikely that shallow water wells at Newberry Estates will experience impacts from the EGS Demonstration Project. However, it would be prudent to monitor a couple of the wells in Newberry Estates to identify changes in turbidity that could be the indirect result of micro-seismic events, if these were to occur. Such an impact is considered temporary and reversible.

What percentage of water used is considered consumptive for purposes of the DWR limited water use license?

The limited water use license (Application LL-1092) issued by the Oregon Water Resources Department (WRD) allows for the use of up to 100 gallons per minute from four wells (points of diversion) within the Newberry "lava" groundwater reservoir, for the purpose of geothermal exploration. This is contingent upon proof of acceptable "mitigation" in the amount of 5.8 acre-feet in the Deschutes Basin above Madras, and is effective until August 1, 2012. The license requires the license-holder to measure and maintain records of total volume pumped, hours pumped, and the beneficial use category to which the water is applied. Annual water use reports must be submitted to the WRD. The license does not specify whether the permitted water use is consumptive, non-consumptive, or both, only that the water is applied to beneficial use. Our interpretation of these license conditions is that 100 percent of the water applied to beneficial use for geothermal exploration would be considered consumptive for the purpose of the limited water use license.

5.0 PAD 29 WELL PUMPING TEST REPORT REVIEW COMMENTS

During the week of September 20, 2010, TRC conducted an aquifer test on the water well at Pad 29 (Schwartz and others, 2010). The following comments are based on our review of the aquifer test report. The well testing procedures followed the proposed work scope outlined in the June 28, 2010 proposal for water supply testing and analysis.

Unfortunately, the problems with the airline and transducer setting resulted in some uncertainty about the conclusions regarding the capacity of the water supply well on Pad 29. There was no observation well nearby that was influenced by the pumping (water well #2 was the closest), and recovery data, which is very important for determining aquifer parameters, was not collected during the 24-hour constant rate test. Only drawdown data based on airline readings was used to estimate aquifer properties.

The water supply well on Pad 29 is constructed with perforated slots in a steel liner. This type of construction results in very little open area and when the well is pumped at higher rates, the well exhibits greater head losses. It is likely given the age of these wells (2+ years) and the natural water quality conditions of the aquifer, that some of the slot openings could be partially plugged by biofouling which further reduces the efficiency of the well. The results of the constant rate pumping test likely indicate that the capacity of this well and the aquifer is less than 700 gpm.

6.0 PAD 16 WATER WELL TESTING PLAN REVIEW COMMENTS

The June 28, 2010 proposal for water supply testing and analysis outlines TRC's proposed approach to determine the long term water supply capacity of the water supply wells on Pad 16 and Pad 29. It also proposes to evaluate aquifer yields if two additional supply wells are installed.

The proposed testing approach and methods are generally acceptable although we do recommend that the length of the constant rate test be extended for as long a period as possible in order to document boundary conditions or other aquifer or well limitations. The geologic conditions at both the Pad 16 and 29 sites are such that aquifer boundary conditions may be present that would not be noticed with a 24-hour duration test. A boundary condition could include a fault, or more likely a change in the transmissivity of the aquifer. A longer pumping period may also allow for a response to be observed in one of the other wells being monitored. This information would greatly improve the accuracy of determining aquifer properties such as transmissivity and permeability. This said, we realize that the maximum storage capacity for a pumping test is about 1.3 million gallons, thus it is unlikely that a pumping test can exceed 48-hours even at a reduced pumping rate.

We would also recommend that during the constant rate pumping period water samples be periodically collected for temperature, pH, and conductivity. Samples should also be collected at the beginning, middle, and end of the test for key water quality parameters that are proposed for monitoring during the connectivity tests.

One last observation, it is critical to the analysis of drawdown and recovery data that accurate water level measurements are obtained. One should not rely on the use of an airline for measurements during the pumping test period. We understand that AltaRock Energy is proposing to use a pressure transducer for the pumping test in the water supply well on Pad 16.

7.0 HYDROLOGY SAMPLING PLAN REVIEW COMMENTS

Based on the number of hydraulic features versus candidate locations for monitoring and considering that groundwater flow is topographically driven from east to west in the project area, we consider the targeted locations chosen for monitoring to be appropriate. However, we do recommended that a purpose-dedicated, water quality and level monitoring well be constructed at a location down-gradient of the pad where pumping and/or stimulation are planned. Such a well should be equipped with a transducer and be sampled using low flow or passive methods. One possible location for this down-gradient well would be NN17 (Figure 5), assuming that in the vicinity of the project site groundwater flows westerly. We also recommend monitoring two wells at Newberry Estates for turbidity, in recognition that this subdivision is the nearest down-gradient groundwater user. In addition, the baseline monitoring should include more than one sampling event to reduce the potential for lab and sampling error influence on baseline results.

We have reviewed in detail, Table 2 (attached) entitled “Potential Impacts and Monitoring Plan” from the AltaRock Energy Memorandum on Newberry Water Monitoring (Callahan, 2010). The table presents an overview of the proposed monitoring plan including analyses and timelines for the identification of impacts to the project site groundwater system along the flank of the volcano as well as groundwater within the caldera. Potential impacts to the project site aquifer that have been identified include excessive drawdown, surface spills or leaks from the sumps, containment of drilling fluids and upward leakage of fluids from the EGS reservoir. Potential impacts to the caldera identified include changes in flow rate and temperature as well as upward leakage of fluids from the EGS reservoir.

While the frequency of water quality sampling for geochemical analysis during stimulation is reasonable, we do recommend that weekly samples are more in order with the volume of water proposed for extraction. Our recommendation is based on the premise that more is better during the initial phase of project development. We concur with the recommended frequency of sample collection for Paulina Hot Spring, East Lake Hot Spring, and a Paulina Lake campground (once a month during and for 6 months after completing the EGS stimulation). In addition to the measurement of standard well head parameters, it is also recommended to monitor for redox potential.

Water level monitoring is proposed to occur on a daily basis in the Pad 29 and Pad 16 water wells. Our experience is that the interpretation of hydraulic response, the identification of aquifer boundaries and drawdown in observation wells is greatly enhanced using data collected via transducers and data loggers. Furthermore, the same transducers can also incorporate temperature and conductivity monitoring (Solinst LTC Levelogger Junior). We recommend installing transducers (with data loggers) in all wells that will be monitored for water quality and to set the frequency of measurement to an interval in the order of 5 minutes. It is also recommended to monitor levels in water well #2 and in at least one of the wells at Paulina Lake Campground. We agree with the argument that monitoring levels in Paulina Creek will likely produce data of limited value. Furthermore, while it is considered unlikely that pumping from the project site aquifer will impact Paulina Lake, it is still considered prudent to monitor water levels in the Lake. The transducer in the lake should be located within a pvc or steel tube that is secured to the shore to minimize the potential for disturbance.

Based on our experience in monitoring water wells in large construction areas, there is potential for vibration (seismic or heavy equipment) to disturb the natural or artificial gravel pack surrounding well screens. This can result in elevated turbidity. We suggest monitoring the wells at the project site for turbidity. While we also believe that the potential is remote for impacts to water quality within the shallow aquifer downgradient of the project site, we believe it would be prudent to conduct pre- and post-stimulation monitoring for turbidity and some basic total metals. The monitoring data could also be used to defend groundwater impact claims from well owners in the Newberry Estates area.

8.0 REFERENCES

AltaRock Energy, undated, Water Usage, Variables Affecting Needed Water Volumes.

Callahan, O., 2010, Memorandum, Newberry Water Monitoring, AltaRock Energy, Inc., December.

Century West Engineering, 1982, La Pine Aquifer Management Plan, Prepared for Deschutes County under Authorization by the Oregon Department of Environmental Quality, Bend, Oregon.

Cole, D.L., 2006, Groundwater Quality Report for the Deschutes Basin, Oregon, DEQ Laboratory and Water Quality Divisions, March.

Crumrine, M.D, Morgan D.S., 1991-1993, Hydrologic, Water-Quality, and Meteorologic Data for Newberry Volcano and Vicinity, Deschutes County, Oregon.

Dames and Moore, 1994, Revised Report-Newberry Geothermal Project, Hydrology Baseline Study, Newberry Volcano, Oregon for CE Exploration Company, 23305-002-043, May 4.

Davenport Newberry Holdings, LLC, 2010, Plan of Exploration, Operations Plan and Drilling Program, Newberry Volcano EGS Demonstration Project, June.

Federal Geothermal Leases, Newberry Volcano EGS Demonstration Project, Issues, Measures and Alternatives.

Finger, J.T., Jacobson, R.D., Spielman, P.B., 1995, Newberry Exploratory Slimhole.

Gannett, M.W., Lite, K.E., Jr., Morgan, D.S., and Collins, C.A., 2001, Ground-water Hydrology of the Upper Deschutes Basin, Oregon: U.S. Geological Survey Water Resources Investigations Report 00-4162.

Greim, H.A., 1994, Toxicity and Ecotoxicity of Sulfonic Acids: Structure-Activity Relationship, April.

King, G., 1991, Technical Reconnaissance Report, Survey of Groundwater Resources, Upper Deschutes River Basin, Oregon, U.S. Bureau of Reclamation, In-house Report.

Manga, M., Rowland, J.C., 2009, Response of Alum Rock Springs to the October 30, 2007 Alum Rock Earthquake and Implications for the Origin of Increased Discharge after Earthquakes, May.

Morgan, D., Hinkle, S.R., Weick, R.J., 2007, Evaluation of Approaches for Managing Nitrate Loading from On-Site Wastewater Systems near La Pine, Oregon: Scientific Investigation Report 2007-5237.

Morgan, D.S., Tanner, D.Q., Crumrine, M.D., 1997, Hydrologic and Water-quality Conditions at Newberry Volcano, Deschutes County, Oregon 1991-95: U.S. Geological Survey Water Resources Investigations Report 97-4088.

Phillips, K.E., 1968, Hydrology of Crater, East, and Davis Lakes, Oregon: U.S. Geological Survey Water-Supply Paper 1859-E.

Sammel, E.A., and Craig, R.W., 1983, Hydrology of the Newberry Volcano Caldera, Oregon: U.S. Geological Survey Water Resources Investigations Report 83-4091.

Schwartz, E.P., Wilson, A., Maslonkowski, D., 2010, Aquifer Test Results of the Pad-29 Well, TRC, October.

Sherrod, D.R., Gannett, M.W., and Lite, K.E., 2002, Hydrogeology of the Upper Deschutes Basin, Central Oregon: A Young Basin Adjacent to the Cascade Volcanic Arc: Field Guide to Geologic Processes in Cascadia: Oregon Department of Geology and Mineral Industries, Special Paper 36.

Spielman, P.B., Finger, J.T., 1995, Well Test Results of Exploration Drilling at Newberry Crater, Oregon.

Stenger, J.L., 2010, Proposal for Water Supply Well Testing and Analysis, AltaRock Project, Newberry Oregon, TRC, June.

Wong, I., Pezzopane, S., Dober, M., Terra, F., 2010, Evaluations of Induced Seismicity/Seismic Hazards and Risk for the Newberry Volcano EGS Demonstration, URS, November.

KLEINFELDER
Bright People. Right Solutions.

Figures

CAD FILE: H:\Geotech\Active Projects\116075 - G - AltaRock Energy\Graphics\ LAYOUT: Layout1

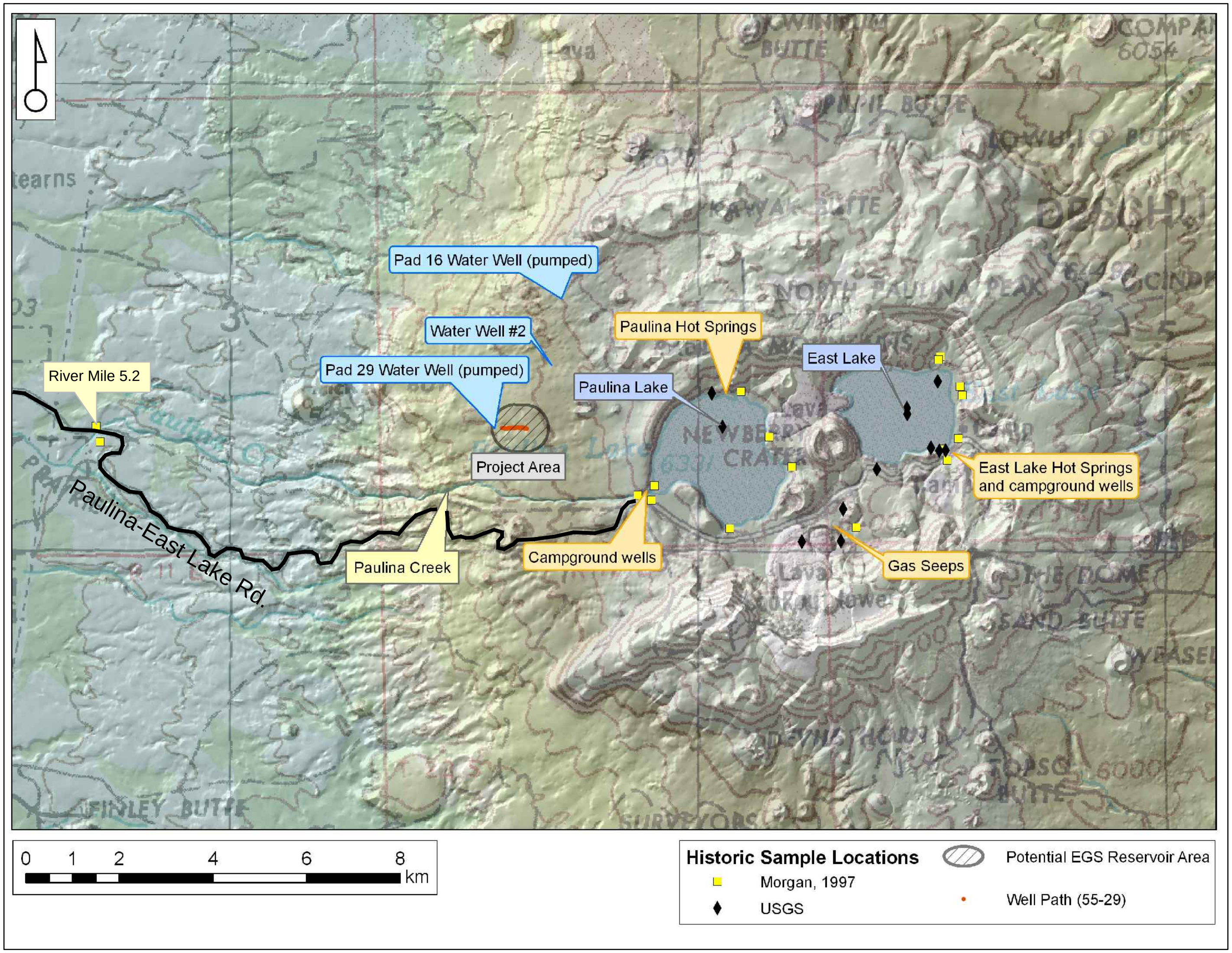


Figure from AltaRock Energy, Inc.

KLEINFELDER
Bright People. Right Solutions.
www.kleinfelder.com

PROJECT NO.	116075
DRAWN:	02/11
DRAWN BY:	TLK
CHECKED BY:	PS
FILE NAME:	116075F1.dwg

PROJECT AREA MAP

INDEPENDENT HYDROLOGIST REVIEW
EGS DEMONSTRATION PROJECT
NEWBERRY, OREGON

FIGURE
1

CAD FILE: H:\Geotech\Active Projects\116075 - G - AltaRock Energy\Graphics\ LAYOUT: Layout1 (2)

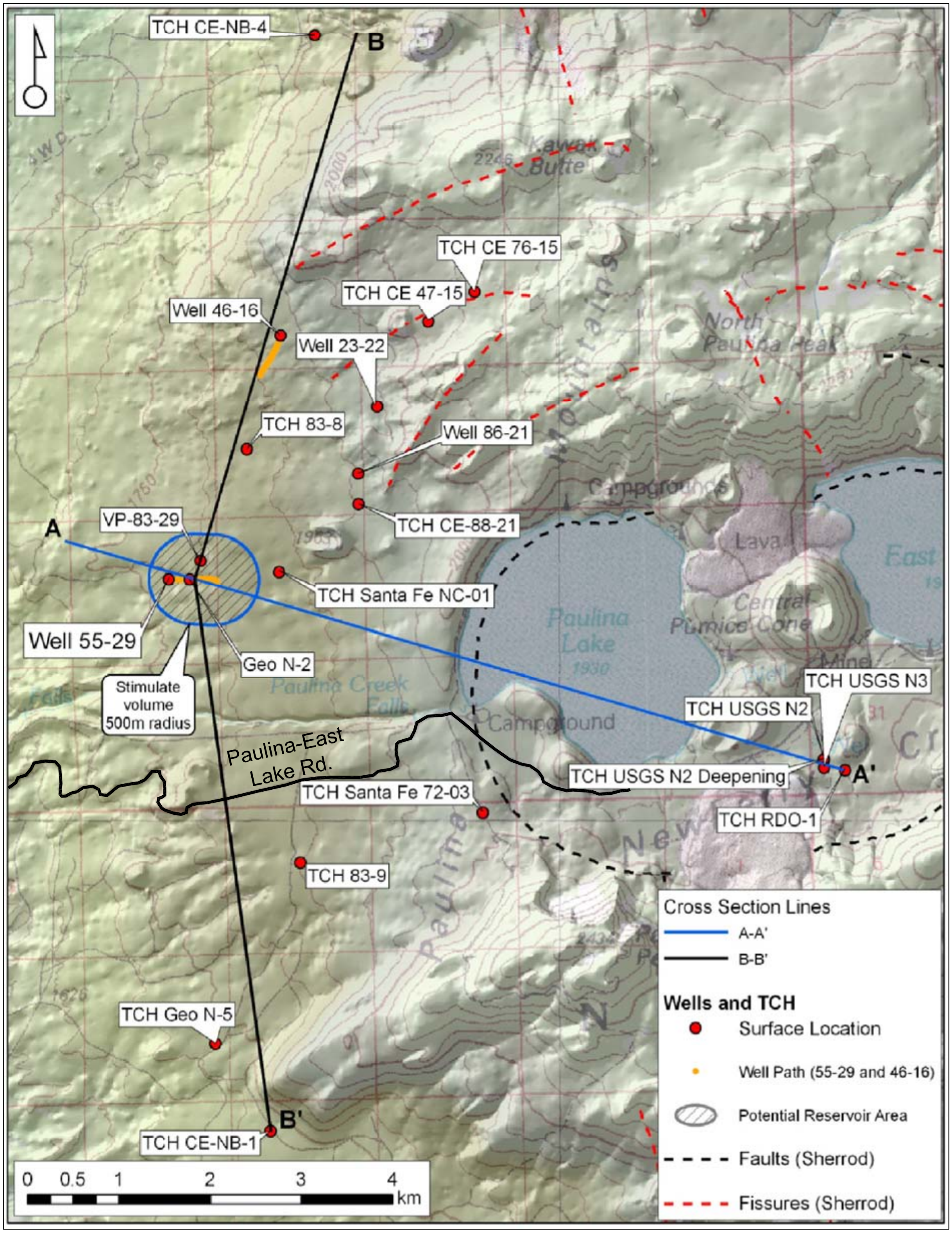


Figure from AltaRock Energy, Inc.

KLEINFELDER
Bright People. Right Solutions.
www.kleinfelder.com

PROJECT NO.	116075
DRAWN:	02/11
DRAWN BY:	TLK
CHECKED BY:	PS
FILE NAME:	116075F2.dwg

CROSS SECTION LOCATION MAP

INDEPENDENT HYDROLOGIST REVIEW
EGS DEMONSTRATION PROJECT
NEWBERRY, OREGON

FIGURE

2

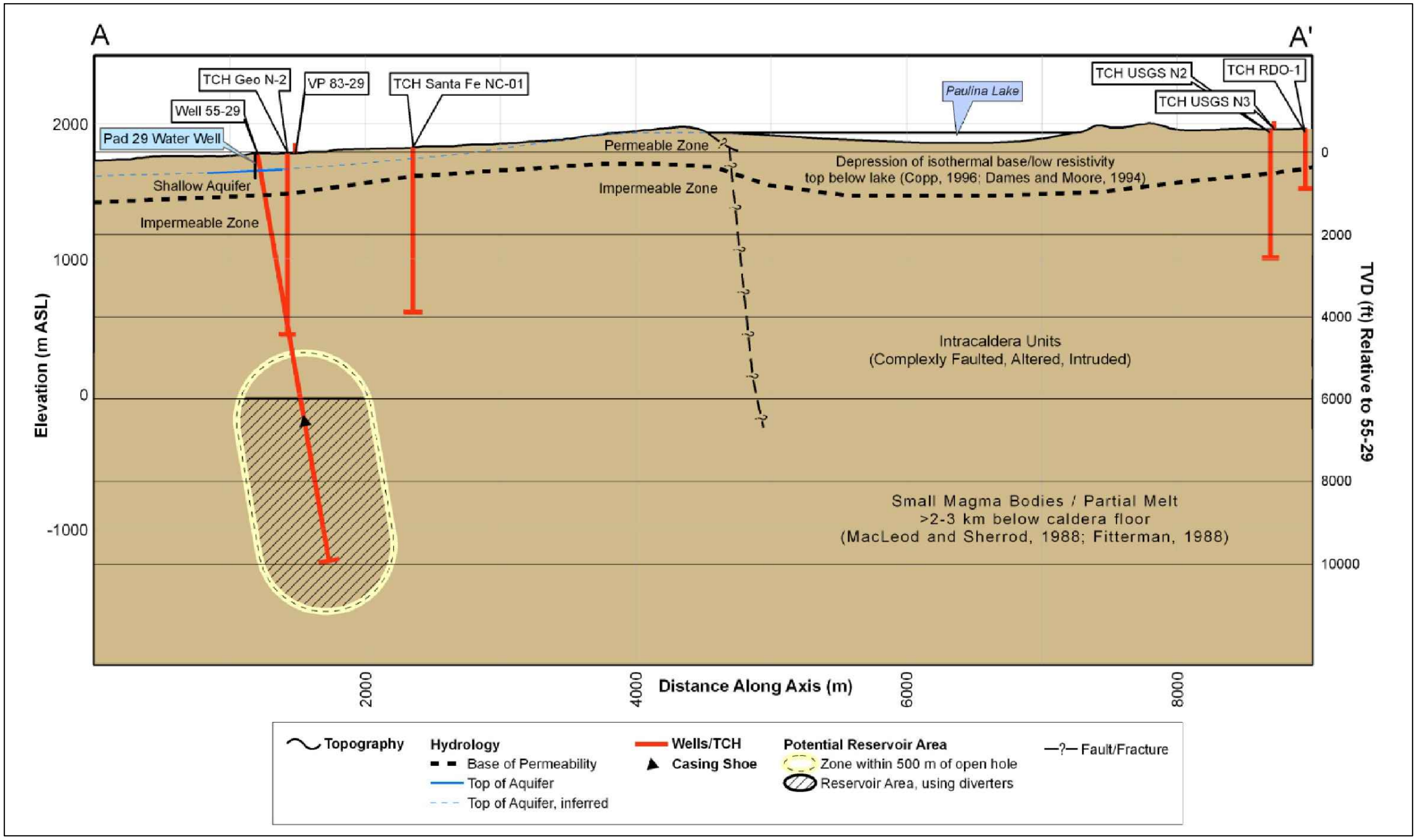


Figure from AltaRock Energy, Inc.

KLEINFELDER
Bright People. Right Solutions.
www.kleinfelder.com

PROJECT NO.	116075
DRAWN:	02/11
DRAWN BY:	TLK
CHECKED BY:	PS
FILE NAME:	116075F3.dwg

CROSS SECTION A-A'

INDEPENDENT HYDROLOGIST REVIEW
EGS DEMONSTRATION PROJECT
NEWBERRY, OREGON

FIGURE 3

CAD FILE: H:\Geotech\Active Projects\116075 - G - AltaRock Energy\Graphics\ LAYOUT: Layout1 (4)

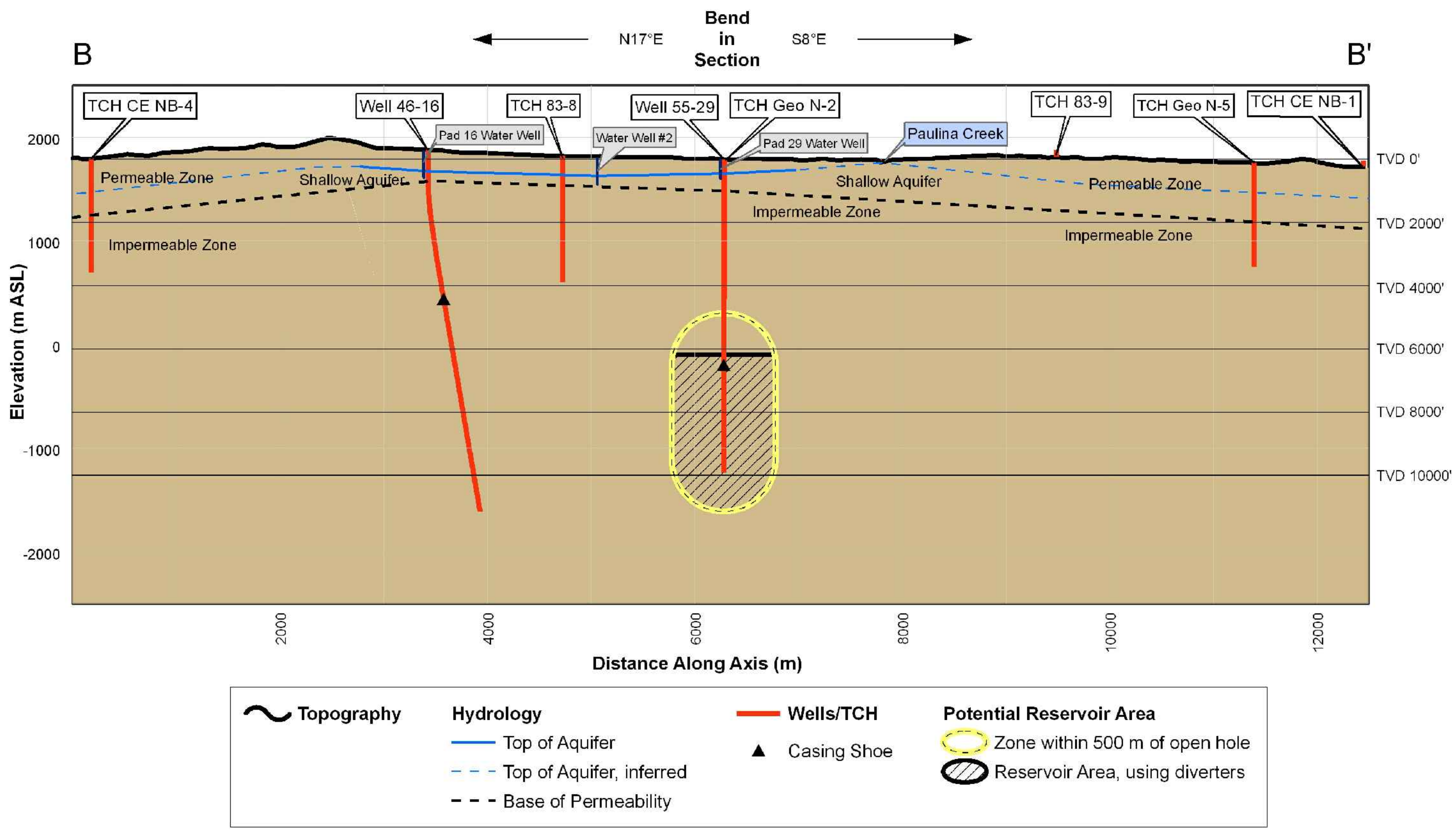


Figure from AltaRock Energy, Inc.

KLEINFELDER
Bright People. Right Solutions.
www.kleinfelder.com

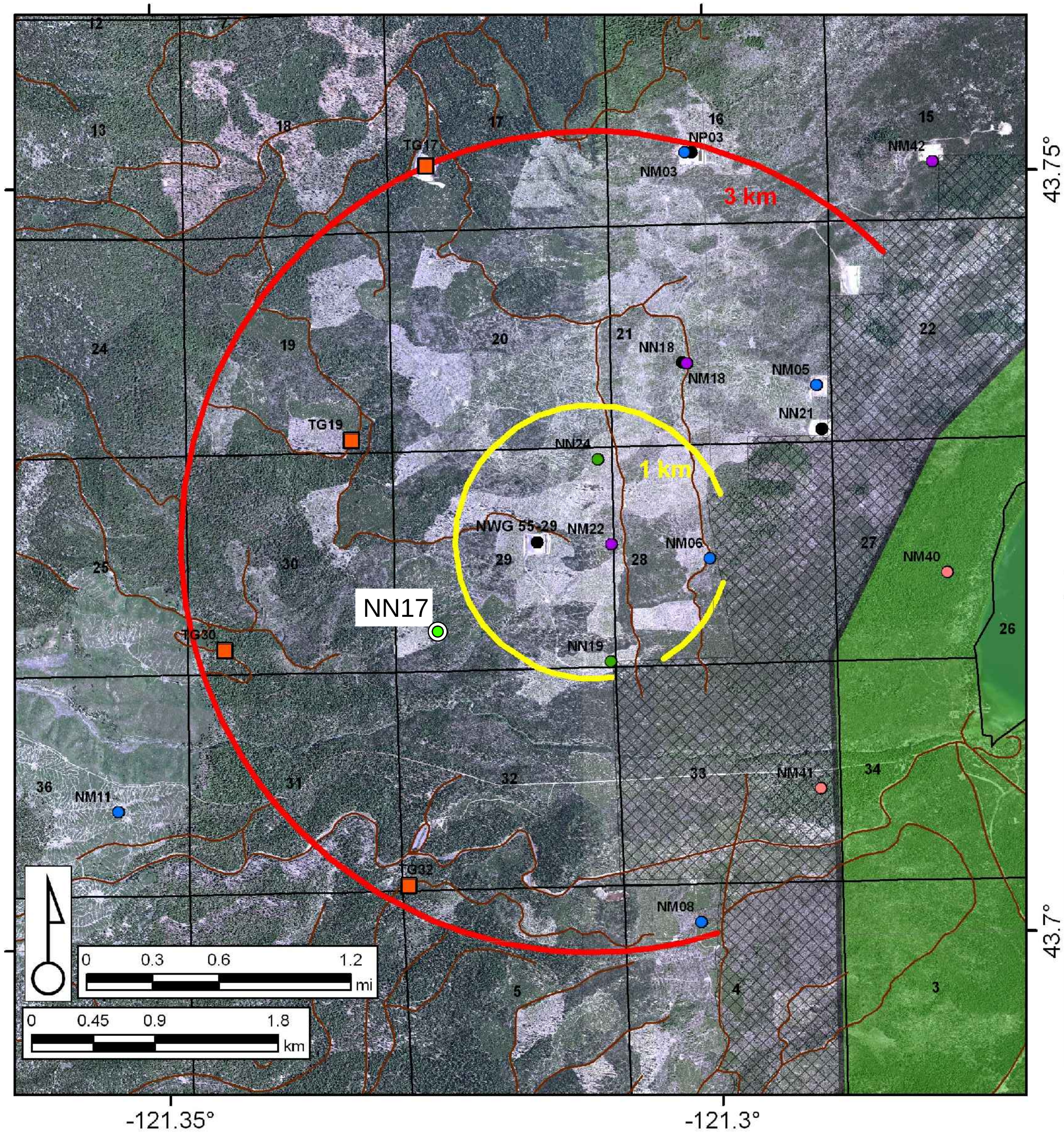
PROJECT NO.	116075
DRAWN:	02/11
DRAWN BY:	TLK
CHECKED BY:	PS
FILE NAME:	116075F4.dwg

CROSS SECTION B-B'

INDEPENDENT HYDROLOGIST REVIEW
EGS DEMONSTRATION PROJECT
NEWBERRY, OREGON

FIGURE
4

CAD FILE: H:\Geotech\Active Projects\116075 - G - AltaRock Energy\Graphics\ LAYOUT: Layout1 (5)



Newberry Microseismic Array Planned Locations (02/09/2011)

Legend

- Existing Holes or Conductor Pipe
- Current - Remain as Surface
- Current Surface Station - BH to be drilled
- Exploration Holes
- New Surface Location - no Solar / Telemetry
- New Surface Location
- Roads
- Sections

Label	Alternative Label(s)	Borehole/Surface
NN19	NBM07	B
NN17	NBM17	B
TG17	TG 17N	B
TG19	TG 19N	B
TG32	TG 32S	B
NN18	Water Well #2	B
NP03	NWC46-16	B
NN21	CE88-21	B
TG30	TG30N, MSA12	B
NN24	450m south of NBM04	B
NM08	NBM08	S
NM22	hypo stim zone	S
NM40	USGS P19	S
NM42	TCH76-15	S
NM11	MSA11	S
NM41	n/a	S
NM05	NBM05, MSA05	S
NM06	MSA06	S - Alt
NM03	NBM03	S - Temp
NM18	Water Well #2	S - Temp

NewbMSA_plan_02_07 Matthew Clyne February 2011

Figure from AltaRock Energy, Inc.

KLEINFELDER
Bright People. Right Solutions.
www.kleinfelder.com

PROJECT NO.	116075
DRAWN:	02/11
DRAWN BY:	TLK
CHECKED BY:	PS
FILE NAME:	116075F4.dwg

POTENTIAL DOWN-GRADIENT MONITORING WELL LOCATION

INDEPENDENT HYDROLOGIST REVIEW
EGS DEMONSTRATION PROJECT
NEWBERRY, OREGON

FIGURE 5

KLEINFELDER

Bright People. Right Solutions.

Tables

ALTAROCK ENERGY INC

Table 2 - Potential Impacts and Monitoring Plan

Water Resource	Potential Impacts	Monitoring Plan: Analysis	Monitoring Plan: Timeline	Comments
Shallow aquifer on flanks of volcano	1. Excessive drawdown (consumption) 2. Surface spills/sump leaks 3. Drilling fluids 4. Leaking reservoir fluids	1. Monitor drawdown in pad 29 and pad 16 water wells 2. Sump chemicals in water wells 3. Barium included in geochemical suite of water well samples 4. Monitor water wells for tracers[4], changes in major element abundances[5], temperature, pH, and conductance	1. During pumping of water wells 2.Only monitored if a major spill occurs 3, 4. Pre-stimulation samples collected at each of the three flank water wells one week prior to EGS stimulation, and every 2 weeks during stimulation.	Water consumption is described elsewhere (Nofziger, 2010), and will comply with permits and mitigation rules. Monitoring and clean up of surface spills (e.g. gasoline/diesel) in the event of an accident will follow the same protocol that would follow any similar spill. Drilling fluids have limited penetration into the formation and are described and permitted elsewhere.
Groundwaters within the caldera (Paulina Hot Springs, East Lake Hot Springs, non-thermal groundwater)	1. Changes in flow rates/temperature at springs 2. Leaking reservoir fluids	1. Monitor springs for changes in temperature, conductance and pH. Standard geochemical suite[5] looking for increased geothermal fluid signature. 2. Monitor campground well and springs for tracers.	1, 2. Pre stimulation samples collected from each site one week prior to EGS stimulation. Temperature, conductance and pH measured at each site daily for the first week, and full sampling suite conducted every two weeks during stimulation. Sampling will continue once a month for 6 months after the stimulation.	Ephemeral changes in gas/fluid flux may be possible through the indirect influence of passing seismic waves. Direct connection, even through complex pathways, is highly unlikely; tracers will be one of the only definitive ways to demonstrate communication.

4 Suggested tracer analysis is naphthalene sulfonate per discussion with Pete Rose (personal communication, 2010).

5 Current list of analytes: Alk, NH_3, As, Ba, B, Ca, Cl, F, Fe, Li, Mg, Hg, K, SiO_2, Na, Sr, SO_4, and the isotopes of hydrogen and oxygen.