Final Report

Geothermal Exploration in Hot Springs, Montana

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EXECUTIVE SUMMARY

Jackola Engineering and Architecture (Jackola) has been contracted by Flathead Electric Cooperative (FEC) to design, oversee, analyze, and report findings from exploratory drilling in Hot Springs, Montana. The project involves drilling deeper in the Camp Aqua well drilled in June 1982 as part of an effort to develop an ethanol plant. The purpose of the current drilling effort is to determine if water at or above 165°F exists for the use in low temperature resource power generation.

Previous geothermal resource study efforts in and around Hot Springs, MT and the Camp Aqua area (NE of Hot Springs) have been conducted through the years. A confined gravel aquifer exists in deep alluvium overlain by approximately 250' of silt and clay deposits from Glacial Lake Missoula. This gravel aquifer overlies a deeper bedrock aquifer. In the Camp Aqua area several wells exist in the gravel aquifer which receives hot water from bedrock fractures beneath the area. Prior to this exploration, one known well in the Camp Aqua area penetrated into the bedrock without success in intersecting fractures transporting hot geothermal water. The exploration associated with this project adds to the physical knowledge database of the Camp Aqua area. The drilling effort provides additional subsurface information that can be used to gain a better understanding of the bedrock formation that is leaking hot geothermal water into an otherwise cold water aquifer.

The existing well used for the exploration is located within the “center” of the hottest water within the gravel aquifer. This lent itself as a logical and economical location to continue the exploration within the existing well. Faced with budget constraints due to unanticipated costs, changing drilling techniques stretched the limited project resources to maximize the overall well depth which fell short of original project goals. The project goal of finding 165°F or hotter water was not achieved; however the project provides additional information and understanding of the Camp Aqua area that could prove valuable in future exploration efforts.

SITE HISTORY & PREVIOUS STUDIES

In the early 1980's, Jackola Engineering initiated a study to develop an agricultural by-products plant utilizing wheat and barley as feedstock. During that study, it was determined that utilizing geothermal resources could significantly reduce operational costs. The Little Bitterroot Valley and the Town of Hot Springs, Montana was identified as a possible source due to its history with geothermal water.

Overview of the Little Bitterroot Valley. The Wild Horse Hot Springs site corresponds to the Camp Aqua area, data courtesy of the Montana Geographic Information Clearinghouse

Figure 1

In early January 1981 the Montana Bureau of Mines and Geology (MBMG) drilled a well approximately 408 feet northeast of the original Camp Aqua well, CA-1. Hydrogeologists Donovan and Sonderegger of the MBMG completed this project and their efforts from 1977-1981 are summarized in the MBMG Open File 80 Final Report listed in the reference section. This well was drilled on the Gossett property and is often referred to as the “Gossett well.” The purpose of their efforts was to evaluate the geothermal resource characteristics with regard to temperature, flow, reservoir characteristics, and to evaluate the geothermal gradient at the test well.

Several studies were conducted in the Little Bitterroot Valley prior to 1981 and the Donovan and Sonderegger report lists this previous work. The US Geological Survey

(Boettcher, 1980) conducted well inventory and water quality analysis of wells in the Bitterroot Valley from 1976 through 1978. Earhart provided unpublished data in 1977 which collected water quality sampling of wells and springs for chemical constituents which would allow geothermometer calculations to be made for these waters. Crosby et al (1974) and Hawe (1975) performed geophysical investigations including gravity, magnetics, electromagnetics, telluric current, and micro earthquake studies were performed near Hot Springs. Qamar (1976) performed borehole temperature logging on a Confederated Salish Kootenai Tribe (CSKT) well near Hot Springs.

The work of Qamar, Crosby et al and Hawe all interpreted the occurrence of hot water in the town of Hot Springs to an east-northeast trending boundary fault which projects east towards the Camp Aqua area. Donovan's and Sonderegger's work reported in MBMG 80 concluded that in the Camp Aqua area it appears that mixing of deep geothermal water with cold water in the gravel aquifer occurs.

As part of Donovan and Sonderegger's work ground water samples collected from the gravel aquifer throughout the Little Bitterroot valley produced temperatures ranging from 63°F to approximately 125°F. Total Dissolved Solids (TDS) and concentrations of $\text{Na}^+/\text{Ca}^+/\text{K}^+$, chloride, Boron, and lithium all increased with increasing water temperature. In general the presence of chloride, Boron, and lithium are indicators of geothermal leakage zones into the gravel (Donovan and Sonderegger). Sampling performed by Donovan and Sonderegger resulted in increasing concentric concentrations of constituents around the Camp Aqua site. These "halos" surrounded the Camp Aqua site to approximately 7.5 miles north to Lonepine as shown in Figure 2 below. This is interpreted as good evidence that geothermal waters are ascending up through bedrock fractures and mixing with cold water in the gravel aquifer in the Camp Aqua area.

Boron, Lithium, and Chloride concentration sample results, extracted and reproduced (for clarity) from Donovan and Sonderegger, MBMG Open File 80, Final Report, 1981

Figure 2

In the same timeframe of Donovan and Sonderegger's work, Jackola Engineering was involved in a well associated with the potential development of an ethanol plant project located at the Camp Aqua Site and is discussed in detail in the Camp Aqua History section below. Several wells in and around the Camp Aqua site, currently Wild Horse Hot Springs, have been drilled over the years. At one point in time or another, each of these wells was referred to as the Camp Aqua Well. In the interest of clarity of this report these wells will be relabeled as follows:

Well Description	Name Used in Report
Camp Aqua, 1913 spa well	CA-1
Camp Aqua Geothermal test well #1, 1981 (LB-141)	Gossett Well
Camp Aqua Temperature Gradient well, 1982	CAT-1
Camp Aqua DNRC Gasahol Well, 1982	CAG-1
Camp Aqua FEC well, 2011-2012	CAE-1

Site plan showing the Camp Aqua well locations, data courtesy of Montana Geographic Information Clearinghouse

Figure 3

The original well, CA-1 was drilled in 1913 to a depth of 240' and unexpectedly produced 125.6°F, artesian water. It is believed that the well flow is restricted by "plugging" attempts made at the time of drilling. An 8 hour flow test conducted on October 22, 1980 produced a constant flow of 127 gpm at approximately 14.5 psig at the well head and a temperature of 125.6°F.

HYDROGEOLOGY BACKGROUND

The Camp Aqua site is located in the Little Bitterroot Valley which is likely a fault controlled valley (LaFave and others). Thick beds of silt and clay deposited by Glacial Lake Missoula underlie the surface and shallow alluvium. Shallow alluvium occurs along the Little Bitterroot River and floodplain as well as tributary streams. These glacial lake deposits overlie deep alluvium which was most likely deposited by a pre-glacial stream system that flowed from north of Niarada to the Flathead River (LaFave and others).

The deep alluvium making up the gravel aquifer, also known as the Lonepine Aquifer, overlies tertiary basin-fill deposits followed by bedrock throughout most of the valley. Bouger gravity anomaly mapping performed by Dresser, 1979 indicates that in the Camp Aqua geothermal area the Lonepine Aquifer overlies a Precambrian bedrock knob (Donovan and Sonderegger). Along fault zones in the Town of Hot Springs and the Camp Aqua area the rock is more permeable and circulates quantities of deep circulating geothermal waters (Donovan and Sonderegger). This phenomenon results in the mixing of cold water from the Lonepine Aquifer with the hot geothermal waters ascending through the bedrock. The intersection of these fault lines is unknown, however appear to be concentrated in the Camp Aqua area. The target depth, proposed but not reached in the CAE-1 Well, was based upon projections of the north-northwest trending, high angle, westward-dipping swarms of en echelon faults visible at the surface in the outcropping argillite rocks adjacent to the Little Bitterroot River. Visual inspection of the rock outcropping produced a westward dip angle of approximately 80° from horizontal with en echelon fractures spaced approximately 8 to 20 feet. These en echelon fractures are believed to extend through the Camp Aqua area between the major faults shown in Figure 4. A NE trending cross-valley fault related to the sediment filled depression extending from Hot Springs through Garceau Gulch exists, which complicates the Camp Aqua area geology (Donovan). Previous studies conclude that the Camp Aqua and the hot wells in Hot Springs likely share the same deep thermal reservoir; however do not appear to be hydraulically connected in the upper 1,500 feet (Donovan).

Simplified Geologic Map of the Camp Aqua Area, data courtesy of Montana Geographic Information Clearinghouse

Figure 4

CAMP AQUA (CAG-1) WELL HISTORY

As part of the 1982 ethanol geothermal investigation conducted by Jackola, a grant was requested from the Montana DNRC which was awarded under grant number 551-881. The purpose of this grant was to help fund the geothermal resource evaluations with the intent of drilling a production well in the suspected area of hottest water in the gravel aquifer. The Camp Aqua property was identified due to several factors which adequately suited the processing of grain for production of ethanol. The Camp Aqua site selection was also based on the previous study efforts. As mentioned above, the USGS, University of Montana Department of Geology, MBMG, and technical papers by numerous individuals provided considerable information related to the gravel aquifer source, transmission, and location of geothermal resources in the Hot Springs area especially near the Camp Aqua site.

Data from Donovan and Sonderegger and previous studies in conjunction with temperature logging by William E. Nork, Inc. was used to draw temperature isotherms in the Camp Aqua area within the gravel aquifer. It was decided that data SE of the 1913 CA-1 well was limited. A temperature gradient well, CAT-1 was proposed and drilled the week of January 25th, 1982. The well was located approximately 1,070 feet S32°E of the CA-1 well. This well was completed in the gravel aquifer and cased to 253 feet below ground surface (bgs) with artesian flow of approximately 175 gpm at 20 feet of head and a wellhead temperature of 111.2°F. A downhole temperature of 119.1°F was measured on May 27th, 1982. The Gossett Well was completed January 1981 to a depth of 1,002 feet bgs and produced 120.2°F water within the gravel aquifer and 105.4°F at the borehole bottom. This additional information allowed for updating the temperature isotherms in the Camp Aqua area and is shown in Figure 5. The trend of the isotherms in the gravel aquifer is similar to the figures generated by Donovan and Sonderegger regarding chemical constituents and their “halo” effect concentrated near the Camp Aqua site. More extensive temperature logging may have resulted in a slightly different isotherm configuration than shown in Figure 5. Donovan reported more extensive gravel aquifer temperature logging in Memoir 58 as shown in Figure 6, which concluded similar results. The hottest water in the gravel aquifer appears to be located within the Camp Aqua area. The northwest-southeast trend in the isotherms suggests a correlation with the northwest trending fault lines shown in Figure 4.

Prepared by WEN INC., February 1982

- - Well which was T-logged 01/07/82
 - - Well which was NOT T-logged
 - ▲ - WEN INC. temperature gradient hole
- example: 85 F - Outflow temperature

Isotherms drawn in the Camp Aqua area based on temperature logging of wells completed in the gravel aquifer by Donovan and Sonderegger and William E. Nork, Inc. (image reproduced for clarity from Jackola and Nork)

Figure 5

Observed groundwater temperatures in the gravel aquifer, image and data provided by MBMG
Memoir 58 (Donovan)

Figure 6

With the updated information, it is believed that the 1913 CA-1 well is located above a fault-swarm zone within the argillite bedrock where geothermal waters are being transmitted from the argillite upward through interconnected fractures into the overlying sand and gravel aquifer. Low permeability glacial lake deposits above the sand and gravel aquifer confine water flow creating artesian conditions.

The combination of data from previous studies coupled with the temperature logging and apparent success of the 1913 CA-1 well pointed towards the probability of completing a successful well for the use in ethanol production in the Camp Aqua area. As a result, the CAG-1 well was sited and completed within the gravel artesian zone approximately 220 feet SE from the 1913 CA-1 well.

The CAG-1 well was drilled by Liberty Drilling of Kalispell in June 1982 and the well log is enclosed in Appendix A. The well was completed into the upper zone of the bedrock at 260 feet bgs with 10" steel casing. Prior to perforating the casing and drilling into the bedrock interface, the water temperature at the wellhead was measured at 128.6°F and approximately 250 gpm artesian flow. When the casing

was advanced into the bedrock, artesian flow stopped. With the drill stem still in the well, the downhole temperature at a depth of 235 feet was measured at 135°F. The well was perforated from 250'-259' within the gravel aquifer. Sonderegger and Wideman of the MBMG performed a preliminary flow test on the well. They reported 1,100 gpm at 121°F at the wellhead and an estimated transmissivity of 125,000 gpd/ft (Jackola and Nork).

Tests have shown that there is an increase in temperature with an increase in depth within the gravel aquifer. This was shown in the 1981 report by Donovan and Sonderegger which observed an approximate 3°F change from top to bottom in the water bearing strata. This phenomena could explain the reduced temperature logged in the gravel zone once the CAG-1 well casing was perforated. This gradient also supports the hypothesis that geothermal leakage is occurring from the bedrock below.

Goethermometer sampling by Donovan and Sonderegger was completed as part of their work. Due to an unknown amount of mixing of geothermal water with cold aquifer water, the exact chemistry of the geothermal source is unknown. This mixing skews goethermometer analyses; however does provide insight to the source temperatures. Donovan's Memoir 58 goes into greater depth on the analysis of goethermometer samples collected as part of the MBMG Gossett Well efforts. Donovan and Sonderegger collected samples from the gravel aquifer and measured the observed temperature and various goethermometer concentrations. When silica concentrations were plotted versus observed temperature from various shallow wells, the data scatter produced was attributed to mixing. Using a straight line estimate compared to the chalcedony curve produced an anticipated source temperature range of 158°F (70°C) to 194°F (90°C) (Donovan and Sonderegger). Samples from the bedrock aquifer intersected by the Gossett Well anticipated the source temperature of about 171°F (77°C) based on interpolation of sample data compared to the chalcedony curve.

PROJECT DESCRIPTION

During the emergence of the ethanol industry, efforts to start up a plant resulted in the drilling of the CAG-1 well. With corn comprising 95% of the primary feed stock, the Corn Growers Association was a major driver behind the industry. It became increasingly difficult to move ethanol production capacity out of the Corn Belt to the viable wheat and barley feedstock sources of Montana. With the termination of the ethanol project, the CAG-1 well has sat with use by the Wild Horse Hot Springs, formerly Camp Aqua Hot Springs.

Through efforts by the Flathead Electric Cooperative, the potential for using the well for industrial purposes has been reinvigorated. FEC with technical support from Jackola and William Nork applied for a U.S. Department of Energy Grant to help fund the exploratory drilling effort. The objectives of the project were to expand on geothermal exploration efforts completed in 1982 by Jackola with a

desire to determine if the fractures carrying hotter geothermal water could be intersected for use in “low temperature resource” power generation.

The application was submitted under the DOE’s GTP Topic Area: Validation of Innovative Exploration Technologies. The appeal of using the Camp Aqua site is that the potential of the geothermal resource was previously characterized through geophysical, geochemical, temperature gradient holes, and subsequent data analysis through 1982. Overall project cost and scope for the exploration is reduced based on the years of background work performed by the previous study efforts mentioned above and utilizing an existing well.

DESIGN & APPROVAL PROCESS

Upon approval of the grant application, several tasks needed to be completed prior to the drilling efforts. First analysis of previous work and resources needed to be reviewed. With no known new study efforts within the Camp Aqua area since the 1980’s, the location was still deemed a viable geothermal resource. Significant study efforts had been completed in the gravel aquifer verifying leakage of geothermal water into the gravel aquifer from below and therefore additional efforts in the deeper bedrock was justifiable.

Second, given the nature of the project, selection of a drilling contractor was best made based on a qualification basis and therefore Requests for Proposals (RFP) needed to be developed. With preliminary design completed and drilling specifications developed, a RFP selection process was undertaken. Upon review of the submittals, the project was awarded to O’Keefe Drilling out of Butte, Montana.

Third, creation of design and construction documents needed to be completed to obtain necessary approvals and aid in the selection of a drilling contractor. The Montana DNRC and Confederated Salish Kootenai Tribe were contacted regarding the project. As an existing well and an exploration well with no intended use, no permitting was required. The Montana DEQ was contacted regarding handling of drill water. No permitting is required as long as no discharge to State waters occurred. Based on the design, no discharge was anticipated. The Region 8 EPA office was contacted regarding the drilling and disposal of drill water. They indicated that no permitting was required for the exploratory drilling effort.

Design efforts regarding the well construction were coordinated with O’Keefe Drilling and the U.S. Department of Energy (DOE). Upon DOE review recommendations for additional positive well control, casing and grouting, potential blow-off prevention, and H2S gas monitoring resulted in additional costs not accounted for in the original design and cost estimates included in the grant application. A large part of the unanticipated cost was associated with constructing and installing a concrete vault around the existing well head to allow for the installation of a valve and possible blow-off preventer while still allowing for the drill rig to operate.

The cost of these changes was absorbed into the drilling budget and therefore reduced the anticipated drilling depth. The original grant application anticipated drilling up to 2,000 feet if the water temperature had not reached the 165°F target at shallower depths. The drilling plan was modified to drill to approximately 500 feet, case and grout the well to that level, and continue drilling deeper as an open borehole until the budget is depleted. With unknowns in any drilling project, the budget needed to be closely monitored as progress continued to ensure that the maximum depth was reached without exceeding the available funds.

Fourth, access to the land needed to be formalized. FEC worked with their attorney and the landowner to enter into an agreement to access the land for the exploration effort. These negotiations took time and extended the start date for drilling.

Fifth, the construction and testing effort will take place. The original intent of the project was to drill in set stages. Prior to drilling, casing the existing well and sealing the gravel production zone was planned. Once drilling started, it was planned to drill to 500 feet and continue in 500 foot increments up to 2000 feet. Each 500 foot increment would be monitored and continued drilling efforts would be analyzed. Provisions for drilling a second well were considered if budget and resources allowed. As mentioned above unanticipated costs reduced the overall drilling budget, impacting the ability to reach targeted depths.

Well testing was anticipated to be performed to assess project outcomes. It was anticipated to conduct temperature logging, a well flow test to define aquifer characteristics, compare findings relative to previous study information and potential power capacity determination based on preliminary test information.

DRILLING SUMMARY

Doug Miller of Kalispell was responsible for completing the site preparations. This work included constructing a pond NW of the drill site, installing an 8" drain pipe from the well pad to the pond location, installing the pre-cast concrete cellar around the existing wellhead, installing a drain line from the cellar, constructing a gravel bed on the east and west ends of the cellar for the drill rig and drill steel truck, and installing concrete structures, pipe, and valves for the pond overflow structure on the existing pond.

Prior to drilling the existing CAG-1 well deeper, the existing gravel aquifer was sealed. The grouting operation consisted of first pressure grouting the perforated zone at a depth of 251-259 feet bgs. The first stage of grouting filled the bottom 19 feet of the casing, or 0.4 cubic yards of grout. Based on pumping 3 cubic yards of

grout, it was reasoned that 2.6 cubic yards was pumped out into the gravel formation.

The second stage of grouting used approximately 5 cubic yards of grout and filled the casing to within 12 feet from the surrounding ground surface. No water was flowing from the well after the grouting operations. Prior to drilling, H₂S safety training was held in Hot Springs for O'Keefe, Jackola, and FEC representatives. With the well grouted and the safety training complete, drilling was scheduled to start.

The drill rig used was a Foremost DR24HD and drilling was started December 19th, 2011. The initial drilling effort was to drill out the grout from the existing casing. When drilling advanced into the bedrock, no water flow was experienced which indicates that the original well casing was adequately anchored into the bedrock, isolating the gravel aquifer.

Drilling progressed into the bedrock; see attached well notes in Appendix B. A significant fracture zone was encountered at a depth of approximately 417 feet bgs. Another was encountered at approximately 428 feet bgs with artesian flow estimated at 20gpm with the drill stem in the well. These fracture zones in conjunction with an increase in rock hardness and loss of circulation significantly slowed drilling progress. O'Keefe tripped out to discover that the bit was extremely worn and a number of the buttons had broken off. With the loss of buttons in the well and the reduced circulation, it was decided that a camera would be run down the well. The well video revealed large voids in the borehole at the 418 and 428 foot bgs and at least a 5" shift in the borehole alignment. The decision was to grout the well to stabilize the borehole in the large void zone.

Once resuming drilling stiff foam was used to improve circulation of the drill cuttings. The drilling improved for a short duration; however another large fracture zone was encountered at 450 feet bgs. The drilling slowed and circulation was reduced. Drilling was slowly advanced to a total depth of 471' bgs with the borehole caving to approximately 468' bgs. Due to concerns of intersecting caving fracture zones for the entire well depth, it was decided that the best way to proceed was to change to Reverse Circulation drilling from dual air rotary.

The reverse circulation would reduce the borehole from 10" diameter to 5 7/8" diameter. Prior to resuming RC drilling, the well was cased and grouted from 471' bgs to the surface with 7" diameter steel. Grouting of the well cut off the artesian flow and therefore was deemed to provide adequate well control.

RC drilling resumed from 471' to 889' bgs. Water was encountered at a depth of 630' bgs and was approximately 60 gpm artesian. An increase in water was encountered at 700' bgs to approximately 125 gpm. Unfortunately with depth, the water temperature decreased similar to the MBMG Gossett well drilled NW of the site. At 889' bgs, it was determined that the drilling budget was depleted. At this stage, O'Keefe tripped out of the well, capped the wellhead and demobilized from

the site. Prior to closing in the well, a temperature log was run using an Insitu LevelTROLL transducer with the results shown in Appendix C.

RESULTS

In addition to temperature monitoring during drilling, Competition Wireline Services from Cut Bank, MT were contracted to perform temperature and gamma ray logging on the CAE-1 well. The testing was performed on May 8th, 2012, approximately 1 month after the well was shut-in after drilling. The graph in Appendix C summarizes temperature versus depth measured in the Gossett Well as reported in MBMG 80, the static and flowing tests performed by Competition Wireline Services on the CAE-1 well, the bottom hole temperature measured in the CAT-1 well in 1982, and the flowing well temperature logged during drilling of the CAE-1 well. This data shows that the greatest temperature in these wells was observed within the gravel aquifer zone at approximately 250 feet bgs, with the CAE-1 well producing the highest observed temperature. The depths have not been corrected for relative wellhead elevations due to lack of survey information; however the area is relatively flat compared to depth and would not significantly impact the observed results.

Appendix E includes a scan of the logs run by Competition Wireline Services. The first pass on the well was performed shut-in. A maximum temperature of 123.9°F was observed at approximately 250 feet bgs which corresponds to the existing gravel aquifer. Since the well is cased and sealed to a depth of 471' bgs, the elevated temperature in this zone is due to transfer of heat from the formation to the casing. In a static state, the water had a chance to stabilize and reflect closely the temperature of the water in the gravel aquifer. Similar to the Gossett well findings summarized in MBMG Open File 80, once in the bedrock, the water temperatures decrease with depth. The lowest temperature during this static log was 101°F at the well bottom.

After this first pass, the well was allowed to flow at approximately 40 gpm. After a period the well was logged on the way in and out of the well. The data shown in Appendix E for the flowing well test is based on logging while removing the instrument. This data shows that below the casing depth of 471' bgs, the water temperature is essentially isothermal, only changing 0.8°F from 101.8°F to 101°F. With a large portion of the water produced by the well encountered below 650' bgs, this isothermal behavior was expected. An increase in the flowing temperature was observed within the casing up to 103.8°F and is attributed to conductive heat gain from the hotter, shallow gravel aquifer. This increase in water temperature was observed during drilling; however the relative increase in temperature was smaller which is attributed to higher flow rates and therefore shorter residence time in the casing.

After performing the static and flowing temperature logs, a gamma ray log was performed. The results of these tests are shown in appendix E. Similar to the

MBMG Gossett well testing, the high gamma is interpreted to correlate to the argillite formation present through the depth of the well. The low gamma measurements are attributed primarily to fracture zones and mineralization within these fracture zones. Some of the fractures encountered resulted in an increase in water. Based on field observations during drilling, fracture zones that produced artesian water occurred at approximately 420' bgs, 470' bgs, 630' bgs, and 700' bgs to total depth. Below 700' the well remained within water bearing zones with minimal increase in artesian flow. Only the fractures below 471' bgs cased depth is contributing flow to the finished CAE-1 well.

Donovan and Sonderegger conducted aquifer testing on the Gossett Well which was completed to a similar depth as the CAE-1. During their testing they monitored 4 surrounding non-flowing wells and 2 flowing wells that were completed in the gravel aquifer to determine if the bedrock aquifer was in communication with the gravel aquifer. A 70 hour flow test was completed with flow rates starting at 543 gpm and ending at 501 gpm. They reported the flowing and recovery transmissivities within the bedrock estimated at 155,000 gpd/foot and 178,000 gpd/foot respectively. A distance-drawdown plot for the observation wells yielded a straight line transmissivity estimate of 257,000 gpd/foot utilizing observation wells greater than one mile from the Gossett Well. As reported by MBMG Open File 80 (Donovan and Sonderegger), observations in the flowing and non-flowing monitoring wells resulted in drawdowns confirming hydraulic communication between the gravel and bedrock aquifer in the Camp Aqua area.

Donovan and Sonderegger concluded based on their study efforts that the Gossett well likely intersected bedding planes dipping to the east that receive gravel aquifer water located to the west of the Gossett well. This results in cooler water than is present in the gravel aquifer located at the wellhead based on the isotherms shown in Figures 5 and 6. Further it was believed that these dipping bedding planes would intersect the fracture system that carries hot geothermal water from below; however precipitation of minerals could have sealed off these bedding planes from the main fracture carrying hot water upward. This potential was observed at the Gossett Well through a grey mud wash and mineralization observed in drill cuttings. Hot water must be rising up the main fault zone since temperatures in the gravel have remained constant since the early 1900's when the original Camp Aqua well was drilled. See Figure 7 below which conceptually summarizes the previous bedrock study findings presented by Donovan and Sonderegger.

Conceptual cross section (east-west) across the Camp Aqua area based on study efforts completed by Donovan and Sonderegger (image extracted and reproduced from Donovan and Sonderegger, 1981)

Figure 7

Due to budget constraints, aquifer testing was not performed as part of this project. However, with the proximity of the CAE-1 well to the Gossett Well and the similar observations made during drilling and temperature logging, it would seem reasonable to expect the aquifer testing would produce similar results with respect to hydraulic connectivity to the gravel aquifer. The schematic cross section shown in Figure 7 is a possible explanation of the observations made in the Gossett and CAE-1 wells. However based on the observance of an echelon faults in the rock outcroppings east of the site, it is anticipated that parallel westward dipping fractures extend west towards the Camp Aqua area. Therefore at shallow depths it is possible that more than one fracture leaks geothermal water to the gravel aquifer. Similar to the location of the geothermal leakage zone, exactly where the colder gravel aquifer water flows into the bedrock is unknown. As theorized by Donovan and Sonderegger, the bedrock aquifer is likely in hydraulic communication with the gravel aquifer west of the well site based on the isotherms shown in figures 5 and 6. It is possible that the NE trending cross-valley fault from Hot Springs could play a role in the communication between the gravel and bedrock aquifers as well, but could not be concluded within the scope of this study. Regardless, mixing between the bedrock and gravel aquifers appears to be isolated from the upward leakage of geothermal water. This isolation is attributed to mineralization within the fractures, therefore sealing off the upward flow from within the CAE-1 well.

Upon review of the Gossett Well log in the Donovan and Sonderegger report, they encountered several fracture zones of soft argillite and quartzite. The driller noted on the Gossett well log that the bit had to be held back in one such soft zone. The

CAE-1 well encountered fracture zones; however the rock was primarily hard and resulted in slow drilling and accelerated wearing of drill bits. The hard rock and caving fracture zones resulted in drilling delays and required a change in the drilling technique.

Water samples were collected from the 1913 well and the CAE-1 and the results are enclosed in the table below. Also included in this table is data from Donovan's MBMG Memoir 58. Based on previous geothermometer analysis by Donovan, limited samples were collected based on the determination that the dissolved silica concentrations for Chalcedony control reported more realistic aquifer temperatures. As previously mentioned, Donovan anticipated a geothermal source temperature of 171°F based on the chalcedony control with corrections made for mixing with cold aquifer water. As the data shows, samples from the bedrock aquifer results in lower source temperatures. This is attributed to cold water originating further from the geothermal leakage source mixing with the bedrock aquifer.

GEOTHERMOMETER SAMPLES								
Well	Sample Depth (ft)	Ca (mg/l)	Mg (mg/l)	K (mg/l)	Na (mg/l)	SiO ₂ (mg/l)	Silica Chalcedony (°C)	Quartz Chalcedony (°C)
Gossett	255	4.2	1.2	3.4	156	50.6	72 (161°F)	103 (217.4°F)
Gossett	261-324	16.7	2.1	2.9	139	38.8	60 (140°F)	91 (195.8°F)
Gossett	261-423	12.5	2.4	3.2	130	37.7	58 (136.4°F)	90 (194°F)
CAG-1	259	2.9	.2	3.1	152	43.2	65 (149°F)	96 (204.8°F)
CAE-1	471-889	13	3	4	142	36.8	57 (134.6°F)	89 (192.2°F)
1913 Well	240	3	ND (<1)	3	168	47.5	69 (156.2°F)	100 (212°F)

Table 1: Summary of current geothermometer samples for CAE-1 well and results reported by Nork and Jackola for original CAG-1 well, and Gossett well sample data extracted from Donovan MBMG Memoir 58. Source temperatures does not account for mixing with cold, non-geothermal waters.

SUMMARY & CONCLUSIONS

The initial project budget with the grant application failed to adequately anticipate unknowns associated with coordination of the design and construction program with the DOE. An increased contingency or specific budget item would have allowed for absorbing the increase while maintaining the drilling budget and potentially reaching the original target depth. The primary goal of this exploration project was to determine in a cost effective manner if the existing well at Wild

Horse Hot Springs could be deepened and intersect the fracture zones that leak hot geothermal water into the otherwise cold gravel aquifer in the Camp Aqua area. The CAE-1 test well was unsuccessful in intersecting these fracture zones. In general, the findings of this study effort were similar to the findings of Donovan and Sonderegger at the Gossett Well reported in the MBMG Open File 80 final report. Similar to their efforts, the temperature of the water decreased with an increase in overall depth. Mineralization was observed in the otherwise argillite dominated drill cuttings, lending itself to a similar conclusion that mineralization of fractures has potentially isolated these main hot water fractures from the bedding fractures penetrated by the CAE-1 and Gossett wells.

The well is cased with 7" steel to a depth of 471' bgs and is 5 5/8" open hole to the approximate 889 foot bgs depth. Based on visual inspections of the well discharge pipe, the well flows approximately 250 gpm and the shut in pressure is 11 psi. The temperature log of the well flowing at 40 gpm produced a wellhead temperature of 103.1°F. Shut-in, the water temperature in the existing gravel zone resulted in a temperature of 123.9°F.

Unfortunately budget limitations cut the exploration efforts short of initial project targets. The well has been left in a condition that allows for future drilling efforts to take place. The cellar and drill pad remain to allow for re-entering the well and continue drilling at a future date. Based on limited historical drilling in the bedrock within the Camp Aqua area, it is difficult to determine if this well would intersect the fracture zones transporting hot water from below. However based on study efforts within the gravel aquifer and analysis of this information, it is believed that the CAE-1 well is located within the highest observed gravel aquifer temperatures and had a high probability of intersecting a fracture zone transporting hot geothermal water. Based on existing efforts and infrastructure, this exploration was completed in a cost effective manner. Future drilling efforts in the CAE-1 would exceed depths documented to date and therefore could be valuable in defining this resource. Work performed by Bill Nork and the previous efforts of Donovan and Sonderegger have concluded that the major fault connected to the geothermal waters in the Camp Aqua area is very steep to nearly vertical, making it more difficult to intersect. Based on observed en echelon faults, it is likely that geothermal waters travel upward through one or more north-northwest trending faults.

The outcome of this exploration effort was not successful; however does provide a benefit for future study efforts. If desired, the well could be drilled deeper or allow for additional testing to be performed. In the Camp Aqua area, this was the second well to be completed in the bedrock beneath the gravel aquifer. Both this well and the Gossett Well could be used to aid in future exploration efforts. The Gossett and CAE-1 wells were completed to similar depths (1,002 and 889' bgs respectively). Drilling deeper in the CAE-1 well may not intersect the targeted fracture zone; however may allow a cost effective way to gain additional knowledge with respect to the bedrock beneath the Camp Aqua area. Another consideration of future exploration efforts could be to use fracturing to potentially connect the

borehole to hydraulically connected fractures carrying geothermal water. Impacts with respect to the environment and surrounding water supplies would need to be considered in utilizing these technologies.

Future study efforts in the Camp Aqua area could benefit from the experiences of this exploration effort. The initial dual air rotary drilling was preferred based on the ease in diverting water and cuttings to a controlled basin; however made accurate collection of samples and estimate of flow more difficult based on the distance to the pipe discharge. Given the fractures encountered, the dual air rotary made maintaining circulation more difficult and added the potential for caving around the bit. The transition to open hole RC drilling allowed for better collection of cutting samples, however provided two streams of well flow to divert to the controlled basin. Future exploration efforts in the CAE-1 would likely benefit from continued use of RC drilling. The argillite, albeit friable, fractured and not especially competent should stay open barring some major seismic event.

As with any exploration effort, there is a risk of being unsuccessful in reaching the project goals. Deepening the CAE-1 well to original project target depths may provide valuable data with respect to the bedrock formation beneath Camp Aqua. With this in mind, upfront geophysical studies may have located the leakage zone more precisely to determine with greater certainty a new well site. This work could include geophysical testing on a tighter grid to more accurately map the bedrock in the Camp Aqua area including the possible use of seismology and gravity surveys. Select shallow drilling (<300 feet) and testing efforts could also be performed to more closely locate zones of geothermal leakage.

This would be a major undertaking that would require work well beyond the scope of this and previous projects. The Confederated Salish and Kootenai Tribe, Compact Commission, and the United States are diligently working towards a comprehensive water rights settlement for the Flathead Indian Reservation. The outcome from these negotiations would have an impact on a detailed study effort and should be considered with any future exploration efforts.

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APPENDIX A – WELL LOGS

CAG-1 Well Log

Location: Camp Aqua Site near Hot Springs, Montana
SE ¼, SW ¼, NE ¼, Section 29, Township 22 North, Range 23 West

Driller: Liberty Drilling Company

Date: July 14th, 1982

Formation Log:

0	-	4	light brown silt clay
4	-	11	tan to light brown silty clay. Tough and rubbery.
11	-	39	Light brown to brown clay. Tough and Rubbery.
39	-	57	Light brown to brown clay with thin layers of gray clay. Tough and rubbery.
57	-	116	Light brown to brown clay with thin layers of gray and dark brown clay. Tough and rubbery.
116	-	151	Medium to dark brown silty clay with layers of blue-gray clay. Some small rock fragments.
151	-	203	Medium to dark brown silty clay with layers of blue-gray clay and seams of dark brown silt. Some rock fragments
203	-	212	Light gray, blue, purple and gray clay. Some thin sand streaks with brown silt and small pebbles.
212	-	216	Sandy light gray to blue and purple clay.
216	-	234	Light gray, blue, purple, and brown clay in alternate layers.
234	-	240	Light gray to blue-gray clay with gravel imbedded and thin layers of sand.
240	-	248	Sand and medium to fine gravel. Water.
248	-	259	Medium to coarse gravel. Some sand. Flowing water.
259	-	260	Rock

Driller Log:

Well flowed in excess of 1160 gallons per minute of 128.6 degrees water through a four inch choke on a 20 hour test. Well produced in excess of 1600 gallons per minute through 19 hours of development with an air lift pump. Shut in pressure at completion of developing and test pumping was 8 to 12 pounds.

Completion Log:

The well is cased from surface to 99' 4" with 12 ¾" O.D. x 0.375 wall black steel water well casing. The well is cased from 3' above surface to 260' with 10" black steel water well casing.

Grouting Log:

A 17 ½" diameter hole was drilled from surface to 99' 4" to accommodate 12 ¾" O.D. Casing and provide an annulus for cement grout. This annulus was grouted with 95 sacks of cement grout to provide a surface seal and prevent flowing water from coming up around the 12 ¾" casing.

Perforating Log:

The 10 3/4" casing was perforated from 250' through 259' with a mills knife with 3/8" x 4" slots. All water that is entering the well is coming through these perforations.

CAE-1 Well Log

Driller: O'Keefe Drilling

Date: March 29th, 2012

<u>Depth</u>	<u>Description</u>
260' – 388'	gray argillite
388' – 400'	gray argillite, less fractured
400' – 410'	harder gray argillite –slow progress
410' – 415'	green gray argillite (softer)
415' – 425'	green gray argillite, large fractures, lost circulation
425' – 435'	blue gray argillite ~33gpm artesian flow
435' – 437'	fractured, slow drilling downhole pressure binds bit
437' – 440'	gray argillite fracture with larger cuttings
440' – 442'	gray argillite with precipitates along fractures – slow drilling
442' – 455'	hard gray argillite, using stiff foam for circulation
455' – 468'	hard gray argillite with white precipitates along fractures, bit bouncing in fractures
468' – 471'	softer gray argillite with pyrite, increase in water highly fractured – Approx. 2' cave-in around bit, install and grout 7" casing to surface, no flow
471'	Change to 5 5/8" RC Drilling no artesian flow
471' – 480'	Hard gray argillite; slow drilling 2 1/2 hr. per foot.
480' – 485'	slightly faster drilling, gray argillite, no water
485' – 498'	hard gray argillite; small fracture zone at 488', no water
498' – 505'	gray argillite with pyrite, slightly faster drilling
505' – 515'	softer gray argillite with pyrite & light tan and white precipitates on rock
515' – 520'	harder blue gray argillite
520' – 535'	blue gray argillite, tan/white precipitates in cuttings, no water
535' – 538'	blue gray argillite, no water
538' – 562'	gray argillite
562' – 563'	gray argillite, water seep – no artesian flow
563' – 600'	gray argillite – overnight swl 88'
600' – 612'	gray argillite with pyrite
612' – 618'	fractured gray argillite – swl 10'
618' – 630'	gray argillite
630' – 640'	gray argillite with pyrite, large cuttings, approximately 60 gpm artesian
640' – 646'	fractured, gray argillite
646' – 660'	gray argillite, less fractured, approx. 100 gpm artesian
660' – 730'	hard gray argillite approx. 125 gpm artesian with bit in well
730' – 820'	hard gray argillite Fracture at 765'

820' – 860' hard gray argillite fracture at 825'
860' – 889' hard gray argillite with pyrite approx. 250 gpm artesian flow w/ bit tripped out.

Borehole Dimensions

0' – 260' existing 1982 well
260' – 471' 10" borehole
471' – 889' 5 7/8" borehole

Casing:

0' – 471' 7" steel

Completion

471' – 889' open hole

Total Depth: 889'

Closed in pressure: 11 psi

Yield: 250 gpm

MONTANA WELL LOG REPORT

Other Options

This well log reports the activities of a licensed Montana well driller, serves as the official record of work done within the borehole and casing, and describes the amount of water encountered. This report is compiled electronically from the contents of the Ground Water Information Center (GWIC) database for this site. Acquiring water rights is the well owner's responsibility and is NOT accomplished by the filing of this report.

[Plot this site on a topographic map](#)
[View water quality for this site](#)
[View scanned well log \(1/27/2011 7:56:13 AM\)](#)

Site Name: MBMG GEOTHERMAL CAMPAQUA TEST
WELL #1 * LB-141
GWIC Id: 6237

Section 7: Well Test Data

Total Depth: 1002
Static Water Level: -25.41
Closed-in Pressure: 11 psi
Water Temperature:

Unknown Test Method *

Yield 500 gpm.
Pumping water level -20.6 feet.
Time of recovery _ hours.
Recovery water level _ feet.

Section 1: Well Owner

Owner Name
GOSSETT, JAY
Mailing Address

City State Zip Code
AURORA IL

Section 2: Location

Township	Range	Section	Quarter Sections
22N	23W	29	SE¼ SE¼ NE¼ NW¼
County			Geocode
LAKE			
Latitude	Longitude	Geomethod	Datum
47.6422	114.5713	UNKNOWN	NAD27
Ground Surface Altitude		Method	Datum Date
2753			

Addition Block Lot

* During the well test the discharge rate shall be as uniform as possible. This rate may or may not be the sustainable yield of the well. Sustainable yield does not include the reservoir of the well casing.

Section 8: Remarks

Section 9: Well Log

Geologic Source

400PRCD - PRICHARD FORMATION OR SLATE

From	To	Description
0	8	DRY LT. BROWN TO BUFF SILT AND CLAYEY SILT - FLECKS OF WHITE ALKALI
8	37	VERY LT. BROWN TO LT. BROWN SILTY CLAY AND CLAYEY SILT, MOIST - NO PEBBLES IN CLAY.
37	57	VERY LIGHT BROWN TO LIGHT BROWN LOOSE FRIABLE SILTY CLAY, BECOMING DARKER BROWN WITH DEPTH
57	88	DENSE RUBBERY LIGHT TO MEDIUM BROWN CLAY - CUTTINGS IN SMALL CHUNKS - HARD LAYER AT 57 FEET
88	100	MEDIUM TO DARK BROWN DENSE RUBBERY CLAY, CUTTINGS IN HARD CHUNKS - HARD LAYER AT 96 FEET
100	120	MEDIUM TO DARK BROWN CLAY AND SILTY CLAY, CUTTINGS .5 TO 1 INCH DIAMETER, NO SAND
120	132	VERY SOFT MEDIUM TO DARK BROWN CLAY, DRILL STRING SINKS UNDER OWN WEIGHT
132	140	MEDIUM TO DARK BROWN CLAY, W/VERY SHARP ANGULAR GRAVEL OR ROCK FRAGMENTS .25 INCH TO 1 INCH DIAMETER (POSS. ICE RAFTED)
140	180	MEDIUM TO DARK BROWN CLAY, SILTY CLAY, NO SAND OR GRAVEL - CUTTINGS RECOVERED IN VERY SMALL LESS THAN .25 INCH CHUNKS
180	190	BROWN TO GREY-BROWN SILTY CLAY AND CLAYEY SILT - NO SAND OR PEBBLES
190	200	MEDIUM BROWN TO GREY-BROWN CLAYEY SILT AND SILTY CLAY - SOME SMALL QUARTZITE FRAGMENTS
200	205	GREY TO GREY-BROWN CLAY AND SILTY CLAY, NO SAND
205	215	MEDIUM GREY TO BLuish-GREY RUBBERY CLAY, NO SILT - SOME THIN (2%) SAND STREAKS,

Section 3: Proposed Use of Water
RESEARCH (1)

Section 4: Type of Work

Drilling Method:

Section 5: Well Completion Date

Date well completed: Saturday, January 10, 1981

Section 6: Well Construction Details

Borehole dimensions

From	To	Diameter
0	104	10
104	1002	6

Casing

From	To	Diameter	Wall Thickness	Pressure Rating	Joint	Type
-2.5	264	6				STEEL
-0.5	104	8				STEEL

Completion (Perf/Screen)

From	To	Diameter	# of Openings	Size of Openings	Description
264	1002	6			OPEN HOLE

Annular Space (Seal/Grout/Packer)

From	To	Description	Cont. Fed?
0	264	CEMENT

		CASING SINKS VERY EASILY- GOOD CUTTING RECOVERY, CHUNKS UP TO 4 INCH LONG
215	239	VERY FINE GREY TO BLUE-GREY, FINE SAND IN THIN STREAKS
239	240	VERY HARD "CAPROCK" - NO CUTTINGS RECOVERED - DRIVE HAMMER REBOUNDS ON IMPACT - MAY BE SULFIDE- INDURATED BLUE CLAY

Driller Certification

All work performed and reported in this well log is in compliance with the Montana well construction standards. This report is true to the best of my knowledge.

Name: DAVE BILLMAYER
Company: BILLMAYER DRILLING
License No: WWW-348
Date
Completed: 1/10/1981

Site Name: MBMG GEOTHERMAL CAMPAQUA TEST WELL #1		
GWIC Id: 6237		
Additional Lithology Records		
From	To	Description
240	244	BLUE SAND AND GRAVEL. COBBLES UP TO 4 INCHES SOME LARGE BOULDERS AT 241 FEET.
244	258	SAND AND GRAVEL, COBBLES AND WATER. COBBLE COMPOSITION IS 60 PERCENT ARGILLITE, 15 PERCENT RED CLAYSTONE, 20 PERCENT QUARTZITE, 3 PERCENT ANDESITIC VOLCANICS, AND 2 PERCENT GNEISS AND METAMORPHICS
258	261	COARSE TO MEDIUM SAND, WELL SORTED, SOME GRAVEL, WATER
261	263	COARSE GRAVEL AND COBBLES, SOME SAND WATER
263	264	MUCH FINE TO MEDIUM GRAINED SAND, SOME GRAVEL, WATER AT 264 FEET.
264	276	FINE GRAINED GREY-GREEN ARGILLITE INTERBEDDED QUARTZITE, SULFIDES (PYRITE) ALONG BEDDING PLANE CLEARAGE, QUARTZITE IS QUARTZOFELDSPATHIC
276	281	GREENISH-GREY QUARTZITE ARGILLITE PYRITE ALONG FOLIATIONS, THIN QUARTZITE STREAKS OR VEINS, THIN FINE FRACTURES FILLED WITH SILICA
281	285	GREENISH-GREY QUARTZITE AND ARGILLITE - BIOTITE FLECKS IN QUARTZITE - VERY LITTLE QUARTZITE - FLOW OF WATER FROM THIN FRACTURES AT 282 FEET.
285	295	GREENISH-GREY QUARTZITE, ARGILLITE, TEMP IS 106 DEGREES F AT 286 FEET. TRIPPED IN WATER AT 290 FEET, FLOW IS 25 GPM CUMULATIVE
295	305	GREEN-GREY QUARTZITE, ARGILLITE WITH PYRITE
305	324	GREENISH-GREY ARGILLITE INTERBEDDED QUARTZITE - PYRITE IN FRACTURES.
324	370	GREENISH GREY ARGILLITE INTERBEDDED QUARTZITE, FINE-GRAINED FRESH FLECKS OF PYRITE
370	406	FINE-GRAINED GREENISH-GREY ARGILLITE, INTERBEDDED QUARTZITE
406	420	HIGHLY FRACTUREY GREEN-GREY ARGILLITE, GREY WASH OF CLAY FROM FRACTURES, MUCH WATER
420	427	ARGILLITE, INTERBEDDED QUARTZITE
427	440	DENSE GREEN ARGILLITE, SEEMS OF SOFT SILICA
440	475	SAME AS ABOVE. GREEN-GREY FRACTURED ARGILLITE
475	520	GREENISH-GREY ARGILLITE, INTERBEDDED QUARTZITE, BIOTITE FLECKS, FRACTURES, BROWN CLAY WASH AT 488
520	578	GREENISH-GREY ARGILLITE, INTERBEDDED QUARTZITE, BIOTITE FLECKS, FRACTURES, BROWN CLAY WASH AT 570 TO 578
578	600	GREY ARGILLITE, FLOW OF WATER OF GREY CLAY FROM 584 TO 592
600	655	FINE-GRAINED GREY ARGILLITE, INTERBEDDED WHITE AND GREY-WHITE QUARTZITE, FLECKS OF BIOTITE-SOME FINE GREY FRESH PYRITE
655	668	SOFT, HIGHLY FRACTURED QUARTZITE AND ARGILLITE, GREY CLAY WASH FROM FRACTURES
		DARK GREY QUARTZITE AND GREY-GREEN ARGILLITE, DENSE, NO

668	712	FRACTURES EVIDENT, SOME CHALCEDONY, PYRITE, FLUORITE IN CUTTINGS
712	733	SOFT FRACTURED ARGILLITE, INTERBEDDED QUARTZITE, VERY SOFT FROM 716 TO 724 FEET AND 728 TO 733 FEET. (HAD TO HOLD BACK BIT)
733	788	VERY DENSE INTERBEDDED QUARTZITE, BOTH DARK GREY AND WHITE, MICA FLAKES, INTERMITTENT SOFT WEATHERED ZONES EVERY 15 FEET.
788	796	SOFT GREY ARGILLITE, BLAST OF GREY CLAY
796	890	INTERBEDDED ARGILLITE AND QUARTZITE, SOFT ZONE AT 870 TO 875 FEET
890	910	VERY HARD DENSE, INTERBEDDED GREY AND WHITE QUARTZITE, NO SOFT ZONES
910	930	INTERBEDDED GREY QUARTZITE, WHITE QUARTZITE AND GREY ARGILLITE
930	948	VERY SOFT FRIABLE GREY QUARTZITE, GRUS-LIKE TEXTURE, INTERBEDDED WITH MEDIUM GREY ARGILLITE, LARGE CHUNKS OF FINE-GRAINED PYRITE-VERY SOFT FROM 935 TO 940 FEET.
948	960	DENSE GREY-BLUR AND GREY ARGILLITE, INTERBEDDED QUARTZITE; SOFT FRACTURED ZONE FROM 956 TO 957 FEET
960	980	VERY FRIABLE DARK GREY ARGILLITE, LITTLE OR NO QUARTZITE
980	996	INTERBEDDED DENSE GREY ARGILLITE AND GREY QUARTZITE
996	1002	SOFT GREY ARGILLITE, FRACTURED

APPENDIX B –WELL NOTES

11-09-2011

- O'Keefe drilling moved onto site.
- Well cap cut off and prepped for pressure grouting scheduled for the next day.
- Initial depth of well was tagged at 257' bgs.

11-10-2011

- Tremie pipe was terminated at 231' below top of casing (toc).
- 3 CY of cement pumped into well. Approximately ½ hour after grouting, a small seep was noticed, but the well did not build pressure.

11-11-2011

- Pressure gauge reads zero psi. Grouting from previous day was tagged at 240' below toc, approximately 17' from the bottom of the well.
- It was estimated 2.6 CY of grout was pumped into formation.
- Tremie line was pulled to 60' below toc. Approximately 5 CY of grout were used.
- No water flowed out of well when cap was removed
- Grout was tagged at 12' below toc, therefore grouting in the tremie pipe. Upper 20' of tremie pipe was pulled from the well.

11-30-2011

- Excavation for well cellar complete
- The cellar and cellar base were placed and appropriate welds made
- Grouting around the well casing and backfill will occur tomorrow.

12-19-2011

- H2S safety training, contingency plan, and CPR training was conducted
- Drilled through the grout to the bedrock interface and no water flow was observed. Drilled to 288' below ground surface (bgs) into the bedrock and no water was observed. Appears grouting job and existing casing successfully sealed of the existing flow.

12-20-2011

- Drilled from 288' – 430' bgs. Rock is primarily gray argillite with green-gray and blue-gray argillite zones encountered.
- Drilling proved more difficult in 430' zone. O'Keefe tripped out, bit was worn. Will trip into well with new bit tomorrow.

- During drilling flow is 250gpm during air lift. While removing the drill stem flow was 20 gpm artesian. Well water was 118°F at the diverter head and 122°F in top of well casing after bit was pulled.

12-21-2011

- At beginning of day there was a 35 gpm artesian flow
- Drilling progressed slowly from 430' to 442'. Lost circulation and rock hardness is believed to be cause of slow progress. Formation consists of gray argillite with zones of blue-gray and green-gray argillite.
- Stiff foam will be used to assist in clearing cuttings from the well.

12-22-11

- The stiff foam helped in clearing the drill hole but drilling progressed only slightly quicker than the previous day.
- The bit was tripped out of the well and was missing several buttons from tri-cone. The drillers have another bit in mind to use. Decide to camera well after the Holidays and O'Keefe's annual safety training.
- Gate valve on well head was shut to control flow from well.

01-09-12

- A camera and transducer was used to log the well.
- Previous grouting in existing gravel zone was intact.
- Between 422' - 427' bgs the well hit a highly fractured zone, with an approximately 24" diameter "cavern" resulting in a lateral shift in the borehole.
- The transducer recorded 114°F at about 250 bgs, corresponding to the existing gravel aquifer. Within the bedrock, the water temperature was recorded at 108°F.
- Well was bailed for missing buttons but none were recovered. Bailer was temporarily stuck in the well; however was successfully removed.
- It was determined to grout the well up past the "cavern" and then drill back through in an attempt to re-align the borehole.

01-10-12

- Bottom of well was grouted. Enough grout was ordered to fill approximately 100 ft. of 10" borehole was used to account for the fractured zones.
- Gate valve on well head was shut to control flow from the well.

01-12-12

- Grout was encountered within 353' bgs resulting in roughly 80 feet of grout.

- Grout was still soft and therefore drilling shut down for the day to allow for more cure time.
- Lift on drill stem of truck malfunctioned and was taken to Missoula for repairs.
- O'Keefe tripped out of well and shut gate valve on well head

01-15-12

- Drilling continued from 382' - 442' bgs. From 420' - 430' where the shift in the borehole alignment occurred, cuttings consisted of mainly grout with some rock; therefore it would appear some straightening of the borehole occurred.
- Drilling continued from 442' - 463' bgs slightly quicker than the previous day of drilling. Cuttings consisted of gray argillite with tan/white precipitates.
- Temperature at the well head was approximately 114°F.

01-16-12

- Drilling continued from 463'. It became easier at 468' and water flow increased to 350 gpm artesian.
- Bit was pulled back from 471' and the hole caved in roughly 2.5 feet. Upon pulling back the bit after drilling through some of the cave in, the bit was hanging up.
- With concerns over cave-in, conversations started between the drill team and Flathead Electric regarding drilling progress. The decision was made to switch drilling methods to reverse circulation from air rotary. Stretching the remaining drilling budget was a priority.
- Temperature at the well head was measured at 111°F.

02-29-2012 and 03-01-2012

- O'Keefe was on site to case and grout the well.
- Prior to grouting, circulation was testing with water and appeared to be working properly.
- Shortly after starting the grout operation, the grout pump became hydraulically locked. It was difficult to tell if the problem was with the well or the grout pump.
- On 03-01-12 the casing was pulled up and the water level in the casing remained constant, therefore the casing is plugged with grout.

03-02-2012

- O'Keefe pulled up the casing and it was still free which likely means grout remained in the casing during first grouting effort.
- Tripped into the well and grout was encountered within 25' of the top of the well.

- The drillers broke through the grout well above the bottom of the casing string and encountered water. The conclusion was that the grout pump (and possibly the rock that passed through their pump screen) caused the problem during the grout operation.
- No grout was thought to have been pumped into the annular space of the well.
- Circulation was verified by blowing air into the well and observing water and air returning in the annular space.

03-07-12

- O'Keefe installed a 10' section of PVC in the bottom of the well, grouted, and pumped a plug down to the PVC pipe forcing grout into the annulus.

03-14-12

- O'Keefe tripped into the well and finalized RC drilling set-up.
- At 460' bgs the plug, grout, and PVC blank were encountered.
- While drilling the rock/grout interface at 470' the drill began "bouncing."
- In the 470' zone, no flow was circulating through the cyclone. Initial thoughts were that the plug and PVC may have clogged the bit.
- Upon tripping out, the drill stem sheared approximately three feet up the last section of drill steel leaving the bit and part of the inside wall of the drill steel in the borehole. It is estimated that 6' remains in the borehole.
- O'Keefe took the broken section of the drill stem back to Butte to determine the best way to retrieve the bit.

03-19-12

- By Friday (3/16/12), O'Keefe was able to remove the bit and portions of the RC drill stem that were in the well.
- Drilling resumed cautiously. Drilling continued to approximately 1 foot beyond the cased and grouted well to a depth of approximately 472' bgs. No water flow was experienced.

03-20-12

- Drilling resumed from 472' - 498' bgs and consists of hard gray argillite and drilling progress was slow.
- A small fracture zone was encountered at approximately 488' but yielded no artesian flow.

03-21-12

- Drilling progressed from 498' - 538' bgs at approximately 2' per hour. Between 505' and 538' the drilling progressed more quickly before slowing during the last 8 feet. The cuttings were gray to bluish argillite with some pyrite. Observed tan/white precipitation on argillite faces.
- No artesian flow, however well does fill with water overnight.
- Drilling stopped early to pick up some parts and pieces being delivered in Missoula.

03-22-12

- O'Keefe tripped out and bit was very worn. It was a new bit earlier this week and most of the buttons were ground off.
- O'Keefe tripped back in with a hammer bit
- Drilling continued from 538' to 618'. Cuttings consisted of Fracture zones were encountered at 562' and 615'. The water encountered at 615' bgs slowed hammer drill progress.
- O'Keefe tripped out to switch to a tri-cone bit.
- Once tripped out water was slowly overflowing diverter head. The temperature at 470' (bottom of casing) was approximately 106°F.

3/23/12

- Drilling occurred from 618' to 660' bgs and the cuttings consisted of hard gray argillite.
- There was a water zone between 630' - 640' bgs, approximately 60 gpm artesian. Cuttings were much larger in this zone and consisted of hard gray argillite with pyrite.
- Less fractured from 640' - 660' bgs.
- O'Keefe tripped out to close the well head valve for the weekend. Flow out of the discharge pipe was estimated at 100 gpm.
- A temperature log was run down the center of the drill steel to a depth of 640' bgs and resulted in a temperature of 103°F.

03/26/12

- O'Keefe travelled from Butte and tripped back into the well and the bit was set at 620' bgs. No drilling occurred today.
- The well was logged inside the center of the drill steel and resulted in a temperature of 103°F.
- Water was flowing over the top of the drill steel while logging the well.

03/27/12

- O'Keefe drilled from 660' - 730' bgs and cuttings consisted of hard gray argillite.
- The water flow was visually estimated to be 125 gpm and overflowing drill steel between new sections.
- The drill cuttings consisted of gray argillite.
- Well head temperatures were measured with handheld thermometer at approximately 106°F.

03/28/12

- O'Keefe drilled from 730' - 820' bgs and cuttings consisted of gray argillite.
- The flow of water was visually estimated to be 125 gpm.
- At 800' bgs it appeared that there was less water flowing from the cyclone, but similar cumulative flow from discharge pipe.
- Well head temperatures were measured with handheld thermometer at approximately 106°F.

03/29/12

- O'Keefe drilled from 820' - 889' bgs and cuttings consisted of hard gray argillite with pyrite. Fractures were encountered at 825' bgs.
- Progress slowed from 860' to 889' bgs.
- Budget information was reviewed and determined that drilling would end at the current location.

03/30/12

- O'Keefe tripped out of well and started demobilizing site.
- The valve was closed off and final clean-up was set for when weather conditions allowed.
- With the bit and drill steel removed the flow was estimated at 250 gpm artesian flow. A temperature log was run on the well and measured 100.3°F at a depth of 879' bgs.

APPENDIX C – DRILLING TEMP. LOGS

Temperature vs. Depth

CAE-1 01-18-12 Flowing	
Depth (ft)	Temp (°F)
450	105.8
450	105.8
450	105.8
448	105.8
411	105.8
381	105.8
310	105.9
237	106.7
157	108.0
64	108.7

CAE-1 03-30-12 Flowing	
Depth (ft)	Temp (°F)
553	100.4
494	100.5
465	100.6
423	100.7
419	100.8
399	100.8
389	100.9
337	100.9
308	101.0
270	101.0
229	101.1
229	101.1
177	101.1
133	101.2
62	101.2
22	101.2
3	101.3
2	101.3
3	101.3
3	101.3

	Gossett Well (MBMG 80)		CAE-1 Static (Comp. Wireline)	CAT-1 (Jackola & Nork)	CAE-1 flowing (Comp. Wireline)
Depth	Temp (°C)	Temp (°F)	Temp (°F)	Temp (°F)	Temp (°F)
0	19.5	67.1			
5	23.9	74.9	67.9		
10	25.5	77.8	71.7		
15	26.3	79.4	75.2		
20	27.2	80.9	76.5		
25	28.0	82.4	77.8		
30	28.8	83.8	79		103.1
35	29.6	85.4	80.1		103.3
40	30.4	86.7	81.5		103.3
45	31.1	87.9	82.9		103.4
50	31.5	88.7	84.1		103.5
55	32.0	89.6	85.8		103.6
60	32.5	90.5	87.4		103.6
65	32.8	91.1	89		103.6
70	32.3	90.2	90.4		103.7
75	33.9	93.0	91.9		103.7
80	34.5	94.0	93.1		103.7
85	34.9	94.9	94.3		103.7
90	35.4	95.7	95.3		103.7
95	35.9	96.7	96.2		103.8
100	36.4	97.6	97.2		103.8
105	36.8	98.3	98.1		103.8
110	37.2	98.9	99.4		103.8
115	37.4	99.4	100.6		103.8
120	37.6	99.8	101.6		103.8
125	38.0	100.4	102.6		103.8
130	38.4	101.2	103.6		103.8
135	38.8	101.9	104.4		103.8
140	39.2	102.6	105.1		103.8
145	39.6	103.3	105.9		103.8
150	40.1	104.1	106.6		103.7
155	40.5	104.8	107.5		103.7
160	40.9	105.7	108.2		103.7
165	41.4	106.5	109.6		103.7
170	42.0	107.6	111.2		103.7
175	42.6	108.6	112.9		103.7
180	43.0	109.3	114.3		103.6
185	43.3	110.0	115.7		103.6
190	43.5	110.4	116.7		103.6
195	43.7	110.7	117.8		103.5

	Gossett Well (MBMG 80)		CAE-1 Static (Comp. Wireline)	CAT-1 (Jackola & Nork)	CAE-1 flowing (Comp. Wireline)
Depth	Temp (°C)	Temp (°F)	Temp (°F)	Temp (°F)	Temp (°F)
200	43.8	110.9	118.8		103.5
205	43.9	111.1	119.6		103.5
210	44.1	111.4	120.5		103.4
215	44.4	111.9	121.2		103.4
220	44.7	112.5	121.9		103.3
225	45.2	113.3	122.5		103.3
230	45.8	114.4	123		103.3
235	46.2	115.2	123.6		103.2
240	46.8	116.3	123.9		103.1
245	47.4	117.4	123.7		103.1
250	47.8	118.0	123.1		103
255	48.3	118.9	122.3	119.1	103
260	48.6	119.4	121.7		102.9
265	47.8	118.0	121		102.9
270	45.9	114.7	120.4		102.9
275	46.1	114.9	119.9		102.8
280	46.4	115.4	119.4		102.8
285	46.4	115.5	118.8		102.7
290	46.3	115.4	118.5		102.7
295	46.1	115.0	118.1		102.6
300	45.9	114.5	117.7		102.6
305	45.8	114.4	117.2		102.6
310	45.6	114.1	116.8		102.5
315	45.6	114.0	116.5		102.5
320	45.5	113.8	116.1		102.5
325	45.4	113.7	115.8		102.5
330	45.3	113.6	115.4		102.5
335	45.3	113.6	115.1		102.5
340	45.3	113.6	114.7		102.4
345	45.3	113.6	114.4		102.4
350	45.3	113.6	114.1		102.3
355	45.3	113.5	113.7		102.3
360	45.1	113.1	113.4		102.3
365	44.9	112.7	113.1		102.3
370	44.5	112.1	112.9		102.2
375	44.2	111.6	112.5		102.2
380	44.0	111.3	112.3		102.2
385	44.0	111.1	112.1		102.2
390	43.9	111.0	111.8		102.2
395	43.8	110.8	111.5		102.1
400	43.6	110.5	111.2		102.1

	Gossett Well (MBMG 80)		CAE-1 Static (Comp. Wireline)	CAT-1 (Jackola & Nork)	CAE-1 flowing (Comp. Wireline)
Depth	Temp (°C)	Temp (°F)	Temp (°F)	Temp (°F)	Temp (°F)
405	43.5	110.3	110.9		102.1
410	43.3	109.9	110.4		102.1
415	43.1	109.5	110		102
420	42.7	108.9	109.7		102
425	42.2	108.0	109.3		102
430	42.0	107.5	109		102
435	41.9	107.4	108.7		101.9
440	41.8	107.2	108.4		101.9
445	41.7	107.1	108.1		101.9
450	41.7	107.0	107.9		101.9
455	41.6	106.9	107.8		101.8
460	41.5	106.7	107.7		101.8
465	41.4	106.4	107.7		101.8
470	41.4	106.4	107.5		101.8
475	41.3	106.3	107.4		101.8
480	41.2	106.1	107.3		101.8
485	41.1	106.0	107.2		101.8
490	41.0	105.8	107.1		101.7
495	40.9	105.6	107		101.7
500	40.9	105.6	106.8		101.7
505	40.9	105.5	106.7		101.7
510	40.8	105.4	106.6		101.7
515	40.7	105.3	106.4		101.6
520	40.7	105.2	106.3		101.6
525	40.7	105.2	106.2		101.6
530	40.7	105.2	106		101.6
535	40.7	105.2	105.8		101.6
540	40.7	105.2	105.7		101.6
545	40.7	105.2	105.5		101.6
550	40.7	105.2	105.3		101.6
555	40.7	105.2	105.2		101.5
560	40.7	105.2	105		101.5
565	40.6	105.2	104.8		101.5
570	40.6	105.1	104.6		101.5
575	40.6	105.1	104.4		101.5
580	40.6	105.1	104.3		101.5
585	40.6	105.1	104.1		101.5
590	40.6	105.1	103.9		101.5
595	40.7	105.2	103.8		101.5
600	40.7	105.3	103.6		101.5
605	40.7	105.3	103.4		101.4

	Gossett Well (MBMG 80)		CAE-1 Static (Comp. Wireline)	CAT-1 (Jackola & Nork)	CAE-1 flowing (Comp. Wireline)
Depth	Temp (°C)	Temp (°F)	Temp (°F)	Temp (°F)	Temp (°F)
610	40.7	105.3	103.2		101.4
615	40.7	105.3	103		101.4
620	40.7	105.3	102.8		101.4
625	40.7	105.3	102.7		101.4
630	40.7	105.3	102.6		101.3
635	40.7	105.3	102.6		101.3
640	40.7	105.3	102.6		101.3
645	40.8	105.4	102.4		101.3
650	40.8	105.4	102.4		101.3
655	40.7	105.3	102.3		101.3
660	40.8	105.4	102.3		101.3
665	40.8	105.4	102.3		101.3
670	40.8	105.4	102.2		101.3
675	40.8	105.4	102.2		101.2
680	40.8	105.4	102.1		101.2
685	40.8	105.4	102.1		101.2
690	40.8	105.4	102		101.2
695	40.8	105.4	102		101.2
700	40.8	105.4	102		101.2
705	40.8	105.4	101.9		101.2
710	40.8	105.4	101.9		101.2
715	40.8	105.4	101.8		101.2
720	40.8	105.4	101.8		101.2
725	40.8	105.4	101.8		101.2
730	40.8	105.4	101.7		101.2
735	40.7	105.3	101.7		101.2
740	40.7	105.3	101.7		101.2
745	40.7	105.3	101.6		101.2
750	40.7	105.3	101.6		101.2
755	40.7	105.3	101.6		101.2
760	40.7	105.3	101.5		101.2
765	40.7	105.3	101.5		101.2
770	40.7	105.3	101.5		101.2
775	40.7	105.3	101.5		101.2
780	40.7	105.3	101.5		101.2
785	40.7	105.3	101.4		101.2
790	40.7	105.3	101.4		101.2
795	40.7	105.3	101.4		101.2
800	40.7	105.3	101.4		101.2
805	40.7	105.3	101.4		101.2
810	40.7	105.3	101.4		101.1

	Gossett Well (MBMG 80)		CAE-1 Static (Comp. Wireline)	CAT-1 (Jackola & Nork)	CAE-1 flowing (Comp. Wireline)
Depth	Temp (°C)	Temp (°F)	Temp (°F)	Temp (°F)	Temp (°F)
815	40.7	105.3	101.3		101
820	40.7	105.3	101.2		101
825	40.7	105.3	101.1		101
830	40.7	105.3	101.1		100.9
835	40.7	105.3	101.1		100.9
840	40.7	105.3	101		101.1
845	40.7	105.3	101.1		101.1
850	40.7	105.3	101.1		101.1
855	40.7	105.3	101.1		101
860	40.7	105.3	101.1		101
865	40.7	105.3	101.1		101
870	40.7	105.3	101.1		101
875	40.7	105.3	101.1		101
880	40.8	105.4	101		101
885	40.8	105.4	101		101
890	40.8	105.4	101		
895	40.8	105.4			
900	40.8	105.4			
905	40.8	105.4			
910	40.8	105.4			
915	40.8	105.4			
920	40.8	105.4			
925	40.8	105.4			
930	40.8	105.4			
935	40.8	105.4			
940	40.8	105.4			
945	40.8	105.4			
950	40.8	105.4			
955	40.8	105.4			
960	40.8	105.4			
965	40.8	105.4			
970	40.8	105.4			
975	40.8	105.4			
980	40.8	105.4

APPENDIX D – DESIGN DRAWINGS

Note - Construction was carried out per the design drawings

FLATHEAD ELECTRIC CO-OP HOT SPRINGS GEOTHERMAL WELL

39372 CAMP AQUA ROAD
HOT SPRINGS, MONTANA

INDEX OF DRAWINGS

SHEET #	SHEET TITLE	RELEASE DATE	LATEST REVISION
T1.0	TITLE SHEET	1/10/11	
C1.0	ORIGINAL SITE SURVEY	1/10/11	10/07/11
C1.1	SITE PLAN	1/10/11	6/20/11

DRAWING LAYOUT

SITE LOCATION MAP

PROPERTY OWNERSHIP MAP

FLATHEAD ELECTRIC COOPERATIVE
HOT SPRINGS GEOTHERMAL WELL
39372 CAMP AQUA ROAD, HOT SPRINGS, MT
SECTION 29, TOWNSHIP 22 NORTH, RANGE 23 WEST

SHEET
TITLE
SHEET

DRAWN: RAE
CHECKED: TAJ
DATE: 01/10/11
SCALE: AS NOTED
JOB#: 100902
REVISIONS:
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FEC_Geo_T00 01/10/11
T0.0
SHEET 1 OF 3

FLATHEAD ELECTRIC COOPERATIVE
HOT SPRINGS GEOTHERMAL WELL
39372 CAMP AQUA ROAD, HOT SPRINGS, MT
SECTION 29, TOWNSHIP 22 NORTH, RANGE 23 WEST

SHEET

SITE PLAN

DRAWN:	RAE
CHECKED:	TAJ
DATE:	01/10/11
SCALE	1" = 40'
JOB#:	100902

REVISIONS:

4-25-2011

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FEC_Geo_C1

01/10/11

C1.1

SHEET 3 OF 3

1 PLAN OF PIT- SHOWN AS PHASE 4
1" = 1'-0"

2 SECTION OF WELL PIT - SHOWN AS PHASE 4
1/2" = 1'-0"

FLATHEAD ELECTRIC
GEOTHERMAL HOTSPRINGS
HOT SPRINGS, MONTANA

SHEET
WELL PIT PLAN
& SECTION

DRAWN:	LMM
CHECKED:	TAJ
DATE:	10/31/11
JOB#:	100902
REVISIONS:	
1	10/7/11
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FLATHEAD ELECTRIC
GEOTHERMAL HOTSPRINGS
HOT SPRINGS, MONTANA

SHEET
WELL PIT
DETAILS

DRAWN:	LMM
CHECKED:	TAJ
DATE:	10/31/11
JOB#:	100902
REVISIONS:	
10/7/11	
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APPENDIX E – TEMP. & GAMMA LOGGING

GAMMA RAY TEMPERATURE LOG

Company Jackola Engineering Well FEC Hot Springs Field County Lake State Montana	Company Jackola Engineering & Architecture				
	Well FEC Hot Springs				
	Field				
	County Lake		State Montana		
	Location				Other Services
	SEC. 29 TWP. 22N RGE. 23W				Elevation
	Permanent Datum		Ground Level		K.B.
	Log Measured From		Ground Level		G.L.
	Drilling Measured From		Kelly Bushing		
Date	8-MAY-2012		Perforated Intervals		
Run Number	ONE		Gun Type		
Log Type	GR/CCL/TEMP		Size		
Depth - Driller	900'		From	To	@
Depth - Logger	885'		From	To	@
Bottom Interval	885'		From	To	@
Top Interval	SURFACE		From	To	@
Fluid in Hole	WATER		From	To	@
Level	FULL		From	To	@
Wellhead PSI	11 PSI		From	To	@
Equipment No.	27 CUT BANK, MT		From	To	@
Witnessed By	TOBY MCINTOSH		Casing Record		
Recorded By	STARBUCK SEIFERT		Size	Weight	From To
Invoice No.	21765		7"		Surface 464'
Bitsize #1					
Bitsize #2					
Cement Time					
API Number					
AFE Number					
			Tubing Record		
			Other Services		

All interpretations are opinions based on inferences from electrical or other measurements and we cannot and do not guarantee the accuracy or correctness of any interpretation, and we shall not, except in the case of gross or willful negligence on our part, be liable or responsible for any loss, costs, damages, or expenses incurred or sustained by anyone resulting from any interpretation made by any of our officers, agents or employees. These interpretations are also subject to our general terms and conditions set out in our current Price Schedule.

Cement Type:

Correlated to: Logged From Ground Level

Remarks:

THANK YOU FOR CHOOSING COMPETITION WIRELINE SERVICE

YOUR CREW TODAY HAS BEEN MEL FUGLE & JIMMY DUVALL

Gamma Ray & Temp Log

Database File: 21765tmpgr.db
 Dataset Pathname: pass9
 Presentation Format: gammagun
 Dataset Creation: Tue May 08 15:15:06 2012
 Charted by: Depth in Feet scaled 1:240

100

200

300

600

700

800

Temp Log Static Fluid

Database File: 21765tmpgr.db
 Dataset Pathname: pass1
 Presentation Format: temp
 Dataset Creation: Tue May 08 11:22:18 2012 by Log SCH 120126
 Charted by: Depth in Feet scaled 1:240

-4	CCL	0.4
65	TEMP (degF)	150
0	LTEN (lb)	300

65	TEMP (degF)	150
-0.3	DTMP (degF)	0.3
60	TEMP2 (degF)	140

TEMP (degF)

100

200

300

600

700

800

1	CCL	0.4
5	TEMP (degF)	150
	LTEN (lb)	300

65	TEMP (degF)		150
-0.3	DTMP (degF)	0.3	
60	TEMP2 (degF)		140
TEMP (degF)

200

300

700

800

Delta Temperature

-4	CCL	0.4
65	TEMP (degF)	150
0	LTEN (lb)	300

101.0		
101.0		
65	TEMP (degF)	150
-0.3	DTMP (degF)	0.3
60	TEMP2 (degF)	140
TEMP		
(degF)

Temp Log Up Pass Flowing

Database File: 21765tmpgr.db
 Dataset Pathname: pass6
 Presentation Format: temp
 Dataset Creation: Tue May 08 13:33:56 2012 by Log SCH 120126
 Charted by: Depth in Feet scaled 1:240

-4	CCL	0.4
65	TEMP (degF)	150
0	LTEN (lb)	300

65	TEMP (degF)	150
-0.3	DTMP (degF)	0.3
60	TEMP2 (degF)	140

TEMP
(degF)

100

200

300

400

-4	CCL	0.4
65	TEMP (degF)	150
0	LTEN (lb)	300

700

800

Line Tension

65	TEMP (degF)	150
-0.3	DTMP (degF)	0.3
60	TEMP2 (degF)	140

Delta Temperature

TEMP
(degF)