

Poncha Hot Springs Thermal Gradient Study

State Purchase Order No. 11-077

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Executive Summary

This study follows from the successful application by the City of Salida for a \$50,000 matching grant from the Colorado Governor's Energy Office to initiate exploration of the potential for geothermal electrical power generation of other increased geothermal use of Poncha Hot Springs, which are on City of Salida land approximately five miles west of Salida. These springs currently supply warm water to the city's municipal pool. The bulk of the grant funds were designated for the drilling of temperature gradient wells, holes in which temperatures could be measured to study the thermal field around the hot springs to investigate the path of the hot water as it rises to the surface. In addition, prior to siting the temperature gradient wells, a collection of all previous relevant studies of the area as well as detailed surface fault mapping was made and compiled into a GIS database for interpretation and selection of the best sites for the wells.

Four new temperature gradient wells were drilled to approximately 260 feet in depth and an existing hole was reopened past a blockage at about 100 feet to 280 feet. Data from these wells were combined from data collected in 2010 from a 650 foot well to the east and information from four wells drilled in the late 1970s/early 1980s to the north. Combined with detailed geological mapping in this study, geophysical data collected by students from the Colorado School of Mines in 2009 and 2010, and an airborne magnetic survey carried out by the U. S. Geological Survey in 2009, we are now confident in our understanding of the shallow portion of the hot spring system as indicated in the thermal gradient contour map compiled from these data. Hot water rises along a fault which is at the surface at the hot springs to the east of the Boy Scout Camp and dips to the north-northeast. A large volume of hot water is not collected in the City of Salida collection system but drains in the subsurface downward and to the west, toward US 285 and Poncha Pass.

Information available in this study provides a shallow thermal gradient anomaly indicative of a potential deeper, hotter reservoir is probably to the north-northeast of the hot springs. A further geophysical survey, a magnetotelluric (MT) survey is recommended to attempt to locate the reservoir at depth before deep drilling.

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Drilling rig on Co 115 ready to drill PS-2d

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Introduction

Location: Poncha Hot Springs are located south of the town of Poncha Springs, Chaffee County, Colorado, in the south east quadrant of the intersection of east-west US Highway 50 with north-south US 285 about 150 mile from Denver on US 285. Figure 1 is a property map of the Poncha Hot Springs area showing the Poncha Springs located on 128 acres of land owned by the City of Salida. Primary neighbors adjacent to the Poncha Hot Springs property are the Farrow family (E. Farrow and Poncha Mtn. Partners) to the east, north and south east, the Town of Poncha Springs to the west and northwest, Colorado State Lands to the southwest, and Bob Mishata and the BLM to the south. These neighbors are currently supportive of this study and likely to be supportive of the development of electrical energy at Poncha Hot Springs.



Figure 1. Property ownership, Poncha Springs, Colorado area. Poncha Hot Springs is located off CR 115 on 128 acres belong to the City of Salida. Principal neighbors include Ed Farrow and Poncha Mountain Partners (E. Farrow) east to the east and north; the town of Poncha Springs to the west and north, Colorado State Land Board to the south west, Bob Mishata to the south west and BLM to the south.

Design: This study was designed to drill 5-6 thermal gradient holes based on known geology, new surface geologic mapping, Colorado School of Mines Geophysical Summer Camp studies of 2009 – 2010, and a 2009 USGS airborne magnetic survey. This study was designed to be submitted by the City of Salida for a competitive grant application opportunity announced by the Colorado Governor’s Energy (GEO) Office in 2010.

Funding: The above grant application to the GEO was submitted by the City of Salida on 1 February, 2011. The grant was awarded to the City of Salida in August, 2010 and a Purchase Order #11-0077 granted in March, 2011. The grant provided \$50,000 to complete a work statement for assembling existing geologic and geophysical data, conducting surface geologic mapping as needed, the development of a GIS database, drilling five to six 250 foot thermal gradient holes, and the completion of the present report of the study. The \$50,000 funds were provided by the Department of Energy under the American Recovery and Reinvestment Act of 2009.

Purpose: The purpose of this study was to determine if a high thermal gradient anomaly exists at the Poncha Hot Springs deposits. If a high thermal gradient anomaly were revealed, it would be then indicative of a potentially high temperature reservoir at depth. A deep reservoir target could be confirmed and tested by subsequent deep reservoir drilling with well testing and subsurface geophysics to determine if such a reservoir could provide sustainable geothermal water to produce economic electrical energy at Poncha Hot Springs.

Previous Work

Numerous geological and geophysical studies have been conducted in the Poncha Hot Springs area by various authors from the United States Geological Survey (USGS), the Colorado Geological Survey (CGS), universities and private companies over the last 100 years. These have been summarized in a feasibility study for the City of Salida compiled by Paul Morgan and Matt Sares of the CGS in 2009 (Morgan & Sares, 2009). Principal among these were hydrological, geochemical, temperature and appraisals by Barrett & Pearl (1976, 1978), Coe et al. (1982) and a reassessment of Colorado hot springs and temperatures (Morgan, private communication). Grauch and Drenth (2009) and Denth et al. (2009) discussed the USGS airborne magnetic surveys that included Poncha Hot Springs and the Southern Upper Arkansas Valley. Van Alstine (1974) described the general geology in the Poncha Hot Springs area. Jay Dick (in Coe et al., 1982) developed an early exploration and development program. Thermal gradient data from late 1970’s exploration by Occidental Petroleum and Petro-Lewis Companies were located. Some electro-magnetic and self-potential geophysical studies at

the Poncha Springs as part of the 2009 and 2010 Colorado School of Mines Geophysical Student Summer Field Camp and reports are included in the present study.

Reference is made in this study primarily to the feasibility report by Morgan and Sares (2009), Colorado School of Mines (CSM) Summer field Camp Reports (2009, 2010) and USGS airborne areal magnetic studies (Grauch and Drenth, 2009).

Figure 2 shows a map from the Morgan and Sares feasibility report showing a compilation of principal geologic and fault mapping from the literature. Many of the faults in various reports do not correspond with one another or apparently in the field. For this reason, surface mapping of the faults in particular was conducted as part of the present study. The reason for this mapping was to assure thermal gradient holes were not sited directly on known faults. The main E - W fault in the mid western sector of Figure 2 with a red segment added is apparently the principal fault controlling the upwelling of the Poncha Hot Springs geothermal waters. The NW-SE fault in the south center of Figure 2 is a major fault that controls the canyon that contains the Poncha Springs Fluorite Mine in its west slope. This mine reportedly contained hot water in its underground workings and may thus overlie a deep geothermal reservoir that extends to the Poncha Hot Springs to the west along the main Poncha Springs Fault. The green dots numbered 1, 2 and 3 in Figure 2 are the approximate locations of the thermal gradient holes drilled in the late 1970's by Occidental Petroleum and/or Petro- Lewis Companies. They yielded above normal thermal gradient

Morgan-Sares Compilation Map

(from report to Salida City Council)



Figure 2. Fault and geologic map Poncha Springs area modified from Morgan and Sares (2009). Green dots are late 1970's thermal gradient holes described in the text.

values: (1) 2 x normal; (2) 1.5 x normal; and (3) 2.5 x normal (60°C/km). A fourth TG hole with a near normal thermal gradient is located a short distance north of the town of Poncha Springs, just off Figure 4. These thermal gradient holes form an outer ring of anomalous thermal gradient values around the more new data collected in this study closer to the Poncha Hot Springs.

Several geophysical studies, including a ground magnetic survey, DC resistivity (dipole-dipole and Werner arrays) surveys, and a self potential (SP) survey were conducted by Colorado School of Mines (CSM) geophysical students at Poncha Hot Springs in 2009 and 2010. These surveys were generally run along north-south lines that crossed the east-west faulting. Some surveys were conducted parallel to the east-west faulting. Of particular interest to this study is a pair of surveys taken from north to south along CR 115 immediately west of the main hot springs area, east of the former Boy Scout Pool (Colorado School of Mines, 2010, Pg. 108). These surveys were aligned north-south, perpendicular to and cross the main Poncha Springs Fault Zone, and were self potential (SP) and direct current electrical resistivity (DC resistivity) surveys. A fault was indicated in these data, the Poncha Springs Fault, dipping at about 60° north towards the southern end of the Upper Arkansas Valley. The results of these surveys are shown in Figure 3.

The Poncha Springs Fault separates the southern footwall Precambrian metamorphic quartzite, schist and diabase from the northern hanging wall rocks consisting of the Pleistocene boulder formation overlying the Miocene - Pliocene Dry Union gravels, sandstones and siltstones. The surveys in Figure 3, have been interpreted as follows. The positive anomaly in the SP survey data is located directly above the trace of the Poncha Springs Fault and to the immediate north. This anomaly was interpreted as indicating upwelling geothermal hot water along the fault zone. The blue zone on the DC resistivity Werner array survey data was interpreted as low resistivity (high conductivity) characteristic of hot geothermal water in mostly Boulder formation and Dry Union sedimentary rocks in the hanging wall of the Poncha Springs Fault. It consists of a northerly expanding "wedge" of hot water dipping 60° to 45° to the north beneath less conductive near-surface rocks north of the fault. [This survey line is included in the geologic map from the GIS database and was considered in the siting of the thermal gradient holes (see Figure 6)].

In 2009, the USGS conducted an airborne magnetic survey of the southern end of the Upper Arkansas Valley, including the area around Poncha Springs (Grauch and Drenth, 2009; Drenth et al., 2009). Some results of this survey are shown in Figure 4. High magnetic response is indicated in the purple (highest) and red colors; low magnetic response is indicated by green and blue (lowest). The Poncha Hot Springs are located in an apparent

Combined DC and SP Results

Poncha Hot Springs DC Resistivity and SP Surveys, May 25, 2010

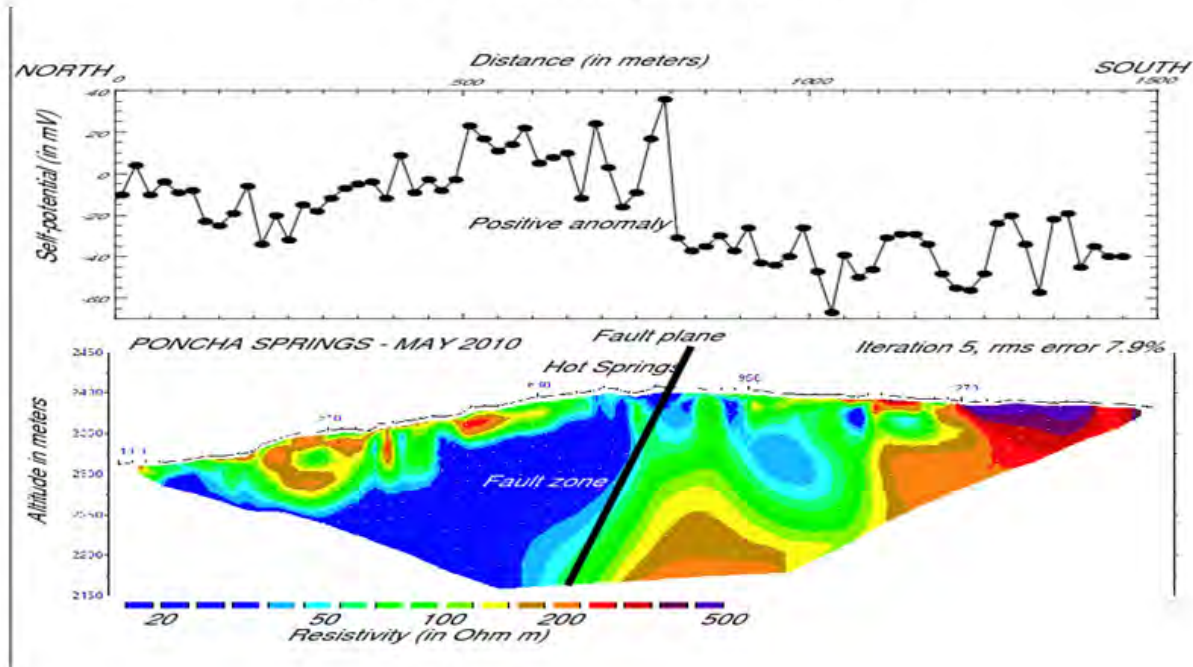


Figure 3. Self potential (SP), upper, and DC resistivity (Werner array), lower, surveys conducted along CR115 west of the Boy Scout Pool at Poncha Hot Springs. The north-south surveys cross the main Poncha Springs Fault in the middle of the survey lines. Precambrian metamorphic rocks comprise the southern footwall of the fault; a Pleistocene boulder formation capping Miocene-Pliocene Dry Union sediments comprise the northern hanging wall of the fault (see Figure 2).

WNW – ESE fault “trough” between two E - W trending zones of high magnetic response. The southern high magnetic zone is interpreted as the Precambrian metamorphic rocks south to the main Poncha Spring Fault. The northern high response zone is interpreted in the USGS report as the “Sausage” anomaly which is an apparent highly magnetic, steeply dipping basic intrusion in the Precambrian rocks beneath the Dry Union sedimentary rocks north of the Poncha Hot Springs. Some previous mapped faults (Grauch and Drench, 2009; Drenth et al., 2009, and Morgan and Sares, 2009) as well as some faults interpreted in the USGS airborne

USGS Airborne Magnetic Survey, 2009

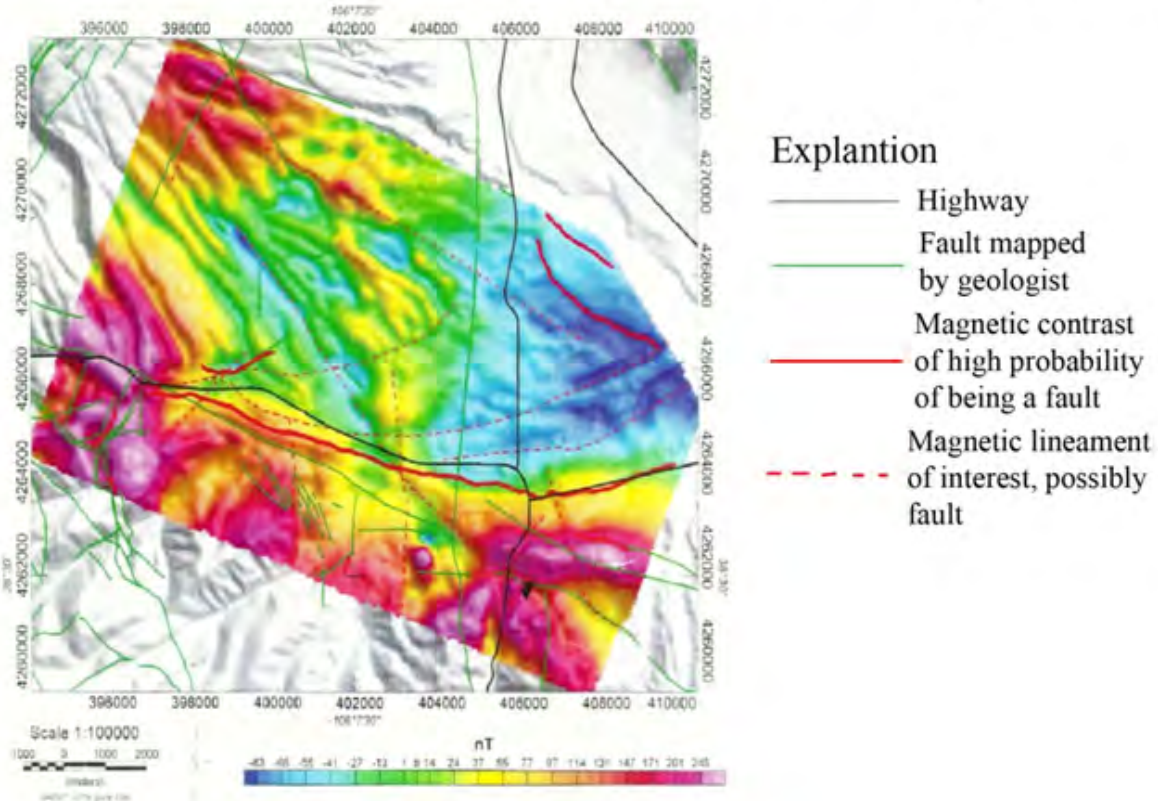


Figure 4. Reduced-to-pole aeromagnetic data from survey of the southern end of the Upper Arkansas Valley (Grauch and Drenth, 2009; Drenth et al., 2009). The aeromagnetic data are shown in shaded color relief, illuminated from the northeast. The city of Poncha Springs is located at the intersection of US 50 (east-west) and US 285 (north-south) in the SE quadrant of the figure. The Poncha Hot Springs are marked by the black triangles south of the highway intersection.

magnetic study occur in the vicinity of the Poncha Hot Springs (see also Figure 5). There is no indication of any specific geophysical feature that identifies the presence of a magmatic heat source for the geothermal waters based on the USGS study.

USGS Airborne Magnetic Survey Interpretation

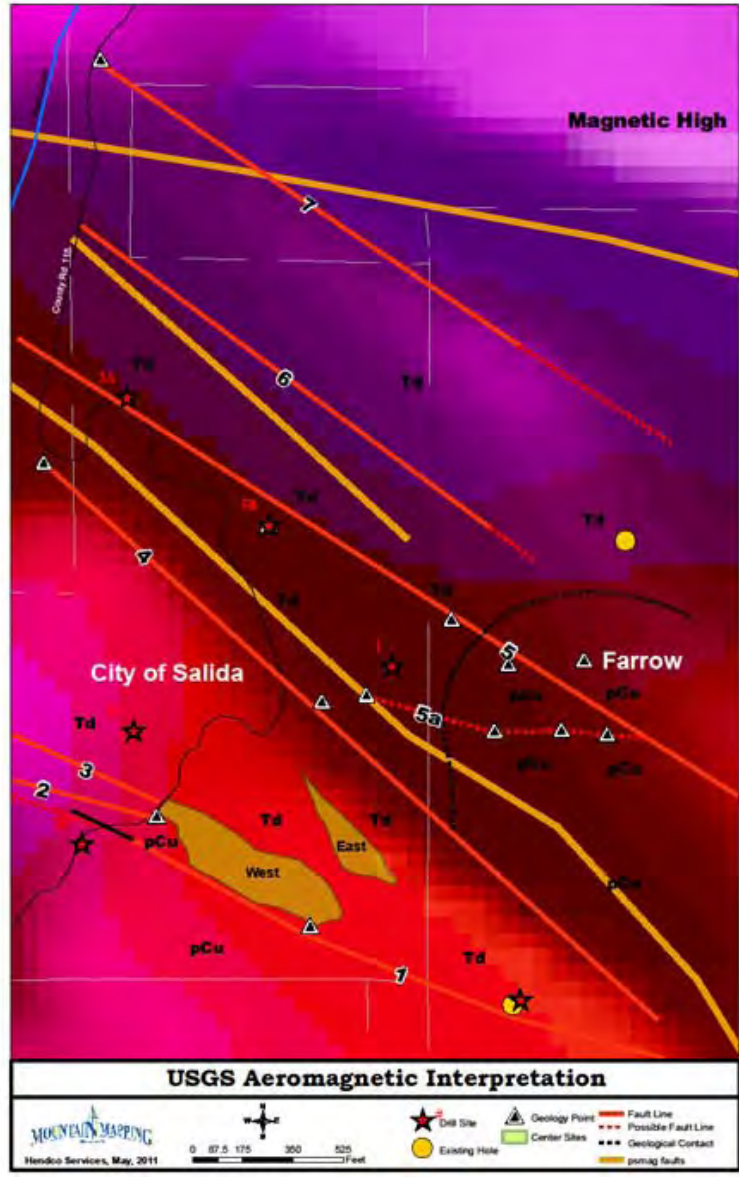


Figure 5. This figure is a good example of a map product produced from the Salida Geothermal GIS Database. It includes geologic map features described below with the USGS airborne magnetic survey described above. This combination allow for better interpretation of geothermal systems (see below)

Current Study Work

Data Compilation. Data compilation consisted of obtaining current and recent studies at Poncha Hot Springs. It included obtaining drilling data for two drill holes on the Farrow

Fluorite Mine Property to the east. Thermal gradient measurements by Paul Morgan were made at both of the holes in 2010. Additional data regarding the Poncha Hot Springs collection system supplying the City Pool in Salida were obtained from the Salida City Staff. Public Works Director Robert Vance was helpful in locating the collection system. The City of Salida was concerned that our thermal gradient drilling would not in any way impact the hot water collections system. Knowledge of the system and its layout was important in siting the thermal gradient holes. This was especially important for the location of the PS-2c hole, sited west of the Boy Scout Camp Pool just below the tufa mounds originally formed from hot springs.

Development of a GIS Database The grant included funds to create a GIS database for all of the map and other data layers developed in this study. Yvonne Barns, Mountain Mapping, created the GIS Database. It consists of numerous data layers including, an aerial photographic map base, geologic map points, geologic maps, Colorado School of Mines geophysical data, USGS Airborne Magnetic Survey maps, drill site, and other map baseline data. This GIS database allows the combining of various map layers to map products such as Figures 5 and 6. The on-going value of this database to the City of Salida is that it can be expanded to include new geologic, geophysical, drilling and other new data developed in any future geothermal work contemplated at the Poncha Hot Springs.

Figure 5 above combines geologic map data described below with the airborne magnetic data from the 2009 USGS study (Grauch and Drenth, 2009; Drenth et al., 2009). In the figure, high magnetic response is in the red grading into purple (higher magnetism) colors. The brown fault lines are those previously mapped and included in the USGS study. Red fault lines are those mapped in the current study and described more fully below. The two brownish globular features in the red zone in the southwest quadrant of the figure are tufa (hot-spring deposited calcium carbonate and silica) caps which are deposited above the hot springs along the faults. The main Poncha Springs fault structure controlling the geothermal system occurs just south of the larger tufa cap. Also shown on this GIS Database Map are the locations of thermal gradient holes.

Figure 5 demonstrates the value of combining data layers in the GIS Database. The main Poncha Spring Fault borders the tufa zones to their south and separates higher magnetic Precambrian metamorphic rocks to the south and the less magnetic Boulder formation and Dry Union sedimentary rocks to the north. The fault appears to dip about 60 ° to the north. The darkening of the red color north of the main fault and tufa zones is interpreted as representing the deepening of the upper contact of the footwall Precambrian metamorphic rocks beneath the less magnetic foot wall Dry Union sediments. Thus the darker colors are interpreted to represent a “trough” of footwall sedimentary rocks overlying

deeper Precambrian rock to the north. This is significant as any deeper geothermal reservoir targeted for later drilling presumably also occurs in this sedimentary “trough” north of the main Poncha Springs Fault.

Surface Geologic Mapping Because the inconsistencies between previous mapper’s fault locations, surface geologic mapping was included as part of this study. The mapping focused primarily on the location of faults and the distribution of the main rock types. Faults and rock types were mapped along the numerous road cuts shown on figure 6. Faults were mapped primarily by their topographic expression and 20 geopoints noted along the road cuts that indicated actual or apparent faulting or shearing. Seven separate faults were mapped as noted by black numbers 1 – 7 from south to north. The main Poncha Spring Fault is Fault 1 along the bottom of the figure. It separates Precambrian metamorphic rock to the south (up mountain slope) from the Pleistocene Boulder formation capped Miocene-Pliocene Dry Union sedimentary rocks north of the main fault. Note that north of Fault 4, the hill east of drill hole PS-1 is underlain by Precambrian metamorphic rocks. Inspection of Figure 6 will show that faults 4 – 7 each lie within four small but sharp canyons.

The green polygonal bodies are the tufa zones that were deposited at the surface of the original 40 springs and seeps. They overlie the City of Salida West and East hot water collection systems which join to provide hot water for the City Pool 5 miles to the east. These springs produce about 145 gpm of water at temperatures up to 158°F.

Figure 6 also shows the trace (dotted line on west part of figure) of the Colorado School of Mines DC electrical resistivity and self potential (SP) surveys along CR 115. The results of these surveys are shown in Figure 3 and have been described above. The yellow dots in Figure 6 indicate higher resistivity, lower conductivity, and lower SP response of the footwall Precambrian metamorphic rocks south of the main Poncha Spring Fault between thermal grading drill sites PS-2D and PS-2C west of the tufa zones. Similarly, the yellow dots north of drill site PS-2C indicate similar conditions in the Dry Union sediments to the north. The blue dots between the yellow dots to the north and south indicate surface or near surface higher conductivity and SP response and lower resistivity. These results were interpreted as upwelling geothermal hot water along the main Poncha Springs Fault and in a deepening wedge down dip to the north above the fault (see text above and Figure 3).

Concern was expressed about drilling PS-2c due west of the hot springs as indicated by the tufa zones. The concern was whether the drilling might disturb the springs and the water supply to the Salida City Pool. (This is discussed further below). As part of the geologic mapping, the area down slope and west of PS-2c, was surveyed for any indication of surface leakage or discharge to the west. None was found. The green pentagon symbol just northwest of PS-2d indicates an active hot spring located down slope along the trace of the

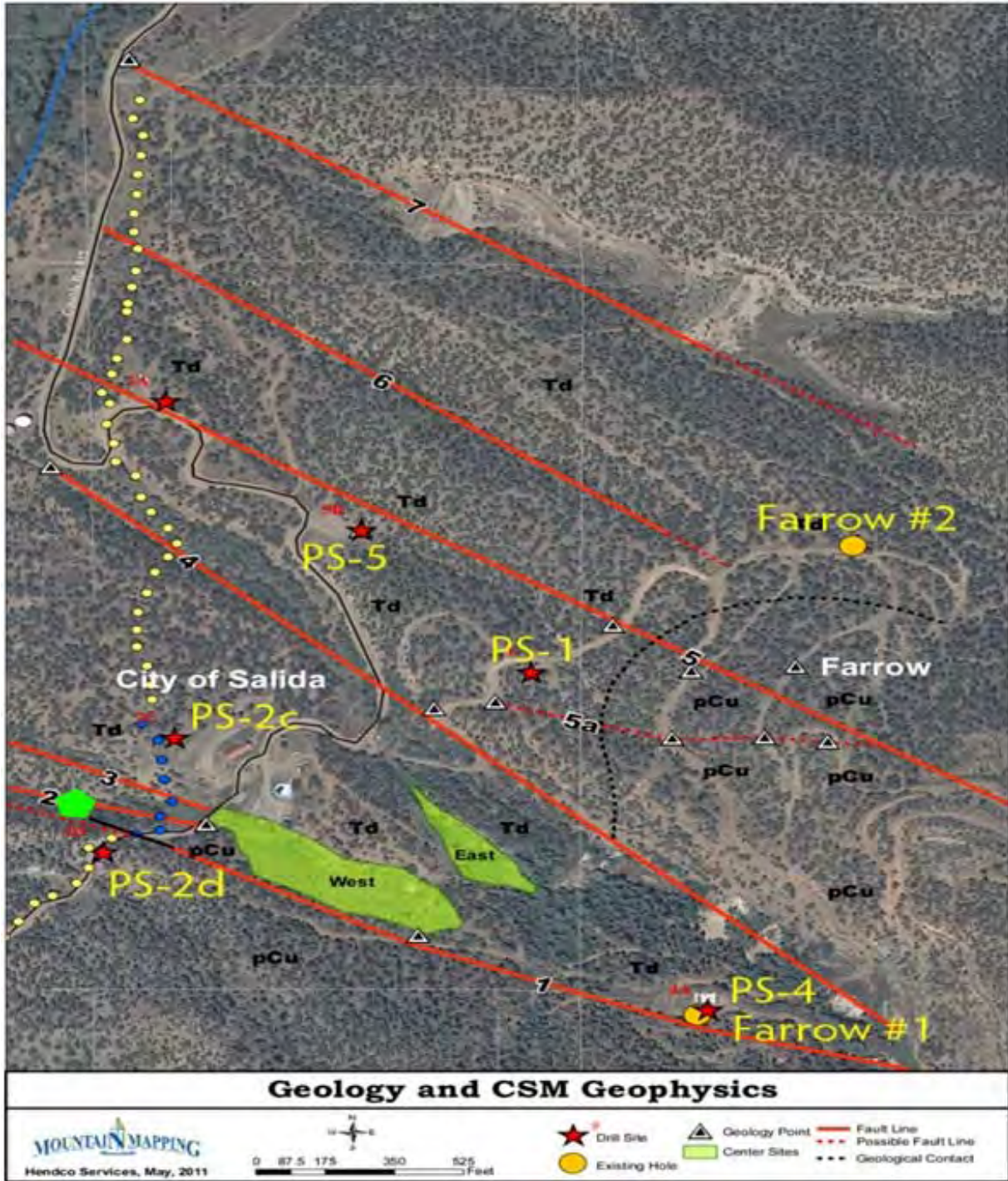


Figure 6. This figure is a GIS Database compilation of the aerial photo base map with the surface geologic mapping of this study. It shows faults (red), tufa deposit (green) above the Poncha Hot Springs and collection system, main rock types, the trace of the CSM DC electricity and SP survey (dots) and the thermal gradient drill sites. The green pentagon next to PS-2d in the SW corner is a natural hot spring along the main fault.

main fault line. This spring apparently has been depositing a tufa deposit for some time. Current precipitation in the stream was analyzed as calcite (calcium carbonate) similar to the tufa caps above the main hot springs to the east.

Siting and Drilling of Thermal Gradient Holes

The awarded grant called for four to five thermal holes of 250' depth. The locations of the holes that were drilled are shown on Figure 6. The siting of five holes was based on the results of the surface geologic mapping. Mapping of the faults (faults 1 – 7, also shown in Figure 6) was deemed necessary so that the thermal gradient holes would not be drilled on a fault or fault zone that might contain geothermal waters. All drilled holes were permitted by the Colorado Division of Water Resources (DWR) as non-consumptive exploration and monitoring holes. These permits are for 2 years and the holes may be re-permitted by the City of Salida in 2013.

Six sites were originally located, but only four holes were actually drilled due to caving and other problems encountered while drilling the first four holes and a limited budget (\$32,000 allocated to drilling out of a total budget of \$50,000). Three holes, PS-1, PS-2c, and PS-5 were drilled to the planned depth of 260'. Holes PS-1 and PS-5 were drilled with casing for the first 40' and completed "open hole" to 260'. These holes penetrated a Pleistocene boulder formation consisting of boulders and cobbles overlying the Miocene – Pliocene Dry Union formation consisting of gravel, sandstone and siltstone sediments.

Hole PS-2d was located in the CR 115 roadway which was closed by Chaffee County at the time of drilling for repairs. This hole was sited in the footwall of the main Poncha Springs fault in Precambrian quartzite, schist and diabase volcanic rocks, directly south of the main Poncha Springs fault. These rocks are highly sheared and altered along the footwall side of the faults. This shearing and fracturing resulted to caving in the drill hole and the decision was made to stop the hole at 80'. Cool water was encountered in the hole at approximately 70 feet.

Holes Farrow #1 (renamed in this study as PS-4) and #2 were drilled prior to the current studies by Ed Farrow, owner of the Poncha Springs Fluorite Mine property immediately east of the City of Salida Poncha Springs property. Farrow #2 was open to 650 feet and measured by Paul Morgan in 2010. Farrow #1 is located near to the main Poncha Springs fault at the location of the old mine office platform. This 300 foot hole was blocked at just over 100 feet when first logged in 2010. It was planned to drill an adjacent hole, PS-4, at this location, but funds were not sufficient for this drilling. However, the drilling

contractor, American Drilling, was able to reopen the hole to 280 feet, and it was re-logged to this depth as part of this study.

Thermal gradient hole PS-2C was sited immediately west of the Poncha Hot Springs Boy Scout Pool and the east-west and east water collection systems under the hot spring tufa surface blanket. This hole was of concern the City of Salida with respect to possible interference with the City Pool water collection system. Special care was taken during the drilling of this well. At 120 feet (see Table 1), minor (4-5 gallons per minute) water was encountered and some caving observed. The hole was then relocated a few feet from the original hole and redrilled and cased to 260 feet depth. The bottom of the hole was sealed prior to inserting 1 inch PVC piping for thermal gradient measurements. No significant water flow was encountered in re-drilling the PS-2c hole and it is believed to be completely sealed from any possible leaking of the geothermal water system. The hole definitely did not penetrate the main hot spring system as the maximum temperature measured in PS-2c was 105°F, over 50°F lower than the maximum measured temperature of the hot springs (158°F).

Logging of Cuttings

Representative samples of drill cuttings were collected for all holes drilled at twenty-foot intervals (one drill-rod length). These samples were split in half. One half of each sample were given to the City of Salida to save for further studies as needed. The second half were prepared for study and logging. A small sample (several ounces) were taken and given to Paul Morgan for alteration and thermal conductivity studies. The remainder of each sample was further split into +12 mesh (gravel), +30 mesh (sand), and -30 mesh (silt and clay) sieve fractions. Each fraction was studied by hand lens examination and logged for % gravel sizes (>1/2 inch, between 1/2 inch and 1/4 inch, and smaller than 1/4 inch) and for particle angularity to determine degree of hydrologic transport. Gravels were classified as to % principal rock types including quartzite, schist, diabase with lesser amounts of volcanic, granite, pegmatitic quartz and feldspar and other miscellaneous rock fragments. The relative amount of the gravel, sand and silt fragments was measured. High gravel and angularity suggest Pleistocene Boulder formation or Precambrian metamorphic rocks, while high sand or silt fractions suggest Dry Union sedimentary material. The cuttings were examined to see if hydrothermal alteration from geothermal waters existed. For the most part, little alteration was observed. Where it was observed, particularly in portions of PS-2c, it included the presence of calcite, a common precipitant in the tufa zone.

Table 1 shows the stratigraphic relation between drill holes based on the logging of the cuttings. In the four drilled cuttings, the rock types recognized were surface soil or man-made material at the tops of some holes, overlying gravels of the Pleistocene Boulder

Table 1. Stratigraphy of thermal gradient drill holes with water intercepts.

Stratigraphy of Temperature Gradient Holes

Hole	PS-1	PS-2C	PS-2D	PS-5		
Elevation	7,952'	7,864'	7,877'	7,795'		
0-20'	Alluv; Bld.	Alluv; Bld.	PreCam.	Alluv; Bld.	Alluv.	Surface alluvium, soil, surface waste
20-40'	Bld. Fm.	Alluv; Bld.	PreCam.	Bld. Fm.	Bld. Fm.	Boulder formation. Pleistocene gravel > sand and fines
40-60'	Dry Un.	Bld. Fm. ●	PreCam.	Bld. Fm.	Blk. PC.	Black diabase gravel; Precambrian
60-80'	Dry Un. ●	Bld. Fm.	PreCam.	Bld. Fm.		
80-100'	Dry Un.	Bld. Fm.		Bld. DU	Dry Un.	Dry Union sediments, Pliocene Sand and fines > gravel
100-120'	Dry Un.	Bld. Fm. ●		Bld. Fm.	●	Water: ● cold; ● warm/hot
120-140'	Dry Un.	Blk. PC.		Dry Un.		
140-160'	Dry Un.	Blk. PC.		Dry Un.		
160-180'	Dry Un.	Blk. PC.		Dry Un.		
180-200'	Dry Un.	Dry Un.		Dry Un.		
200-220'	Dry Un.	Dry Un.		Dry Un.		
220-240'	Dry Un.	Dry Un.		Dry Un.		
240-260'	Dry Un.	Dry Un.		Dry Un.		

Formation, which in turn overly gravel, sand and silt of the Dry Union sedimentary rocks (gravel, sand and silt). This general sequence was observed in PS-1, PS-2c and PS-5. A unique stratigraphic segment consisting mostly of fragments of a black diabase (course basalt) occurs at 120'-180' in PS-2c. The top of this interval was where some caving occurred and drilling was restarted using drill casing to 260' bottom depth. Minor hot water was encountered in PS-2c at the 40'-60' and 100'-120' intervals. Minor cold water was observed at the 60'-80' interval in PS-1 and at 70' in PS-2d.

Temperature Measurements

Multiple temperature logs were run in all four temperature-gradient holes drilled at Poncha Hot Springs ranging from about a day after drilling up to more than a month after drilling. Temperature measurements were made either at 1 foot or 10 foot intervals with a precision of better than 0.02 degrees Fahrenheit (°F). Multiple temperature logs were run under similar conditions in a previously drilled hole that was re-opened during the summer 2011 drilling operations. This hole was previously open to just over 100 feet and was known as Farrow #1: The re-opened hole could be logged to 280 feet and was renamed PS-4. A sixth hole, known as Farrow #2, open to 670 feet, had been previously logged at 10 foot intervals in

summer 2010. Details of the equipment used for making all temperature and the resulting digital temperature logs are given in the Appendix 1.

More than one temperature log was run in each hole to ensure that temperature disturbances associated with the process of drilling were dissipated before the final temperature log was run. Figure 7 shows the results of four temperature logs run in the hole PS-1 over the period of about a month. The first log, run on July 15, 2011, shows the greatest deviation from the other logs and at 40 feet and below is systematically a few degrees, or fewer, hotter than the later temperature measurements. This temperature difference is the result of heating of the walls of the drill-hole by circulation of the drilling fluid (primarily hot air mist). Near the top of the hole the disturbance is greater because the circulation took place for a longer time and the difference between the temperature of the rock and the drilling fluid was greater than at the bottom of the hole. Above 40 feet the first log shows much higher temperatures than the later logs. These short-lived “high” temperatures are the result of heat released by the curing of cement behind the casing in the upper section of the hole. On the surface, or upper-section of casing was cemented, and for about three days heat is released by this cement as it chemically hardens. After a week most of this heat has been absorbed into the surrounding rock and sediment. The temperature log run on July 22, about 10 days after drill is very similar to the final logs, and the log run on August 2, just under three weeks after drilling, is essentially identical to the final log on August 15. We may therefore conclude that transient temperature disturbances associated with drilling dissipate within two to three weeks at this site.

The temperatures in PS-1 rapidly increase above about 25 feet, as shown in Figure 7. This rapid increase is seen in all the temperature logs in this study. The significance of this rapid increase is simply that the temperature logs were run during the summer. The average ground surface temperature at Poncha Hot Springs is about 50°F, and this is the temperature to which the temperature at depth equilibrates. However, at any time during the year, the surface ground temperature is controlled by the season, hotter in summer and colder in winter. The temperature profile therefore curves to meet the appropriate seasonal ground surface temperature. If the temperature log were run during the winter the temperature above 25 feet would bend toward lower temperatures. The variable temperature behavior in the upper portion of the temperature curve is known as the *annual wave*.

For geothermal exploration, the most significant portion of the temperature log is the portion below the annual wave. In Figure 7, this would be the portion of the curve below about 30 feet. In this section the curve is approximately a straight line and the slope of this line in terms of the rate of increase in temperature with depth is called the *geothermal gradient*. The geothermal gradient is usually given in units of degrees Fahrenheit per

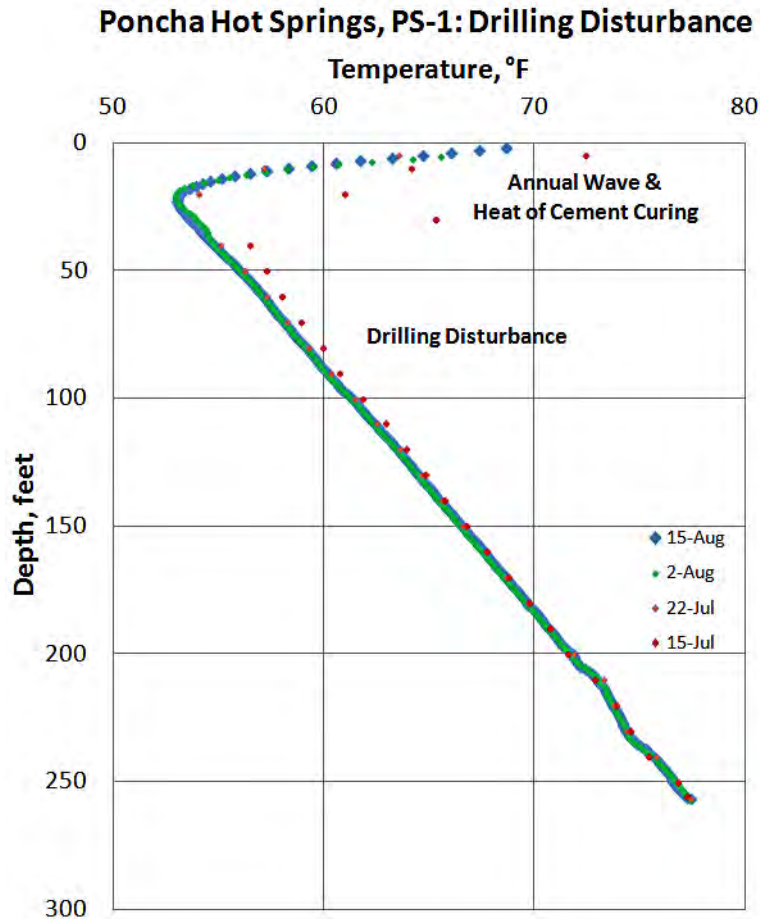


Figure 7. Four temperature logs from PS-1, recorded on July 15, July 22, August 2, and August 15, 2011.

hundred feet ($^{\circ}\text{F}/100\text{ ft}$) [or degrees Celsius per kilometer ($^{\circ}\text{C}/\text{km}$): $1.0^{\circ}\text{F}/100\text{ ft} = 18.25^{\circ}\text{C}/\text{km}$]. Typical non-geothermal values of the geothermal gradient are 1.1 to $1.6^{\circ}\text{F}/100\text{ ft}$., averaging about 1.4 .

Temperature Gradient Data

Temperature logs and the resulting gradient data will be presented from six drill-holes, the four drilled during summer 2011 as part of this project (PS-1, PS-2c, PS-2d, and PS-5), one existing hole re-opened as part of this project (formerly Farrow #1, renamed PS-4), and one previously logged in summer 2010 (Farrow #2). The locations of these holes are shown in Figure 6. The data will be present in order of increasing geothermal gradients with the exception of the last hole discussed (PS-2d).

Farrow #2. The temperature log from Farrow #2 is shown in Figure 8. This hole was drilled years before it was logged and was logged only once at 10 foot intervals. The geothermal

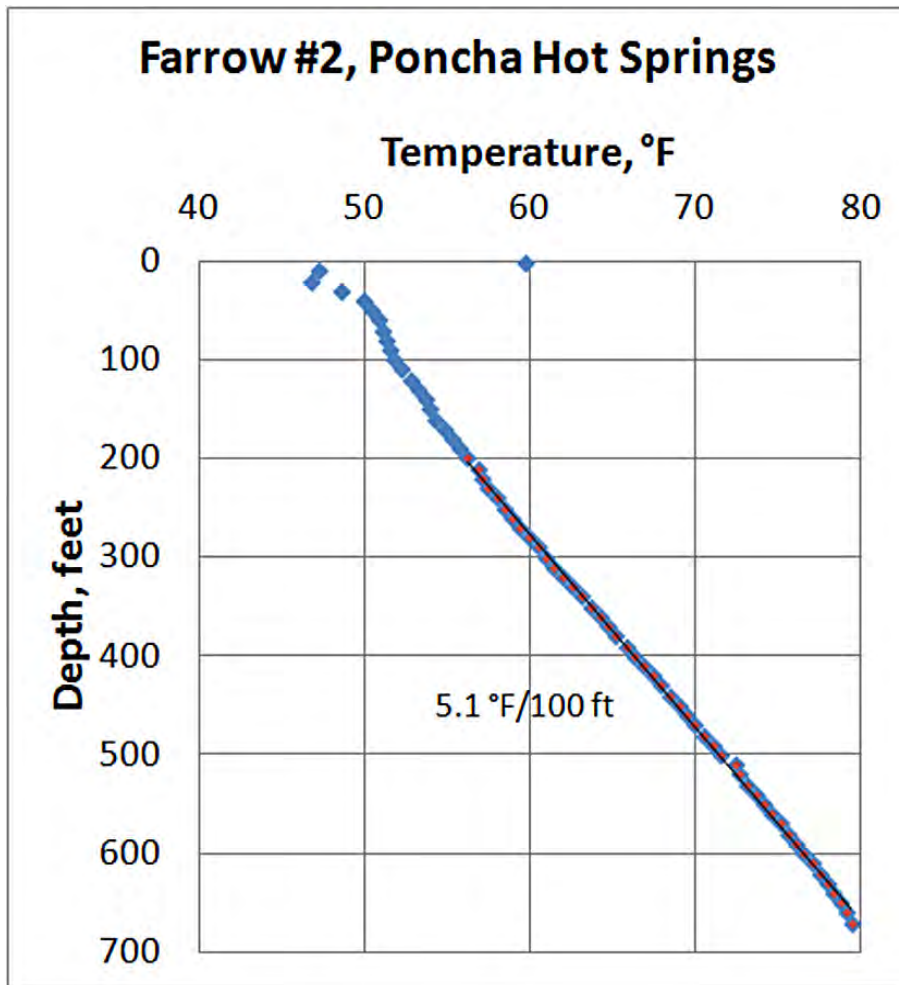
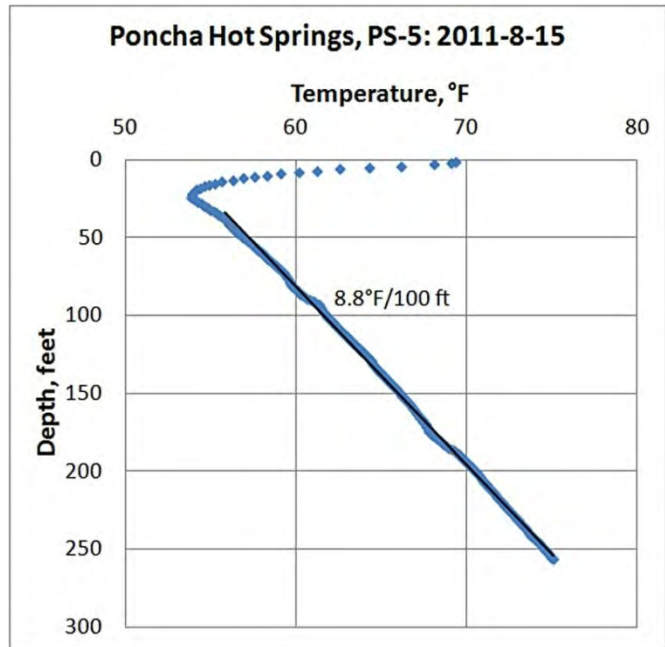


Figure 8. Temperature log recorded in Farrow #2. The red dot indicate the depth range over which the geothermal gradient indicated was calculated

gradient is non-linear above about 200 feet. Part of the non-linearity in this zone may be associated with changes in thermal conductivity of the sedimentary materials caused by changes in water content, but these changes have not been investigated as this is a relatively deep hole. Below 200 feet the geothermal gradient is 5.1°F/100 ft. This is significantly above background.

PS-5. PS-5 was the last specific temperature gradient hole drilled for this project and the final temperature log run in this hole is shown in Figure 9. The temperature-depth data are fairly linear below the annual wave, from about 40 feet to total depth. Small variations from linearity are thought to be associated with variations in thermal conductivity. The gradient of a linear fit to the data is 8.8°F/100 ft.

Figure 9. Temperature log recorded in PS-5. The black line indicates the average geothermal gradient and the depth range over which the geothermal gradient indicated was calculated.



PS-1. PS-1 was the first temperature gradient hole drilled for the project and the final temperature log run in this hole is shown in Figure 10. The data from this hole are similar to the data from PS-5 but the linear fit to the data is slightly higher with a gradient of 10.4°F/100 ft. Thus, with three good linear datasets, Farrow #2, PS-5. and PS-1, the geothermal gradient has increased from 5.1 to 8.8 to 10.4°F/100 ft, up to about six to nine times background.

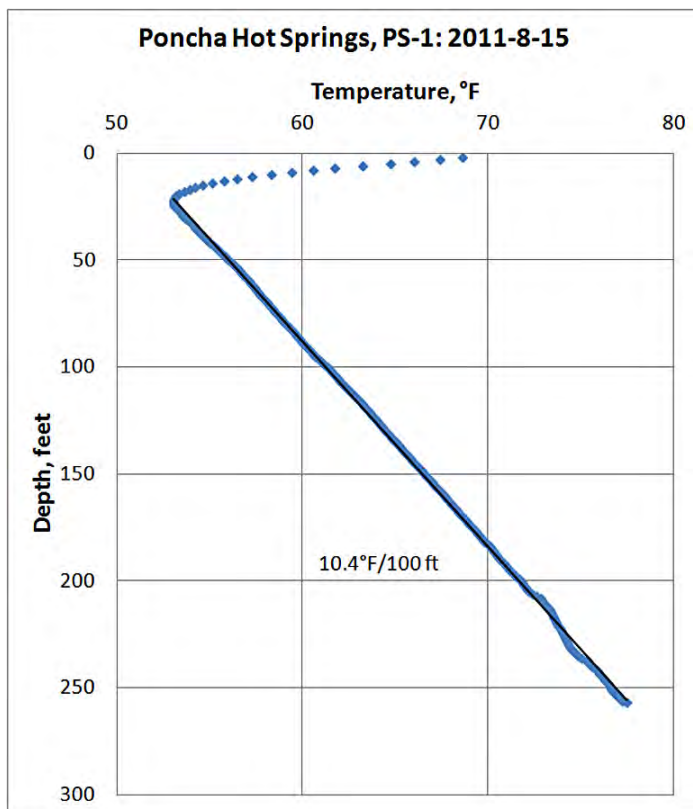
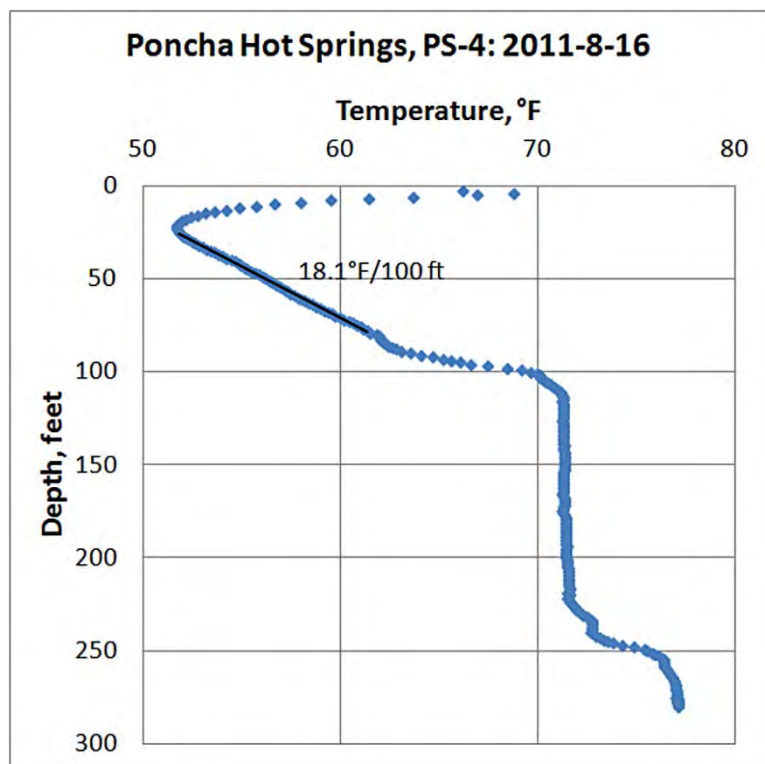


Figure 10. Temperature log recorded in PS-1. The black line indicates the average geothermal gradient and the depth range over which the geothermal gradient indicated was calculated.

PS-4. PS-4 had been logged twice in 2010 to just over 100 feet under its former designation as Farrow #1. The final temperature log run in the hole re-opened to 280 feet as PS-4 is shown in Figure 11. The logs run in the upper portion of the hole in 2010 only differ from the final log in the uppermost part of the hole in the annual wave as they were run in different seasons of the year. The PS-4 log is significantly different from the previous datasets presented. The data show an approximately linear increase of temperature with depth between about 32 and 80 feet with a temperature gradient of 18.1°F/100 ft. Below 80 feet, however, the temperature profile is irregular: there is a very rapid increase in temperature between about 90 and 100 feet, almost no increase in temperature between 115 and 225 feet, and then variable rates of increase in temperature from 225 feet to the bottom of the hole at 280 feet.

Figure 11. Temperature log recorded in PS-4. The black line between about 25 and 80 feet indicates the average geothermal gradient and the depth range over which the geothermal gradient indicated was calculated.



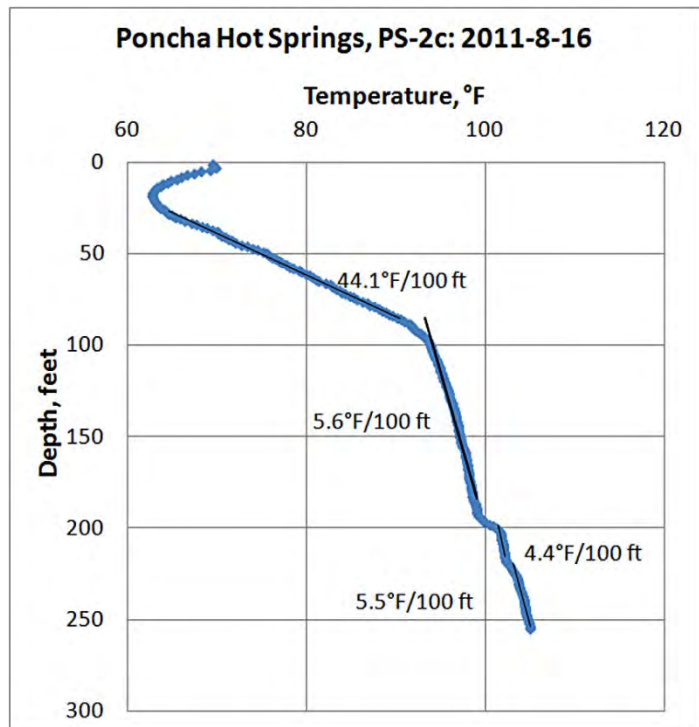
These irregularities in the temperature profile are characteristic of heat transport by a vertical component of water flow. The water flow can be vertical in the annulus between the borehole casing and the rock, with water entering and exiting this space at different levels, or it may be a vertical component of diffuse water flow in the rock formation, changing at different levels as the permeability of the rock changes (see above). Water flow is very efficient in transporting heat, and a vertical flow as slow as a few inches per year can result in near-zero geothermal gradients. In the near vertical sections of the temperature profile in Figure 11, there is probably a slow vertical component of water flow from the bottom of the section to the top of the section. The very high (near horizontal) section of the profile above near vertical section is an increase in the temperature gradient to accommodate the increase

in heat flow from the water flow. Each “step” in the profile indicates a zone of vertical water flow. Water flow can only transfer heat – it cannot make heat. The temperature at a depth of 150 feet in PS-4 is about 76°F, almost the same as the temperature at 250 feet in PS-1. Therefore, despite the higher geothermal gradient in the upper section of PS-4, the overall geothermal gradient in PS-4 is considered to be approximately equal to the gradient in PS-1. PS-4 was collared in a cleared bench in slope wash of Precambrian and alluvium from the steep hill to the south and the hole was located in the hanging wall, very close to the main Poncha Springs fault. The results from PS-4 do not indicate rising hot water on the fault at this location, but the fault may contribute to the heat transfer by water flow seen in the temperature log of this hole.

PS-2c. PS-2c was the hole drilled closest to Poncha Hot Springs and was carefully monitored during drilling by both Drs. Henderson and Morgan so that drilling could be stopped and the hole plugged if necessary if there was any indication that the hole would penetrate the main hot spring system. The volume of drilling fluid exiting the hole relative to the volume of fluid pumped into the drill string and the temperature of the drilling fluid exiting the hole were both monitored: any sudden increase in volume of fluid exiting the hole or increase in temperature to close to the hot spring temperature (158°F) would have been taken as an indication that the hot spring system had been penetrated or that the hole was approaching the system. However, neither of these conditions occurred during the drilling of PS-2c. The final temperature log run in PS-2c is shown in Figure 12. The bottom hole temperature measured was 105.1°F at just over 255 feet, significantly cooler than the hot spring temperature of 158°F.

Figure 12. Temperature log recorded in PS-2c. Geothermal gradients were calculated over four different depth ranges for the hole as indicated by the black lines which indicate the average geothermal gradients for each calculation.

Figure 12. Temperature log recorded in PS-2c



A very high geothermal gradient of 44°F/100 ft was measured in PS-2c from about 30 to 90 feet. This is the highest reliable geothermal gradient that has been measured over more than a 50 foot depth section in a drill-hole in Colorado to date. Between about 90 and 100 feet, however, the gradient decreases significantly and from about 100 to 190 feet the gradient is 5.6°F/100 ft. Perhaps significantly, this is the depth interval in which the cuttings indicated black sands, probably eroded diabase. There are two “steps” in the temperature profile beneath 190 feet, and two more linear sections with gradients of 4.4°F/100 ft between about 200 and 215 feet and 5.5°F/100 ft between about 220 and total depth at 255 feet. The major change in gradient cannot be explained by a change in thermal conductivity of the sedimentary section alone, although it is thought to occur at about the level of the water table where the pores in the rocks go from air-filled to water-filled. The temperature profile in the upper 90 feet of the hole is controlled by the temperature at the top of the water table at this location, 93 to 94°F. Changes in lithology may control the rate at which water flows below the water table.

A fully constrained reconstruction of the water flow system from the hot springs to PS-2c is impossible with the information available, but we believe that much of the hot water rising at the springs does not reach close enough to the surface to be collected in the City of Salida hot-water capture system but “leaks” out of the system as part of the groundwater system. Groundwater flow is driven by the slope of the water table, which generally follows the general slope of the topography: around the Poncha Springs hot springs the general slope is to the north-west, becoming more westerly at the location of PS-2c. The temperature log in PS-2c indicates that there is a general water flow from the west from Poncha Hot Springs. There is an active spring, indicated by the green pentangle in Figure 6, which is fed by part of this water flow to the west.

As the hot water spreads to the west it cools to the surface and the temperatures measured in PS-2c are significantly cooler than the maximum temperature of 158°F measured in the hot spring waters. If PS-2c were deepened we predict that temperatures in the hole would increase until a temperature of about 158°F, at which point the temperature increase would be very low until regional depth at which 158°F is the temperature, at which depth the temperature would increase again at the regional geothermal gradient.

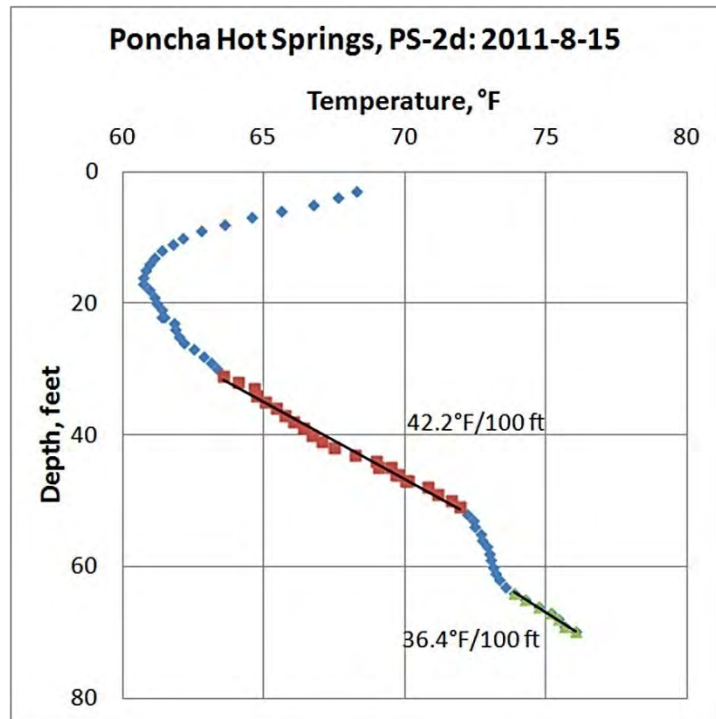
In drilling PS-2c the sedimentary rocks were found to be variable in composition (See Table I). The “steps” in the temperature profile are probably zones in which the flow is blocked and in which the heat transfer is conductive, as in the air-filled rocks above the water table. Changes in the geothermal gradient between these impermeable zones may indicate changes in permeability and changes in the horizontal flow rates, lower gradients indicating higher flow rates.

PS-2d. The most southerly hole, PS-2d, was the only hole drilled in Precambrian basement rocks. Before extensive ground reconnaissance was carried out at least one hole in the Precambrian basement rocks to the south of Poncha Hot Springs was proposed with the goal of obtaining a reliable geothermal gradient/heat flow measurement in this zone. However, although a number of tracks/jeep trails were shown on old maps to cross this area, none were accessible and the cost of opening a suitable path for a drilling rig was considered to be prohibitive on our limited budget. The only maintained road crossing the Precambrian outcrop in the area is Chaffee County Road 115 (Co 115), a dirt road. This is the road from the town of Poncha Springs to Poncha Hot Springs, and continues south down the side of the mountain to meet US Highway 285 going south through Poncha Pass. Co 115 passes into Precambrian rocks almost immediately as it passes Poncha Hot Springs at the main fault, but it also narrows at this point and is on a steep mountain slope winding in and out of erosional drainages in the mountainside. PS-2d was located on the east side of Co 115 on a small spur on the mountainside, approximately 100 yards south of the main Poncha Springs Fault, the interface between sedimentary rocks and the Precambrian. The hole was located on a spur not a valley in the hope that there would be less subsurface weathering of the rocks beneath the more resistant spur. Before drilling started, however, we considered this site marginal at best because of its location on a steep mountainside and evidence in rocks cropping out along cuts in the roadside that there was significant footwall shearing, alteration, and weathering in the exposed Precambrian.

Drilling PS-2d ran into problems almost immediately because of caving in the hole. Surface casing was set at about 40 feet, but caving continued beneath this depth, indicating that the hole would probably need to be continuously cased during drilling. Continuous casing is slower than drilling without casing and is also more expensive as casing remains in the hole. The hole was therefore abandoned at about 80 feet deference to moving on to the more critical hole PS-2c. The final temperature log run in PS-2d is shown in Figure 13 to a depth of about 70 feet.

There are no good linear sections in the temperature profile from PS-2d. The most linear section is from about 32 to 51 feet and has a gradient of 42.2°F/100 ft. Below 51 feet there is a “step” down in the temperature profile an a short linear section from about 64 feet to the total depth logged at about 75 feet, with a gradient of 36.4°F/100 ft. We do not believe that the base of PS-2d reached the main water table, but from inspection of the outcrops of Precambrian in road cuts we observed narrow zones through which water was percolating. These zones could represent perched water tables and could transmit small flows of hot water above the main water table. Thus, the difference in the geothermal gradient between 32 and 51 feet and the gradient between 64 and 75 feet could be caused by water flow in a perched aquifer in the zone between 51 and 64 feet. This flow is likely to be

Figure 13. Temperature log recorded in PS-2d. The red and green symbols indicate the sections over which geothermal gradients were calculated. These gradients are considered to be very tentative and not regionally significant.



very small and only in the temperature range of 72 to 74°F, but it would explain the “step in the temperature profile.

Synthesis and Interpretation of Temperature Logging Results

Two distinct thermal regimes were encountered in the temperature logs in this study, linear thermal gradients where a the thermal gradient is reliable, at least over the depth of the hole, and temperature logs with variable thermal gradients indicating heat transfer by water flow within the depth range of the hole. For the single linear thermal gradients, these gradients can probably be extrapolated to depth at least to the temperature of the hot springs, that is 158°F. For example, PS-1 has a gradient of 10.4°F/100 ft and extrapolates back to the surface at about 50°F. The depth at which 158°F would be reach if this gradient continues is given by $(158 - 50)/10.4$ hundred feet, or about 1,040 feet. As the gradient decreases, the extrapolated depth to 158°F increases, so the depth to the hot water source probably increases to the north-northeast away from the hot springs and the controlling main Poncha Springs fault.

An attempt has been made to contour the average geothermal gradient around the hot springs as shown in Figure 14. These contours were drawn by hand and are based on the data from the interpretation of the temperature logs, the surface location of the hot springs, indications of shallow hot water from the Colorado School of Mines electrical resistivity

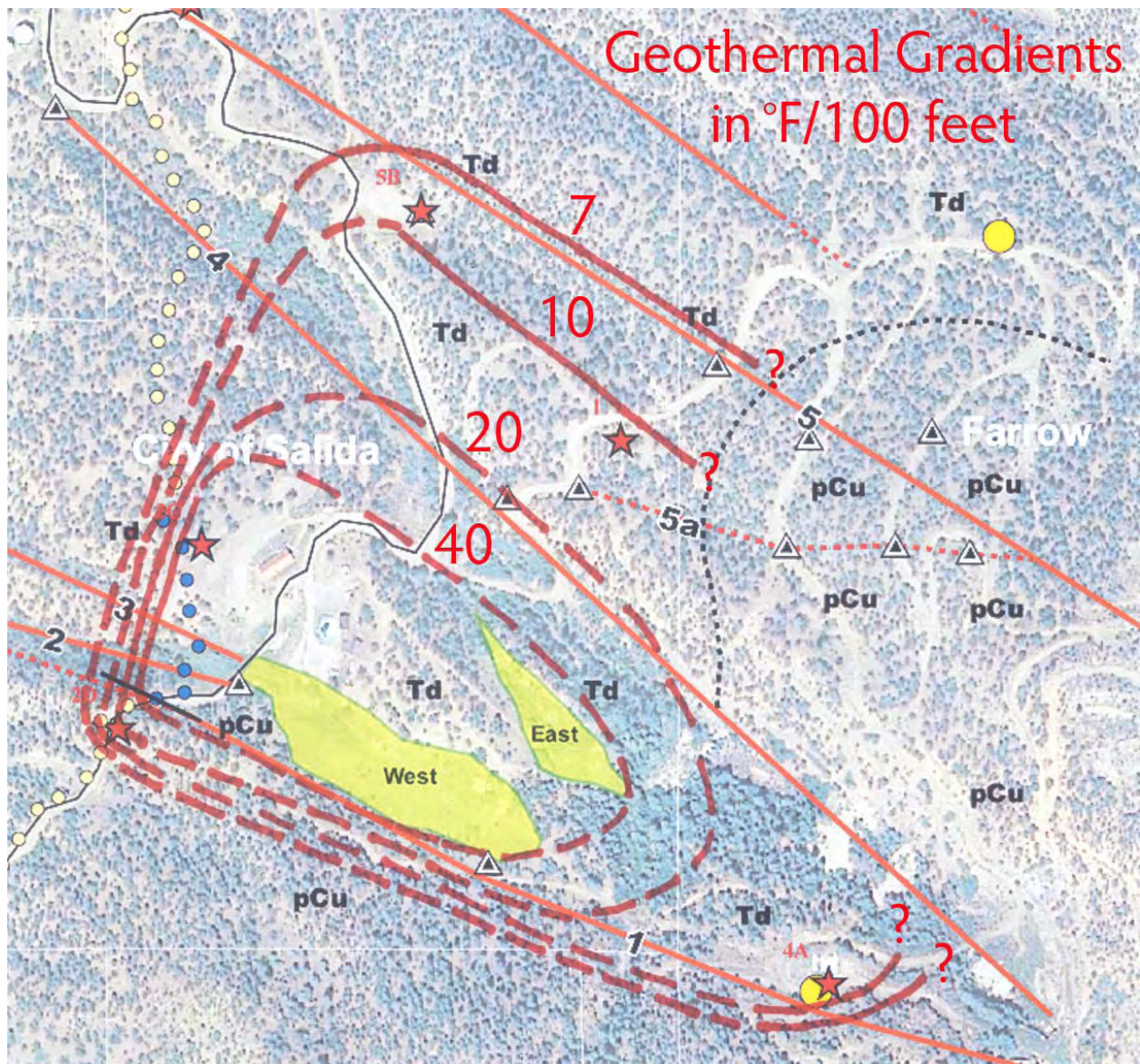


Figure 14. Hand-contoured map of the Poncha Hot Springs area. Contours are based on the results of temperature logs, the Colorado School of Mines geophysical surveys, surface geology and mapped faults. Contours are labeled in °F/100 feet and contour intervals are not evenly spaced. Drill hole sites from 2010 are indicated by yellow filled circles; drill hole sites from 2011 (this study) are indicated by red filled stars.

results along Co 115, and mapped and inferred faults and other geology in the area. The contours are poorly constrained in many locations, but their general pattern is thought to be consistent with the geological and geophysical data available, and a reasonable model for the origin of the hot springs.

Poncha Hot Springs are located at the southern end of the Upper Arkansas Valley and the geological structure at this location is a major normal fault, a fault in which dips typically at 60 to 70 degrees near the surface with the upper side (hanging wall) of the fault moving down relative to the lower footwall side of the fault. At Poncha Hot Springs the main fault is approximately east-west, it dips to the north, and the north side of the fault dropped the valley down relative to the mountains to the south. The proximity of Poncha Hot Springs to where this fault cuts the surface, and where the fault forms the boundary between Precambrian and younger rocks, strongly suggests that the fault forms the conduit for hot water to rise to the surface for the springs.

The decrease in geothermal gradient to the north-northeast away from Poncha Hot Springs and the surface outcrop of the fault is consistent with increasing depth to the hot water in the fault as the fault dips in this direction. There is no rapid increase or decrease in gradient with distance from the springs, but a steady decrease, indicating that the water does not significantly change temperature in this section of the fault. Chemical geothermometers indicate that the spring water is a mixture of water from a significantly hotter reservoir, 250 to 300°F, and cooler water infiltrating from rain water and snow melt. Presumably this mixing occurs further to the north, and at greater depth than sampled by the temperature data in the present study.

Recommendations for Further Exploration Based on New Temperature Data

The most significant result of the data collected from the new temperature studies has been to delineate two distinct thermal regimes associated with Poncha Hot Springs, a zone of spreading, cooling hot water immediately around the springs, and a zone of increasing geothermal gradients immediately north of the hot springs which maps the dipping fault along which the hot water is rising. Previous geophysical studies along Co 115 indicated an electrical anomaly consistent with geothermal fluids west of the hot springs, and suggested that this was an area of interest for further studies. The new data show that temperatures in this zone are lower than the hot-springs temperature and that the zone is likely a zone of lateral flow and cooling from the main hot springs. A more prospective area for further studies is probably to the north where the hot water appears to rise along the major valley-bounding fault.

More information is required before the sites for one or more deep test wells may be located. Probably the most useful next exploration phase would be a magnetotellurics (MT)

survey. MT is a very low frequency combined magnetic and electrical technique for probing the natural electrical structure of the earth to a depth of several thousand feet. Hot water has a lower electrical resistance than cold water and MT is generally successful in locating geothermal reservoirs at greater depths than other techniques. Other materials, such as metallic ore bodies and graphite also have low electrical resistance and the results of MT surveys are not unique in delineating geothermal reservoirs. However, in the vicinity of Poncha Hot Springs, a low electrical resistance body at depth is highly likely to be a geothermal reservoir. An MT survey would provide additional evidence to support the water chemistry geothermometry for a high temperature reservoir at depth. It would also indicate the location (geographic center) of the reservoir at depth which may be offset to the north of the surface contoured thermal gradient anomaly shown in Figure 14.

If an MT survey yield positive results, locating a potential geothermal reservoir at depth, before drilling an expensive deep reservoir test well, we recommend the drilling of one or two 1,000 to 1,500 foot deep geothermal gradient test wells. The purpose of these wells would not be to drill to the depth of the reservoir, but to confirm the interpretation of the MT results as a geothermal reservoir and to give an indication of the temperature of the reservoir. These wells could probably be drilled for about \$100,000 to \$200,000 each, including all testing, as opposed to more than \$2,000,000 for drilling and testing a deep test well. Temperature data from intermediate-depth temperature gradient wells that confirm temperatures significantly hotter than the surface hot springs would confirm the inferences from other data that a high-temperature reservoir would exist at depth. Such evidence would be very compelling in terms of obtaining additional funding for deep test wells. To reach reservoir temperatures of 250°- 300°F necessary for efficient heat transfer production of electricity, it is estimated the deep reservoir will be at 2,000' – 3,000' depth. The two exploration phases we recommend for the immediate future are therefore an MT survey and intermediate-depth temperature gradient hole drilling. If successful, these next phases will provide a reasonable deep reservoir target for deep test wells to confirm the existence of a sustainable reservoir capable of producing economic geothermal electrical energy at Poncha Hot Springs.

Conclusions

Six principal conclusions are drawn from this geological, geophysical and thermal gradient study at Poncha Hot Springs.

1. A significant, high thermal gradient anomaly exists the Poncha Hot Springs area and is the highest such anomaly measured in Colorado to date.
2. Geological fault structures including the main E-W Poncha Hot Springs Fault, and step down subsidiary faults to the north appear to control the upwelling and flow of the geothermal waters from depth.
3. Previous geothermometry studies indicate the possible presence of a high temperature reservoir at depth (third highest in Colorado, Morgan).
4. The City of Salida property containing the Poncha Hot Springs is surrounded by neighbors who have expressed support, rather than opposition, to the development of geothermal electricity from the Poncha Hot springs geothermal resource.
5. Finally, the above observations suggest the Poncha Hot Springs can have a high temperature reservoir at depth capable of producing geothermal electrical energy in significant amounts.
6. It is recommended the City of Salida consider conducting an magnetotelluric survey (MT) followed by one or two medium depth (1,000' – 1,500') thermal gradient holes to further validate and outline the location of a potential sustainable geothermal reservoir at depth for future deep testing.

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Appendix 1 - Temperature Logging Methodology

All drill holes in the Poncha Hot Springs area associated with this study were logged with a portable logging unit comprising a hand winch with approximately 2,000 feet of cable, an electrical resistance temperature sensor mounted on the end of the cable, and surface equipment to measure the resistance of the probe at the surface that compensated automatically for the electrical resistance of the cable. The depth of the probe was measured by a mechanical counter mounted to a precision-machined grooved wheel (sheave wheel) over which the cable passed as it entered the drill hole. The hand which is shown in Figure A1. The sheave wheel with mechanical counter, mounted in the collar of a drill hole

with the cable entering the hole, is shown in Figure A2.



Figure A1. Hand logging winch. Height and length of winch are approximately 18 inches. Width (without winding handle) is approximately 15 inches. Cable has four conductors with an outside diameter of approximately 0.1 inches. Electrical connection while winding is maintained through slip-rings in the far side of the

winch.

Figure A2. Sheave wheel with mechanical counter. Counter was calibrated in tenths of a revolution and the wheel was machined so that one revolution was equal to one foot of cable passing down the drill hole. The assembly was clamped to the drill hole casing.



The temperature sensor used was a platinum resistance thermometer (PRT), also known as a resistance temperature device (RTD) with a nominal resistance of 1,000 Ω at 32°F (0°C). These sensors increase in resistance as temperature increases with very predictable parameters and have very low drift. The precision of the sensors is 0.002°F (0.001°C) and their accuracy for temperature gradient measurements is $\pm 0.02^\circ\text{F}$ ($\pm 0.01^\circ\text{C}$). The sensor was configured in the probe and cable to make a four-wire resistance measurement with two insulated conductors leading from each of the two sides of the sensor to the surface. Some multimeters are configured to make four-wire resistance measurements in which a small, constant, calibrated current is passed through two of the conductors and through the sensor while the other generated across the sensor by this current is measured using the other two conductors. The resistance is then calculated from the measured voltage divided by the calibrated current. This configuration has the advantage that the measurement is independent of the resistance of the conductors, in this case the cable resistance. As the cable is heated in the drill hole its resistance generally changes, so a measurement technique which eliminates the resistance of the cable is important for accurate temperature logging.

Appendix 2 - Temperature Data from Final Logs

Farrow #1 - 38° 29.740' N, 106° 04.452' W, elev. 8175 feet.

Logged 12-10-2010

Depth	Temp.	Depth	Temp.
z_m	T_°C	z_ft	T_°F
1.5	5.1	5	41.2
3.0	10.2	10	50.4
6.1	12.1	20	53.7
9.1	12.1	30	53.8
12.2	12.6	40	54.7
15.2	13.4	50	56.1
18.3	14.2	60	57.6
21.3	15.2	70	59.4
24.4	16.2	80	61.2
27.4	17.7	90	63.8
30.5	21.0	100	69.9
33.5	21.7	110	71.0

Farrow # 2 - 38° 30.005' N, 106° 4.363' W, elev. 8036

Logged 5-20-2010

Depth z_m	Temp. T_°C	Depth z_ft	Temp. T_°F				
0.6	15.4	2	59.7	131.1	20.0	430	67.9
3.0	8.5	10	47.2	134.1	20.3	440	68.5
6.1	8.2	20	46.7	137.2	20.6	450	69.1
9.1	9.2	30	48.6	140.2	20.9	460	69.5
12.2	10.0	40	50.0	143.3	21.1	470	70.0
15.2	10.2	50	50.4	146.3	21.4	480	70.6
18.3	10.5	60	50.9	149.4	21.7	490	71.1
21.3	10.6	70	51.1	152.4	22.0	500	71.6
24.4	10.8	80	51.4	155.4	22.5	510	72.5
27.4	10.9	90	51.6	158.5	22.6	520	72.6
30.5	11.0	100	51.8	161.5	22.9	530	73.2
33.5	11.3	110	52.3	164.6	23.2	540	73.7
36.6	11.5	120	52.8	167.6	23.4	550	74.2
39.6	11.8	130	53.2	170.7	23.7	560	74.6
42.7	12.0	140	53.7	173.7	24.0	570	75.2
45.7	12.2	150	53.9	176.8	24.2	580	75.6
48.8	12.4	160	54.3	179.8	24.5	590	76.1
51.8	12.7	170	54.8	182.9	24.8	600	76.6
54.9	12.9	180	55.3	185.9	25.1	610	77.1
57.9	13.2	190	55.8	189.0	25.3	620	77.5
61.0	13.5	200	56.3	192.0	25.6	630	78.0
64.0	13.8	210	56.9	195.1	25.8	640	78.4
67.1	14.0	220	57.1	198.1	26.0	650	78.8
70.1	14.2	230	57.5	201.2	26.2	660	79.1
73.2	14.5	240	58.0	204.2	26.4	670	79.5
76.2	14.7	250	58.4				
79.2	15.0	260	58.9				
82.3	15.2	270	59.4				
85.3	15.5	280	60.0				
88.4	15.8	290	60.5				
91.4	16.1	300	60.9				
94.5	16.4	310	61.5				
97.5	16.7	320	62.0				
100.6	17.0	330	62.6				
103.6	17.3	340	63.1				
106.7	17.6	350	63.7				
109.7	17.9	360	64.2				
112.8	18.2	370	64.7				
115.8	18.4	380	65.2				
118.9	18.8	390	65.8				
121.9	19.1	400	66.3				
125.0	19.4	410	66.9				
128.0	19.7	420	67.4				

PS-1 - 38° 29.933' N, 106° 04.535' W. elev. 7667 feet

Logged 8-15-2011

Depth_m	T_°C	Depth_ft	T_°F	***	Depth_m	T_°C	Depth_ft	T_°F	***	Depth_m	T_°C	Depth_ft	T_°F
0.6	20.4	2.1	68.7		26.9	15.5	88.1	60.0		53.1	20.6	174.1	69.0
0.9	19.7	3.1	67.4		27.2	15.6	89.1	60.1		53.4	20.6	175.1	69.1
1.2	18.9	4.1	66.0		27.5	15.7	90.1	60.2		53.7	20.7	176.1	69.3
1.6	18.2	5.1	64.7		27.8	15.7	91.1	60.3		54.0	20.8	177.1	69.4
1.9	17.4	6.1	63.2		28.1	15.8	92.1	60.4		54.3	20.8	178.1	69.5
2.2	16.5	7.1	61.8		28.4	15.8	93.1	60.5		54.6	20.9	179.1	69.6
2.5	15.9	8.1	60.6		28.7	15.9	94.1	60.6		54.9	20.9	180.1	69.7
2.8	15.2	9.1	59.4		29.0	16.0	95.1	60.7		55.2	21.0	181.1	69.7
3.1	14.6	10.1	58.3		29.3	16.0	96.1	60.8		55.5	21.0	182.1	69.9
3.4	14.1	11.1	57.3		29.6	16.1	97.1	61.0		55.8	21.1	183.1	70.0
3.7	13.6	12.1	56.5		29.9	16.2	98.1	61.1		56.1	21.2	184.1	70.1
4.0	13.2	13.1	55.8		30.2	16.2	99.1	61.2		56.4	21.2	185.1	70.2
4.3	12.9	14.1	55.2		30.5	16.3	100.1	61.4		56.7	21.3	186.1	70.3
4.6	12.6	15.1	54.6		30.8	16.4	101.1	61.5		57.0	21.3	187.1	70.4
4.9	12.3	16.1	54.2		31.1	16.4	102.1	61.6		57.3	21.4	188.1	70.5
5.2	12.2	17.1	53.9		31.4	16.5	103.1	61.7		57.6	21.4	189.1	70.6
5.5	12.0	18.1	53.6		31.7	16.5	104.1	61.8		57.9	21.5	190.1	70.7
5.8	11.9	19.1	53.4		32.0	16.6	105.1	61.9		58.2	21.5	191.1	70.8
6.1	11.8	20.1	53.2		32.3	16.7	106.1	62.0		58.6	21.6	192.1	70.9
6.4	11.7	21.1	53.1		32.6	16.7	107.1	62.1		58.9	21.7	193.1	71.0
6.7	11.7	22.1	53.1		32.9	16.8	108.1	62.2		59.2	21.7	194.1	71.1
7.0	11.7	23.1	53.0		33.3	16.9	109.1	62.3		59.5	21.8	195.1	71.2
7.3	11.7	24.1	53.1		33.6	16.9	110.1	62.4		59.8	21.8	196.1	71.3
7.7	11.7	25.1	53.1		33.9	17.0	111.1	62.6		60.1	21.9	197.1	71.4
8.0	11.8	26.1	53.2		34.2	17.0	112.1	62.7		60.4	22.0	198.1	71.5
8.3	11.9	27.1	53.3		34.5	17.1	113.1	62.8		60.7	22.0	199.1	71.7
8.6	11.9	28.1	53.4		34.8	17.2	114.1	62.9		61.0	22.1	200.1	71.8
8.9	12.0	29.1	53.5		35.1	17.2	115.1	63.0		61.3	22.1	201.1	71.9
9.2	12.0	30.1	53.6		35.4	17.3	116.1	63.1		61.6	22.2	202.1	71.9
9.5	12.1	31.1	53.8		35.7	17.4	117.1	63.2		61.9	22.2	203.1	72.0
9.8	12.2	32.1	53.9		36.0	17.4	118.1	63.3		62.2	22.3	204.1	72.1
10.1	12.2	33.1	54.0		36.3	17.5	119.1	63.4		62.5	22.3	205.1	72.2
10.4	12.3	34.1	54.1		36.6	17.5	120.1	63.5		62.8	22.5	206.1	72.4
10.7	12.3	35.1	54.2		36.9	17.6	121.1	63.6		63.1	22.6	207.1	72.6
11.0	12.4	36.1	54.3		37.2	17.6	122.1	63.7		63.4	22.7	208.1	72.8
11.3	12.5	37.1	54.4		37.5	17.7	123.1	63.8		63.7	22.7	209.1	72.9
11.6	12.5	38.1	54.5		37.8	17.7	124.1	63.9		64.0	22.8	210.1	73.0
11.9	12.6	39.1	54.7		38.1	17.8	125.1	64.0		64.3	22.8	211.1	73.1
12.2	12.7	40.1	54.8		38.4	17.9	126.1	64.1		64.6	22.9	212.1	73.2
12.5	12.7	41.1	54.9		38.7	17.9	127.1	64.2		65.0	23.0	213.1	73.3
12.8	12.8	42.1	55.1		39.0	18.0	128.1	64.3		65.3	23.0	214.1	73.4

13.1	12.9	43.1	55.2	39.3	18.0	129.1	64.4	65.6	23.0	215.1	73.4
13.4	12.9	44.1	55.3	39.7	18.1	130.1	64.5	65.9	23.1	216.1	73.5
13.7	13.0	45.1	55.4	40.0	18.1	131.1	64.6	66.2	23.1	217.1	73.5
14.1	13.1	46.1	55.6	40.3	18.2	132.1	64.7	66.5	23.1	218.1	73.6
14.4	13.2	47.1	55.7	40.6	18.2	133.1	64.8	66.8	23.2	219.1	73.7
14.7	13.2	48.1	55.8	40.9	18.3	134.1	64.9	67.1	23.2	220.1	73.7
15.0	13.3	49.1	55.9	41.2	18.3	135.1	65.0	67.4	23.2	221.1	73.8
15.3	13.3	50.1	56.0	41.5	18.4	136.1	65.1	67.7	23.3	222.1	73.9
15.6	13.4	51.1	56.2	41.8	18.5	137.1	65.2	68.0	23.3	223.1	73.9
15.9	13.5	52.1	56.3	42.1	18.5	138.1	65.3	68.3	23.3	224.1	74.0
16.2	13.6	53.1	56.4	42.4	18.6	139.1	65.4	68.6	23.4	225.1	74.1
16.5	13.6	54.1	56.5	42.7	18.6	140.1	65.5	68.9	23.4	226.1	74.1
16.8	13.7	55.1	56.6	43.0	18.7	141.1	65.6	69.2	23.4	227.1	74.2
17.1	13.7	56.1	56.7	43.3	18.7	142.1	65.7	69.5	23.5	228.1	74.2
17.4	13.8	57.1	56.8	43.6	18.8	143.1	65.8	69.8	23.5	229.1	74.3
17.7	13.9	58.1	56.9	43.9	18.9	144.1	65.9	70.1	23.5	230.1	74.4
18.0	13.9	59.1	57.1	44.2	18.9	145.1	66.0	70.4	23.6	231.1	74.4
18.3	14.0	60.1	57.2	44.5	19.0	146.1	66.2	70.7	23.6	232.1	74.5
18.6	14.0	61.1	57.2	44.8	19.0	147.1	66.3	71.0	23.7	233.1	74.7
18.9	14.1	62.1	57.3	45.1	19.1	148.1	66.4	71.4	23.7	234.1	74.7
19.2	14.1	63.1	57.4	45.4	19.1	149.1	66.5	71.7	23.8	235.1	74.9
19.5	14.2	64.1	57.5	45.8	19.2	150.1	66.6	72.0	23.9	236.1	75.1
19.8	14.2	65.1	57.6	46.1	19.3	151.1	66.7	72.3	24.1	237.1	75.3
20.1	14.3	66.1	57.7	46.4	19.3	152.1	66.8	72.6	24.1	238.1	75.4
20.5	14.3	67.1	57.8	46.7	19.4	153.1	66.9	72.9	24.2	239.1	75.5
20.8	14.4	68.1	57.9	47.0	19.4	154.1	67.0	73.2	24.2	240.1	75.6
21.1	14.4	69.1	58.0	47.3	19.5	155.1	67.1	73.5	24.3	241.1	75.8
21.4	14.5	70.1	58.1	47.6	19.5	156.1	67.2	73.8	24.4	242.1	75.9
21.7	14.6	71.1	58.2	47.9	19.6	157.1	67.3	74.1	24.4	243.1	76.0
22.0	14.6	72.1	58.3	48.2	19.7	158.1	67.4	74.4	24.5	244.1	76.1
22.3	14.7	73.1	58.4	48.5	19.7	159.1	67.5	74.7	24.6	245.1	76.2
22.6	14.7	74.1	58.5	48.8	19.8	160.1	67.6	75.0	24.6	246.1	76.3
22.9	14.8	75.1	58.6	49.1	19.8	161.1	67.7	75.3	24.7	247.1	76.4
23.2	14.8	76.1	58.7	49.4	19.9	162.1	67.8	75.6	24.7	248.1	76.5
23.5	14.9	77.1	58.8	49.7	19.9	163.1	67.9	75.9	24.7	249.1	76.5
23.8	15.0	78.1	58.9	50.0	20.0	164.1	68.0	76.2	24.8	250.1	76.6
24.1	15.0	79.1	59.0	50.3	20.1	165.1	68.1	76.5	24.8	251.1	76.7
24.4	15.1	80.1	59.2	50.6	20.1	166.1	68.2	76.8	24.9	252.1	76.8
24.7	15.1	81.1	59.3	50.9	20.2	167.1	68.3	77.1	24.9	253.1	76.9
25.0	15.2	82.1	59.4	51.2	20.2	168.1	68.4	77.4	25.0	254.1	77.0
25.3	15.3	83.1	59.5	51.5	20.3	169.1	68.5	77.8	25.1	255.1	77.1
25.6	15.3	84.1	59.6	51.8	20.3	170.1	68.6	78.1	25.1	256.1	77.3
25.9	15.4	85.1	59.7	52.2	20.4	171.1	68.7	78.2	25.3	256.7	77.5
26.2	15.4	86.1	59.8	52.5	20.5	172.1	68.8				
26.5	15.5	87.1	59.9	52.8	20.5	173.1	68.9				

Logged 8-16-2011

Depth_m	T_°C	Depth_ft	T_°F	***	Depth_m	T_°C	Depth_ft	T_°F	***	Depth_m	T_°C	Depth_ft	T_°F
0.3	20.8	1.1	69.5		26.2	32.5	86.1	90.5		52.2	36.8	171.1	98.2
0.6	20.9	2.1	69.6		26.5	32.8	87.1	91.0		52.5	36.8	172.1	98.2
0.9	21.1	3.1	70.0		26.9	33.0	88.1	91.5		52.8	36.8	173.1	98.2
1.2	20.7	4.1	69.3		27.2	33.1	89.1	91.7		53.1	36.8	174.1	98.3
1.6	20.2	5.1	68.3		27.5	33.2	90.1	91.8		53.4	36.9	175.1	98.3
1.9	19.7	6.1	67.4		27.8	33.3	91.1	92.0		53.7	36.9	176.1	98.4
2.2	19.3	7.1	66.7		28.1	33.5	92.1	92.3		54.0	36.9	177.1	98.4
2.5	18.9	8.1	66.1		28.4	33.7	93.1	92.6		54.3	36.9	178.1	98.4
2.8	18.6	9.1	65.5		28.7	33.8	94.1	92.9		54.6	36.9	179.1	98.5
3.1	18.3	10.1	64.9		29.0	34.0	95.1	93.1		54.9	37.0	180.1	98.5
3.4	18.0	11.1	64.4		29.3	34.1	96.1	93.3		55.2	37.0	181.1	98.6
3.7	17.8	12.1	64.0		29.6	34.2	97.1	93.5		55.5	37.0	182.1	98.6
4.0	17.6	13.1	63.7		29.9	34.2	98.1	93.6		55.8	37.0	183.1	98.6
4.3	17.4	14.1	63.3		30.2	34.3	99.1	93.8		56.1	37.0	184.1	98.7
4.6	17.3	15.1	63.1		30.5	34.4	100.1	93.9		56.4	37.1	185.1	98.7
4.9	17.2	16.1	62.9		30.8	34.4	101.1	94.0		56.7	37.1	186.1	98.9
5.2	17.1	17.1	62.8		31.1	34.4	102.1	94.0		57.0	37.2	187.1	98.9
5.5	17.1	18.1	62.8		31.4	34.5	103.1	94.1		57.3	37.2	188.1	99.0
5.8	17.1	19.1	62.8		31.7	34.5	104.1	94.2		57.6	37.2	189.1	99.0
6.1	17.2	20.1	63.0		32.0	34.6	105.1	94.2		57.9	37.2	190.1	99.0
6.4	17.3	21.1	63.1		32.3	34.6	106.1	94.3		58.2	37.3	191.1	99.1
6.7	17.3	22.1	63.1		32.6	34.7	107.1	94.4		58.6	37.3	192.1	99.1
7.0	17.4	23.1	63.3		32.9	34.8	108.1	94.6		58.9	37.4	193.1	99.3
7.3	17.4	24.1	63.4		33.3	34.8	109.1	94.7		59.2	37.5	194.1	99.4
7.7	17.6	25.1	63.7		33.6	34.8	110.1	94.7		59.5	37.6	195.1	99.6
8.0	17.9	26.1	64.1		33.9	34.9	111.1	94.8		59.8	37.7	196.1	99.9
8.3	18.0	27.1	64.4		34.2	34.9	112.1	94.9		60.1	37.8	197.1	100.0
8.6	18.1	28.1	64.6		34.5	35.0	113.1	94.9		60.4	38.0	198.1	100.5
8.9	18.3	29.1	65.0		34.8	35.0	114.1	95.0		60.7	38.3	199.1	100.9
9.2	18.6	30.1	65.5		35.1	35.0	115.1	95.1		61.0	38.5	200.1	101.2
9.5	18.9	31.1	66.0		35.4	35.1	116.1	95.2		61.3	38.6	201.1	101.5
9.8	19.1	32.1	66.5		35.7	35.1	117.1	95.2		61.6	38.7	202.1	101.6
10.1	19.5	33.1	67.2		36.0	35.2	118.1	95.3		61.9	38.7	203.1	101.7
10.4	19.9	34.1	67.8		36.3	35.2	119.1	95.4		62.2	38.8	204.1	101.8
10.7	20.2	35.1	68.4		36.6	35.2	120.1	95.4		62.5	38.8	205.1	101.8
11.0	20.5	36.1	68.9		36.9	35.3	121.1	95.5		62.8	38.8	206.1	101.8
11.3	20.8	37.1	69.5		37.2	35.4	122.1	95.6		63.1	38.8	207.1	101.9
11.6	21.1	38.1	70.0		37.5	35.4	123.1	95.7		63.4	38.9	208.1	102.0
11.9	21.2	39.1	70.2		37.8	35.5	124.1	95.8		63.7	38.9	209.1	102.0
12.2	21.4	40.1	70.6		38.1	35.5	125.1	95.9		64.0	38.9	210.1	102.1
12.5	21.6	41.1	71.0		38.4	35.5	126.1	95.9		64.3	38.9	211.1	102.1

12.8	21.9	42.1	71.4	38.7	35.5	127.1	96.0	64.6	38.9	212.1	102.1
13.1	22.1	43.1	71.7	39.0	35.6	128.1	96.0	65.0	39.0	213.1	102.1
13.4	22.3	44.1	72.1	39.3	35.6	129.1	96.1	65.3	39.0	214.1	102.2
13.7	22.6	45.1	72.7	39.7	35.6	130.1	96.1	65.6	39.0	215.1	102.2
14.1	23.0	46.1	73.4	40.0	35.7	131.1	96.2	65.9	39.0	216.1	102.2
14.4	23.4	47.1	74.1	40.3	35.7	132.1	96.3	66.2	39.0	217.1	102.3
14.7	23.7	48.1	74.6	40.6	35.8	133.1	96.4	66.5	39.1	218.1	102.4
15.0	24.0	49.1	75.2	40.9	35.8	134.1	96.4	66.8	39.2	219.1	102.5
15.3	24.2	50.1	75.6	41.2	35.8	135.1	96.5	67.1	39.3	220.1	102.7
15.6	24.4	51.1	75.8	41.5	35.9	136.1	96.6	67.4	39.4	221.1	102.9
15.9	24.5	52.1	76.2	41.8	35.9	137.1	96.6	67.7	39.4	222.1	103.0
16.2	24.8	53.1	76.6	42.1	35.9	138.1	96.7	68.0	39.5	223.1	103.1
16.5	25.0	54.1	77.0	42.4	35.9	139.1	96.7	68.3	39.6	224.1	103.2
16.8	25.2	55.1	77.3	42.7	36.0	140.1	96.7	68.6	39.7	225.1	103.4
17.1	25.4	56.1	77.8	43.0	36.0	141.1	96.8	68.9	39.7	226.1	103.5
17.4	25.7	57.1	78.2	43.3	36.0	142.1	96.9	69.2	39.8	227.1	103.6
17.7	25.9	58.1	78.6	43.6	36.1	143.1	96.9	69.5	39.8	228.1	103.6
18.0	26.2	59.1	79.1	43.9	36.1	144.1	97.0	69.8	39.8	229.1	103.7
18.3	26.4	60.1	79.5	44.2	36.1	145.1	97.0	70.1	39.8	230.1	103.7
18.6	26.6	61.1	79.9	44.5	36.1	146.1	97.0	70.4	39.9	231.1	103.8
18.9	26.8	62.1	80.3	44.8	36.1	147.1	97.1	70.7	39.9	232.1	103.8
19.2	27.1	63.1	80.7	45.1	36.2	148.1	97.1	71.0	40.0	233.1	103.9
19.5	27.3	64.1	81.2	45.4	36.2	149.1	97.1	71.4	40.0	234.1	104.0
19.8	27.5	65.1	81.5	45.8	36.2	150.1	97.2	71.7	40.0	235.1	104.1
20.1	27.9	66.1	82.2	46.1	36.2	151.1	97.2	72.0	40.1	236.1	104.1
20.5	28.1	67.1	82.6	46.4	36.3	152.1	97.3	72.3	40.1	237.1	104.2
20.8	28.3	68.1	83.0	46.7	36.3	153.1	97.3	72.6	40.1	238.1	104.3
21.1	28.5	69.1	83.3	47.0	36.3	154.1	97.4	72.9	40.2	239.1	104.3
21.4	28.7	70.1	83.7	47.3	36.4	155.1	97.4	73.2	40.2	240.1	104.4
21.7	28.9	71.1	84.0	47.6	36.4	156.1	97.5	73.5	40.2	241.1	104.4
22.0	29.1	72.1	84.4	47.9	36.5	157.1	97.7	73.8	40.2	242.1	104.4
22.3	29.4	73.1	84.9	48.2	36.5	158.1	97.8	74.1	40.2	243.1	104.4
22.6	29.6	74.1	85.2	48.5	36.6	159.1	97.8	74.4	40.3	244.1	104.5
22.9	29.8	75.1	85.6	48.8	36.6	160.1	97.8	74.7	40.3	245.1	104.5
23.2	30.1	76.1	86.2	49.1	36.6	161.1	97.8	75.0	40.3	246.1	104.5
23.5	30.5	77.1	86.8	49.4	36.6	162.1	97.9	75.3	40.3	247.1	104.6
23.8	30.6	78.1	87.1	49.7	36.6	163.1	97.9	75.6	40.4	248.1	104.6
24.1	30.9	79.1	87.6	50.0	36.6	164.1	97.9	75.9	40.4	249.1	104.7
24.4	31.1	80.1	88.1	50.3	36.7	165.1	98.0	76.2	40.4	250.1	104.8
24.7	31.4	81.1	88.5	50.6	36.7	166.1	98.0	76.5	40.5	251.1	104.8
25.0	31.6	82.1	88.8	50.9	36.7	167.1	98.1	76.8	40.5	252.1	104.9
25.3	31.8	83.1	89.3	51.2	36.7	168.1	98.1	77.1	40.5	253.1	105.0
25.6	32.0	84.1	89.7	51.5	36.7	169.1	98.1	77.4	40.6	254.1	105.0
25.9	32.3	85.1	90.1	51.8	36.8	170.1	98.2	77.8	40.6	255.1	105.1

PS-2d - 38° 29.827' N, 106° 04.761' W, elev. 7867 feet

Logged 8-16-2011

Depth_m	T_°C	Depth_ft	T_°F	***	Depth_m	T_°C	Depth_ft	T_°F	***	Depth_m	T_°C	Depth_ft	T_°F
0.9	20.1	3.0	68.3		7.9	16.8	26.0	62.2		14.3	21.1	47.0	70.0
1.2	19.8	4.0	67.6		8.2	17.0	27.0	62.5		14.6	21.6	48.0	70.8
1.5	19.3	5.0	66.8		8.5	17.1	28.0	62.9		14.9	21.8	49.0	71.2
1.8	18.7	6.0	65.6		8.8	17.3	29.0	63.1		15.2	22.0	50.0	71.6
2.1	18.1	7.0	64.6		9.1	17.4	30.0	63.4		15.5	22.2	51.0	71.9
2.4	17.6	8.0	63.6		9.4	17.5	31.0	63.6		15.8	22.3	52.0	72.2
2.7	17.1	9.0	62.8		9.8	17.8	32.0	64.1		16.2	22.5	53.0	72.4
3.0	16.7	10.0	62.1		10.1	18.1	33.0	64.7		16.5	22.5	54.0	72.5
3.4	16.5	11.0	61.8		10.4	18.2	34.0	64.8		16.8	22.6	55.0	72.7
3.7	16.3	12.0	61.4		10.7	18.4	35.0	65.1		17.1	22.6	56.0	72.8
4.0	16.2	13.0	61.1		11.0	18.6	36.0	65.4		17.4	22.7	57.0	72.9
4.3	16.1	14.0	60.9		11.3	18.8	37.0	65.8		17.7	22.8	58.0	73.0
4.6	16.0	15.0	60.8		11.6	18.9	38.0	66.0		18.0	22.8	59.0	73.0
4.9	16.0	16.0	60.7		11.9	19.1	39.0	66.4		18.3	22.9	60.0	73.1
5.2	16.0	17.0	60.7		12.2	19.3	40.0	66.7		18.6	22.9	61.0	73.2
5.5	16.1	18.0	60.9		12.5	19.5	41.0	67.1		18.9	23.0	62.0	73.3
5.8	16.2	19.0	61.1		12.8	19.7	42.0	67.5		19.2	23.1	63.0	73.5
6.1	16.2	20.0	61.2		13.1	20.1	43.0	68.2		19.5	23.2	64.0	73.8
6.4	16.3	21.0	61.4		13.4	20.5	44.0	69.0		19.8	23.5	65.0	74.3
6.7	16.4	22.0	61.5		13.7	20.8	45.0	69.5		20.1	23.7	66.0	74.7
6.7	16.3	22.0	61.4		14.0	21.0	46.0	69.8		20.4	24.0	67.0	75.2
7.0	16.6	23.0	61.8		14.3	21.2	47.0	70.1		20.7	24.1	68.0	75.4
7.3	16.6	24.0	61.9		13.7	20.6	45.0	69.0		21.0	24.3	69.0	75.7
7.6	16.7	25.0	62.0		14.0	20.9	46.0	69.7		21.3	24.5	69.9	76.0

Logged 8-16-2011

Depth_m	T_°C	Depth_ft	T_°F	***	Depth_m	T_°C	Depth_ft	T_°F	***	Depth_m	T_°C	Depth_ft	T_°F
0.9	19.0	3.0	66.2		29.6	19.7	97.0	67.5		58.2	21.9	191.0	71.5
1.2	20.4	4.0	68.8		29.9	20.3	98.0	68.5		58.5	21.9	192.0	71.5
1.5	19.4	5.0	66.9		30.2	20.7	99.0	69.2		58.8	21.9	193.0	71.5
1.8	17.6	6.0	63.7		30.5	20.9	100.0	69.6		59.1	21.9	194.0	71.5
2.1	16.4	7.0	61.5		30.8	21.1	101.0	70.0		59.4	21.9	195.0	71.5
2.4	15.3	8.0	59.5		31.1	21.2	102.0	70.1		59.7	21.9	196.0	71.5
2.7	14.4	9.0	58.0		31.4	21.2	103.0	70.1		60.0	21.9	197.0	71.5
3.0	13.7	10.0	56.7		31.7	21.2	104.0	70.2		60.4	21.9	198.0	71.5
3.4	13.2	11.0	55.7		32.0	21.3	105.0	70.4		60.7	21.9	199.0	71.4
3.7	12.7	12.0	54.9		32.3	21.4	106.0	70.5		61.0	21.9	200.0	71.4
4.0	12.3	13.0	54.2		32.6	21.4	107.0	70.6		61.3	21.9	201.0	71.5
4.3	12.0	14.0	53.7		32.9	21.5	108.0	70.8		61.6	21.9	202.0	71.5
4.6	11.7	15.0	53.1		33.2	21.6	109.0	70.9		61.9	21.9	203.0	71.5
4.9	11.5	16.0	52.8		33.5	21.7	110.0	71.0		62.2	22.0	204.0	71.5
5.2	11.4	17.0	52.5		33.8	21.8	111.0	71.2		62.5	22.0	205.0	71.5
5.5	11.2	18.0	52.2		34.1	21.8	112.0	71.2		62.8	22.0	206.0	71.5
5.8	11.1	19.0	52.0		34.4	21.8	113.0	71.3		63.1	22.0	207.0	71.5
6.1	11.0	20.0	51.8		34.7	21.8	114.0	71.3		63.4	22.0	208.0	71.6
6.4	11.0	21.0	51.7		35.1	21.8	115.0	71.3		63.7	22.0	209.0	71.6
6.7	11.0	22.0	51.7		35.4	21.8	116.0	71.3		64.0	22.0	210.0	71.6
7.0	11.0	23.0	51.7		35.7	21.8	117.0	71.3		64.3	22.0	211.0	71.6
7.3	11.0	24.0	51.7		36.0	21.8	118.0	71.3		64.6	22.0	212.0	71.6
7.6	11.0	25.0	51.8		36.3	21.8	119.0	71.3		64.9	22.0	213.0	71.6
7.9	11.1	26.0	51.9		36.6	21.8	120.0	71.3		65.2	22.0	214.0	71.6
8.2	11.1	27.0	52.0		36.9	21.8	121.0	71.3		65.5	22.0	215.0	71.6
8.5	11.2	28.0	52.2		37.2	21.8	122.0	71.3		65.8	22.0	216.0	71.6
8.8	11.3	29.0	52.3		37.5	21.8	123.0	71.3		66.1	22.0	217.0	71.6
9.1	11.4	30.0	52.5		37.8	21.8	124.0	71.3		66.4	22.0	218.0	71.6
9.4	11.5	31.0	52.7		38.1	21.8	125.0	71.3		66.8	22.0	219.0	71.5
9.8	11.6	32.0	52.8		38.4	21.8	126.0	71.2		67.1	22.0	220.0	71.6
10.1	11.7	33.0	53.0		38.7	21.8	127.0	71.3		67.4	22.0	221.0	71.6
10.4	11.8	34.0	53.2		39.0	21.8	128.0	71.3		67.7	21.9	222.0	71.5
10.7	11.9	35.0	53.4		39.3	21.8	129.0	71.3		68.0	22.0	223.0	71.6
11.0	12.0	36.0	53.6		39.6	21.8	130.0	71.3		68.3	22.0	224.0	71.6
11.3	12.1	37.0	53.8		39.9	21.8	131.0	71.3		68.6	22.1	225.0	71.7
11.6	12.2	38.0	54.0		40.2	21.8	132.0	71.3		68.9	22.1	226.0	71.8
11.9	12.4	39.0	54.2		40.5	21.8	133.0	71.3		69.2	22.2	227.0	71.9
12.2	12.5	40.0	54.5		40.8	21.8	134.0	71.3		69.5	22.2	228.0	72.0
12.5	12.6	41.0	54.7		41.1	21.8	135.0	71.3		69.8	22.3	229.0	72.1
12.8	12.7	42.0	54.9		41.5	21.8	136.0	71.3		70.1	22.3	230.0	72.2
13.1	12.8	43.0	55.0		41.8	21.8	137.0	71.3		70.4	22.4	231.0	72.3

13.4	12.9	44.0	55.1	42.1	21.8	138.0	71.3	70.7	22.5	232.0	72.5
13.7	12.9	45.0	55.3	42.4	21.8	139.0	71.3	71.0	22.6	233.0	72.6
14.0	13.1	46.0	55.5	42.7	21.9	140.0	71.3	71.3	22.6	234.0	72.7
14.3	13.2	47.0	55.7	43.0	21.8	141.0	71.3	71.6	22.6	235.0	72.7
14.6	13.3	48.0	55.9	43.3	21.8	142.0	71.3	71.9	22.6	236.0	72.7
14.9	13.4	49.0	56.1	43.6	21.9	143.0	71.3	72.2	22.6	237.0	72.7
15.2	13.5	50.0	56.2	43.9	21.9	144.0	71.3	72.5	22.6	238.0	72.7
15.5	13.6	51.0	56.4	44.2	21.9	145.0	71.3	72.8	22.6	239.0	72.7
15.8	13.6	52.0	56.6	44.5	21.9	146.0	71.3	73.2	22.6	240.0	72.7
16.2	13.7	53.0	56.7	44.8	21.9	147.0	71.3	73.5	22.7	241.0	72.8
16.5	13.8	54.0	56.9	45.1	21.9	148.0	71.3	73.8	22.8	242.0	73.0
16.8	13.9	55.0	57.0	45.4	21.9	149.0	71.3	74.1	22.9	243.0	73.2
17.1	14.0	56.0	57.2	45.7	21.9	150.0	71.3	74.4	23.0	244.0	73.3
17.4	14.1	57.0	57.3	46.0	21.9	151.0	71.3	74.7	23.1	245.0	73.5
17.7	14.2	58.0	57.5	46.3	21.9	152.0	71.3	75.0	23.2	246.0	73.8
18.0	14.3	59.0	57.7	46.6	21.9	153.0	71.3	75.3	23.5	247.0	74.3
18.3	14.4	60.0	57.9	46.9	21.8	154.0	71.3	75.6	23.8	248.0	74.9
18.6	14.5	61.0	58.0	47.2	21.8	155.0	71.3	75.9	24.1	249.0	75.4
18.9	14.6	62.0	58.2	47.5	21.8	156.0	71.3	76.2	24.2	250.0	75.6
19.2	14.7	63.0	58.4	47.9	21.8	157.0	71.3	76.5	24.3	251.0	75.8
19.5	14.8	64.0	58.6	48.2	21.8	158.0	71.3	76.8	24.4	252.0	75.9
19.8	14.9	65.0	58.8	48.5	21.8	159.0	71.3	77.1	24.5	253.0	76.1
20.1	15.0	66.0	59.0	48.8	21.8	160.0	71.3	77.4	24.6	254.0	76.3
20.4	15.1	67.0	59.2	49.1	21.8	161.0	71.3	77.7	24.7	255.0	76.4
20.7	15.2	68.0	59.4	49.4	21.8	162.0	71.3	78.0	24.7	256.0	76.4
21.0	15.3	69.0	59.6	49.7	21.8	163.0	71.3	78.3	24.7	257.0	76.4
21.3	15.4	70.0	59.7	50.0	21.8	164.0	71.3	78.6	24.7	258.0	76.4
21.6	15.5	71.0	60.0	50.3	21.8	165.0	71.3	78.9	24.7	259.0	76.5
21.9	15.7	72.0	60.2	50.6	21.8	166.0	71.2	79.2	24.7	260.0	76.5
22.3	15.8	73.0	60.4	50.9	21.8	167.0	71.3	79.6	24.8	261.0	76.6
22.6	15.9	74.0	60.7	51.2	21.9	168.0	71.4	79.9	24.8	262.0	76.6
22.9	16.0	75.0	60.8	51.5	21.9	169.0	71.4	80.2	24.8	263.0	76.7
23.2	16.1	76.0	61.0	51.8	21.9	170.0	71.4	80.5	24.9	264.0	76.8
23.5	16.2	77.0	61.2	52.1	21.9	171.0	71.4	80.8	24.9	265.0	76.8
23.8	16.3	78.0	61.4	52.4	21.9	172.0	71.4	81.1	24.9	266.0	76.9
24.1	16.4	79.0	61.5	52.7	21.8	173.0	71.3	81.4	25.0	267.0	76.9
24.4	16.6	80.0	61.9	53.0	21.8	174.0	71.3	81.7	25.0	268.0	77.0
24.7	16.7	81.0	62.0	53.3	21.8	175.0	71.3	82.0	25.0	269.0	77.0
25.0	16.7	82.0	62.0	53.6	21.8	176.0	71.3	82.3	25.0	270.0	77.0
25.3	16.7	83.0	62.1	53.9	21.9	177.0	71.4	82.6	25.0	271.0	77.0
25.6	16.7	84.0	62.1	54.3	21.9	178.0	71.4	82.9	25.0	272.0	77.0
25.9	16.8	85.0	62.3	54.6	21.9	179.0	71.4	83.2	25.0	273.0	77.0
26.2	16.9	86.0	62.5	54.9	21.9	180.0	71.4	83.5	25.0	274.0	77.1
26.5	17.0	87.0	62.6	55.2	21.9	181.0	71.4	83.8	25.0	275.0	77.1
26.8	17.1	88.0	62.8	55.5	21.9	182.0	71.4	84.1	25.1	276.0	77.1
27.1	17.3	89.0	63.1	55.8	21.9	183.0	71.4	84.4	25.1	277.0	77.1

27.4	17.5	90.0	63.5	56.1	21.9	184.0	71.5	84.7	25.1	278.0	77.1
27.7	17.8	91.0	64.1	56.4	21.9	185.0	71.5	83.8	25.0	275.0	77.0
28.0	18.2	92.0	64.7	56.7	21.9	186.0	71.5	84.1	25.0	276.0	77.0
28.3	18.4	93.0	65.2	57.0	21.9	187.0	71.5	84.4	25.0	277.0	77.1
28.7	18.7	94.0	65.6	57.3	21.9	188.0	71.5	84.7	25.0	278.0	77.1
29.0	18.9	95.0	66.1	57.6	21.9	189.0	71.5	85.0	25.1	279.0	77.1
29.3	19.2	96.0	66.6	57.9	21.9	190.0	71.5	85.3	25.1	280.0	77.1

Logged 8-16-2011

Depth_m	T_°C	Depth_ft	T_°F	***	Depth_m	T_°C	Depth_ft	T_°F	***	Depth_m	T_°C	Depth_ft	T_°F
0.3	20.8	1.1	69.4		26.5	15.7	87.1	60.3		52.8	19.9	173.1	67.7
0.6	20.6	2.1	69.1		26.9	15.8	88.1	60.5		53.1	19.9	174.1	67.8
0.9	20.1	3.1	68.1		27.2	15.9	89.1	60.7		53.4	19.9	175.1	67.8
1.2	19.0	4.1	66.2		27.5	16.0	90.1	60.8		53.7	20.0	176.1	68.0
1.6	18.0	5.1	64.3		27.8	16.1	91.1	61.0		54.0	20.0	177.1	68.0
1.9	17.0	6.1	62.6		28.1	16.2	92.1	61.2		54.3	20.1	178.1	68.1
2.2	16.2	7.1	61.2		28.4	16.3	93.1	61.4		54.6	20.2	179.1	68.3
2.5	15.6	8.1	60.2		28.7	16.3	94.1	61.4		54.9	20.2	180.1	68.4
2.8	15.1	9.1	59.1		29.0	16.4	95.1	61.5		55.2	20.3	181.1	68.5
3.1	14.6	10.1	58.3		29.3	16.4	96.1	61.5		55.5	20.3	182.1	68.6
3.4	14.2	11.1	57.6		29.6	16.4	97.1	61.6		55.8	20.4	183.1	68.7
3.7	13.8	12.1	56.9		29.9	16.5	98.1	61.6		56.1	20.5	184.1	68.9
4.0	13.5	13.1	56.3		30.2	16.5	99.1	61.7		56.4	20.6	185.1	69.0
4.3	13.2	14.1	55.7		30.5	16.5	100.1	61.8		56.7	20.6	186.1	69.1
4.6	12.9	15.1	55.3		30.8	16.6	101.1	61.9		57.0	20.7	187.1	69.3
4.9	12.7	16.1	54.9		31.1	16.6	102.1	62.0		57.3	20.8	188.1	69.4
5.2	12.6	17.1	54.6		31.4	16.7	103.1	62.1		57.6	20.9	189.1	69.5
5.5	12.4	18.1	54.4		31.7	16.7	104.1	62.1		57.9	20.9	190.1	69.6
5.8	12.3	19.1	54.2		32.0	16.8	105.1	62.2		58.2	21.0	191.1	69.7
6.1	12.3	20.1	54.1		32.3	16.8	106.1	62.3		58.6	21.0	192.1	69.8
6.4	12.2	21.1	54.0		32.6	16.9	107.1	62.4		58.9	21.1	193.1	69.9
6.7	12.2	22.1	53.9		32.9	16.9	108.1	62.5		59.2	21.1	194.1	70.0
7.0	12.2	23.1	53.9		33.3	17.0	109.1	62.6		59.5	21.2	195.1	70.1
7.3	12.2	24.1	53.9		33.6	17.0	110.1	62.7		59.8	21.2	196.1	70.2
7.7	12.2	25.1	54.0		33.9	17.1	111.1	62.8		60.1	21.3	197.1	70.3
8.0	12.3	26.1	54.1		34.2	17.1	112.1	62.9		60.4	21.3	198.1	70.4
8.3	12.4	27.1	54.3		34.5	17.2	113.1	63.0		60.7	21.4	199.1	70.4
8.6	12.5	28.1	54.4		34.8	17.2	114.1	63.0		61.0	21.4	200.1	70.5
8.9	12.5	29.1	54.6		35.1	17.3	115.1	63.1		61.3	21.5	201.1	70.6
9.2	12.6	30.1	54.7		35.4	17.3	116.1	63.2		61.6	21.5	202.1	70.7
9.5	12.7	31.1	54.8		35.7	17.4	117.1	63.3		61.9	21.5	203.1	70.8
9.8	12.8	32.1	55.0		36.0	17.4	118.1	63.4		62.2	21.6	204.1	70.9
10.1	12.9	33.1	55.2		36.3	17.5	119.1	63.5		62.5	21.6	205.1	70.9
10.4	12.9	34.1	55.3		36.6	17.6	120.1	63.6		62.8	21.7	206.1	71.0
10.7	13.0	35.1	55.4		36.9	17.6	121.1	63.7		63.1	21.7	207.1	71.1
11.0	13.1	36.1	55.6		37.2	17.7	122.1	63.8		63.4	21.7	208.1	71.1
11.3	13.2	37.1	55.7		37.5	17.7	123.1	63.9		63.7	21.8	209.1	71.2
11.6	13.2	38.1	55.8		37.8	17.8	124.1	64.0		64.0	21.8	210.1	71.3
11.9	13.3	39.1	56.0		38.1	17.8	125.1	64.1		64.3	21.9	211.1	71.4
12.2	13.3	40.1	56.0		38.4	17.9	126.1	64.2		64.6	21.9	212.1	71.5
12.5	13.4	41.1	56.0		38.7	17.9	127.1	64.2		65.0	22.0	213.1	71.5

12.8	13.4	42.1	56.1	39.0	18.0	128.1	64.3	65.3	22.0	214.1	71.6
13.1	13.4	43.1	56.2	39.3	18.0	129.1	64.4	65.6	22.0	215.1	71.7
13.4	13.5	44.1	56.3	39.7	18.0	130.1	64.5	65.9	22.1	216.1	71.8
13.7	13.6	45.1	56.4	40.0	18.1	131.1	64.5	66.2	22.1	217.1	71.9
14.1	13.6	46.1	56.5	40.3	18.1	132.1	64.6	66.5	22.2	218.1	71.9
14.4	13.7	47.1	56.6	40.6	18.1	133.1	64.7	66.8	22.2	219.1	72.0
14.7	13.7	48.1	56.7	40.9	18.2	134.1	64.8	67.1	22.3	220.1	72.1
15.0	13.8	49.1	56.8	41.2	18.2	135.1	64.8	67.4	22.3	221.1	72.2
15.3	13.9	50.1	56.9	41.5	18.3	136.1	64.9	67.7	22.4	222.1	72.3
15.6	13.9	51.1	57.1	41.8	18.3	137.1	65.0	68.0	22.4	223.1	72.4
15.9	14.0	52.1	57.2	42.1	18.4	138.1	65.1	68.3	22.5	224.1	72.4
16.2	14.1	53.1	57.3	42.4	18.4	139.1	65.2	68.6	22.5	225.1	72.5
16.5	14.1	54.1	57.4	42.7	18.5	140.1	65.3	68.9	22.6	226.1	72.6
16.8	14.2	55.1	57.5	43.0	18.5	141.1	65.3	69.2	22.6	227.1	72.7
17.1	14.2	56.1	57.6	43.3	18.6	142.1	65.4	69.5	22.6	228.1	72.8
17.4	14.3	57.1	57.7	43.6	18.6	143.1	65.5	69.8	22.7	229.1	72.8
17.7	14.3	58.1	57.8	43.9	18.7	144.1	65.6	70.1	22.7	230.1	72.9
18.0	14.4	59.1	57.9	44.2	18.7	145.1	65.7	70.4	22.8	231.1	73.0
18.3	14.5	60.1	58.0	44.5	18.8	146.1	65.8	70.7	22.8	232.1	73.1
18.6	14.5	61.1	58.1	44.8	18.8	147.1	65.9	71.0	22.9	233.1	73.2
18.9	14.6	62.1	58.2	45.1	18.9	148.1	66.0	71.4	22.9	234.1	73.2
19.2	14.6	63.1	58.3	45.4	18.9	149.1	66.1	71.7	23.0	235.1	73.3
19.5	14.7	64.1	58.4	45.8	18.9	150.1	66.1	72.0	23.0	236.1	73.4
19.8	14.7	65.1	58.5	46.1	19.0	151.1	66.2	72.3	23.0	237.1	73.5
20.1	14.8	66.1	58.6	46.4	19.0	152.1	66.3	72.6	23.1	238.1	73.6
20.5	14.8	67.1	58.7	46.7	19.1	153.1	66.3	72.9	23.1	239.1	73.6
20.8	14.9	68.1	58.8	47.0	19.1	154.1	66.4	73.2	23.2	240.1	73.7
21.1	15.0	69.1	58.9	47.3	19.2	155.1	66.5	73.5	23.2	241.1	73.8
21.4	15.0	70.1	59.0	47.6	19.2	156.1	66.6	73.8	23.3	242.1	73.9
21.7	15.1	71.1	59.1	47.9	19.3	157.1	66.7	74.1	23.3	243.1	74.0
22.0	15.1	72.1	59.2	48.2	19.3	158.1	66.8	74.4	23.4	244.1	74.1
22.3	15.2	73.1	59.3	48.5	19.3	159.1	66.8	74.7	23.4	245.1	74.2
22.6	15.2	74.1	59.4	48.8	19.4	160.1	66.9	75.0	23.5	246.1	74.3
22.9	15.3	75.1	59.5	49.1	19.4	161.1	67.0	75.3	23.5	247.1	74.4
23.2	15.3	76.1	59.5	49.4	19.5	162.1	67.1	75.6	23.6	248.1	74.4
23.5	15.3	77.1	59.6	49.7	19.5	163.1	67.1	75.9	23.6	249.1	74.5
23.8	15.3	78.1	59.6	50.0	19.6	164.1	67.2	76.2	23.7	250.1	74.6
24.1	15.4	79.1	59.7	50.3	19.6	165.1	67.3	76.5	23.7	251.1	74.7
24.4	15.4	80.1	59.7	50.6	19.6	166.1	67.3	76.8	23.8	252.1	74.8
24.7	15.4	81.1	59.8	50.9	19.7	167.1	67.4	77.1	23.8	253.1	74.8
25.0	15.5	82.1	59.9	51.2	19.7	168.1	67.5	77.4	23.8	254.1	74.9
25.3	15.5	83.1	60.0	51.5	19.8	169.1	67.6	77.8	23.9	255.1	75.0
25.6	15.6	84.1	60.1	51.8	19.8	170.1	67.6	78.0	23.9	255.9	75.1
25.9	15.6	85.1	60.1	52.2	19.8	171.1	67.7				
26.2	15.7	86.1	60.2	52.5	19.8	172.1	67.7				

Appendix 3 - Contents of CD-ROM

The accompanying CD-ROM includes all temperature logs recorded from the drill holes discussed in this report. The logs are recorded in Excel spreadsheet files with the name of the drill hole as the file name and the date that the log was run as the sheet name.

The files included are:

File Name	Sheet Name
<i>Farrow_#1</i>	<i>5-26-2010</i>
	<i>12-10-1020</i>
<i>Farrow_#2</i>	<i>5-20-2010</i>
<i>PS-1</i>	<i>7-15-2011</i>
	<i>7-22-2011</i>
	<i>8-2-2011</i>
	<i>8-15-2011</i>
<i>PS-2c</i>	<i>7-26-2011</i>
	<i>8-2-2011</i>
	<i>8-16-2011</i>
<i>PS-2d</i>	<i>7-20-2011</i>
	<i>8-2-2011</i>
	<i>8-16-2011</i>
<i>PS-4</i>	<i>7-29-2011</i>
	<i>8-3-2011</i>
	<i>8-16-2011</i>
<i>PS-5</i>	<i>7-29-2011</i>
	<i>8-3-2011</i>
	<i>8-16-2011</i>

Depths and temperature are recorded as meters and °C, and feet and °F, respectively.

Excel 2007 or higher is required to read the files on this disk.

Appendix 3 - Selected Photographs Taken During Study



Drill crew feeding PVC pipe into drill hole PS-2c



Temperature logging PS-2c at four feet per minute.



Warm spring on western hill slope below drill holes PS-2c and PS-2d