New Mexico EPSCoR

RESEARCH INFRASTRUCTURE IMPROVEMENT (RII 4)
PROPOSAL DEVELOPMENT PROCESS

SCIENCE WHITE PAPER

FOR DISCUSSION
OCTOBER 21, 2011

TITLE: THE ROLE OF GEOTHERMAL & BRACKISH WATER RESOURCES IN THE WATER-ENERGY NEXUS

LEAD AUTHOR: MARK PERSON (NMT)

CONTRIBUTING AUTHORS: LAURA CROSSEY (UNM), KARL KARLSTROM (UNM), CAITI STEELE (NMSU), LUZ ELENA MIMBELA (NMSU), SHARI KELLY (NMT), GLENN SPINELLI (NMT), REBECCA REISS (NMT)

New Mexico EPSCoR Program is funded in part by the National Science Foundation award #0814449 and the State of New Mexico. Any opinions, findings, conclusions, or recommendations expressed in the material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

NSF EPSCOR
The Role of Geothermal & Brackish Water Resources in the Water-Energy Nexus

Mark Person (NMT), Laura Crossey (UNM), Karl Karlstrom (UNM), Luz Elena Mimbela (NMSU), Caiti Steele, (NMSU), Shari Kelly (NMT), Glenn Spinelli (NMT), Rebecca Reiss (NMT)

Date: November 20, 2011

Background:

Geothermal energy utilization not only reduces greenhouse gas emissions but can also consume lower amounts of water per unit of electricity generated. For example, a typical 10 MWe binary geothermal power plant consumes between about 1500-5000 acre-feet per year (Clark et al. 2011). These plants use geothermal fluids to heat volatile hydrocarbon compounds (the working fluid) with boiling points lower than 100 ^{o}C in a closed loop. Most of the produced groundwater is then reinjected with estimated water losses between 60-230 acre-feet per year (0.2 gal/kWh). A typical coal-power plant, on the other hand, uses about 0.85 gal/kWh (four time more water that a binary geothermal plant; Clark et al. 2011).

The State of New Mexico is endowed with relatively high background heat flow (Roy et al. 1972; Reiter, 2009) and permeable, fractured bedrock. This combination has given rise to numerous low-temperature (< 80 ^{o}C) geothermal systems throughout the state (Summers, 1976; Summers and Colpitts, 1980; Witcher, 2002a-h; Figure 1B). The US Geological Survey recent national geothermal assessment ranked New Mexico 7th for it's known (Table 1) (Williams et al. 2008). New Mexico is already a leader in the geothermal greenhouse and aquiculture industries. Witcher (2002) reports that a total of 52 acres of greenhouses are being heated by geothermal energy generating annual gross receipts of 12 million dollars. High temperature resources have

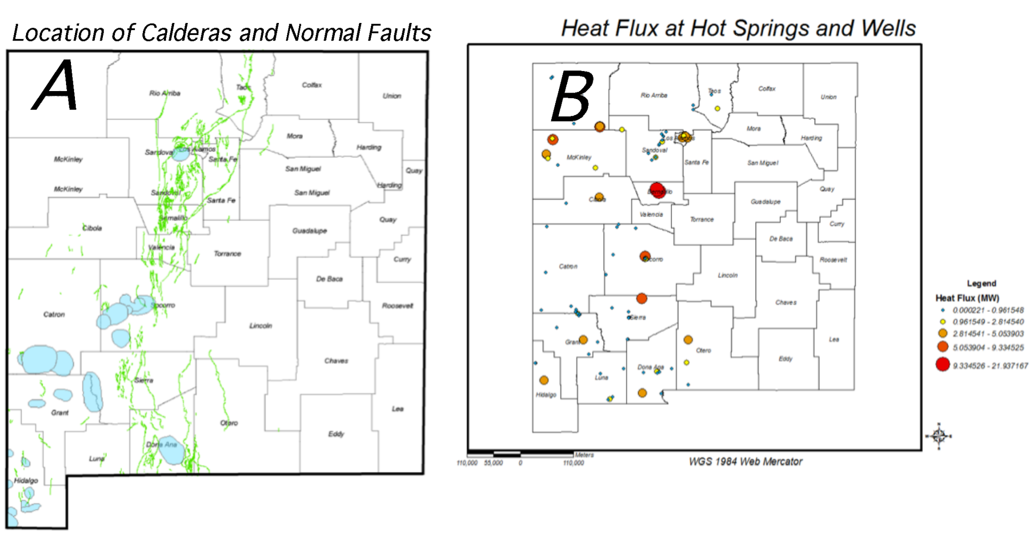

Figure 1 *(A) Location of normal faults (green) and caldera ring fracture systems (green) across New Mexico. Many geothermal features in the state (e.g. Lightingdoc, Hildago County; Socorro Springs, Socorro County) occur at the intersections of these structural features. (B) Total heat flux in Megwatts (J; MW) at geothermal production wells and hot springs. Heat flux is calculated based on the discharge rate and temperature (J = QrcT; were Q is the volumetric discharge, r is the water density, c is fluid heat capacity, and T is temperature).*

*__Table 1__. New Mexico Geothermal Reserves**

Known Conventional Geothermal Resources (mW)	Undiscovered Conventional Geothermal Resources (mW)	Deep Engineered Geothermal System Potential (mW)
170	1484	55,700

*Williams et al. 2008

been identified at relatively shallow depths within the Valles Caldera (Duchane and Brown, 2002; Figure 2A, 2C) and in the southwestern corner of the state in Hildago County (Witcher, 2002a) suggesting the potential for electric power generation (Figure 1B). The USGS and our own independent estimates indicate that the known geothermal potential between 163-170 mW of energy (Figure 1B). Some of these resources occur at the intersection of fault zones and ring fracture systems associated with ancient volcanic centers that trend SW-NE across the state (Figure 1A). Others are associated with gaps in Tertiary confining units (Barroll and Reiter, 1990) or young volcanic zones such as the Valles Caldera complex in Northern New Mexico (Goff, 2010).

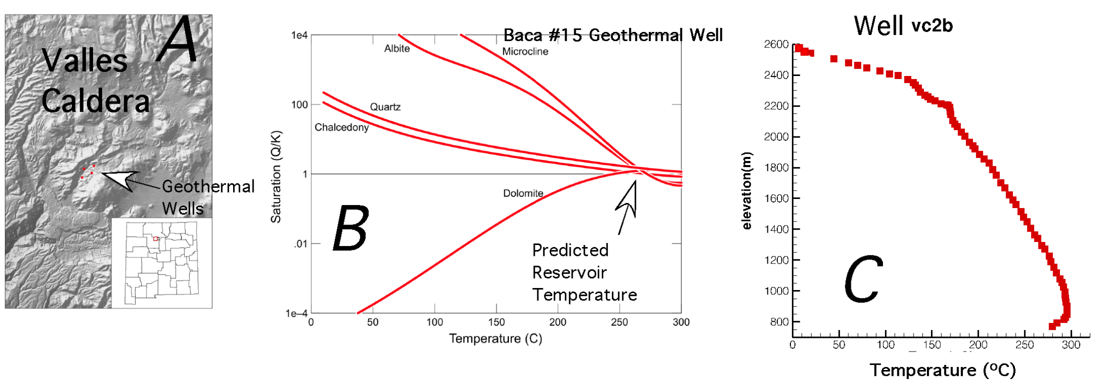

Figure 2. (A) Location of Valles Caldera geothermal system in New Mexico. (B) Predicted reservoir temperature using geothermometer methodology based on equilibrium mineral saturation indices. (C) Temperature verse depth profile for Valles Caldera well VC2b.

One issue associated with the utilization of geothermal waters for direct use or power generation is the need to drill costly re-injection wells to dispose of the spent fluids. Reinjection is typically undertaken because many geothermal waters are brackish or saline and can't be discharged safely into adjacent streams. However, spent geothermal fluids could potentially be utilized by bio-diesel facilities since brackish waters are needed to optimize algae growing conditions. Alternatively, state-of-the-art desalinization technologies could address this problem by removing salts and metals converting geothermal fluids into a valuable water resources. Within the past few years, deep brackish waters are increasingly being looked upon as a potential resource for growing cities using state-of-the-art desalinization technologies. While an updated geothermal assessment of the New Mexico is underway, we know little about the nature of brackish water resources throughout the state. No systematic study has been done to understand the geologic and geochemical controls on subsurface salinity conditions or the potential impacts of large scale brackish water withdraws.

While the locations of numerous hot springs are known across New Mexico, there is a dearth of information regarding the depths of fluid circulation, plumbing, and life cycles of New Mexico's geothermal systems. Even less is known about the occurrence and controls on brackish water resources in the state. The salinity of pore fluids have been reported for oil wells but these have not be systematically studied. Very saline fluids are known to exist in deep reservoirs of the Permian Basin in southeastern New Mexico and within the San Juan Basin in northwestern New Mexico. Brackish waters occur along the Rio Grande Rift where many of our geothermal resources are situated.

Proposed Research

We propose to focus on the water-energy nexus by: 1) Assessing the linkages between different alternative energy and desalination technologies and 2) better understand the controls on New Mexico's low-temperature geothermal and brackish water resources. We propose to address the following questions as part of this proposal:

Q1. Can utilization of low temperature, brackish geothermal resources within New Mexico help make bio-diesel production more cost effective? Are there significant energy savings when geothermal and bio-diesel are used conjunctively?

Research Plan: We propose to address this question through careful comparison of energy savings from utilizing geothermal energy as part of a bio-diesel pilot production facility on the campus of NMSU run by Dr. Luz Elena Mimbela. With support from the Department of Energy, Dr. Mimbela has developed a bio-diesel pilot facility within a geothermally-heated greenhouse. This has enabled her to extend the life of the facility through the winter months without using any electrical power for heating. We proposed to conduct a detailed energy analysis of her facility to determine the cost benefit analysis of using geothermal/solar energy. [Luz-Elena…we need more specifics about your facility (e.g. capacity, connection to geothermal system at NMSU, etc.) and what NSF Espcor and add to this facility to look at the above question....please add input here on what you would like to see happen….should NSF construct an equivalent facility heated strictly by electricity? What graduate student or post-doc support would you request?]

Q2. What are the geologic and geochemical controls on geothermal and brackish water resources within the state of New Mexico? Are faults critical to New Mexico's geothermal resources or are they mainly associated with the presence of young volcanics? Are gaps in Tertiary confining units control the locus of upflow of brackish geothermal fluids? Are geothermal systems in New Mexico driven by gradients in water table topography or by free convection? Are brackish water resources controlled by the presence of evaporite deposits such as the Yeso Formation in the Albuquerque Basin for deep saline, crustal fluids which migrate upwards along faults? How does permeability of sedimentary and crystalline rocks vary in geothermal systems within the state?

Research Plan: We propose to acquire surface electrical resistivity and magenoteleric exploration systems to characterize the salinity/geothermal resources of our state. These systems can map resistivity providing indirect information about salinity and fluid temperatures. We would also propose to build a petrophysical lab to analyze rock cores at elevated pressure-stress conditions using a constant rate of strain device. This will allow us to assess the storativity and transimissivity of brackish water reservoirs. While surface geophysical surveys can provide important insights into regional salinity and temperature patterns, at the end of the day, you need to drill a well to provide ground truth. Thus, we also propose to purchase a small air hammer rig from Atlas-Copco to drill shallow geothermal gradient holes as well as collect geochemical samples and rock core down to 300 feet. This may help us identify new blind geothermal systems (i.e. ones with no surface expressions such as Lighingdoc, Hildago County, NM) based on surface resistivity anomalies and determine whether shallow brackishwater upflow zones exist are associated with geothermal areas. We can also measure vertical hydraulic gradients to determine if the geothermal systems are driven by free- or forced-convection. The petrophysical laboratory at New Mexico Tech would benefit from the NM Bureau of Geology and Mineral Resources core facility. Rock core could also be collected using the Atlas-Copco Rig. Finally, we plan to develop high performance computer models of groundwater flow, heat, and solute mass transport to better understand the plumbing of our brackish and geothermal resources using the computer simulation code PGEOFE (Cohen et al. 2009). This will require developing geologically referenced grids in collaboration with Los Alamos National Labs (LaGrit Software).

Q3. How deep and long-lived are New Mexico's geothermal systems? What is the depth of fluids circulation for New Mexico's prominent geothermal systems such as at Rincon or LightingDock?

Research Plan: Some of New Mexico's hot springs host fauna that must have evolved in situ (e.g. Socorro Springs Isopod and White Sands Puppfish at Malpais Springs and Salt Creek; (Shuster, 1981, Pittenger and Springer, 1999) suggesting that these hot springs are long-lived. Thus, DNA dating techniques may provide a means of dating hot spring longevity. We propose to work with Dr. Rebecca Reiss at NMT to attempt to date these endangered species using DNA methods. [Rebecca Reiss input here] Dating of hot spring terrace deposits represents another means of determining the age of the hot springs. [Laura Crossey, Karl Karlstrom input here]

The depth of fluid circulation can be estimated using geochemical geothermometers which provide information on maximum temperatures a fluid has seen. However, traditional geothermometers based on SiO_2, Na-K, Na-K-Ca, and K-Mg (Fournier & Truesdell, 1973; Fournier, 1977; Arnorsson, 1983; Giggenbach, 1988) have been shown to consistently overestimate temperatures for moderate to low temperature geothermal systems in the Basin and Range (Shevenell and De Rocher, 2005). Determination of mineral saturation indices has been found to produce better estimates of known reservoir temperatures than the use of traditional geothermometers (Reed and Spycher, 1984; Figure 2B). We propose to use the geochemical speciation approach in combination with 3D hydrothermal modeling at several selected sites (e.g. Lightingdoc, Rincon) to better understand the depth of fluid circulation within New Mexico's geothermal systems.

Enhancing Infrastructure

In order to assess NM geothermal and brackish water resources, we propose to acquire the following:

1. Quanetc Spartan MT Deep Resistivity Sounding System (~ 200k).
2. AGI SuperSting Electrical Resistivity System ($161k)
3. GCTA Triaxial Rock Testing System (RTX-3000; $219k).
4. Atlas Copco blast hole Rig & air compressor, and trailer ()

5. 2 MacPro Workstations ($24k)
6. Grid generation (Los Alamos Subcontract ~$40k/year…LANL has been a subcontractor to Person on other NSF grants in this capacity)

Mark Person and Shari Kelly at the New Mexico Bureau of Geology and Mineral Resources will be responsible for drill rick and petrophysical testing equipment. The surface geophysics equipment could also be housed at NM Tech (Glenn Spinelli). However, the utilization of these surface geophysical systems could benefit from a new geophysics faculty line with an expertise in surface resistivity geophysics and MT sounding.

References

Arnorsson, S., 1983. Chemical equilibria in Icelandic geothermal systems. Implications for chemical geothermometry investigations. Geothermics, v. 12: p. 119-128.

Barroll, M. W., and Reiter, M., 1990, Analysis of the Socorro hydrothermal system: central New Mexico: Journal of Geophysical Research, v. 95, no. B13, p. 21949-21963.

Caine, J., Evans, J. P., and Craig, F., 1996, Fault zone architecture and permeability structure: Geology, v. 24, n. 11, p. 1025-1028.

Chamberlin, R. M., 1983, Cenozoic domino-style crustal extension in the Lemitar Mountains, New Mexico —A Summary: New Mexico Geological Society, Guidebook 34, p. 111–118.

Clark, C.E, Harto, C. B., Sullivan, J. L, and M. Q. Wang, 2011, Water use in the development and operation of geothermal power plants, Argonne National Lab Report ANL/EVS/R-105, 74 p.

Cohen, D., Person M. , Wang, P. Gable, C. Hutchinson, D., Marksamer, A. Dugan, B. Kooi, H. Groen, K., Lizarralde, D. and R. L. Evans, Origin and Extent of Fresh Paleowaters Beneath the Atlantic Continental Shelf, 2009, Groundwater, Volume 48 Issue 1, p. 143 – 158.

Duchane, D. and D. Brown, 2002, Hot dry rock (HDR) geothermal energy research and development at Fenton Hill, NM, Oregon Institute of Technology-Geo Heat Center Bulletin, v. 23(4), p. 13-19.

Fournier. R. O., and Truesdell, A.H, 1977, An empirical Na-K-Ca geothermometer for natural waters. Geochimica et Cosmochimica Acta, v. 37, p. 1255-1275.

Fournier. R. O, 1977, Chemical geothermometers and mixing models for geothermal systems, Geothermics, v. 5: p. 41-50.

Giggenbach, W. F. 1988, Geothermal solute equilibria, Derivation of Na-K-Mg-Ca geoindicators, Geochimica et Cosmochimica Acta, v. 52, p. 2749-2765.

Gross, G.W., and Wilcox, R., 1983, Groundwater circulation in the Socorro geothermal area: New Mexico Geological Society, Guidebook 34, p. 311-318.

Manning, C., and Ingebritsen, S., 1999, Permeability of the continental crust, The implications of geothermal and metamorphic systems: Reviews of Geophysics, v. 37, p. 127-150

Reiter, M., 2009, Heat-flow anomalies crossing New Mexico along La Ristra seismic profile, Lithosphere; v. 1; no. 2; p. 88–94.

Person, M., Banerjee, A., Hofstra, D., Sweetkind, D., and Y. Gao, 2008, Hydrologic Models of Modern and Fossil Geothermal Systems withinin the Great Basin: Implications for Carlin-Type Gold Mineralization, Geosphere, vol. 4, no. 5, pp.888-917, Oct 2008

Person, M., Banerjee, A., Hofstra, D., Sweetkind, D., and Y. Gao, 2008, Hydrologic Models of Modern and Fossil Geothermal Systems withinin the Great Basin: Implications for Carlin-Type Gold Mineralization, Geosphere, vol. 4, no. 5, pp.888-91.

Person, M., Raffensperger, J., Ge. S., and G. Garven, 1996, Basin-Scale Hydrogeological Modeling, *Reviews of Geophysics*, 34, 61-87

Pittenger, J.S. and C.L. Springer. 1999. Native range and conservation of White Sands pupfish (*Cyprinodon tularosa*). The Southwestern Naturalist 44:157-165.

Plummer, N. Bexfield, L., Anderholm, S. and Sanford, W. and E. Busenberg, 2004, Hydrochemical tracers in the middle Rio Grande Basin, USA: 1. Conceptualization of groundwater flow, Hydrogeology Journal (2004) 12:359–388

Reed, M. and N. Spycher, 1984, Therreitcal chemical thermometry on geothermal waters: Problems and methods, Geochimica et Cosmochimica Acta, v. 78, 1479-1492.

Reiter, M. Hydrogeothermal studies in the Albuquerque Basin- a geophysical investigation of groundwater flow characteristics, NMBGMR Circular 211, 74 p.

Roberts, R.B. (1977). "Absolute scale of thermoelectricity". *Nature* **265** (5591): 226–7. Bibcode 1977Natur.265..226R. doi:10.1038/265226a0

Schevenell, L. and De Rocher, T., 2005, Evaluation of chemical geothermomoeters for calculating reservoir temperatures at Nevada Geothermal Power Plants, GRC Transactions, v. 29, p. 303-307.

Shuster, S. 1981, Life history characteristics of Thermosphaeroma thermophylum, The Socorro Isopod (Crustacea: Peracarida), Biology Bulletin, v. 161, p. 291-302.

Summers, W. K., 1976. “Catalog of Thermal Waters in New Mexico,” *New Mexico Bureau of Mines and Mineral Resources Hydrologic Report 4*, 80 p.

Summers, W. K. and R. M. Colpitts, 1980. “Preliminary Appraisal of the Hydrothermal-Resource Potential of the Gila Hot Springs Area, Grant and Catron Counties, New Mexico,” W. K.

Summers and Associates, Inc. Report prepared for D. A. “Doc” and Ida Campbell, Gila Hot Springs, New Mexico, 102 p.

Swanberg, C. Morgan, P. Stoyer, C. and J. Witcher, 1977, An appraisal study of the geothermal resources of Arizona and adjacent areas in New Mexico and Unta and their value for delaination and other uses, New Mexico Energy Research and Development Institute, n. 14-06-300-2582, 76 p.

Williams, Colin F., Reed, Marshall J., Mariner, Robert H., DeAngelo, Jacob, Galanis, S. Peter, Jr., 2008, Assessment of moderate- and high-temperature geothermal resources of the United States: U.S. Geological Survey Fact Sheet 2008-3082, 4 p.

Witcher, J., 2002a, Geothermal Energy in New Mexico, Oregon Institute of Technology-Geo Heat Center Bulletin, v. 23(4), p. 2-6.

Witcher, J., 2002b, Truth or Consequences, New Mexico – A Spa City, Oregon Institute of Technology-Geo Heat Center Bulletin, v. 23(4), p. 20-24.

Witcher, J., 2002c, Gila Hot Springs, Oregon Institute of Technology-Geo Heat Center Bulletin, v. 23(4), p. 25-29.

Witcher, J., 2002e, Masson Radium Springs Farm, Oregon Institute of Technology-Geo Heat Center Bulletin, v. 23(4), p. 42-44.

Witcher, J., 2002f, J&K Growers, Las Cruces NM, Oregon Institute of Technology-Geo Heat Center Bulletin, v. 23(4), p. 45.

Witcher, J., 2002g, Faywood Hot Springs, Oregon Institute of Technology-Geo Heat Center Bulletin, v. 23(4), p. 46.

Witcher, J., 2002h, Ojo Caliente – America’s Oldest Spa, Oregon Institute of Technology-Geo Heat Center Bulletin, v. 23(4), p. 47.

Witcher, J., Schoenmacker, R., Polka, R., and R. Cunniff, 2002, Geothermal Energy at New Mexico State University in Las Curces, Oregon Institute of Technology-Geo Heat Center Bulletin, v. 23(4), p. 30-36.

Zhener, R., Coolbaugh, M. and L. Schevenell, 2006, Regional groundwater geochemical trends in the Great Basin: Implications for geothermal exploration, GRC Transactions, v. 30, p. 117-124.