Final Technical Report

Delivery of Geothermal Relevant Data and Metadata

for

Arizona

compiled by the

Arizona Geological Survey

Arizona Geological Survey contribution to the
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INTRODUCTION

The Arizona Geological Survey is the prime contractor and administrator for the 3-year National Geothermal Data System (NGDS) State Geothermal Data Project under the US Department of Energy (DOE) Geothermal Technologies Program. The State Geothermal Data Project objective is to expand and enhance the NGDS by deploying and populating a national, sustainable, distributed, interoperable network of state geological survey-based providers. These providers are developing, collecting, serving, and will maintain geothermal-relevant data that operates as an integral component of NGDS. As a result the geothermal industry, the public, and policy makers will have access to consistent and reliable data, providing easier access to information while reducing the high cost and risk of exploration drilling.

The State Geothermal Data Project is developing the knowledge and data foundation necessary for discovery and development of large-scale energy production and other practical applications, such as direct use and residential/commercial ground source heat pumps. The project incorporates not only high-temperature potential, but also moderate and low-temperature geothermal potential. The project, through its cyber infrastructure, will help lead to innovative exploration technologies through increased data availability on geothermal energy capacity.

The focus of this project is to expose data to encourage high-temperature, or high-enthalpy, geothermal electricity production at power plants. Although geothermal energy research is most often focused on high-temperature electricity production, particularly in areas of recent tectonic activity with warm near-surface temperatures such as the western U.S., there are other geothermal resources in Arizona that could be exploited for direct use—ground source heat pumps (GSHP), aqua-culture, and in agriculture, as well as by new emerging technologies. Efficient, low-cost geothermal systems have the potential to become an important part of Arizona’s energy conservation.

The AZGS contribution for Arizona data to the NGDS provided collection, compilation, and online access of relevant geothermal information, including thermal water well, thermal springs, borehole temperature; oil & gas and mineral exploration well data; aqueous and rock chemistry; active faults, volcanic vents, and geological maps; and numerous geothermal related records, reports, and publications. Geothermal and geological data along with input from other researchers are particularly valuable for cost-effective planning of geothermal systems. This geologic and
geothermal data can help provide basic geologic reconnaissance for geotechnical evaluations needed for high-temperature or direct use installations, thus helping to lower initial costs.

Arizona’s Basin and Range Province basins with high-to-moderate heat flow and general tendency of basin fill to have favorable permeability, especially fractured and faulted deep basin-fill rock units, provide potential for large-volume conductive geothermal resources. In Arizona, temperatures increase with depth below the surface in a near-linear geothermal gradient. Temperatures measured in oil and gas wells greater than 8,000 feet deep may exceed 100 °C. Thermal waters can also materialize at the surface as hot springs with temperatures exceeding 50°C, although most thermal springs temperatures in Arizona range from 20°C to 50°C.

Arizona is in an arid region with a large agricultural economic base and large, rapidly growing metropolitan areas. There is significant competition between rural agricultural regions and cities over current and future use and control over ground water to include the low-temperature geothermal water sources (Witcher 1995). Large power generation facilities for providing electricity for communities require deep wells at considerable cost, but abundant existing deep water-supply wells and irrigation wells have potential for conversion to private and smaller commercial geothermal direct-heat uses. Geothermal space heating and district heating are becoming more popular in areas where the resource is co-located with population and feasible for community facilities with large heating/cooling loads, such as schools. Geothermal systems have potential to be incorporated in new developments, especially in areas that are experiencing urban growth. Geothermal aquaculture and greenhousing is a major direct-use application with noticeable growth in Arizona. Many geothermal direct-use applications have potential to conserve water while enhancing the value of farm production per acre (Witcher 1995).

Geothermal energy is considered a renewable resource because heat flow is continual from the asthenosphere and radiogenic rocks to the Earth’s lithosphere, and could be used directly for producing electricity where, generally, temperatures are greater than 100°C, for direct use applications with temperatures between 50-100°C, and for space heating with temperatures below 50°C to provide building heating and cooling.
DATA DELIVERY

In Arizona, the AZGS collected data from across several state agencies (Arizona Department of Water Resources, AZ Department of Environmental Quality, Arizona Oil and Gas Conservation Commission, and the Arizona Geological Survey), from hard copy US Geological Survey (USGS) data printouts archived at AZGS, from the Colorado and New Mexico geologic surveys that provided “at risk” hard copy geothermal/heat flow data for preservation, and various collections of existing geothermal data and reports. Over 37 deliverable data categories/items with 24 web map services were added to the repository. Over 50,000 records were submitted and made available for online access. The data include references, geothermal reports bibliography, volcanic vent features, active faults, an online interactive geology map, “at risk” temperature data (USGS and AMAX), “at risk” temp-depth gradient data (Marshall Reiter), “at risk” heat flow data (Charles Shearer), direct use site data, deep well temperatures, lithology, and geophysical logs, and more. For Arizona, over 4,000 document metadata for existing and newly scanned documents, 4,000 well and spring features, 2,500 geophysical and temperature logs, 4,000 borehole temperatures, 33,500 chemistry data (aqueous and rock), drill stem tests, heat flow and thermal conductivity data, volcanic vent features, and other data were provided for online access as and ESRI service, web map services, web feature services, and downloadable data in interoperable exchange content models or reports and documents.

The AZGS supplemental ‘new data’ collection project provided new thermal spring and well aqueous chemistry, rock chemistry, geothermometry data, and temperature data for 17 thermal springs, and geological investigation for three thermally active areas associated with hot springs in southeastern Arizona to map the geology and structure in an effort to determine thermal groundwater origins. A final report was produced presenting Arizona geothermal background, data collection methods and results, and new geologic maps for Aqua Caliente Spring, Hooker Hot Springs, and the Pinaleño Mountains-Safford Basin geothermal area.

Arizona’s contributions to the NGDS project that resulted from these efforts are outlined briefly in the Project Goals Accomplished section. Geothermal and geological data compiled and provided for Arizona under the NGDS project are listed under the Year in which the deliverable data was proposed to be completed.
PROJECT GOALS ACCOMPLISHED

Arizona Year 1 Deliverables

*Geothermal Documents and References Metadata for Arizona (1,448 records)*

Documents as miscellaneous geothermal reports and publications for research within Arizona were made available to the NGDS. Metadata for 1,432 geothermal, geology, basin, and groundwater reports were provided for inclusion into the NGDS data repository and USGIN Catalog.

http://catalog.usgin.org/geoportal/catalog/main/home.page

Metadata for an additional 15 geothermal documents as maps, reports, and technical books for geothermal resources within Arizona were provided for inclusion into the NGDS data repository and USGIN Catalog.

http://repository.stategeothermaldata.org/repository/resource/3592f7bc37ea27adea06455fbf42d465/

The Arizona Geothermal References, a list of published geothermal reports, maps, and documents, was compiled and made available for download as a pdf in the NGDS data repository.

http://repository.stategeothermaldata.org/repository/resource/98ddf901b9782a25982e01af3b0477a5/

*Geothermal Resource Maps of Arizona*

Geothermal data was compiled in 1982 and interpreted by James C. Witcher, Claudia Stone, and W. Richard Hahman, Sr. of the State of Arizona Bureau of Geology and Mineral Technology, a Division of the University of Arizona, Tucson, currently the Arizona Geological Survey. Two maps were produced, one in 1982 and the updated map in 2003, showing geothermal resources of Arizona from thermal data compiled from James C. Witcher thermal springs and wells database for Arizona. The original map data was compiled in 1982, then updated in 2002 for the Geo-Heat Center, Oregon Institute of Technology, State Geothermal Database, [Compact Disk], February 2002. The final map was prepared by Patrick Laney and Julie Brizzee in 2003 at the Idaho National Engineering and Environmental Laboratory for the DOE EERE Geothermal Technologies program. Both maps at a Scale 1:500,000, 500 feet contour intervals. The 1982 map shows thermal spring and well locations, temperatures, heat flow data, areas of low temperature geothermal resources, and Known Geothermal Resource Areas (KGRAs). The 2003 geothermal map illustrates geothermal resource locations and temperature range, resource use (aquaculture, space heating, spas/resorts, KGRAs), and land ownership using the J.C. Witcher updated database for locations and temperatures.

http://repository.stategeothermaldata.org/repository/resource/3592f7bc37ea27adea06455fbf80830f/

*Geologic Map of Arizona (1 interactive map)*

Arizona’s statewide geologic map is now available online. The map may be viewed using a web browser, or viewed and queried using either Google Earth or ESRI's ArcGIS explorer. In addition, the data are published as a KML, ArcGIS, WMS and WFS web services for use in other client applications. Google Earth accesses the data via the KML service. ArcGIS users can connect to either the ArcGIS service or Open Geospatial Consortium (OGC) Web Map Service or Web Feature Service. The web map service/web feature service may be accessed by any client that implements the OGC interfaces for these services (e.g. Quantum GIS, Manifold...). Many web feature service clients can save data out as shape file or in other GIS-compatible formats.

http://www.azgs.az.gov/services_azgeomap.shtml
**Active Faults for Arizona (1,741 records)**

These data were originally compiled in 1998 as part of an effort coordinated by the USGS to compile data and map information on Quaternary faults throughout the world. The database has recently been revised with much more accurate fault mapping, incorporation of new data on fault activity, and inclusion of additional fault zones, primarily in northern Arizona. The data structure is set up to provide systematic information on each fault zone. The individual fault data sheets include information on map and data sources, fault location, geologic setting of the fault, the geomorphic expression of the fault, recency of fault movement, fault slip rate(s), and fault zone length and orientation. Faults are grouped into slip rate categories of <0.02 mm/yr, < 0.2 mm/yr, and <1 mm/yr. This summarizes available data on active Arizona faults. A compilation of Active Fault features was compiled by the AZGS and USGS, and published as web feature service, web map service, an ESRI service and as an Excel workbook for download for the NGDS data repository.

http://repository.stategeothermaldata.org/repository/resource/4e6b8f72f7d6c3856f092c6b8500f41b/.

**Hot Springs Descriptions for Arizona (129 records)**

The Thermal Springs data is a compilation of 129 thermal spring features and temperature observations throughout Arizona. The data was obtained from James Witcher, and previous published reports including Thermal Springs List for the United States (Berry et al., 1980) Preliminary Geothermal Assessment of the Harquahala-Tonopah Area (Jones and Campbell, 1979), Chemical, Isotopic, and Gas Compositions of Selected Thermal Springs in Arizona, New Mexico, and Utah (Mariner, Presser, and Evans, 1977), Assessment of Geothermal Resources of the United States – 1978 (Muffler and Guffanti, 1979), An Appraisal Study of the Geothermal Resources of Arizona (Swanberg et al, 1977), and Thermal Springs of the United States and Other Countries of the World (Waring, 1965). The spring’s data were made available as a web feature service, web map service, an ESRI service, and an Excel workbook for download.

http://repository.stategeothermaldata.org/repository/resource/4e6b8f72f7d6c3856f092c6b85018dd1/.

**Hot Springs Aqueous Chemistry for Arizona (104 records)**

The Hot Springs Aqueous Chemistry data is a compilation of 104 records for Aqueous Spring Chemistry observations from 37 springs compiled from previously collected data reported by the Arizona Department of Environmental Quality Water Quality Division (2010), USGS, James Witcher (1995), Waring (1965), Swanberg et al (1977), and Mariner et al (1977). The data compilation is published as a web feature service, web map service, an ESRI service and an Excel workbook for the NGDS data repository.

http://repository.stategeothermaldata.org/repository/resource/4e6b8f72f7d6c3856f092c6b85022be6/.

**Arizona Thermal Wells Aqueous Chemistry (1,365 records)**

Aqueous well chemistry was compiled from Jim Witcher, Swanberg, and others’ geothermal wells data for thermal wells throughout Arizona, compiled by the AZGS and published as a web feature service, a web map service, an ESRI service, and as an Excel workbook for the NGDS data repository. Data are provided for Minor Dissolved Constituents, Major Dissolved Constituents, Base Metals, Common Analytes, and Water Quality. Data for 408 wells including 1,365 analyte suite records were included as a Year-1 deliverable.

http://repository.stategeothermaldata.org/repository/resource/50b3a9b3bec98d3d491e2187c528aba3/
Oil and Gas Well Headers for Arizona (1,146 records)
Oil and Gas well header observation records for 1,146 wells in Arizona were compiled from data provided by the Arizona Oil and Gas Conservation Commission (AZOGCC) from well files and AZOGCC database, and published as a web feature service, web map service, an ESRI service and an Excel workbook for the NGDS data repository.
http://repository.stategeothermaldata.org/repository/resource/98ddf901b9782a25982e01af3b10c739/

Oil and Gas Well Log Data for Arizona (2,471 records)
Data was compiled from 2,471 scanned geophysical and temperature well logs for oil and gas wells provided by the AZOGCC. These data contain basic information describing well log data and providing URL links to download PDFs of each log. Data are published as a web feature service, web map service, an ESRI service and an Excel workbook for the NGDS data repository.
http://repository.stategeothermaldata.org/repository/resource/ba2f0b9d21f71acfe10609f76e3551c7/

Lithology Logs for Arizona Oil and Gas Wells (20 records)
These records describe data for 20 lithological well logs for oil and gas wells provided by the AZOGCC and compiled by the Arizona Geological Survey. Lithology log data are published as a web feature service, web map service, an ESRI service and an Excel workbook for the NGDS data repository. The lithology logs are combined with geophysical logs for the data repository and services.
http://repository.stategeothermaldata.org/repository/resource/ba2f0b9d21f71acfe10609f76e3551c7/

Oil and Gas Well Borehole Temperatures for Arizona (622 records)
This dataset contains 622 records for bottom-hole temperature data compiled from oil and gas well logs provided by the AZOGCC by the AZGS. Temperature readings for the oil and gas boreholes are generally recorded on geophysical logs. The well log observation data is available as a web feature service, web map service, an ESRI service and an Excel workbook for the NGDS data repository.
http://repository.stategeothermaldata.org/repository/resource/4e6b8f72f7d6c3856f092c6b8501195f/

Temp-Depth Logs and Profiles (25 records)
Discreet temperature and associated depth data from 25 oil and gas wells in Arizona was transferred into Temperature-Depth data reporting format in use by the USGS for Long Valley caldera geothermal sites. Individual Temperature-Depth logs are online for download as an Excel workbook through the NGDS data repository and USGIN Catalog.
http://repository.stategeothermaldata.org/repository/resource/a748ce233a25e3e0dd00c9865d04ec4e/

Drill Stem Tests (652 records)
This collection of 652 drill stem test data was provided by the AZOOGCC and compiled by the AZGS. The data was published as a web feature service, web map service, an ESRI service, and as an Excel workbook for the NGDS data repository and USGIN Catalog.
http://repository.stategeothermaldata.org/repository/resource/98ddf901b9782a25982e01af3b12d98e/

Well Chemistry Dataset (2,470 records)
The well chemistry data is a collection of aqueous chemistry observations compiled from previous works by Swanberg et al. (1977), James Witcher (1995-2002), and Heindle et al. (1961). Data collected from 410 thermal wells throughout Arizona provided 2,470 well chemistry observation records. The data are divided into Minor Dissolved Constituents, Major Dissolved Constituents, Base Metals, Common Analytes, and Water Quality worksheets. The chemistry data
Arizona Year 2 Deliverables

Geothermal Documents and References Metadata for Arizona (50 records)
Arizona geothermal and groundwater research reports including Isotopic Data were provided as a metadata compilation for 10 documents. The individual documents are available through the NGDS data repository and the USGIN Catalog.

Metadata compiled for 5 reports produced as guidelines and geothermal ground source heat pump (GSHP) installation design, including soil and rock classification, determining conductivity, uses and standards, include *Ground Source Heat Pumps Conductivity Information* and other related documents. Metadata were compiled by the AZGS and made available as an Excel workbook for the NGDS. The individual documents are available through the NGDS data repository and the USGIN Catalog.

AMAX Well Headers (220 records)
Data was compiled from hard copy field records from AMAX field records for wells in Arizona. The well records were provided to AZGS by the Southern Methodist University. The URL links to download the AMAX field records with photographs were provided as a Related Resource in each well header record. Water temperature, discharge, location and other data is provided on the forms. Well header data was published as a web feature service, web map service, an ESRI service and an Excel workbook for download.

AMAX Borehole Temperature Observations (220 records)
Borehole temperature observations were compiled from hard copy AMAX field records for wells in Arizona. The well records were provided to AZGS by Southern Methodist University. Borehole temperature observations were compiled with other Arizona BHT data and published as web feature service, web map service, an ESRI service and an Excel workbook for download.

Heat flow (99 records)
Heat flow observations were digitized from Charles Shearer’s (c.1979) “at risk” legacy data for Arizona wells. Charles R. Shearer produced a regional Terrestrial Heat-Flow Study in Arizona in 1979 for his Thesis for PhD at the New Mexico Institute of Mining and Technology. The supporting hard copy data was provided to AZGS by the New Mexico Institute of Mining and Technology for inclusion into the NGDS for preservation. A total of 99 heat flow
measurements were derived from his data and published as a web feature service, web map service, an ESRI service, and an Excel workbook for download.
http://repository.stategeothermaldata.org/repository/resource/98ddf901b9782a25982e01af3b11ba52/

**Temperature-Depth Logs and Profiles /Temperature Gradient Calculations (40 records)**
Marshall Reiter’s Socorro hard copy temperature gradient materials were stored in his garage. Temperature-Depth log data and profiles, and associated scanned documents from Reiter's unpublished thermal data, were recovered by New Mexico Institute of Mining and Technology and provided the Arizona-related data to AZGS for preservation. Temperature data provides a first order guide to locations of thermal anomalies that might indicate new geothermal resources. Marshall Reiter's geothermal research documentation contains temperature data and heat flow data for water wells throughout Arizona. Temperature-Depth graphic profiles were created from the thermal data. These data are provided for download as original scanned documents in PDF, Excel files containing groups of temperature-depth logs and graphic profiles (Parts I-VI), individual well temperature-depth data and profiles, and PDF scans of heat flow calculation documents (some heat flow wells have no location data). During Year-2, 40 Temperature-Depth profiles were added to the NGDS data repository. The scanned files contain hand written calculations and field notes for measurement records for 53 wells, plus a list of sites by county.
http://repository.stategeothermaldata.org/repository/resource/9e15e1a59b768b330d029e86dc04a9d3/

**Arizona Department of Environmental Quality Deep Water Well Headers (1,669 records)**
Water temperatures and data for deep wells can provide valuable geothermal resources. The Arizona Department of Environmental Quality provided water well records for all of Arizona. The data was sorted and thinned by selecting thermal wells with temperatures above 77°F (25°C) (average ambient air temperature) and deeper than 500 feet. The data for 1,669 well headers were deduplicated against Arizona Department of Water Resources well data and published as a web feature service, web map service, an ESRI service, and an Excel workbook for download.
http://repository.stategeothermaldata.org/repository/resource/98ddf901b9782a25982e01af3b10c739/

**Arizona Department of Environmental Quality Deep Water Well Water Aqueous Chemistry (29,572 records)**
Water chemistry provides geothermometry data that may indicate source of anomalously thermal water. Water quality and aqueous chemistry is also important for designing productions systems. Data collected from 1,669 thermal water wells throughout Arizona provided 29,572 well chemistry observation records. The data are divided into Water Quality, Common Analytes and Major Dissolved Constituents worksheets. The chemistry data is published as a web feature service, a web map service, an ESRI service, and as an Excel workbook for download (ADEQ Year-2 Additional Well Chemistry) for the NGDS.
http://repository.stategeothermaldata.org/repository/resource/50b3a9b3bec98d3d491e2187c528aba3/

**Oil & Gas Temperature-Depth Logs and Graphic Profiles for Select Wells (26 records)**
Temperature-Depth logs and graphic profiles were compiled for 26 select oil and gas wells in Arizona. The logs and profiles were made available for distribution and published as a web feature service, a web map service, an ESRI service, and for download as an Excel workbook with resource URL links to files for download.
http://repository.stategeothermaldata.org/repository/resource/a748ce233a25e3e0dd00c9865d04ec4e/
**Thermal Well Headers –ADWR, USGS (Witcher) (1,219 records)**

Well header records in Arizona were collected for an additional 1,219 wells in Year-2 from the Arizona Department of Water Resources and USGS holes of opportunity. The data were published as a web feature service, a web map service, an ESRI service, and as an Excel workbook for download from the NGDS.

http://repository.stategeothermaldata.org/repository/resource/98ddf901b9782a25982e01af3b10c739/

**Arizona Department of Water Resources, Wells 35 Lithology Logs (2,357 records)**

Arizona Borehole Lithology Intervals data were provided for shallow wells by the Arizona Department of Water Resources from their Wells-35 database, a compilation of data from private contractors. The lithology interval data were compiled by the AZGS into 2,357 records and published as a web feature service, web map service, ESRI service, and an Excel workbook for download from the NGDS.

http://repository.stategeothermaldata.org/repository/resource/6e84ef507102d99c8d5b44d3c2a2cb9d/

**Springs Features Aqueous Chemistry (83 records)**

Spring and Well Aqueous Chemistry observations were provided by Robert H. Mariner (USGS) to the AZGS for inclusion into the USGIN Catalog. These data (Year-2) were not included in the James Witcher database for thermal wells and springs (Year-1). The data was compiled into NGDS interoperable exchange format and published as a web feature service, web map service, ESRI service, and an Excel workbook for download from the NGDS.

http://repository.stategeothermaldata.org/repository/resource/dc2950e94fd12022579c7307b626223c/

**Rock Chemistry (9 records)**

An additional deliverable for Rock Chemistry was provided by Jon Spencer from State Map project rock chemistry data. The Arizona rock chemistry observations are for samples collected from the Mammoth Quadrangle (9 records). Data are accessible as a web feature service, web map service, ESRI service, and an Excel workbook for download from the NGDS.

http://repository.stategeothermaldata.org/repository/resource/dc2950e94fd12022579c7307b626223c/

**USGS Produced Waters Aqueous Chemistry (75 records)**

The USGS Produced Waters Aqueous Chemistry was submitted to replace the Year-2 Soil Temperature deliverable. The soil depths reported by the Department of Agricultural were minimal (12-18”) and therefore not pertinent data for ground source heat pump systems as had been anticipated. However, 75 records for produced water chemistry data provided by the USGS were added to the Spring and Well Aqueous Chemistry observations and published as a web feature service, web map service, ESRI service, and an Excel workbook for download. This data was compiled by the AZGS and made available for distribution through the NGDS.

http://repository.stategeothermaldata.org/repository/resource/dc2950e94fd12022579c7307b626223c/

**Arizona Year 3 Deliverables**

**Geothermal Documents Metadata for Arizona (188 records)**

Metadata for two geothermal and groundwater research reports for Arizona, including isotopic data, were provided through the NGDS data repository and the USGIN Catalog.

http://repository.stategeothermaldata.org/repository/resource/6e84ef507102d99c8d5b44d3c2a2cb9d/

Geothermal related documentation including historical reports, maps, temperature profiles, gradient graphs, photos, and other geothermal data were generated by the USGS for Vekol Valley Geothermal research. A banker box full of hard copy data files generated by John Sass (USGS) were donated to the AZGS by the Colorado Geological Survey to be digitally archived in the
NGDS. A total of 76 “At Risk” research documents and maps were scanned as PDFs. An additional 50 temp-depth and other log types were provided and converted to useable data. Metadata for each document was compiled for submission into the NGDSs repository and USGIN Catalog.

http://repository.stategeothermaldata.org/repository/resource/cf53f876662f70c8350fac5d97760076/

In addition, documentation including historical maps, temperature profiles, gradient graphs, reports, charts, and photographs were generated by the USGS for Alpine Geothermal Field research. This data was included in the banker box of hard copy data, files of John Sass (USGS), donated to the AZGS by the Colorado Geological Survey to be archived in the NGDS. Over 19 “At Risk” research documents were scanned as PDFs. In addition, 26 temp-depth tables and profiles were provided and converted to useable data. Metadata for each document was compiled for submission into the NGDS data repository and USGIN Catalog.

http://repository.stategeothermaldata.org/repository/resource/50ec3aefb656b70647f32e38bc457cc2/

Metadata was compiled for 15 Geothermal Reports for Arizona and Technical Books documenting geothermal information and technical guidelines. The compilation is published as an Excel workbook containing header features including title, description, author, citation, originator, distributor, and resource URL links to scanned maps for download. Metadata for each document was compiled for submission into the NGDS data repository and USGIN Catalog.

http://repository.stategeothermaldata.org/repository/resource/50ec3aefb656b70647f32e38bc373007/

**Geothermal Direct Use (2 records)**

Geothermal Direct Use reports and conductivity data was provided for two Arizona school sites:

The *Formation Thermal Conductivity Test and Data Analysis* was provided by Geothermal Resource Technologies, Inc. (Colorado). This report provides a general overview of the test and procedures that were used to perform the thermal conductivity test, along with a plot of the data in real time and in a form used to calculate the formation thermal conductivity. The work was performed at Desert View Elementary School site in Phoenix, AZ, in April 2010. This data was provided by the AZGS for dissemination by the NGDS.

http://repository.stategeothermaldata.org/repository/resource/50ec3aefb656b70647f32e38bc457cc2/

The *Formation Thermal Conductivity Test and Data Analysis* was provided by Geothermal Resource Technologies, Inc. (Colorado) for Cactus Shadows High School site in Cave Creek, AZ. This report provides a general overview of the test and procedures that were used to perform the thermal conductivity test, along with a plot of the temperature vs. time data in real time, and calculated thermal diffusivity. The work was performed at Desert View Elementary School in January 2009. This data was provided by the AZGS for dissemination by the NGDS.

http://repository.stategeothermaldata.org/repository/resource/50ec3aefb656b70647f32e38bc457a2a/

**Thermal Conductivity at Direct Use Sites (2 records)**

Thermal conductivity observation data from two tests conducted by Geothermal Resource Technologies, Inc. (Colorado) at Cactus Shadows High School site in Cave Creek, AZ and Desert View Elementary School site in Phoenix, AZ. Thermal conductivity data were compiled by the AZGS for inclusion into the NGDS. The data is published as a web feature service, a web map service, an ESRI service and as an Excel workbook for download.

http://repository.stategeothermaldata.org/repository/resource/50ec3aefb656b70647f32e38bc373007/
**Springerville Volcanic Vent Features (394 records)**
Data for the Springerville volcanic field, a monogenetic volcanic field located in east-central Arizona, was provided by the Southwest Research Institute - Center for Nuclear Waste Resource Areas (SRI-CNWRA), San Antonio, Texas. Vent feature data were collected from SRI-CNWRA and compiled as interoperable exchange data by the AZGS for inclusion into the NGDS. The data include 394 feature records for volcanic vents in the area of Springerville, AZ. The data is published as a web feature service, a web map service, an ESRI service, and as an Excel workbook for download.

http://repository.stategeothermaldata.org/repository/resource/4e6b8f72f7d6c3856f092c6b8502561a/

**Springerville Volcanic Vents Rock Chemistry (675 records)**
Chemistry analytical results for rocks samples collected from the Springerville volcanic field were provided by SRI-CNWRA, San Antonio, Texas. A total of 675 geochemistry records for Major Elements, Isotopic Series, and Trace Elements were compiled by the AZGS. The workbook contains 18 worksheets, including information about the template, notes related to revisions of the template, resource provider information, the data (in three tabs named for the layers in the web service), a field list (data mapping view) and vocabularies (data valid terms). This data was made available for distribution through the NGDSs project as a web feature service, web map service, ESRI service, and an Excel workbook for download.

http://repository.stategeothermaldata.org/repository/resource/9e15e1a59b768b330d029e86dc1bc4c4/

**Temperature-Depth Logs and Profiles /Temperature Gradient Calculations (41 records)**
(See YR 2 entry) Marshall Reiter’s Socorro geothermal database materials were stored in his garage. Some of the hard copy data were recovered by New Mexico Institute of Mining and Technology and provided Arizona-related data to the AZGS for archiving. In Year 3, an additional 41 Temp-depth profiles were added the NGDS data repository. The scanned files contain hand written calculations and field notes for measurement records, plus a list of sites by county.

http://repository.stategeothermaldata.org/repository/resource/9e15e1a59b768b330d029e86dc04a9d3/

**Heat Flow –Shearer Data (100 records)**
Heat flow observations collected by Charles R. Shearer c.1979 were extracted from Shearer’s Thesis for PhD, New Mexico Institute of Mining and Technology, titled: *A Regional Terrestrial Heat-Flow Study in Arizona*. One hundred heat flow records were compiled from Shearer’s data by the AZGS and published as a web feature service, a web map service, ESRI service, and as an Excel workbook for download through the NGDS.

http://repository.stategeothermaldata.org/repository/resource/98ddf901b9782a25982e01af3b11ba52/

**National Cave and Karst Research Institute: Geothermal Direct Use Site Metadata (8 records)**
Eight miscellaneous documents and photographs were provided by NCKRI (National Cave and Karst Research Institute) for the geothermal Ground Source Heat Pump system installed at the headquarters building in Carlsbad, NM. Metadata were compiled by the AZGS and made available for distribution and published as an Excel workbook through the NGDS.

http://repository.stategeothermaldata.org/repository/resource/a748ce233a25982e01af3b11ba70/

**Supplemental Thermal Springs Geothermometry and Geologic Investigation**

**Supplemental Data Report**
Under the DOE NGDS Supplemental Data project to discover new geothermal data, the AZGS investigated the geochemical makeup of groundwater from 17 select thermal springs and wells during late 2012 through 2013. In addition, related geological context was investigated to

Final Technical Report
Delivery of Geothermal Relevant Data and Metadata for Arizona 2014
evaluate potential groundwater transport mechanism(s) and heat source(s) relevant to geothermal energy production. Chemical analysis of thermal groundwater may be used to estimate subsurface temperatures by applying chemical geothermometry techniques; thus, attempting to specify reservoir temperatures and to model possible sources of heat. The geothermometry model devised by Tom Powell and William Cummings (Powell and Cummings, 2010) supports many of the common graphic analyses of water chemistry used to interpret hot spring and thermal well groundwater in geothermal exploration and development. The model provides geochemistry interpretative tools for exploring and characterizing the properties of both volcanic and forced-convection geothermal reservoirs. Cross-plots and ternary diagrams are generated from measured concentrations of chemical species using formulas based on equilibrium reactions and empirical relationships. These geochemistry interpretation tools help integrate geothermal geochemistry with geoscience data in building resource conceptual models directed at geothermal exploration and development (Powell and Cummings, 2010). This report summarizes our findings and presents supporting data in various tables and ternary diagrams and provides details geological maps for three resource areas.

http://repository.stategeothermaldata.org/repository/resource/b0ac52a9d32d8fd576fde11ae403455f/
References

Arizona Department of Environmental Quality, 2010. Selected springs data from ADEQ Arizona Springs database. Data is accessible in USEPA STORET (http://www.epa.gov/storet/), STOrage and RETrieval, is the nation's repository for water quality data collection storage.


