INEEL State Geothermal Resource Map Information

Introduction

The Idaho National Engineering and Environmental Laboratory (INEEL) produced geothermal resource maps of 13 western states for the Department of Energy (DOE). These geothermal resource maps were prepared for the general public to:

- Be used as an educational tool
- Promote the use of geothermal resources, depicting general trends and geothermal occurrences in the western U.S.
- Provide other information of interest (e.g., land use, political boundaries, direct use applications, etc.)
- Provide a starting point for state working groups, communities, organizations, companies, and individuals interested in identifying geothermal resources

GeoPowering the West

The maps were produced for the DOE GeoPowering the West activity. DOE's GeoPowering the West (GPW) activity (http://www.eere.energy.gov/geothermal/deployment_gpw.html) works with the U.S. geothermal industry, power companies, industrial and residential consumers, and federal, state, and local officials to provide technical and institutional support to state-level activities. By demonstrating the benefits of geothermal energy, GPW increases state and regional awareness of opportunities to enhance local economies and strengthen our nation's energy security while minimizing environmental impact. Geothermal energy represents a major economic opportunity for the American West, an area characterized by a steadily increasing population, that requires reliable sources of heat and power. GPW is pursuing this opportunity by:

- Bringing together national, state and local stakeholders for state-sponsored geothermal development workshops;

- Working with public power companies and rural electric cooperatives to promote use of geothermal power;
- Promoting increased federal use of geothermal energy;
- Helping American Indians identify and develop geothermal resources on tribal lands; and
- Sponsoring non-technical educational workshops.

These maps are considered an ongoing project and will be updated periodically.

The Western States Maps Produced by the INEEL

Geothermal resource maps were prepared for the following western states: Alaska, Arizona, California, Colorado, Hawaii, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, Washington, and Wyoming. All of the maps present general information on land use, geothermal wells and springs, geothermal direct use applications, and areas with geothermal potential. Data for the maps were gathered from a number of different sources. Due to time and funding limitations, these maps do not represent and exhaustive search of geothermal data for each state. Many state agencies have additional information on geology, water chemistry, flow rates and many other topics of interest to geothermal resource users. A brief description of what data is included on the maps is presented below. In addition there are links to some websites with geothermal information for western states.

Regions of Known or Potential Geothermal Resources

The areas on the INEEL State maps listed as "Regions of Known or Potential Geothermal Resources" were digitized from geothermal maps of each state that were published by NOAA in the 1980 – 1983 time frame, and are now out-of-print. The original descriptions for the areas now included in the INEEL maps are listed below in the section NOAA State Maps. On the original NOAA maps, these areas were generally shaded in gray. Some of the original NOAA state maps divided the areas of geothermal potential into two categories (e.g., to separate areas with higher probabilities for geothermal resources). In cases where there was more than one category (Light gray, Dark gray, etc.) for the thermal waters, the INEEL maps combined those areas during the digitizing process. The "Regions of Known or Potential Geothermal Resources" on the New Mexico, Idaho, Utah and Oregon Geothermal Resources Maps produced by the INEEL differ from the original NOAA maps. Modifications were made based on reviews by individuals with significant knowledge of the geothermal resources of those states.
Because the NOAA maps are no longer in print we are providing the ArcInfo Interchange (E00) files for areas of geothermal potential that we digitized from the NOAA maps. We called the combined areas "Regions of Known or Potential Geothermal Resources". These are provided as standard ESRI Arc files that can be used with many GIS software applications.

Well and Spring Data

Information on wells and springs plotted on the INEEL Geothermal Resource Maps came from a number of sources. The primary source of data was the Geo-Heat Center State Geothermal Databases, a CD produced by the Geo-Heat Center, Oregon Institute of Technology, 3201 Campus Drive, Klamath Falls, OR, 97601. The Geo-Heat Center maintains a website at http://geoheat.oit.edu/ . There were many instances where a well or spring in this database did not have enough location data to allow it to be plotted on the map, and therefore were not included on the INEEL maps. As more data becomes available, the maps will be updated.

Additional spring information came from the following websites;
http://www.soak.net/
http://www.hotspringsenthusiast.com/USsprings.asp

http://www.ngdc.noaa.gov/cgi-bin/seg/m2h?seg/springs.men

Some well and spring information came from personal communication with researchers in various states. Those cases are listed or referenced on the specific maps in the reference section.

An exhaustive search of well and spring information on each state was not performed, therefore the INEEL has chosen not to make the E00 files with this information available. The information used on the INEEL maps is readily available in spreadsheet format from the sites listed above.

Geothermal Direct Use Data

Geothermal direct use application data on the INEEL maps came predominately from the Geo-Heat Center Database CD. Some direct use information came from personal communication with researchers in various states. Those cases are listed or referenced on the specific maps. It is recognized that there are many other geothermal direct use of applications in the states mapped. In some cases information on commercial operations using geothermal resources was available, but without adequate location information (Latitude/Longitude or Sec/Twp/Rge) to be able to plot the location. Conversely, some identified direct use facilities may no longer be in operation. Business and private use of geothermal resources for direct use applications is constantly changing and difficult to accurately track.

Because an exhaustive search of geothermal direct use applications in each state was not performed, the E00 files with this information are not being made available. The information used on the INEEL maps is readily available in spreadsheet format from the sites listed above.

Land Status and Other Geopolitical Map Data

Land status and geopolitical information on the INEEL state geothermal resource maps came from numerous sources. The ESRI Data and Maps Media Kit that is released with ESRI software has a considerable amount of the data used to prepare these maps. Information was also obtained from the GIS Data Depot web page http://data.geocomm.com/. This site was especially useful for Digital Elevation Model (DEM) data for the individual states. 1:250,000 data was used for the hillshade. Some data were also obtained from websites hosted by the individual states.

Because this information is updated periodically and available to the public, the E00 files with this information are not being made available.

Files available on the INEEL website:

- PDF versions of each state map are available for download
- JPG versions of each state map are available for download
- E00 ARCInfo Interchange files of the “Regions of Known or Potential Geothermal Resources” are available for download
- Metadata files for each of the states are available for download

The NOAA State Maps

Below is the reference information from each of the 13 geothermal state maps published by NOAA that were used to obtain the “Regions of Known or Potential Geothermal Resources”, plotted in the INEEL geothermal resource maps. Cases where these areas were modified for the INEEL maps are noted at the end of the individual state descriptions.

Alaska

Map Title: Geothermal Resources of Alaska, 1983

Geothermal Data compiled and interpreted by the Division of Geological and Geophysical Surveys, Alaska Department of Natural Resources

Map produced by the
National Geophysical Data Center
National Oceanic and Atmospheric Administration
for the
Geothermal and Hydropower Technologies Division
United States Department of Energy

Thermal Waters

Light Gray. Region of Alaska favorable for the discovery at shallow depth (less than 1000m) of thermal water of sufficient temperature for direct-heat applications. It is probable that only small areas of this region are truly underlain by such thermal water; the region represents that part of the state that deserves exploration for thermal areas. The region is defined on the basis of various geothermal and tectonic phenomena such as locations of thermal wells and springs, above-normal heat flow, youthful volcanism, mineralization, and seismicity.

Map Scale: 1:2,500,000
Alaska E Series Map
National geodetic vertical datum of 1929
Modified transverse mercator projection
Base map supplied by U.S. Geological Survey
Topographic maps scale 1:250,000 and other official sources

Arizona

Map Title: Geothermal Resources of Arizona, 1982

Geothermal data compiled and interpreted by James C. Witcher, Claudia Stone, W. Richard Hahman, Sr. of the State of Arizona Bureau of Geology and Mineral Technology, A Division of the University of Arizona, Tucson

Map prepared by the
National Geophysical and Solar-Terrestrial Data Center
National Oceanic and Atmospheric Administration
for the
Division of Geothermal Energy
United States Department of Energy

Low Temperature Geothermal Waters

Gray areas are favorable for discovery and development of low-temperature (lower than 100°C) geothermal resources. They are defined on the basis of thermal springs, thermal wells, and ground-water, geologic and geophysical surveys. These gray areas are modified, in the light of later information, from those shown in the U.S. Geological Survey Circular 790 (Muffler, 1979). Existing knowledge does not in general permit the inference that thermal waters may be found everywhere within the depicted areas, nor do the boundaries represent certain knowledge of the areal extent of the geothermal resources. The boundaries are subject to change as new information is obtained.

Map Scale: 1:500,000
1927 North American Datum
Lambert conformal conic projection based on standard parallels 33° and 45°

California

Map Title: Technical Map Of The Geothermal Resources of California, 1983
California Geologic Data Map Series
Map NO. 5 – Technical Map of the Geothermal Resources of California

Geothermal data compiled in 1981 by the Division of Mines and Geology

Map produced by the
National Geophysical Data Center
National Oceanic and Atmospheric Administration
for the
Geothermal and Hydropower Technologies Division
United States Department of Energy

Thermal Waters

Dark gray. Area known or inferred to be underlain at shallow depth (less than 1,000m) by thermal water of sufficient temperature for direct heat applications. It is not implied that thermal water will be found everywhere within the area; the boundaries are subject to change as new information is obtained. Individual areas are defined on the basis of locations of thermal springs and wells and on know or inferred local geologic and hydrologic conditions.

Light gray. Region of California favorable for the discovery at shallow depth (less than 1000m) of thermal water of sufficient temperature for direct heat applications. It is probable that only small areas of this region are truly underlain by such thermal water; the region represents that part of the state that deserves exploration for thermal areas. The region is defined on the basis of various geothermal and tectonic phenomena at such as locations of thermal wells and springs, above-normal heat flow, youthful volcanism, mineralization, and seismicity. A map depicting heat flow in California is provided as Figure 1 of the accompanying text.

Map Scale: 1:750,000
1927 North American Datum
Lambert conformal conic projection based on standard parallels 33° and 45°
Base map is reduced from the 1:500,000 scale topographic map of California (U.S. Geological Survey, 1970)

Colorado

Map Title: Geothermal Resources of Colorado, 1980
Colorado Geological Survey Map Series 14

Geothermal data compiled by the Colorado Geological Survey

Map produced by
National Geophysical and Solar-Terrestrial Data Center
National Oceanic and Atmospheric Administration
For the
Division of Geothermal Energy
United States Department of Energy

Low-Temperature Geothermal Waters

Area of significant lateral extent favorable for discovery and development of local sources of low-temperature (<90°C) water. Areas are defined on the basis of thermal springs, wells and geohydrologic settings generally favorable for recovery of thermal water. Existing knowledge does not in general permit the inference that thermal water may be found everywhere within the depicted areas, nor do the boundaries represent certain knowledge of the areal extent of the geothermal systems.

Map Scale: 1:500,000
1927 North American Datum
Lambert conformal conic projection based on standard parallels 33° and 45°
Base map data compiled in 1968

Hawaii

Map Title: Geothermal Resources of Hawaii, 1983

Geothermal Data compiled and interpreted by Hawaii Institute of Geophysics, University of Hawaii

Map produced by the
National Geophysical Data Center
National Oceanic and Atmospheric Administration
for the
Geothermal and Hydropower Technologies Division
United States Department of Energy

Thermal Waters

Dark Gray Areas denote locations in which geophysical or geochemical evidence suggests that there is greater than a 50% probability of encountering a geothermal resource having a temperature greater than 200°C within 3 kilometers of the surface.

Light Gray Areas denote locations where geothermal resources may exist, but evidence suggests that the probability of encountering a geothermal resource having a temperature greater than 200°C within 3 kilometers of the surface is 50% or less.

The boundaries for these areas were drawn on the basis of geophysical and geochemical evidence and on the basis of the inferred structure and thermal resources of the individual volcanoes on each island. It is unlikely that geothermal resources will be found everywhere within the gray areas; however, the boundaries are believed to encompass all probable geothermal areas within the State of Hawaii.

Map Scale: 1:500,000
Old Hawaiian Datum
Lambert conformal conic projection based on standard parallels 20°40’ and 23°20’

Idaho

Map Title: Geothermal Resources of Idaho, 1980
Geothermal Investigations in Idaho, Part 9, Potential for Direct Heat Application of Geothermal Resources: Idaho Department of Water Resources Water Information Bulletin No. 30, Plate 1

Map prepared for
Idaho Department of Water Resources
By
National Geophysical and Solar-Terrestrial Data Center
National Oceanic and Atmospheric Administration
and
Division of Geothermal Energy
United States Department of Energy

Low Temperature Geothermal Waters

Area of significant lateral extent favorable for discovery and development of local sources of low-temperature (<90°C) water. Areas are defined on the basis of thermal springs, wells, and geohydrological settings generally favorable for recovery of thermal water. Existing knowledge does not in general permit the inference that thermal water may be found everywhere within the depicted areas, nor do the boundaries represent certain knowledge of the areal extent of the geothermal systems.

Map Scale: 1:500,000
1927 North American Datum
Lambert conformal conic projection based on standard parallels 33° and 45°

The Regions of "Known or Potential Geothermal Resources" depicted on the Idaho Geothermal Resources Map prepared by the INEEL were significantly modified from those areas digitized from the 1980 NOAA map following a review of the draft map by INEEL and other individuals with in-depth knowledge of Idaho geothermal resources.

Montana

Map Title: Geothermal Resources of Montana, 1981

Compiled by John L. Sondergger and R.N. Bergantino

Geothermal Data compiled by the Montana Bureau of Mines and Geology

Map produced by the
National Geophysical and Solar-Terrestrial Data Center
National Oceanic and Atmospheric Administration
for
Division of Geothermal Energy
United States Department of Energy

Low-Temperature Geothermal Waters

Existing knowledge does not permit the inference that thermal water will be found everywhere with the gray areas, nor do the boundaries represent precise knowledge of the areal extent of geothermal systems or aquifers.

Bounded darker gray. Areas where discovery and development of additional sources of low-temperature (less than 100°C) water for direct heat application are highly probable. Areas are defined on the basis of thermal springs and/or thermal wells, plus geohydrologic settings generally favorable for recovery of thermal water at depths of less than 1000 meters.

Unbounded lighter gray. West of the 109th meridian: Areas which, because of their geologic history and similarity to areas with know thermal systems, are expected to contain geothermal

resources suitable for direct heat applications, in addition to the depicted wells and springs. The primary exploration targets are valley fill sedimentary units (less than 1000 meters in depth) receiving water from deeper basement sources. North of Garrison the area is significantly expanded to maintain private data confidentiality. East of the 109th meridian: Areas without thermal springs or shallow thermal wells, but which contains the Madison Group and deeper aquifers with water temperatures of 60°C (140°F) or greater (modified from U.S. Geological Survey Open-File Report 81-629). In much of the area wells must be deeper than 2000 meters. Holes of opportunity may be economically viable; however, corrosiveness or salinity of the water and/or limited well yield caused by low aquifer permeability or cementing of casing may impede utilization of this resource. Most successful wells have been located near structural highs. Potential users of this resource are advised to contact the Montana Bureau of Mines and Geology for information about specific areas.

Map Scale: 1:1,000,000
1927 North American Datum
Lambert conformal conic projection based on standard parallels 33° and 45°

Nevada

Map Title: Geothermal Resources of Nevada, 1983

Geothermal data compiled and interpreted by Dennis T. Trexler, Thomas Flynn, Brian A. Koenig, George Ghusn, Jr. of the Division of Earth Sciences Environmental Research Center, University of Nevada, Las Vegas

Map produced by the
National Geophysical Data Center
National Oceanic and Atmospheric Administration
for the
Geothermal and Hydropower Technologies Division
United States Department of Energy

Low-Temperature Geothermal Waters

Dark Gray. Areas with water temperature greater than 40°C or where temperatures of 40°C or greater may be encountered at depths less than 500m.

Light Gray. Area favorable for the discovery of thermal water at shallow depth (<1000m) of sufficient temperature for direct heat applications. It is probable that only small areas of this region are underlain by such thermal water; the region represents that part of the state that deserves further exploration.

Local sources of thermal water may be discovered in areas of Nevada not covered by light or dark gray. Existing data do not document the presence or lack of usable thermal water at shallow depths.

Map Scale: 1:500,000
1927 North American Datum
Lambert conformal conic projection based on standard parallels 33° and 45°
Base map supplied by the U.S. Geological Survey

New Mexico

Map Title: Geothermal Resources of New Mexico, 1980

Geothermal data compiled by the New Mexico Energy Institute at New Mexico State University

Map produced by the
National Geophysical and Solar-Terrestrial Data Center
National Oceanic and Atmospheric Administration
for
Division of Geothermal Energy
United States Department of Energy

Low Temperature Geothermal Waters

(**Darker gray**) Area most favorable for discovery and development of low-temperature (<90°C) geothermal resources, defined on the basis of thermal springs, thermal wells, and geohydrologic settings. Areas are modified from those defined in U.S. Geological Survey Circular 790. See Sammel, E.A., 1979, Occurrence of low-temperature geothermal waters in the United States.

(**Lighter gray**) Additional parts of the Rio Grande rift and other areas which may also be suitable for geothermal discovery but for which data are too sparse or not sufficiently diagnostic to justify inclusion in the darker gray area.

Note. Existing knowledge does not in general permit the inference that thermal waters may be found everywhere within the depicted areas, nor do the boundaries represent certain knowledge of the areal extent of the geothermal systems.

Map Scale: 1:500,000
1927 North American Datum
Lambert conformal conic projection based on standard parallels 33° and 45°

The Regions of "Known or Potential Geothermal Resources" depicted on the New Mexico Geothermal Resources Map prepared by the INEEL were significantly modified from those areas digitized from the 1980 NOAA map following a review of the draft map by James C. Witcher at New Mexico State University.

Oregon

Map Title: Geothermal Resources of Oregon, 1982

Geothermal Data compiled by the Oregon Department of Geology and Mineral Industries

Map produced by the
National Geophysical Data Center
National Oceanic and Atmospheric Administration
for the
Geothermal and Hydropower Technologies Division
United States Department of Energy

Thermal Waters

Dark Gray. Area known or inferred to be underlain at shallow depth (less than 1,000m) by thermal water of sufficient temperature for direct heat applications. It is not implied that thermal water will be found everywhere within the area; the boundaries are subject to change as new information is obtained. Individual areas are defined on the basis of location of thermal springs and wells and on known or inferred local geologic and hydrologic conditions.

Light Gray. Region favorable for the discovery at shallow depth (less than 1,000m) of thermal water of sufficient temperature for direct heat applications. It is probable that only small areas of this region are truly underlain by such thermal water; the region represents that part of the state that deserves exploration for thermal areas. The region is defined on the basis of various

geothermal, volcanic, and tectonic phenomena such as thermal wells and springs, above-normal heat flow, youthful volcanism, mineralization, seismicity, and anomalous concentrations of faults and lineaments.

Map Scale: 1:500,000
1927 North American Datum
Lambert conformal conic projection based on standard parallels 33° and 45°
Base Map Revised in 1979

The Regions of "Known or Potential Geothermal Resources" depicted on the Oregon Geothermal Resources Map prepared by the INEEL were significantly modified from those areas digitized from the 1982 NOAA map following a review of the draft map by individuals with in-depth knowledge of Oregon geothermal resources.

Utah

Map Title: Geothermal Resources of Utah, 1980

Geothermal Data compiled by the Utah Geological and Mineral Survey

Map prepared by the
National Geophysical and Solar-Terrestrial Data Center
National Oceanic and Atmospheric Administration
for the
Division of Geothermal Energy
United States Department of Energy

Low-Temperature Geothermal Waters

Area of significant lateral extent favorable for discovery and development of local sources of low-temperature (<90°C) water. Areas are defined on the basis of thermal springs, wells, and geohydrologic settings generally favorable for recovery of thermal water. Existing knowledge does not in general permit the inference that thermal water may be found everywhere within the depicted areas, nor do the boundaries represent certain knowledge of the areal extend of the geothermal systems.

Map Scale: 1:500,000
1927 North American Datum
Lambert conformal conic projection based on standard parallels 33° and 45°

The Regions of "Known or Potential Geothermal Resources" depicted on the Utah Geothermal Resources Map prepared by the INEEL were significantly modified from those areas digitized from the 1980 NOAA map following a review of the draft map by individuals with in-depth knowledge of Utah geothermal resources.

Washington

Map Title: Geologic Map GM-25, Geothermal Resources of Washington, 1981

Geothermal data compiled by the Division of Geology and Earth Resources, Washington Department of Natural Resources

Map produced by the
National Geophysical and Solar-Terrestrial Data Center
National Oceanic and Atmospheric Administration

for the
Division of Geothermal Energy
United States Department of Energy

Thermal Waters

Dark Gray Areas. Darker gray area is known or inferred to be underlain by low-temperature (lower that 100°C) to high-temperature (higher that (150°C) thermal water.

Light Gray Areas. Unbounded lighter gray area is favorable for exploration for, and development of, thermal water of sufficient temperature (20°C and higher) for direct heat applications.

In the Cascade Range physiographic province low-temperature to high-temperature resources are indicated by stratovolcanoes and basaltic volcanic fields less that one million years old, geologically young silicic (andesitic and dacitic) volcanic centers, and hot springs and fumaroles. The Cascades geothermal systems have the best potential for high-temperature development in Washington. In southeastern Washington (generally the Columbia Basin physiographic province) light gray area includes wells with bottom-hole temperatures of 20°C and higher, and gradients higher than 45°C/km. Here, although neither temperatures nor gradients are spectacular, exploitable low-temperature thermal water underlies large areas at shallow depth (less than 1000m). It is not implied that thermal water will be found everywhere in the gray areas. In southeastern Washington cold wells are interspersed with warm wells. Absence of gray shading does not indicate there is no possibility of finding geothermal resources; it means only that surface and subsurface manifestations are not now known. Ongoing exploration and study will continue to refine the delineation of Washington's geothermal resources.

Map Scale: 1:500,000
1927 North American Datum
Lambert conformal conic projection based on standard parallels 33° and 45°
Base map revised in 1976

Wyoming

Map Title: Geothermal Resources of Wyoming, 1983

Geothermal data compiled and interpreted by Henry P. Heasler with assistance from B.S. Hinckley, K.G. Buelow, S.A. Spencer, and E.R. Decker of the Department of Geology and Geophysics, University of Wyoming

Map produced by the
National Geophysical Data Center
National Oceanic and Atmospheric Administration
for the
Geothermal and Hydropower Technologies Division
United States Department of Energy

Low-Temperature Geothermal Waters

Dark gray denotes areas known or inferred to be underlain at shallow depth (less than 1000m) by low-temperature (less than 90°C) thermal water with potential for direct heat applications. Areas are defined on the basis of thermal springs, temperature gradients, heat flow, geology, and hydrology.

Light gray denotes areas known or inferred to be underlain by aquifers containing thermal waters with temperatures higher than 50°C. See map explanation for discussion of methodology used to define these areas. Over much of the light gray areas, depth to 50°C thermal water is greater than 1500m.

Existing knowledge does not permit the inference that thermal water may be found everywhere, nor exclusively, within the gray areas, nor do the boundaries represent certain knowledge of the areal extent of geothermal systems or aquifers.

Map Scale: 1:500,000
1927 North American Datum
Lambert conformal conic projection based on standard parallels 33° and 45°