Environment and Natural Resources Trust Fund
2009 Phase 1 Request for Proposals (RFP)

LCCMR ID: A07

Project Title: Minnesota's Geothermal Energy Production Requires Heat Flow Mapping

Total Project Budget: $ $300,000

Proposed Project Time Period for the Funding Requested: July 2009 - June 2011 (2 yrs)

Other Non-State Funds: $ 35,000

First Name: Steven **Last Name:** Hauck

Sponsoring Organization: UMD, NRRI

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Region:	County Name:	City / Township:
Statewide	Statewide	

Summary: Heat flow under Minnesota is represented by four data points. Three are invalid. Energy companies need detailed heat flow/temperature maps to evaluate the feasibility of local geothermal energy production.

Main Proposal: 0808-1-037-proposal-NRRI-EGG Final LCCMR 2009-2011 Heat Flow Map Proposal, Aug

Project Budget: 0808-1-037-budget-NRRI Final 2009 LCCMR Project Budget, Aug. 25, 2008.xls

Qualifications: 0808-1-037-qualifications-Project Manager S Hauck.doc

Map: 0808-1-037-maps-NRRI-EGG Geothermal Final Attachment 1 - Maps.doc

PROJECT TITLE: Minnesota's Geothermal Energy Production Requires Heat Flow Mapping

PROJECT STATEMENT

Assessment of the geothermal potential of Minnesota requires accurate knowledge of temperatures at depths up to 5 km. Drilling for temperature (T) measurements is prohibitively costly. However, acquisition of heat flow data:

- using existing, shallow boreholes (100-300meters), with existing geological and geophysical data on crustal properties will make accurate T vs. depth estimates; and
- will allow preparation of an accurate heat flow map to guide future geothermal energy development in MN.

There are only four data points within MN, and about 90 under Lake Superior (see map). All but one of these data points came from samples collected 2.5m (8.2ft.) under a lake. These data points have been affected by climate forcing, i.e., wind, seasonal variation in surface temperature, etc. over time in turn affects the temperature readings to a depth of about 300ft./91.4m. If MN energy companies are going to study the feasibility of adding geothermal power to produce electricity, there must be a good scientific baseline from which to plan for future geothermal energy production. This proposal is a necessary first step to obtain good scientific data.

Geothermal energy is a clean, renewable, and consistent source of electricity that has the capability to provide much of the nation's baseline electrical power and space heating needs. Geothermal energy production, or heat-mining, began in the US in the early 1900s and currently exists in three forms:

- individual heating and cooling systems (ground source heat pumps);
- area or district heating systems (borehole heat exchangers, single or multiple, <4.5km/14,764ft.); and
- enhanced or engineered deep geothermal systems (EGS; >5km/16,404ft.).

The Earth's interior heat derives from a number of sources including radiogenic heating, processes of mantle and core formation and differentiation, delayed radiogenic heating, earthquakes, and tidal friction. To effectively determine the heat flow in MN, a large and strategically located set of T gradient measurements are required.

Most of MN's geologic basement rocks consist of >2.5 billion year old rocks. These rocks are granites and non-granitic rocks (gneisses, greenstones, metasedimentary, etc.). Radioactive heat generation in granitic rocks is typically 22 times greater than non-granitic rocks. About half of the basement rocks in MN are granitic, but none of the existing heat flow measurements were made over granites. This sampling bias contributes to the low estimate of heat flow in MN. In addition to heat flow measurements, analyses of the radioactivity in old granites, i.e., the heat generated from decay of uranium, thorium, and potassium, can be determined. Along with bottom hole T readings from mineral exploration drill holes and water wells ≥300ft./91.4m deep, thermal conductivity measurements (thermal conductivity is a rocks ability to conduct heat) and radioactivity measurements can add useful heat flow data.

This study is important as society, and Minnesota in particular, identifies potential renewable energy sources for production of energy rather than coal, natural gas, and nuclear power. Geothermal energy is one of those potential sources. The US is the largest producer of geothermal energy in the world, but only 0.4% of the US electrical production comes from geothermal energy. This production occurs in the western US, primarily, CA, NV, and NM. The heat flow data are critical for determining the economics of installing geothermal power plants because a major EGS expense is drilling, and heat flow data allow accurate determination of depth to target temperatures.

A valuable scientific bonus of making T vs. depth measurements in boreholes is the recovery of an accurate record of surface T changes for the past several hundred years. Radiative heating and heat exchange between the ground and air directly control the ground surface T. Transient changes in surface T diffuse downward in the subsurface and affect the geothermal gradient. In the upper 20-30m/65.6-98.4ft., annual signals remain detectable. In the upper 70-80m/229.7-262.5ft., signals from the past decade are detectable, and century-scale signals are detectable over lengths of hundreds of meters. This new method of climate change research provides a direct record of past Ts, unlike proxy data, i.e., tree rings, paleobotany, stable isotopes, and lake salinity that rely on analogy or transfer functions.

DESCRIPTION OF PROJECT RESULTS

Result 1: Collect downhole T from over 100 water wells and exploration drill holes. Budget: $ 209,020

Description – DNR Waters and USGS water well databases have over 6,400 wells >300ft./91.4m deep. We will measure statewide in >100 available, accessible, and static water wells and mineral exploration drill holes ≥300ft./91.4m the: 1) downhole T gradient; 2) bottom hole T; and 3) where solid rock is available, the thermal conductivity of the rock types.

Deliverable	Completion Date
1. A new heat flow, T gradient, and T versus depth maps of MN.	June 20, 2011

Result 2: Collect, analyze, and describe 100 granite samples. **Budget: $ 77,844**

Description – 1) collect up to 100 granite samples from drill core and outcrops throughout the State; 2) chemically analyze the samples for major, minor, trace elements, and isotopes of potassium, thorium, and uranium; 3) describe the minerals and textures of the samples; and 4) compile data and use in heat flow calculations.

Deliverables	Completion Date
1. A database of all chemical, mineralogical, and petrological (textures) information for each collected sample.	June 20, 2011
2. Describe how granites contribute to the heat flow in Minnesota.	

Result 3: A final report with the new heat flow and temperature vs. depth maps. **Budget: $ 48,136**

Description – A final report (NRRI Tech. Rept.) to accompany the new heat flow and T vs. depth and T gradient maps, publish the results in a peer-reviewed journal, and present the results at a national geothermal energy meeting.

Deliverables	Completion Date
1. The final report will include: 1) a description of and interpretation of all data and other aspects of the project; 2) new heat flow map of MN; 3) temperature versus depth maps; 4) temperature gradient map; 5) database of all information collected; and 6) interpretation of the climate data in the first 100m of the water wells and drill holes sampled.	June 20, 2011
2. Deliver all the heat flow and related data for placement in the: 1) Southern Methodist University heat flow database; and 2) Global Heat Flow database at the University of North Dakota at Grand Forks to be included in all new national and international heat flow and temperature versus depth maps.	

PROJECT STRATEGY AND TIMELINE

A. Project Partners

DNR Waters (Michael MacDonald, Hydrologist) is a co-operator on this project by providing access to their Observation wells throughout Minnesota.

U.S. Geological Survey will be co-operators on this project by providing access to wells at the U.S.G.S. Akeley Field Station in Hubbard County.

Permanent University Trust Fund (Dr. Donald Fosnacht, NRRI) will be providing $35,000 for the project.

B. Project Impact

Current heat flow/temperature vs. depth maps show the rocks under MN to be cold, i.e., an energy company must drill >7.5 km to obtain enough heat to operate a geothermal plant. However, the data to produce these maps is based on four boreholes within the State, and three of the sites were collected 2.5 meters (8.2ft.) under lakes and about 90 sites under Lake Superior were also collected at these depths. These data are not representative of the heat flow under MN because these shallow holes have been affected by climate forcing. This new study will collect downhole T data from static/stable wells, ≥300ft./9 1.4m and drill holes≥300ft. /91.4m deep, where the effects of climate forcing are not observed. The new maps will provide Minnesota-based energy companies with excellent baseline data to evaluate the economics of constructing EGS or deep geothermal plants.

C. Time

Since the water wells and drill holes to be surveyed are distributed across the State, it will take two years of field time to: 1) locate, collect, and process all of the temperature data; and 2) collect, analyze, and describe the granite samples.

D. Long-Term Strategy

The long-term strategy for this work is to get MN electrical energy producers to develop EGS, including deep Borehole Heat Exchanger systems, in MN that will create renewable, local energy sources and local jobs, with little to no pollutants to the surrounding communities. These maps will define areas for additional testing, i.e., closer-spaced wells to define the resource, and ultimately drilling deep holes to develop the resource.

Project Budget

Minnesota's Geothermal Energy Production Requires Heat Flow Mapping

IV. TOTAL PROJECT REQUEST BUDGET

BUDGET ITEM	AMOUNT	% FTE
Personnel: (2 year period, including fringe)		
Steven Hauck (NRRI)	$ 41,567	15%
Mark Severson (NRRI)	$ 52,096	22%
John Heine (NRRI)	$ 51,019	31%
Contracts:	$ -	
Dr. William Gosnold, University of North Dakota, Grand Forks. Dr. Gosnold will be co-PI and will provied the equipment, training, granite isotope chemistry, revise the final heat flow map, assist with data collection, and co-write the final report.	$ 78,639	
	$ -	
Equipment/Tools: Dr. Gosnold will provide downhole temperature equipment.	$ -	
Other: *List by item and explain.*	$ -	
Travel - Mileage, lodging, and meals for 3 people to travel to well sites for two years (5-6 mos./yr.), and Dr. Gosnold's travel costs to sample wells and drill holes, and to collect granite samples in outcrop and in the DNR Hibbing drill	$64,298	
Granite Chemistry - Analytical costs for whole rock, trace element, and U, Th, K radioactive isotope analyses on about 100 samples.	$ 8,800	
Polished thin sections - Cost of making (grinding & polishng to 30μm) about 100 polished thin sections at an outside laboratory.	$ 2,600	
Shipping - granite samples for chemical analyses and polished thin sections.	$ 981	
PROJECT BUDGET REQUEST TO LCCMR	**$ 300,000**	
Funds provided by Permanent University Trust Fund	**$ 35,000**	
TOTAL PROJECT FUNDS	**$ 335,000**	

V. OTHER FUNDS

SOURCE OF FUNDS	AMOUNT	Status
Remaining $ From Previous Trust Fund Appropriation:	Not Applicable	
Other Non-State $ Being Leveraged During Project Period:		
Other State $ Being Spent During Project Period: Permanent University Trust Fund (PUTF)	$ 35,000	*Secured*
In-kind Services During Project Period:	Not Applicable	
Past Spending: Geothermal Research by S. Hauck since March, 2008 (NRRI State Special)	$ 47,000	

Steven A. Hauck, Deputy Director
Economic Geology, Particle/Material Characterization, and By-Product Utilization/Remediation Section
Minerals Division
Center for Applied Research and Technology Development
Natural Resources Research Institute, University of Minnesota Duluth
Adjunct Research Fellow - Dept. of Geosciences, University of Minnesota, Duluth – (2002 to present).

M.S. - Geology, University of North Carolina, Chapel Hill, North Carolina, 1977
B.A. with Honors in Geology - Albion College, Albion, Michigan, 1971.

Natural Resources Research Institute (NRRI) (1987 to present)
Deputy Director/Program Director (Nov. 1999 to present)
Oversees eight professional geologists covering research in non-ferrous, ferrous, industrial minerals, environmental remediation, particle and material characterization, and by-product usage, including project budgets, project execution, report editing, and report completion. Research on the Duluth Complex Cu-Ni-PGE and Cr occurrences, diamond exploration techniques and possibilities in Minnesota, and heat-mining/goethermal possibilities in Minnesota.
Research Fellow (Feb. 1994 – Nov. 1999) – Manager Economic Geology Group/Researcher
Senior Scientist (Aug. 1987 – Feb. 1994) – Supervisor Economic Geology Group/Researcher
Scientist – (July 1985 – Feb. 1994) Project Development/Supervisor with 5-8 geologists/Researcher

Union Carbide Corporation (1977-1985)
Senior Uranium Exploration Geologist/Exploration Geologist – Uranium exploration east of the Colorado Front Range.

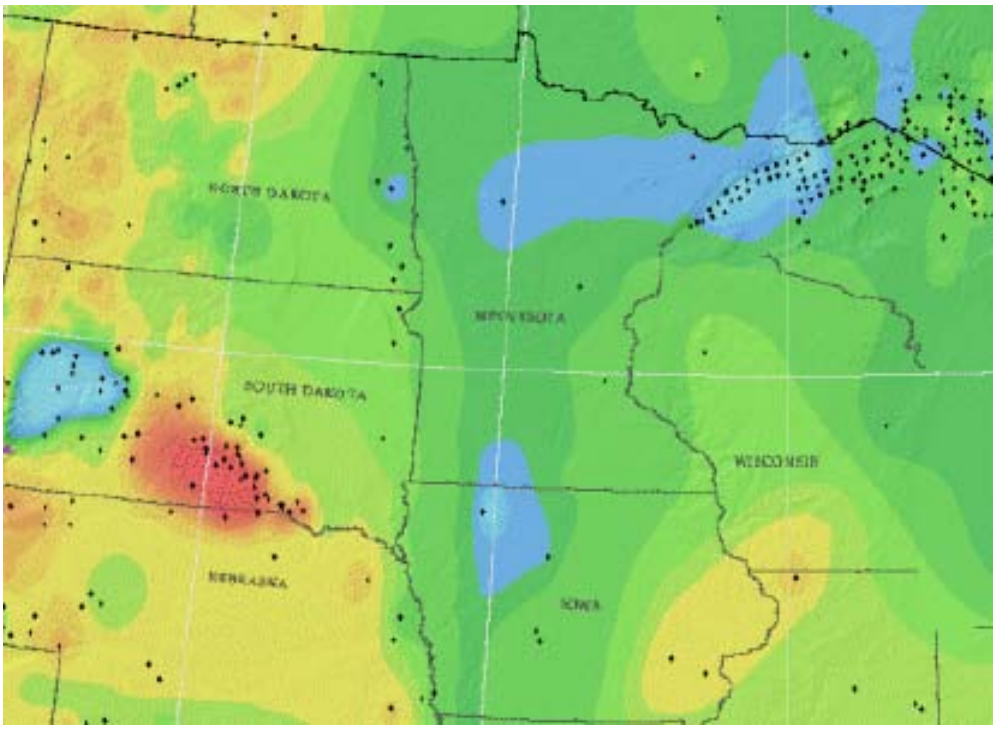
Amoco Production Company, Summer Geologist (May-August, 1975), Louisiana.

NRRI Projects
Duluth Complex Cu-Ni-PGE Projects - Mr. Hauck started with NRRI 23 years ago. His first project was to log drill core in the Duluth Complex with the emphasis on determining the platinum, palladium, and gold content of the copper-nickel mineralization drilled in the 50s-70s. He has managed several projects to continue this evaluation, as well as to determine the rock layering in several intrusions of the Duluth Complex. To date, 1.1 million feet of old and new drill core has be relogged (geological description of the rocks), most by Mr. Mark Severson (also on this project), with assistance by Mr. Hauck. This basic geological description of the rocks and Cu-Ni-PGE mineralization established the baseline data needed to attract mining companies to further explore the Duluth Complex and develop the Cu-Ni-PGE deposits.
Minnesota Clays – Mr. Hauck has research and managerial experience with regional and local clay characterization surveys in the Minnesota River Valley and throughout the State, clay/ceramic/light weight aggregate product development program, and clay geophysics research in part funded by LCMR in 1989 through the Minerals Resources Research Center (UM-Twin Cities).
Other projects: Archean gold and base metal mineralization, Archean geochemistry, biogeochemical prospecting, airborne imaging scanner survey.

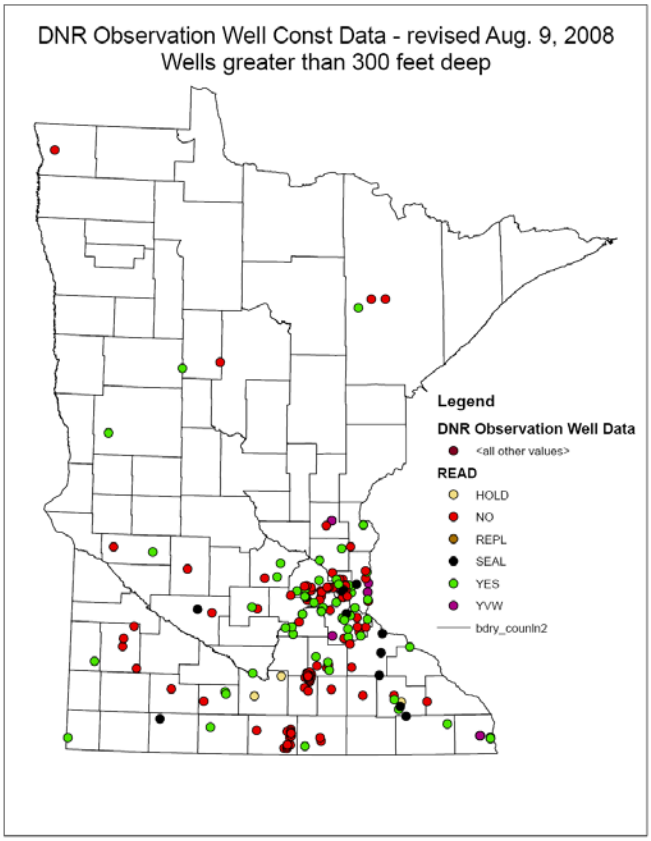
Publications – Author or Co-Author
Peer-Reviewed - 12
NRRI Internal Reports (33) - Duluth Complex (Cu-Ni-PGE deposits) – 14; Minnesota Clays – 13; Geochemistry – 8; Iron Ore – 4; and VMS & SEDEX – 4

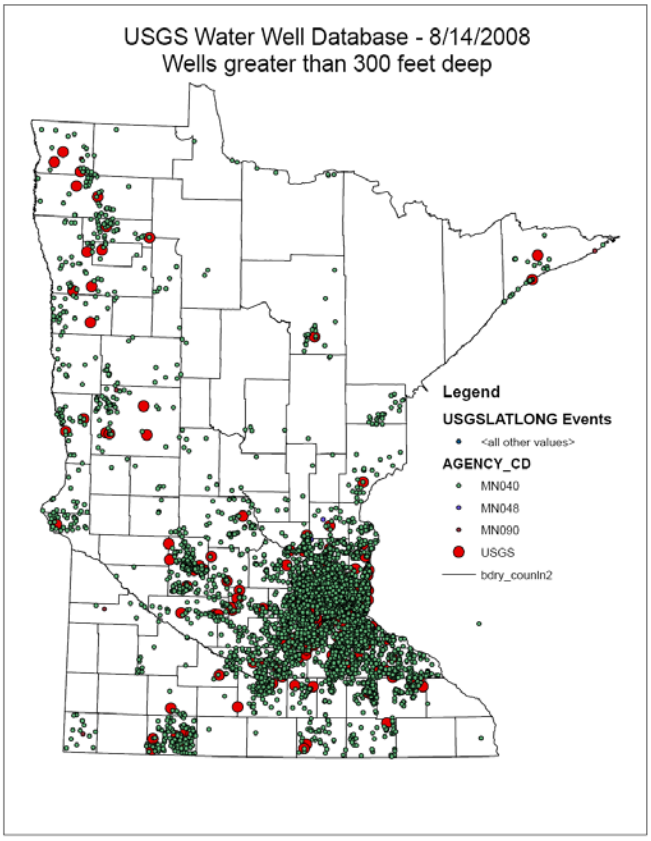
Natural Resources Research Institute Mission Statement
NRRI was established in 1983 to encourage economic growth for Minnesota's natural resources-based industries while keeping watch over that growth's impact on the environment.

Minnesota's Geothermal Energy Production Requires Heat Flow Mapping



Only four data points define the low heat flow (mW/m^2) for MN. In S-C S. Dak. is a cluster of boreholes with high heat flow. Dark area in W-C S. Dak. is a low heat flow area as is Lake Superior. Iowa light area has moderate heat flow.





These plots of water wells from the DNR Waters Observation well and USGS databases show the distribution of MN water wells ≥300 ft. deep. Not shown are available exploration drill holes in Lake, Aitkin, and Carlton Counties.