

[2014] Project Abstract

For the Period Ending June 30, 2017

PROJECT TITLE: Innovative Groundwater-Enhanced Geothermal Heat Pump Study

PROJECT MANAGER: Jimmy Randolph and Martin Saar

AFFILIATION: University of Minnesota

MAILING ADDRESS: Dept. of Earth Sciences, John T. Tate Hall Room 150, 116 Church Street SE

CITY/STATE/ZIP: Minneapolis/MN/55455

PHONE: (952) 457-8959

E-MAIL: rando035@umn.edu

WEBSITE: n.a.

FUNDING SOURCE: Environment and Natural Resources Trust Fund

LEGAL CITATION: M.L. 2014, Chp. 226, Sec. 2, Subd. 08b

M.L. 2016, Chapter 186, Section 2, Subdivision 18

APPROPRIATION AMOUNT: \$196,000

AMOUNT SPENT: \$196,000

AMOUNT REMAINING: \$0

Overall Project Outcomes and Results

The objective of this project was to provide extensive numerical modeling and lab demonstration of a novel geothermal/groundsource heat pump (GHP) that was previously-devised and underwent initial modeling at the University of Minnesota.

GHP's can reduce energy requirements for heating/cooling, which account for approx. 48% of average US residential energy usage, by 75%. However, traditional GHPs are expensive, and their performance is difficult to predict before installation. Our novel, groundwater-enhanced GHP method/technology should substantially reduce GHP costs while improving performance and predictability by taking advantage of the thermal transport properties of groundwater in a closed-loop fashion so that no groundwater is used and no contaminants are introduced to the subsurface.

This project sought to determine whether the groundwater-enhanced GHP was technically feasible through a combination of detailed numerical simulation and simple lab tests. For the numerical modeling, we used the codes COMSOL and OpenGeoSystem to simulate operation of our GHP in a geologic environment, specifically examining heat transfer between the GHP and groundwater over a variety of temperatures and fluid flow rates. For lab testing, we constructed a simple, simulated GHP environment and a basic version of our novel heat exchanger, permitting the performance of this exchanger to be tested and compared against conventional GHP units. Our numerical and lab results indicated that under a broad range of conditions, our novel GHP performs very effectively, with the practical result that fewer boreholes – as little as 1/5th to 1/10th – would be needed in real-world GHP installations using this approach as compared to conventional technologies. As boreholes are up to 50% of the cost of GHP installations, our method/technology should make GHP's more economically viable.

To follow this project and demonstrate commercial viability of the groundwater-enhanced GHP, we must next demonstrate the technology in a series of full field tests. To that end, we have several pending grant proposals submitted or in process, and we have engaged a local engineering firm to construct these field studies. Our ultimate objective is to increase the use of GHP's in MN and beyond, decreasing emissions and energy costs related to heating and cooling.

Project Results Use and Dissemination

To date, dissemination of project results has been limited in order to ensure that the design and performance of the novel groundwater-enhanced GHP remain confidential prior to filing of a patent application. As noted in the

workplan, an intellectual property disclosure was submitted to the UMN Office for Technology Commercialization prior to initiation of this project.

Once a patent application has been submitted, we intend to submit our research for publication in a peer-reviewed journal.



Environment and Natural Resources Trust Fund (ENRTF)

M.L. 2014 Work Plan

Date of Report: January 12, 2018
Date of Next Status Update Report: n.a.
Date of Work Plan Approval: June 4, 2014
Project Completion Date: March 31, 2017
Does this submission include an amendment request? No

PROJECT TITLE: Innovative Groundwater-Enhanced Geothermal Heat Pump Study

Project Managers: Martin Saar and Jimmy Randolph
Organization: University of Minnesota
Mailing Address: Dept. of Earth Sciences, 310 Pillsbury Dr SE 116 Church Street SE
City/State/Zip Code: Minneapolis, MN 55455
Telephone Number: (612) 626-4164 Lab, (952)457-8959 Randolph
Email Address: saarm@ethz.ch and j.randolph@terracoh-age.com
Web Address: <http://www.geo.umn.edu/orgs/geofluids/>

Location: Hennepin and Ramsey Counties, Minnesota

Total ENRTF Project Budget:	ENRTF Appropriation:	\$196,000
	Amount Spent:	\$196,000
	Balance:	\$0

Legal Citation: M.L. 2014, Chp. 226, Sec. 2, Subd. 08b
M.L. 2016, Chapter 186, Section 2, Subdivision 18

Appropriation Language:

\$196,000 the second year is from the trust fund to the Board of Regents of the University of Minnesota to analyze and validate a new geothermal pump method and technology that will reduce heat pump costs and improve performance and predictability. This appropriation is subject to Minnesota Statutes, section 116P.10.

Carryforward: (a) The availability of the appropriations for the following projects are extended to June 30, 2017: (9) Laws 2014, chapter 226, section 2, subdivision 8, paragraph (b), Innovative Groundwater-Enhanced Geothermal Heat Pump Study.

I. PROJECT TITLE: Innovative Groundwater-Enhanced Geothermal Heat Pump Study

II. PROJECT STATEMENT:

Space and water heating and cooling consume 48% of all energy used in an average US residence, and generally that energy is supplied by natural gas or fossil-fuel-derived electricity. Geothermal heat pumps (GHPs) can reduce energy requirements for heating/cooling by 75%. However, traditional GHPs are expensive, and their performance is difficult to predict before installation. We propose to analyze and validate a novel GHP method/technology that is expected to substantially reduce GHP cost while improving performance and predictability.

GHPs can be used anywhere in the world because they use the shallow subsurface as a thermal capacitor, removing heat during winter months to provide space/water heating and returning heat during the summer to provide cooling. They function by boosting the temperature of heat extracted from the ground using compression. Traditional GHPs require considerable wells and/or excavation – their main cost – and are space-intensive. Thus, in the US, they have achieved minimal market penetration (3% of the heating, ventilation and air conditioning (HVAC) market). However, in areas with higher energy costs, such as Sweden and Switzerland, GHPs constitute up to 75% of the HVAC market, indicating there is significant room for growth in the US.

Conventional GHPs ignore groundwater flow and focus on heat exchange with subsurface rocks and sediments. However, groundwater carries heat much more effectively than rock and as such, our novel GHP system and technology specifically acknowledge groundwater flow. This groundwater-enhanced GHP takes advantage of the thermal transport properties of groundwater but in a closed-loop fashion so that no groundwater is used and no contaminants are introduced to the subsurface. Preliminary simulations suggest that our system is far more efficient, less space intensive and thus less costly than conventional systems.

The ultimate objective of this project is to determine the viability of groundwater-enhanced GHPs using numerical modeling and lab/field testing of a prototype. Early-stage modeling and validation of the novel technology/ approach have been completed. This project modifies existing GHP technology while incorporating established hydrogeologic practices and information; thus, we feel the new technology is well-positioned for success. The novel GHP would be smaller and cheaper than existing systems, permitting faster payback periods, more widespread GHP use, and helping GHPs become a significant renewable energy technology.

An Intellectual Property Disclosure has been filed with the Office for Technology Commercialization at the UMN. The UMN may pursue patent protection and as such, some information concerning this proposal is currently confidential. This proposal thus provides less detail than it would otherwise.

III. PROJECT STATUS UPDATES:

Project Status as of December 31, 2014: Project is underway even though there was no spending before January 1, 2015. Grant setup with sponsored projects at U of M took longer than expected but is now setup.

Modeling studies of geothermal heat pump systems has begun with simulations of surface systems in Geodesigner 3.3 completed. Targets for ground water flow volumes have been established to meet typical heating and cooling demands in environments ranging from Texas to Manitoba with a focus on Minnesota. Simulations of subsurface heat exchange systems using Comsol and OpenGeoSystem are in their early phases.

One student worker has now been hired to the project and the hours assigned to Jimmy Randolph have been increased keep the project on schedule.

Project Status as of June 30, 2015 (updated to November 20, 2015): Activities 1 and 2 are advancing rapidly with initial modeling nearing completion.

Modeling with OpenGeoSystem, in lieu of Comsol modeling, are in advanced stages with working models of porous media and fracture flow in vertical and horizontal orientations. We are working with OpenGeoSystem staff to refine heat transport capability.

Design of laboratory scale model in progress. Will be ordering materials shortly.

Project Status as of January 31, 2016:

Modeling of full coupled ground water flow and geothermal heat pump system completed using Comsol. Simulations in OpenGeoSystem confirmed results.

Monitoring results from a potential field trial site show ample ground water flow in a geologic setting typical for this application. Results from the Williamson Hall Platteville will show strong ground water flow within a short open hole interval as has been observed in previous studies.

Amendment Request (02/16/2016):

We are requesting additional time to complete this project, as well as a shift of funds from equipment to staff time. Specifically, we would like to shift funds for Activity 2, Outcome 3 from equipment to staff, and similarly for Activity 3, Outcome 1. Additional time (three months) to complete this project is requested because numerical modeling to design and numerically test the novel heat exchanger has taken longer than expected. Moreover, it took longer than expected to find a qualified individual to complete said modeling and design. Consequently, we were not able to finish the installation of field equipment before the winter of 2015-2016, which delayed field testing and the critical verification of performance for the novel heat exchanger. The equipment needed for laboratory and field testing will cost less than expected, thus we are also requesting a shift of some funds from equipment to staff salaries, permitting staff the needed time to complete Activities 2, 3 and 4. Without the additional time and associated funding of staff, we do not expect to be able to effectively complete construction and field testing of the novel subsurface geothermal heat exchanger.

Amendment Approved: 05/25/2016

Project Status as of September 30, 2016 (Updated to December 19, 2016):

Modeling of coupled ground water flow and geothermal heat pump system has been completed using Comsol. Simulations in OpenGeoSystem confirmed results. Numerous heat exchangers for use in a well have been designed, tested numerically, and constructed. An approximation of a well has been built in the lab, allowing for flow of water across the constructed heat exchangers and testing of heat transfer rates between well and heat exchange fluids. The experimental setup permits measurement of fluid flow rates and fluid temperatures, allowing accurate calculation of heat transfer rates and efficacy.

Amendment Request (12/19/2016):

We are requesting additional time to complete this project, as well as a shift of funds from equipment to staff time. Specifically, we would like to shift funds for Activity 4, Outcome 1 from equipment to staff. Additional time (six months, finishing March 31, 2017) to complete this project is requested because construction and testing of the heat exchanger prototype required more time than originally anticipated, and staffing changes (i.e., the departure of our Graduate Research Fellow prior to finishing analyses) delayed completion of final analyses and project reports. The equipment needed for prototype testing was less expensive to acquire and build than initially expected, freeing funds for staff to complete Activity 4. Without the additional time and funding for staff, we do not anticipate being able to effectively finalize project analyses, distribution of results, or project reporting.

Project Status as of March 31, 2017 (Reported January 12, 2018):

Overall Project Outcomes and Results:

PROJECT ABSTRACT:

The objective of this project was to provide extensive numerical modeling and lab demonstration of a novel geothermal/groundsource heat pump (GHP) that was previously-devised and underwent initial modeling at the University of Minnesota.

GHP's can reduce energy requirements for heating/cooling, which account for approx. 48% of average US residential energy usage, by 75%. However, traditional GHPs are expensive, and their performance is difficult to predict before installation. Our novel, groundwater-enhanced GHP method/technology should substantially reduce GHP costs while improving performance and predictability by taking advantage of the thermal transport properties of groundwater in a closed-loop fashion so that no groundwater is used and no contaminants are introduced to the subsurface.

This project sought to determine whether the groundwater-enhanced GHP was technically-feasible through a combination of detailed numerical simulation and simple lab tests. For the numerical modeling, we used the codes COMSOL and OpenGeoSystem to simulate operation of our GHP in a geologic environment, specifically examining heat transfer between the GHP and groundwater over a variety of temperatures and fluid flow rates. For lab testing, we constructed a simple, simulated GHP environment and a basic version of our novel heat exchanger, permitting the performance of this exchanger to be tested and compared against conventional GHP units. Our numerical and lab results indicated that under a broad range of conditions, our novel GHP performs very effectively, with the practical result that fewer boreholes – as little as 1/5th to 1/10th – would be needed in real-world GHP installations using this approach as compared to conventional technologies. As boreholes are up to 50% of the cost of GHP installations, our method/technology should make GHP's more economically viable.

To follow this project and demonstrate commercial viability of the groundwater-enhanced GHP, we must next demonstrate the technology in a series of full field tests. To that end, we have several pending grant proposals submitted or in process, and we have engaged a local engineering firm to construct these field studies. Our ultimate objective is to massively increase the use of GHP's in MN and beyond, decreasing emissions and energy costs related to heating and cooling.

IV. PROJECT ACTIVITIES AND OUTCOMES:

ACTIVITY 1: Detailed numerical modeling of innovative GHP system.

Description: We will extensively expand upon existing models in order to study the new GHP system under a variety of configurations and geologic conditions relevant to Minnesota. This modeling will further examine the efficacy of the novel method and determine optimal system design. The GHP subsurface component can be installed vertically, using wells, or horizontally in trenches or horizontal boreholes. The former is less space-intensive and, thus, well-suited for urban areas while the latter may be less costly and suited for rural or industrial spaces. The new GHP is anticipated to require far less space and require significantly fewer boreholes than conventional systems under either configuration. However, numerical modeling is needed to determine space needs and overall system design for varied geologic conditions.

Summary Budget Information for Activity 1:

ENRTF Budget: \$ 18,500
Amount Spent: \$ 18,500
Balance: \$ 0

Activity Completion Date: Dec. 31, 2014

Outcome	Completion Date	Budget
---------	-----------------	--------

1. Development and testing of base case GHP numerical models using Comsol simulator.	September 1, 2015	\$ 18,500
--	-------------------	-----------

Activity Status as of: December 31, 2014

Modeling studies of conventional geothermal heat pump systems has begun with simulations of surface systems in Geodesigner 3.3 completed. Targets for ground water flow volumes have been established to meet typical heating and cooling demands in environments ranging from Texas to Manitoba with a focus on Minnesota. Simulations of the proposed subsurface heat exchange systems using Comsol and OpenGeoSystem are in their early phases.

Activity Status as of: November 20, 2015

Modeling of base case GHP scenarios completed in Open Geo System. Working on refining models for laboratory and field scale applications in Activity 2. Changes were made to the Personnel funding for Dr. Martin Saar, as reflected in line 14 of the Budget Sheet. No changes were made to his total amount of wages and benefits, but their timeframe was accelerated – instead of being spent over two years, the wages and benefits were spent over the first six months of the project because Dr. Saar was thereafter relocating to Switzerland. For changes made in line 17 of the Budget Sheet, see the next page.

Activity Status as of January 31, 2016:

Modeling of base case GHP scenarios completed in OpenGeoSystem and confirmed with Comsol simulations.

Activity Status as of September 30, 2016 (Updated to December 19, 2016):

Modeling of base case GHP scenarios completed in OpenGeoSystem and confirmed with Comsol simulations.

Final Report Summary:

Modeling of base case GHP scenarios completed in OpenGeoSystem and confirmed with Comsol simulations. Models have shown promising results regarding the performance of the novel groundwater enhanced GHP.

ACTIVITY 2: Prototype subsurface unit modeling, design and construction.

Description: The groundwater-enhanced GHP incorporates a novel subsurface heat exchange unit, which is projected to decrease the GHP subsurface footprint, substantially reducing installation costs while making the system more serviceable than conventional GHPs. This activity will finalize the design of a prototype unit, test the unit in geologic models, and construct a small prototype. The budget for this activity has not been changed, but we are requesting that funds be shifted from equipment construction to staff time to reflect the additional time that was required to numerically design the prototype equipment. We have been able to economize on the manufacturing costs of the prototype to permit this change.

Summary Budget Information for Activity 2:

ENRTF Budget: \$ 69,500
Amount Spent: \$ 69,500
Balance: \$ 0

Activity Completion Date: May 31, 2016

Outcome	Completion Date	Budget
1. Finalize design of the prototype subsurface heat exchange unit.	March 31, 2015	\$ 24,500
2. Incorporate the subsurface heat exchange unit into geologic numerical models.	June 31, 2015	\$ 5,000
3. Have prototype subsurface unit constructed at UM machining facilities.	May 31, 2016	\$ 40,000

Project Status as of December 31, 2014:

Preliminary designs are being worked out with Jimmy Randolph taking the lead on Activity 2.

Project Status as of November 20, 2015:

Plans for prototype near completion. Have pulled together a bill of materials and defined needs for prototype lab space. Have begun integrating the heat exchange unit into numerical models. Changes were made to the Personnel funding for a Graduate Research Assistant, as reflected in line 17 of the Budget Sheet. No changes were made to the total amount of wages and benefits. But instead of hiring a part-time Graduate Research Assistant for two years, a Graduate Research Fellow was hired full-time for 1.5 years. Difficulties in identifying an appropriate candidate for the position necessitated the change; however, because of differences in fringe costs, total work hours for the Graduate Research Fellow can be greater than for the Research Assistant.

Project Status as of January 31, 2016:

Designs for a prototype system are completed with model simulations testing a variety of configurations, tubing materials, cross-sectional shapes, and diameters. Simulations have required more intensive computational time than expected.

Project Status as of September 30, 2016 (Updated to December 19, 2016):

Designs for a prototype system are completed with model simulations testing a variety of configurations, tubing materials, cross-sectional shapes, and diameters. Several simple heat exchangers have been constructed and tested.

Final Report Summary:

Designs for a prototype system are completed with model simulations testing a variety of configurations, tubing materials, cross-sectional shapes, and diameters. Several simple heat exchangers have been constructed and tested. We have also entered into a relationship with a local company that can revise designs and construct heat exchangers for future field and commercial testing.

ACTIVITY 3: Prototype laboratory testing, numerical verification.

Description: The prototype subsurface GHP unit will be tested in a lab setting. From numerical studies, we have determined that testing of the heat exchanger in a lab setting, involving installation of the exchanger in a box filled with sediment, will not provide us as much substantive information as installing and testing the unit in a field setting. Thus, this activity has been redefined, with the focus on finalizing the design and construction of the subsurface heat exchanger, together with flow testing the unit to ensure it operates as expected prior to installation in a well. Funds are requested to be shifted from equipment to staff time, reflecting the change in focus and to account for the additional time that was required to numerically model and design the novel heat exchanger.

Summary Budget Information for Activity 3:

ENRTF Budget: \$ 55,500
Amount Spent: \$ 55,500
Balance: \$ 0

Activity Completion Date: March 31, 2016

Outcome	Completion Date	Budget
1. Refine the design of the subsurface heat exchanger unit, following initial numerical and physical designs.	Sept. 30, 2015	\$ 42,500
2. Operate the GHP prototype; comparison of lab and numerical results.	March 31, 2016	\$ 13,000

Activity Status as of December 31, 2014

Activity 3 has not commenced as of December 31, 2014.

Activity Status as of June 30, 2015 (updated to November 20, 2015):

Preliminary design of laboratory scale heat exchanger in progress. Using model results from Activities 1 and 2 to help design actual heat exchange unit.

Activity Status as of January 31, 2016: Preliminary design of laboratory scale heat exchanger in progress. Using model results from Activities 1 and 2 to help design actual heat exchange unit.

Activity Status as of September 30, 2016 (Updated to December 19, 2016): Final design and construction of the laboratory scale heat exchanger have been completed. Several simple units were built, with improvements made in each successive generation. The final prototype unit has been flow tested and shown to function as expected.

Final Report Summary:

Final design and construction of the laboratory scale heat exchanger have been completed. Several simple units were built, with improvements made in each successive generation. The final prototype unit has been flow tested and shown to function as expected.

ACTIVITY 4: Prototype field testing.

Description: The prototype subsurface unit will be installed in a groundwater monitoring well – selected to be similar to wells used for commercial GHP operation – on the UM campus. Location will be found on Minneapolis or St. Paul Campus to allow easy access and monitoring by staff. Geophysical logging, in coordination with the Minnesota Geological Survey, will determine the hydrologic connectivity of the selected well. It will be connected to a conventional GHP surface unit, housed in a small enclosure, to test the prototype operation over a variety of operating conditions. We will install monitoring devices to facilitate analysis of GHP performance and subsurface impacts.

We are requesting additional time to complete this activity because numerical modeling to design and numerically test the novel heat exchanger has taken longer than expected. Moreover, it took longer than expected to find a qualified individual to complete said modeling and design. Consequently, we were not able to complete the installation of field equipment before the winter of 2015-2016, which delayed field testing and the critical verification of performance for the novel heat exchanger. The budget for this activity has not been changed.

We are further requesting additional time to complete this activity. Design and construction of the prototype unit and the test well took longer than originally expected, and staff changes (i.e., the departure of the Graduate Research Fellow) delayed completion of data analysis, final reporting and dissemination of project results. The overall budget for this activity has not changed, but we request that funds be shifted from equipment to staff time. Equipment for this activity was acquired and constructed for less than originally budgeted, freeing funds for staff time.

Summary Budget Information for Activity 4:

ENRTF Budget: \$ 52,500
Amount Spent: \$ 52,500
Balance: \$ 0

Activity Completion Date: March 31, 2017

Outcome	Completion Date	Budget
1. Install subsurface prototype in a well; construct surface facility.	June 30, 2016	\$ 20,000
2. Operate and analyze prototype system.	September 30, 2016	\$ 42,500

Activity Status as of December 31, 2014

Activity 4 has not commenced as of December 31, 2014.

Activity Status as of June 30, 2015 (updated to November 20, 2015):

Activity 4 has not commenced as of November 20, 2015.

Activity Status as of January 31, 2016:

Prototype test hole has been identified and design of heat exchange system specific to test hole is in early phases of work.

Activity Status as of September 30, 2016 (Updated to December 19, 2016):

A simulated well has been constructed, and monitoring equipment (including flow rate and temperature sensors) has been installed. The prototype heat pump has been installed in the well and operated over a variety of fluid temperature and flow rate scenarios. Considerable data has been collected, and initial analysis of said data is begun.

Final Report Summary:

A simulated well has been constructed, and monitoring equipment (including flow rate and temperature sensors) has been installed. The prototype heat pump has been installed in the well and operated over a variety of fluid temperature and flow rate scenarios. Considerable data has been collected, and we have completed our analyses at this stage (additional analyses of the data may happen in the future). The prototype unit functions approximately as expected, generating far more heat transfer in a single unit than conventional GHP's.

V. DISSEMINATION:

Description: Project results will be reported in peer reviewed publications and patent documents.

Status as of December 31, 2014:

No presentations, publications, or patents to date.

Status as of June 30, 2015 (updated to November 20, 2015):

No presentations, publications, or patents to date.

Status as of January 31, 2016:

No presentations, publications, or patents to date.

Status as of September 30, 2016 (Updated to December 19, 2016):

No presentations, publications, or patents to date.

Final Report Summary: March 31, 2017 (Updated to January 12, 2018):

No presentations, publications, or patents to date. Several confidential grant proposals for follow-up work have been submitted and are pending. External contractors for follow-up work have been engaged. Articles for peer-reviewed journal publication are in preparation and will be completed once a provisional patent application has been filed.

VI. PROJECT BUDGET SUMMARY:

A. ENRTF Budget Overview:

Budget Category	\$ Amount	Explanation
Personnel:	\$156,129	[Dr. Martin O Saar (PI, associate professor 6% time per year for first 6 months, salary 83.4% of cost, fringe benefits 16.6% of cost)], Dr. Jimmy B Randolph (co-PI, research assistant, 4% time per year for two years, salary 74.1% of cost, fringe benefits 25.9% of cost) and 25% time for 15 months in 2016 and 2017, Scott Alexander (co-PI, Research Scientist 72% salary,

		28% benefits, 2 years, 35% time position, Graduate Research Fellow 100% time per year for 1.75 years salary 75% of cost, fringe benefits 25% of cost.
Equipment/Tools/Supplies:	\$ 12,000	Supplies for developing, monitoring, and analyzing performance of lab and field scale prototypes.
Capital Expenditures over \$5,000:	\$ 20,087	Prototype Geothermal Heat Pump Subsurface Interface, including design, machining, and ancillary supplies; and Geothermal Heat Pump surface unit with related automated controls and surface heat exchanger.
Other:	\$ 7,784	Repairs and maintenance of GHP prototype system and surface components by UM machine shops (\$2,284), and downhole geophysical logging of the geologic formation in which the prototype unit will be tested, for analysis for prototype performance, to determine hydrologic flow conditions and measure subsurface impacts (\$5,500). Logging will be done in coordination with the Minnesota Geologic Survey using MGS and rented equipment.
TOTAL ENRTF BUDGET: \$ 196,000		

Explanation of Use of Classified Staff: N/A

Explanation of Capital Expenditures Greater Than \$5,000: The field scale Geothermal Heat Pump will require custom design, machining, and assembly of a functional prototype (estimated cost 19,500) as part of Activity 2, Field scale testing was able to be completed effectively without the use of an off-the-shelf GHP surface unit. Equipment will continue to be used for on-going research at UM through its useful life. If the use changes UM would pay back the Environment and Natural Resources Trust Fund an amount equal to either the cash value received or a residual value approved by the LCCMR director if it is sold.

Number of Full-time Equivalent (FTE) Directly Funded with this ENRTF Appropriation: 1.8 FTE

Number of Full-time Equivalent (FTE) Estimated to Be Funded through Contracts with this ENRTF Appropriation: N/A

B. Other Funds:

Source of Funds	\$ Amount Proposed	\$ Amount Spent	Use of Other Funds
Non-state			
Saar Departmental Start Up funding	\$ 40,000	\$ 40,000	Existing computational hardware (computer workstations, linux cluster) and software licenses (Comsol Multiphysics and TOUGH2).
UM Facilities and Mgmt	\$ 20,000	0	Monitoring well on UM campus.
State			
	\$ 0	\$ 0	
TOTAL OTHER FUNDS:	\$ 60,000	\$ 40,000	

VII. PROJECT STRATEGY:

A. Project Partners: UMN Facilities and UMN Office for Technology and Commercialization.

B. Project Impact and Long-term Strategy:

A successful prototype-scale demonstration of the novel GHP system would be followed by a full-scale system design. Thereafter, we will approach the UMN facilities division to investigate installing a full system on campus to heat/cool the to-be-renovated Tate Hall or the Biomedical Discovery District. Soon, the UMN will require additional heating infrastructure, which could be supplied renewably with the new GHP technology/approach rather than with natural gas, which dominates the current heating system. In addition, we anticipate approaching, with the assistance of the UMN Office for Technology Commercialization, a commercial entity to pursue statewide implementation of the novel GHP technology. GHPs that are less costly, more predictable, and more serviceable – such as what we propose – could reduce Minnesota’s fossil fuel requirements for heating and cooling by 50%, substantially reducing the state’s greenhouse gas emissions and providing massive environmental benefits.

Non-confidential results of all studies will be published in peer-reviewed journals, such as the Hydrogeology Journal, and presented at conferences including the Midwest Groundwater Conference.

C. Spending History:

Funding Source	M.L. 2008 or FY09	M.L. 2009 or FY10	M.L. 2010 or FY11	M.L. 2011 or FY12-13	M.L. 2013 or FY14
UM Earth Sciences – computer modeling of GHP systems.			\$35,000	\$35,000	

VIII. ACQUISITION/RESTORATION LIST: N/A

IX. VISUAL ELEMENT or MAP(S): See attached visual element.

X. ACQUISITION/RESTORATION REQUIREMENTS WORKSHEET: N/A

XI. RESEARCH ADDENDUM: N/A

XII. REPORTING REQUIREMENTS:

Periodic work plan status update reports will be submitted no later than January 31, 2015; July 31, 2015; and January 31, 2016; September 30, 2016; January 31, 2017. A final report and associated products will be submitted between June 30 and August 15, 2017.

Environment and Natural Resources Trust Fund												
M.L. 2014 Project Budget												
Project Title: <i>Innovative Groundwater-Enhanced Geothermal Heat Pump Study</i>												
Legal Citation: <i>Fill in your project's legal citation from the appropriation language - this will occur after the 2014 legislative session.</i>												
Project Manager: <i>Martin Saar and Jimmy Randolph</i>												
Organization: <i>University of Minnesota</i>												
M.L. 2014 ENRTF Appropriation: \$ 196,000												
Project Length and Completion Date: 3 Years, June 30, 2017												
Date of Report: 1/12/2018												
ENVIRONMENT AND NATURAL RESOURCES TRUST FUND BUDGET	Activity 1 Budget	Amount Spent	Activity 1 Balance	Activity 2 Budget	Amount Spent	Activity 2 Balance	Activity 3 Budget	Amount Spent	Activity 3 Balance	Activity 4 Budget	Amount Spent	Activity 4 Balance
BUDGET ITEM	<i>Detailed numerical modeling 18,500</i>			<i>Prototype design & construction 69,500</i>			<i>Prototype lab scale testing & verification 55,500</i>			<i>Prototype field testing 52,500</i>		
Personnel (Wages and Benefits)	\$18,500	\$18,500	\$0	\$50,000	\$50,000	\$0	\$54,500	\$54,500	\$0	\$33,129	\$33,129	\$0
Dr. Martin O Saar - PI, associate professor 6% time for first 6 months of project, salary 83.4% of cost, fringe benefits 16.6% of cost (~\$4,187).												
Dr. Jimmy B Randolph - co-PI, research assistant, 4% time per year for two years, salary 74.1% of cost, fringe benefits 25.9% of cost (~\$4,606). 25% time for 15 months in 2016 and 2017.												
Scott Alexander - co-PI, Research Scientist, 35% time per year for two years, 72% salary, 28% benefits (\$47,423)												
Graduate Research Fellow 100% time per year for 1.75 years salary 75% of cost, fringe benefits 25% of cost.												
Equipment/Tools/Supplies												
Supplies: Outdoor enclosure, electrical connections, and heat pump-to-well connections for prototype operation.	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$3,500	\$3,500	\$0
Supplies: Monitoring supplies to measure subsurface and surface conditions during geothermal heat pump prototype testing.	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$7,500	\$7,500	\$0
Supplies: Laboratory supplies - including monitoring tools, heater, water pumps, tubing, to allow testing of prototype geothermal heat exchanger prior to installation.	\$0	\$0	\$0	\$0	\$0	\$0	\$1,000	\$1,000	\$0	\$0	\$0	\$0
Capital Expenditures Over \$5,000												
Equipment: Prototype Geothermal Heat Pump Subsurface Interface, including design, machining, and ancillary supplies.	\$0	\$0	\$0	\$19,500	\$19,500	\$0	\$0	\$0	\$0	\$0	\$0	\$0
Equipment: Geothermal heat pump surface unit with related automated controls and surface heat exchanger. Costs for required equipment here were much less than originally anticipated.	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$587	\$587	\$0
Other												
Repair and Maintenance: of GHP prototype system and surface components by UM machine shops	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$2,284	\$2,284	\$0
Geophysical Logging Services: Downhole geophysical surveys of the geologic formation in which the prototype unit will be tested, for analysis for prototype performance, to determine hydrologic flow conditions and measure subsurface impacts. Logging will be done in coordination with the Minnesota Geologic Survey using MGS and rented equipment.	\$0	\$0	\$0		\$0	\$0	\$0	\$0	\$0	\$5,500	\$5,500	\$0
COLUMN TOTAL	\$18,500	\$18,500	\$0	\$69,500	\$69,500	\$0	\$55,500	\$55,500	\$0	\$52,500	\$52,500	\$0