

M.L. 2011 Project Abstract

For the Period Ending June 30, 2014

PROJECT TITLE: Trout Stream Springshed Mapping in Southeast Minnesota – Phase III

PROJECT MANAGER: E. Calvin Alexander, Jr.

AFFILIATION: U of MN

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FUNDING SOURCE: Environment and Natural Resources Trust Fund

LEGAL CITATION: M.L. 2011, First Special Session, Chp. 2, Art.3, Sec. 2, Subd. 05b2

APPROPRIATION AMOUNT: \$ 280,000

Overall Project Outcome and Results

Trout streams depend on a steady supply of clean, cold water which comes from groundwater springs. These trout springs are under increasing pressure from changing land use, climate change, and groundwater withdrawals for domestic use, mining, agriculture, and energy production. Delineation of the recharge areas or springsheds of trout springs using dye tracing is a necessary first step in the conservation and protection of the trout stream coldwater supplies. This project focused on delineating groundwater springsheds both in the Galena Group limestone karst areas of Fillmore and Olmsted counties, where this work has been done for over 30 years, and in the Cambrian St. Lawrence Formation and Tunnel City Group bedrock across southeast Minnesota. Prior to this project, no springsheds had been delineated in the St. Lawrence or Tunnel City bedrock units. We demonstrated that springs discharging from these units receive surface water recharge from sinking streams and that this recharge moves hundreds of feet per day through the bedrock. This has rewritten our understanding of the hydrology of southeast Minnesota and has demonstrated that these springs, which we formerly believed to be well-protected from land surface activities, are much more vulnerable than we previously realized. Overall, during this project we mapped 41 groundwater springsheds (delineated by dye tracing) and 54 surface water springsheds (surface watersheds sending water to a point where it sinks underground into a groundwater springshed). Twelve of the groundwater springsheds and sixteen of the surface water springsheds are in the St. Lawrence Formation and Tunnel City Group. The groundwater springshed delineated areas total 50,708 acres and the surface water delineated areas total 124,447 acres. Prior to this project there was a total of 54,091 acres of both springshed types delineated. Springsheds were delineated in Dakota, Dodge, Fillmore, Goodhue, Houston, Mower, Olmsted, Wabasha and Winona counties.

Project Results Use and Dissemination

Information from this project was widely disseminated. A map of the delineated springsheds and a document on Spring Assessment Protocols were produced and submitted to the LCCMR and will be published by the Minnesota Geological Survey. The springshed coverage is being used by state and local governments to target areas for conservation efforts and for Clean Water Fund project ranking. The springshed mapping will be used by the DNR for Silica Sand Mining Trout Stream Setback permitting and in Water Appropriation permit review.

Project information was presented to numerous groups including the SE MN Water Resources Board, Root River Technical Advisor Group, Fillmore County Local Water Planning committee, Southeast Minnesota County and State Feedlot officers, Midwest Federal Agency Senior Managers, and at Silica Sand mining forums in Red Wing, Lewiston, La Crescent, and Winona.

On the ground information was presented during tours of the southeast; groups that went “on tour” include Minnesota Groundwater Association, MPCA/DNR field staff, SE Minnesota water advocacy groups, Geological Society of America, Minnesota Association of Professional Soil Scientists, and state and federal agency staff from Minnesota, Iowa, and Wisconsin.

A paper on the St. Lawrence tracing work has been published in the journal Carbonates and Evaporites. The springshed mapping work was the subject of two stories on Minnesota Public Radio. Project results were presented at numerous scientific meetings including the 11th and 12th Multidisciplinary Conference on Sinkholes and the Environmental and Engineering Aspects of Karst, the Minnesota Groundwater Association, the Midwest Groundwater Conference, the Geological Society of America, The Driftless area Symposium, and at a Winona State University Geology Department seminar.



Environment and Natural Resources Trust Fund (ENRTF) M.L. 2011 Work Plan

Date of Status Update: 9/18/2014
Date of Next Status Update: Final Report
Date of Work Plan Approval: 8/11/2011
Project Completion Date: 6/30/2014 **Is this an amendment request?** Yes

Project Title: Trout Stream Springshed Mapping in Southeast Minnesota - Phase III

Project Manager: E. Calvin Alexander, Jr.

Affiliation: U of MN

Address: 450 McNamara Alumni Ctr, 200 Oak St SE

City: Minneapolis **State:** MN **Zipcode:** 55455

Telephone Number: (612) 624-3517

Email Address: alexa001@umn.edu

Web Address:

Location:

Counties Impacted: Dakota, Dodge, Fillmore, Goodhue, Houston, Mower, Olmsted, Rice, Wabasha, Washington, Winona

Ecological Section Impacted: Paleozoic Plateau (222L)

Total ENRTF Project Budget:	ENRTF Appropriation \$:	280,000
	Amount Spent \$:	250,159
	Balance \$:	29,841

Legal Citation: M.L. 2011, First Special Session, Chp. 2, Art.3, Sec. 2, Subd. 05b2

Appropriation Language:

\$250,000 the first year and \$250,000 the second year are from the trust fund to continue to identify and delineate water supply areas and springsheds for springs serving as cold water sources for trout streams and to assess the impacts from development and water appropriations. Of this appropriation, \$140,000 each year is to the Board of Regents of the University of Minnesota and \$110,000 each year is to the commissioner of natural resources.

I. PROJECT TITLE: Innovative Springshed Mapping for Trout Stream Management-Continuation (U of MN)

II. PROJECT SUMMARY: Trout streams depend on a steady supply of clean, cold water to exist. Minnesota’s karst lands contain 173 designated trout streams each of which is sourced from springs. Those trout springs are under increasing pressure from changing land use. Additional large groundwater withdrawals for energy production and other development loom in the future. Delineation of the recharge areas or springsheds of the trout springs is a crucial first step in the protection of the trout fisheries and the restoration of those that have been degraded. This project is to develop innovative identification and delineation tools to determine the supply areas (springsheds) for springs serving as coldwater sources for modern and historic trout streams and assessing impacts on them from land and water development.

III. PROJECT STATUS UPDATES:

IV. PROJECT ACTIVITIES AND OUTCOMES:

ACTIVITY 1: Innovative Trout Springshed Maps and Reports

Description: Springsheds that feed source springs of trout streams will be delineated in the Galena, Prairie du Chien, and St. Lawrence karst lands. Maps of the springsheds will be transferred to the U of M for web posting and will be linked to the DNR web site. The existing temperature-monitoring network will be maintained and expanded as equipment and sites are available. The results of our dye tracing, spring monitoring, and hydrostratigraphy investigations will be used to develop spring assessment protocols.

Summary Budget Information for Activity 1:

ENRTF Budget: \$ 280,000
Amount Spent: \$ 250,159
Balance: \$ 29,841

Activity Completion Date:

Outcome	Completion Date	Budget
1. Innovative Trout Springshed Maps and Reports (Conduct dye traces and field investigations for springshed map production, maps and reports of completed traces and spring parameter monitoring including spring assessment protocol development).	30 June 2014	\$280,000

(See also the companion U of M project work program Activity 1)

Activity Status as of 13 May 2013

Thirty-one new dye traces have been conducted in the Galena, Prairie du Chien and St. Lawrence Karsts since the start of the biennium – in cooperation with Jeff Green at the MN DNR. These traces have refined and extended previously mapped springsheds and defined new springsheds. Successful traces in the Prairie du Chien Karst have been extended northward into the Trout Brook springshed south of Miesville in Dakota County. The headwaters springs of Trout Brook have some of the highest nitrate levels observed in SE MN trout streams. A pdf of Joel Groten’s Trout Brook report is attached below.

The karst phenomena discovered in the previous biennium's project in the St. Lawrence Formation is now known to extend from Houston County north through Winona County into Wabasha County. Many of Minnesota's best trout streams are fed by springs emerging from the St. Lawrence. The temperature monitoring network has emphasized long term data sets from the springs feeding the Crystal Springs, Peterson and Lanesboro State Fish Hatcheries. Shorter term temperature monitoring has been successful in two springs in Dakota County's Trout Brook.

Two Research Assistants, Betty Wheeler and Kelsi Ustipak, have been working on this project since 1 July 2012. Kelsi has been conducting field work in cooperation with the DNR setting up and running dye traces. She has been conducting fluorometric analyses of the resulting charcoal detector and water samples, analyzing the data and writing reports on the dye traces in each area. This provides the new data for the springshed maps and assessment protocols. Betty has been adding all of Kelsi's new data to a comprehensive data base of all of the historic dye traces we have been able to document. That new data base includes data from previous decades of traces sponsored by the LCMR and LCCMR and other agencies and individuals. Dye tracing in Minnesota apparently started in 1941 when the predecessor of the Minn. Dept. of Health conducted dye traces to combat water pollution problems in the karst around Harmony and Canton in Fillmore County. Betty's data base is supplying information to Jeff Green's regional scale springshed mapping efforts. This data base will be made available on a web site when it is finished and will be accessible to any interested users.

The subcontract to Tony Runkel, Bob Tipping and Julia Steenberg at the Minnesota Geological Survey has proven to be a key element in our work. The MGS staff have provided refined stratigraphic information on the dye input points and the trout springs. Their data have significantly improved our understanding of the hydrogeology of Trout Springsheds – and our dye traces have fundamentally changed the conceptual models of SE Minnesota's hydrogeology. The MGS staff is constructing new structural contour maps which are revealing how subtle structures affect ground water flow and the locations of the trout springs in SE Minn.

In addition to the close partnership with Jeff Green and the DNR and contractual relationship with the MGS, ongoing partnerships with the MPCA and MDA are making significant contributions to our efforts. The MDA is providing valuable contacts with the local agricultural community and helping significantly with field work in selected areas. MPCA ongoing monitoring programs are building on our springshed maps and MPCA staff have made significant contributions to this project's field work.

Finally, college students are making significant contributions to the effort through class dye traces, Undergraduate Research Opportunity Grants and NSF sponsored REU summer internships.

Good progress has been made on all of the Activity 1 project goals. Dye traces and field investigations are progress very well. Springshed maps and reports are being finished. The spring parameter monitoring system is accumulating interesting, informative and useful information. The spring assessment protocol are on track and emphasizing practical, direct steps to evaluate trout streams.

Amendment Request:

1. We request that the end date of this project be extended to June 30, 2014. This project started late in part due to the shutdown of the state government. An extension of the end date will allow more time to achieve better outcomes, more detailed publications, more complete reports which incorporate more of the historic data and results. It will allow time for constructive comments and suggestions on the GIS based springshed maps and data bases to be incorporated into these major products.

Approved by LCCMR on 15 May 2013.

Final Report Summary: 15 September 2014

Research Scientist Kelsy Ustipak completed her work and left the project at the end of June 2013. Betty Wheeler continued as a 75% time Research Scientist through the end of June 2014. Betty has assembled end-of-project final documents on dye tracing efforts funded by the LCCMR since 2007. Triple dye traces were conducted with NSF Summer Interns Jacob Phipps and Alexa LaQua in Forestville Mystery Cave State Park in summer 2013. Quantitative traces were conducted at Bridge Creek in Houston County in the fall of 2013. A dual dye trace was conducted in the Galena karst of Olmsted County in cooperation with the Olmsted County SWCD in the spring of 2014. Work has focused on compiling and interpreting data for the production of the Spring Assessment Protocols and Springshed Map.

In addition to supplying very important stratigraphic and structural information for the dye tracing efforts, MGS staff have reestablished a working interface to the Karst Features Data Base. Location information on about five thousand new sinkholes, springs and other karst features have been added to the KFDB in support of the dye tracing and springshed mapping efforts.

Amendment Request 15 September 2014

In order to balance final total expenditures, this is a request to move funds from Travel Expenses to Salaries.

Amendment Approved _____

V. DISSEMINATION:

Description: GIS-based maps and written reports of the springsheds will be prepared and disseminated to the LCCMR, interested residents and to local, regional and state resource managers and regulators interested in specific targeted areas. Interim dye trace results will be available as GIS shape files and derived products on a dye trace by dye trace basis. Data tables of discharge and chemistry will be available as developed. Spring assessment protocols will be published and made available to local and state agency staff.

Status as of 13 May 2013

Results of this joint project are being disseminated to all levels of society as rapidly as they are completed. At the local level copies of reports and papers are sent directly to the private land owners involved when they are finalized. County officials are actively using our results and suggesting additional locations for work. An invited talk at the Eagle Bluff Environmental Learning Center on "The Impact of Karst on Agriculture" was presented on 6 April 2013. A similar version of that talk was presented at the Driftless Area Symposium in LaCrosse, WI in March 2012. On 16-18 April 2013 Jeff Green and I presented a Short Course on Karst Hydrogeology to the MPCA and County Feed Lot Officers and staff in Oronoco, MN.

At the state scale presentations on various aspects of the results of this project are regularly presented at Minn. Ground Water Association spring and fall meetings. At the national scale talks and posters are regularly presented at Geological Society of America, American Geophysical Union, and Sinkhole Conference Meetings.

Finally, a very strong synergistic working relationship has been established between the U of Mn, DNR, MGS, MPCA and MDA as we each build on the latest research of each other's groups.

Final Report Summary: 1 August 2014

Information from this project was widely disseminated. A map of the delineated springsheds and a document on Spring Assessment Protocols were produced and submitted to the LCCMR and will be published by the Minnesota Geological Survey. The springshed coverage is being used by state and local governments to target areas for conservation efforts and for Clean Water Fund project ranking. The springshed mapping will be used by the DNR for Silica Sand Mining Trout Stream Setback permitting and in Water Appropriation permit review. The 14th Multidisciplinary Conference on Sinkholes and the Engineering and Environmental Impacts of Karst is scheduled to be held in Rochester, Minnesota 5-9 October 2015. This will further disseminate the Minnesota karst hydrogeology information gained by several decades of LCMR and LCCMR supported research to a local, state, national and international community of karst resource managers.

Project information was presented to numerous groups including the SE MN Water Resources Board, Root River Technical Advisor Group, Fillmore County Local Water Planning committee, Southeast Minnesota County and State Feedlot officers, Midwest Federal Agency Senior Managers, and at Silica Sand mining forums in Red Wing, Lewiston, La Crescent, and Winona. On the ground information was presented during tours of the southeast; groups that went “on tour” include Minnesota Groundwater Association, MPCA/DNR field staff, SE Minnesota water advocacy groups, Geological Society of America, Minnesota Association of Professional Soil Scientists and state and federal agency staff from Minnesota, Iowa and Wisconsin.

A paper on the St. Lawrence tracing work was published in the journal *Carbonates and Evaporites*. The springshed mapping work was the subject of two stories on Minnesota Public Radio. Project results were presented at numerous scientific meetings including the 11th and 12th Multidisciplinary Conference on Sinkholes and the Environmental and Engineering Aspects of Karst, the Minnesota Groundwater Association, the Midwest Groundwater Conference, the Geological Society of America, The Driftless area Symposium and at a Winona State University Geology Department seminar.

VI. PROJECT BUDGET SUMMARY:

A. ENRTF Budget:

Budget Category	\$ Amount	Explanation
Personnel:	\$ 193,059	1 Research Assistant (50%), 1 Research Specialist (90%), P.I. (8%), Research Scientist (12%), Under graduate lab assistant.
Equipment/Tools/Supplies/Analytical:	\$ 35,900	Field equipment, dye, sampling supplies
Travel Expenses in MN:	\$ 20,041	Mileage and expenses
Contract with MGS	\$ 31,000	1 month/year of Tony Runkel and Bob Tipping
TOTAL ENRTF BUDGET:	\$ 280,000	

Number of Full-time Equivalent (FTE) funded with this ENRTF appropriation: 1.75

B. Other Funds:

Source of Funds	\$ Amount Proposed	\$ Amount Spent	Use of Other Funds
U of Mn (1 m/yr for Alexander)	\$20,848		P.I salary
TOTAL OTHER FUNDS:	\$ 20,848	\$20,848	

VII. PROJECT STRATEGY:

A. Project Partners: Minnesota Department of Natural Resources, total from appropriation \$220,000

B. Project Impact and Long-term Strategy: By delineating springsheds and making web-based maps available, this project will provide critical information for the protection and management

of the springs that form the coldwater streams of southeast Minnesota. This information is critical for Total Maximum Daily Load (TMDL) implementation strategies, impaired waters remediation, ground water protection and allocation issues, and local land and water management decisions.

Karst ground water flow is the most complex hydrogeologic environment in Minnesota. Springs are the natural features that return groundwater to surface waters. Karst springs respond much faster to surface recharge than is expected from conventional hydrology theory. Karst springs exhibit a wide range of rapid responses to recharge events. Springs integrate all of the natural and anthropogenic processes that occur in their recharge areas – in their individual springsheds. Springshed mapping is critical component of karst aquifer characterization. Long-term resources are needed to gather and maintain the parameters necessary to realistically, effectively manage karst springs in Minnesota and to train staff and resource managers in the use of the available karst data. LCMR and LCCMR have played a leading role in the effort to understand and manage Minnesota’s karst springs

The availability of high-resolution LiDAR maps, scheduled for July 2009, will produce a flood of new information showing the locations of karst features. We anticipate that new information will have a major impact on the springshed mapping project.

C. Spending History:

Funding Source	M.L. 2005 or FY 2006-07	M.L. 2007 or FY 2008	M.L. 2008 or FY 2009	M.L. 2009 or FY 2010	M.L. 2010 or FY 2011
ENRTF appropriation to U M		250,000			
ENRTF appropriation to UM				250,000	

VIII. ACQUISITION/RESTORATION LIST:

IX. MAP(S): Attached

X. RESEARCH ADDENDUM:

Covington, Luhmann, Myre, Perne, Jones, Alexander, and Saar (2014) Relationships between conduit properties and the damping and retardation of thermal pulses in karst conduits. Abst submitted to the Fall 2014 AGU Meeting in San Francisco.

Luhmann, A.J, M.D. Covington, J.M. Myre, M. Perne, S.W. Jones, E.C. Alexander, Jr., M.O. Saar (2014) Thermal damping and retardation in karst conduits. *Hydrol. Earth Syst. Sci. Discuss.*, 18, 1-54. www.hydrol-earth-syst-sci-discuss.net/18/2014
doi: 10.5194/hessd-18-1-2014

Phipps, Jacob D., Alexa J. LaQua and E. Calvin Alexander, Jr. (2013) Springsheds and water quality in Forestville Mystery Cave State Park, Minnesota. Poster 135-7, GSA Program with Abstracts, v. 47, n. 7, p. 353.

Alexander, E. Calvin Jr. (2013) Mystery Cave, Minnesota: A window into the paleohydrology of the Upper Mississippi Valley. Abstract 276-9, GSA Program with Abstracts, v. 47, n. 7, p. 640.

Alexander, E. Calvin Jr., Anthony C. Runkel, Robert G. Tipping and Jeffrey A. Green (2013) Deep time origins of sinkhole collapse failures in sewage lagoons in SE Minnesota. *In: (Lewis Land, Daniel H. Doctor and J. Brad Stephenson editors) NCKRI Symposium 2 Proceedings of the 13th Multidisciplinary Conference on Sinkholes and the Engineering and Environmental Impacts of Karst*, Carlsbad, New Mexico, published on-line by NCKRI, Carlsbad, NM, p. 285-292. ISBN 978-0-9795422-7-5

Rahimi, Mina and E. Calvin Alexander Jr. (2013) Locating sinkholes in LiDAR coverage of a glacio-fluvial karst, Winona County, MN. *In: (Lewis Land, Daniel H. Doctor and J. Brad Stephenson editors) NCKRI Symposium 2 Proceedings of the 13th Multidisciplinary Conference on Sinkholes and the Engineering and Environmental Impacts of Karst*, Carlsbad, New Mexico, published on-line by NCKRI, Carlsbad, NM, p. 469-480. ISBN 978-0-9795422-7-5

- Alexander, Scott C., Mina Rahimi, Erik Larson, Cody Bomberger, Brittany Greenwaldt and E. Calvin Alexander, Jr. (2013) Combining LiDAR, aerial photography and pictometric tools for karst features database management. *In:* (Lewis Land, Daniel H. Doctor and J. Brad Stephenson editors) *NCKRI Symposium 2 Proceedings of the 13th Multidisciplinary Conference on Sinkholes and the Engineering and Environmental Impacts of Karst*, Carlsbad, New Mexico, published on-line by NCKRI, Carlsbad, NM, p. 441-448. ISBN 978-0-9795422-7-5
- Luhmann, Andrew J., Matthew D. Covington, Scott C. Alexander, Su Yi Chai, Benjamin F. Schwartz, Joel T. Groten and E. Calvin Alexander, Jr. (2013) Comparison of discharge, chloride, temperature, uranine, δD , and suspended sediment responses from a multiple tracer test in Karst. *Carbonates and Evaporites*, v. 28, p. 191-199. Published online 13 Feb 2013, DOI 10.1007/s13146-013-0127-8.
- Anger, Cale T. and E. Calvin Alexander, Jr., (2012) Bench-scale models of dye breakthrough curves. *Carbonates and Evaporates*, Published online 10 Oct 2012, DOI 10.1007/s13146-012-0092-7.
- Luhmann, Andrew J., Matthew D. Covington, Scott C. Alexander, Su Yi Chai, Benjamin F. Schwartz, Joel T. Groten and E. Calvin Alexander, Jr. (2012) Comparing Conservative and Nonconservative Tracers in Karst and Using Them to Estimate Flow Path Geometry. *Journal of Hydrology*, Vol. 448-449, p. 201-211.
- Alexander, E. Calvin, Jr., Jeffrey A. Green, Anthony Runkel and Katherine J. Logan (2011) Southeastern Minnesota karst hydrogeology: New insights from data loggers, tracing, LiDAR and hydrophysics. *in* Miller, J.D., Jr., Hudak, G.J., Wittkop, C. and McLoughlin, P.I. eds., *Archean to Anthropocene: Field Guides to the Geology of the MidContinent of North America: Geological Society of America Field Guide 24*, p. 243-257.
- Brick, Greg and E. Calvin Alexander, Jr. (2011) Early Graphic Representations of Groundwater Nitrate Concentrations, *Ground Water*, first published online Dec., 2011 at: DOI: 10.1111/j.1745-6584.2011.00896.x; then in *Ground Water*, v. 50, no 2, Mar-Apr. 2012, p 319-322.
- Luhmann, Andrew J., Matthew D. Covington, Andrew J. Peters, Scott C. Alexander, Cale T. Anger, Jeffrey A. Green, Anthony C. Runkel and E. Calvin Alexander, Jr. (2011) Classification of Thermal Patterns at Karst Springs and Cave Streams, *Ground Water*, Vol 49, no.3, p 324-334. (Published on line: 16 Jul 2010, DOI: 10.1111/j.1745-6584.2010.00737.x)
- Runkel, Anthony C., Robert R. Tipping, Perry M. Jones, Jessica R. Meyer, Beth L. Parker, E.C. Alexander, Jr., Julia R. Steenberg (2013) A Multilevel Monitoring System Provides New Insights into a Bedrock Aquitard in Southeastern Minnesota. *Hydrogeology and Public Health: Connecting Science, Education and Policy*. Minn. Ground Water Association Spring Conference, St. Paul, MN, 24 Apr 2013.
- Alexander, E. Calvin, Jr. Jeffrey Green (2013) Introduction to Karst, MN Karst–Nature and Occurrence, Karst Aquifer Characterization (three invited talks). *Minnesota Karst Landscape’s Interactions with Feedlots*, Minn. Pollution Control Agency, Oronoco, MN, 16-18 April, 2013.
- Alexander, E. Calvin, Jr. (2013) Impact of Karst on Agriculture (invited talk). Dinner on the Bluff, Eagle Bluff Environmental Learning Center, Lanesboro, MN, 6 Apr 2013.
- Garmon, William Travis, Peters, Joseph Paul, Ustipak, Kelsi R. and Alexander, E. Calvin, Jr. (2012) Mapping karst springsheds in Fillmore County, Minnesota: Increasingly nuanced interpretations (poster 163-7). *Abstracts with Programs*, 4-7 November 2012 GSA Annual Meeting & Exposition, Charlotte, NC, p. 413.
- Wheeler, Betty J., Alexander, Scott C., Green, Jeffrey, A., and Alexander, E. Calvin, Jr. (2012) Ground water tracing information database for Minnesota. (poster) *The 57th Annual Midwest Ground Water Conference: Groundwater Opportunities and Conflicts in the 21st Century: Economy to Ecology, Program with Abstracts*. 1-2 Oct. 2012, Earle Brown Heritage Center, Brooklyn Park, MN. Hosted by the Minnesota Ground Water Association.
- Alexander, Scott C., Rahimi Kazerooni, Mina, Larson, Erik, Bomberger, Cody, Greenwaldt, Brittany, and Alexander, E. Calvin, Jr. (2012) The combined application of LiDAR, aerial photography and pictometric tools for sinkhole delineation. (poster) *The 57th Annual Midwest Ground Water Conference: Groundwater Opportunities and Conflicts in the 21st Century: Economy to Ecology, Program with Abstracts*. 1-2 Oct. 2012, Earle Brown Heritage Center, Brooklyn Park, MN. Hosted by the Minnesota Ground Water Association.
- Ustipak, Kelsi R., Green, Jeffrey A., and Alexander, E. Calvin, Jr. (2012) Integration of water tracing and structural geology for the delineation of springsheds. (poster) *The 57th Annual Midwest Ground Water Conference: Groundwater Opportunities and Conflicts in the 21st Century: Economy to Ecology, Program with Abstracts*. 1-2 Oct. 2012, Earle Heritage Center, Brooklyn Park, MN. Hosted by the Minnesota Ground Water Association.
- Green, Jeffrey A., Runkel, Anthony, and Alexander, E. Calvin, Jr. (2012) Karst hydrogeology investigations in the Cambrian St. Lawrence Aquitard. (talk) *The 57th Annual Midwest Ground Water Conference: Groundwater Opportunities and*

Conflicts in the 21st Century: Economy to Ecology, 1-2 Oct. 2012, Earle Brown Heritage Center, Brooklyn Park, MN. Hosted by the Minnesota Ground Water Association.

Alexander, E. Calvin, Jr., Runkel, Anthony Green, Jeffrey A. (2012) Deep time in the Upper Mississippi Valley Karst. (talk) *The 57th Annual Midwest Ground Water Conference: Groundwater Opportunities and Conflicts in the 21st Century: Economy to Ecology*, 1-2 Oct. 2012, Earle Brown Heritage Center, Brooklyn Park, MN. Hosted by the Minnesota Ground Water Association.

Barr, Kelton D. L. and Alexander, E. Calvin, Jr. (2012) Examples of hypogenic karst collapse structures in the Twin Cities Metropolitan Area, Minnesota. (talk) *The 57th Annual Midwest Ground Water Conference: Groundwater Opportunities and Conflicts in the 21st Century: Economy to Ecology*, 1-2 Oct. 2012, Earle Brown Heritage Center, Brooklyn Park, MN. Hosted by the Minnesota Ground Water Association.

Talbot, Michael T. and Alexander, E. Calvin, Jr. (2012) The impact of karst on agriculture. (invited talk). Minn. Ground Water Association Meeting, 19 April 2012, Earle Brown Center, St. Paul, MN.

Alexander, E. Calvin, Jr. (2012) The impact of karst on agriculture (invited, keynote address). 5th Driftless Area Symposium, 27-28 March, 2012, La Crosse, WI.

Anderson, Julia, Runkel, Anthony, Tipping, Robert G., Barr, Kelton D., and Alexander, E. Calvin, Jr. (2011) Hydrostratigraphy of a fractured, urban aquitard. Abstract 110-4, 2011 Geological Society of America Meeting & Exposition, *Abstracts with Programs*, Vol. 43, No. 5, p. 289.

Brick, Greg, Alexander, E. Calvin, Jr., Watkins, Justin and Lundy, James R. (2011) Surface and groundwater nitrate databases for southeastern Minnesota, USA. Poster 108-3, 2011 Geological Society of America Meeting & Exposition, *Abstracts with Programs*, Vol. 43, No. 5, p. 285-286.

Ladd, Bethany S., and Alexander, E. Calvin, Jr. (2011) Dye tracing in the Jordan Sandstone near the Crystal Springs State Fish Hatchery, Winona County, Minnesota. Poster 108-4, 2011 Geological Society of America Meeting & Exposition, *Abstracts with Programs*, Vol. 43, No. 5, p. 286.

Luhmann, Andrew J., Covington, Matthew D., and Alexander, E. Calvin, Jr. (2011) Using a multi-tracer experiment to estimate flow path geometry. Abstract 135-7, 2011 Geological Society of America Meeting & Exposition, *Abstracts with Programs*, Vol. 43, No. 5, p. 342.

Green, Jeffrey A., and Alexander, E. Calvin, Jr. (2011) Dye tracing observations from the Prairie du Chien Group in Minnesota, Abstract 60-11, 2011 Geological Society of America Meeting & Exposition, *Abstracts with Programs*, Vol. 43, No. 5, p. 167.

Talbot, Michael T. and Alexander, E. Calvin, Jr. (2011) The impact of karst on agriculture.

- a. (abstract) (eds.: Engel, Annette Summers, Engel, Scott, Moore, Paul J., DuChene, Harvey) Carbonate Geochemistry: Reactions and Processes in Aquifers and Reservoirs, Billing, MT, 6-9 August 2011, Karst Waters Institute Special Publication 16, KWI, P.O. Box 1442, Leesburg, VA 20177, p. 69.
- b. 1 November, Soft Rock Seminar, Geology and Geophysics Dept. Seminar, Univ. of Minn.
- c. 9 November, Minn. Speleological Survey, Bloomington, Minn.

XI. REPORTING REQUIREMENTS:

Periodic work plan status update reports will be submitted not later than 15 January 2012, 15 July 2012, 15 January 2013, and 1 August 2014. A final report and associated products will be submitted between June 30 and August 1, 2014 as requested by the LCCMR.

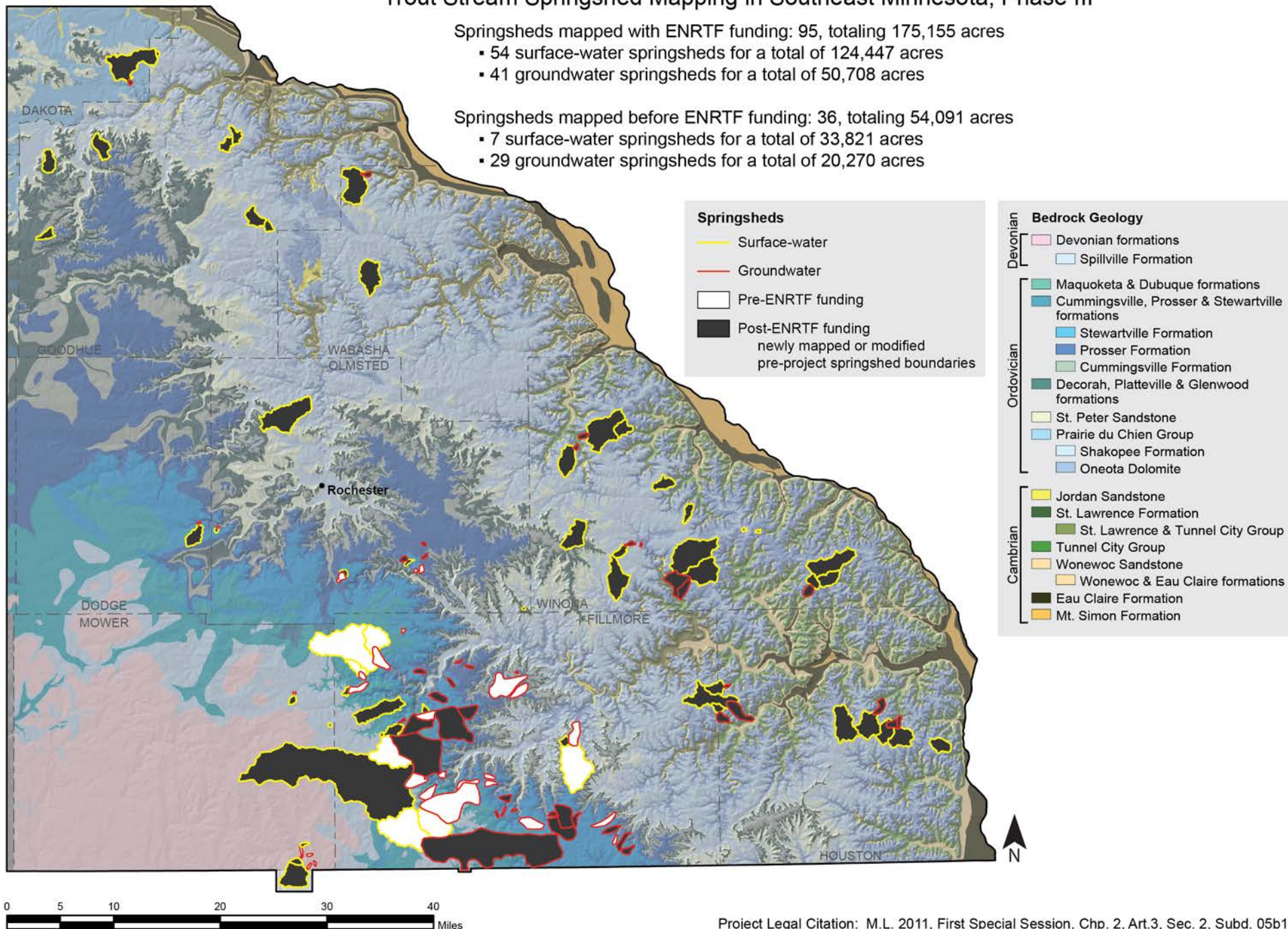
Trout Stream Springshed Mapping in Southeast Minnesota, Phase III

Springsheds mapped with ENRTF funding: 95, totaling 175,155 acres

- 54 surface-water springsheds for a total of 124,447 acres
- 41 groundwater springsheds for a total of 50,708 acres

Springsheds mapped before ENRTF funding: 36, totaling 54,091 acres

- 7 surface-water springsheds for a total of 33,821 acres
- 29 groundwater springsheds for a total of 20,270 acres



Attachment A: Budget Detail for M.L. 2011 (FY 2012-13) Environment and Natural Resources Trust Fund Projects				
Project Title: <i>Innovative Springshed ampping for Trout Stream Management</i>				
Legal Citation: <i>M.L. 2011, First Special Session, Chp. 2, Art.3, Sec. 2, Subd. 05b2,</i>				
Project Manager: E. Calvin Alexander, Jr.				
M.L. 2011 (FY 2012-13) ENRTF Appropriation: \$ 280,000				
Project Length and Completion Date: 30 June 2014				
Final Report 18 September 2014				
ENVIRONMENT AND NATURAL RESOURCES TRUST FUND BUDGET	Activity 1 Budget	Activity 1 budget Revised 9/25/2014	Amount Spent	Balance
Innovative Trout Springshed maps and Reports				
Personnel: Research Assistant: 2 years (50% 12 months per year) = \$77,781 Research Specialist: 2 year (90% 12 months per year) = \$56,716 Dr. E. Calvin Alexander, Jr.: 1 month per year salary & benefits for 2 years = \$20,848 Scott Alexander: 1.5 months per year salary & benefits for 2 years = \$16,805 undergraduate lab assistant: 2 years = \$20,909	\$193,059	\$193,412	\$193,412	\$0
Equipment/Tools /Supplies : Equipment: nitrate data loggers; temperature, conductivity, stage data loggers = \$20,000 Supplies: dye, charcoal, bottles, lab and field chemicals, lab and field expendable supplies = \$7,500	\$27,500	\$27,500	\$10,513	\$16,987
Analytical Expenses: Cation/anion analyses - Geology Lab at U of M approximately \$40 per sample, ~162 samples - \$6,500 Isotope analyses - Texas State, San Marcos, TX, approximately \$15 per sample, ~100 samples - \$1,500 (The Texas State lab has been used for previous phase of the proeject and continues to have the best capability available for this work at a reasonable price.	\$8,000	\$8,000	\$6,349	\$1,651
Travel & Subsistence In-state: mileage and expenses = \$20,041 (per amounts in University plan for employee expenses reimbursement)	\$20,441	\$20,088	\$8,885	\$11,556
Contracts: MGS Tony Runkel: 1 month per year and benefits for 2 years (8% time, 1 month per year) = \$16,000 Bob Tipping: 1 month per year and benefits for 2 years (8% time, 1 month/year) = \$15,000	\$31,000	\$31,000	\$31,000	\$0
COLUMN TOTAL	\$280,000	\$280,000	\$250,159	\$30,194