Environment and Natural Resources Trust Fund

2027 Request for Proposal

General Information

Proposal ID: 2027-197

Proposal Title: Subsurface Irrigation Design

Project Manager Information

Name: Otto Strack

Organization: U of MN - College of Science and Engineering

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Project Basic Information

Project Summary: We develop tools for designing subsurface irrigation systems in Minnesota's agricultural system, helping to conserve our valuable water resources.

ENRTF Funds Requested: $264,000

Proposed Project Completion: June 30, 2029

LCCMR Funding Category: Small Projects (G)

Secondary Category: Water (B)

Project Location

What is the best scale for describing where your work will take place?

Region(s): Metro, Central, NE, NW, SE, SW,

What is the best scale to describe the area impacted by your work?

Statewide

When will the work impact occur?

In the Future

Narrative

Describe the opportunity or problem your proposal seeks to address. Include any relevant background information.

The production of agricultural crops requires the use of large volumes of water to achieve optimal crop yields. For instance, the production of an acre of corn requires about 2 acre-feet of water per year. In Minnesota, much of the water for crop production is supplied through central pivot irrigation systems. While central pivot technology has advanced significantly over the last 50 years, it still wastes some of the water needed by crops. Any waste of water reduces available future groundwater supplies; this is detrimental to the need to meet human as well as overall ecosystem needs. In addition, the conventional means of irrigation management is highly susceptible to causing the leaching of crop nutrients, such as nitrate, to underlying groundwater resources.

The most efficient and ideal way of irrigation that is currently available is subsurface drip-irrigation, which is ideal for crops of high value such as fruit trees, and high-value vegetable crops, but due to its relatively high cost it is not suitable for row crops such as potatoes, corn, or soybeans.

An alternative to irrigation by sprinkler systems is urgently needed to increase water use efficiency and to reduce the potential leaching of crop nutrients such as nitrate.

What is your proposed solution to the problem or opportunity discussed above? Introduce us to the work you are seeking funding to do. You will be asked to expand on this proposed solution in Activities & Milestones.

Our solution is to replace above-ground irrigation by subsurface irrigation, thus avoiding evaporation losses that occur in sprinkler irrigation, and reducing the potential for nutrient leaching. We propose using underground perforated pipes through which water is supplied under pressure, spaced equally as in Figure 1. In this concept the pipes are placed far enough below the surface not to be damaged by heavy farm production equipment. A newly developed mathematical formulation (based on the analytic element method) for saturated water flow in the subsurface has demonstrated that this proposed idea for subsurface irrigation is feasible, and that the formulation can be utilized in the design (depth, spacing and diameter of pipes, and pressure applied in the pipes) of the subsurface irrigation system.
A limitation of the current model is that is neglects the unsaturated flow in the root zone above the suspended water table. To resolve this limitation the model developed for flow in the saturated zone will be coupled with a model for unsaturated flow in the root zone above the water table.

What are the specific project outcomes as they relate to the public purpose of protection, conservation, preservation, and enhancement of the state's natural resources?

The new subsurface irrigation approach will provide a more efficient means of applying water to crops in areas of the state where irrigation is currently practiced, and those areas projected to be needing supplemental irrigation in the future as water demands for crop growth increase. It is hypothesized that the proposed approach will contribute to the reduction in nitrate leaching to groundwater and surface waters.

Activities and Milestones

Activity 1: Development and testing of the subsurface irrigation design tool

Activity Budget: $86,000

Activity Description:
The design tool is based on the well-known analytic element method (AEM) developed by Otto Strack. The analytic element method solves the equation for groundwater flow for specified field conditions. In this case the field condition involves perforated subsurface pipes parallel to each other in the field at an optimum depth below the ground surface. The pipes are hooked up to a water supply and water is pumped into the pipes; the injected water then flows through the perforations into the surrounding soil, producing a water table at some depth below the plant roots. Unsaturated flow then occurs from the water table up to the plant roots to meet the daily water consumptive needs of the plants. To quantify this unsaturated flow we will couple a model for unsaturated flow to the existing model for saturated flow. The design tool will be available from Github and will be open source.

Activity Milestones:

Description	Approximate Completion Date
Adapt and refine the analytic element solution and implement it in a computer program	December 31, 2026
Couple the analytic element solution with a solution for unsaturated flow above the water table.	May 31, 2027

Activity 2: Generalization of the design tool to adapt to field conditions

Activity Budget: $74,000

Activity Description:
Generalize both the theory and its implementation and test the model. Both the theory and the program are suitable at present for an infiltration area isolated from the outside, i.e., all the water in the area is provided via the pipes and nothing comes from outside. This should be generalized to include other boundaries, such as fixed water levels, to adapt to more general field conditions where some water also comes from the outside.

Activity Milestones:

Description	Approximate Completion Date
Test the model to prove the efficacy of the subsurface irrigation approach.	December 31, 2027

Activity 3: Including transient conditions

Activity Budget: $60,000

Activity Description:
It will be determined how much time is needed for the water level to reach the desired elevation. It will be determined whether this can be done by generalizing the AEM solution, otherwise it will be investigated by using a numerical solution.

Activity Milestones:

Description	Approximate Completion Date
Include transient flow in the model	December 31, 2027

Activity 4: project management

Activity Budget: $44,000

Activity Description:
The team will establish a Technical Advisory Committee (TAC) with experts from the Minnesota Department of Agriculture (MDA), Minnesota Pollution Control Agency (MPCA), and Minnesota Department of Natural Resources. The TAC will meet every three months while the full project team will meet monthly. Leveraging our existing relationships, we will establish a stakeholder group from cities, counties, watershed districts/organizations, and non-profits.

A draft and final report will provide documentation of the project to explain the proposed design tool. Following the completion of the final report, our Team will develop draft and final training slides, then conduct a one-hour workshop (recorded) on the proposed tool. The spreadsheet tool, workshop and user documentation will be stored on UMN websites. The project results and tool will be presented to audiences at Minnesota's annual Water Resources Conference and at a national irrigation conference.

Our team will provide periodic updates to the LCCMR as contracted. The updates will include documentation of the TAC meetings, status of the tasks, discussion of unexpected issues and resolutions, and any results to date.

Activity Milestones:

Description	Approximate Completion Date
Finalize proposed TAC members	August 31, 2027
Present a one-hour training webinar	April 30, 2028
Draft and final report	May 31, 2028

Project Partners and Collaborators

Name	Organization	Role	Receiving Funds
John Nieber	University of Minnesota	Modeling unsaturated flow and plant water uptake. Modeling transient water flow due to dynamic water applications and changing water uptake by plants.	Yes

Dissemination

Describe your plans for dissemination, presentation, documentation, or sharing of data, results, samples, physical collections, and other products and how they will follow ENRTF Acknowledgement Requirements and Guidelines.
The model will be presented at the annual Minnesota Water Resources conference, and there will be a one-hour training seminar. We will also look for an opportunity to present at an irrigation conference. In addition, we propose to submit an article for publication in a refereed journal. We will work closely with practitioners through the project TAC.

Long-Term Implementation and Funding

Describe how the results will be implemented and how any ongoing effort will be funded. If not already addressed as part of the project, how will findings, results, and products developed be implemented after project completion? If additional work is needed, how will this work be funded?
The project will produce a computer program suitable for design purposes, in the public domain and downloadable from Github, including a manual for the program. The computer program will use practical data: evaporation rate (crop-dependent), hydraulic conductivity, and depth to bedrock.
Depending on the outcome of this work, we plan the submission of a follow-up proposal for field implementation and testing of the concept.

Other ENRTF Appropriations Awarded in the Last Six Years

Name	Appropriation	Amount Awarded
Mapping Aquifer Recharge Potential	M.L. 2023, , Chp. 60, Art. 2, Sec. 2, Subd. 04h	$391,000
Protecting Minnesota's Headwaters of the Mississippi/Pineland Sands	M.L. 2023, , Chp. 60, Art. 2, Sec. 2, Subd. 04m	$1,693,000
Quantifying Environmental Benefits of Peatland Restoration in Minnesota	M.L. 2023, , Chp. 60, Art. 2, Sec. 2, Subd. 08l	$754,000
Flood and Drought Modeling for Minnesota	M.L. 2024, , Chp. 83, Art. , Sec. 2, Subd. 04j	$499,000
Road Salt Pollution of Surface Waters from Groundwater	M.L. 2024, , Chp. 83, Art. , Sec. 2, Subd. 08n	$622,000
Pilot Water Budget Framework for Managing Water Withdrawals	M.L. 2025, First Special Session, Chp. 1, Art. 2, Sec. 2, Subd. 04s	$198,000

Project Manager and Organization Qualifications

Project Manager Name: Otto Strack

Job Title: Professor of Civil and Geological Engineering

Provide description of the project manager's qualifications to manage the proposed project.
Otto Strack has over 50 years experience in teaching and research of groundwater modeling and soils mechanics at the University of Minnesota. He has written 3 textbooks and numerous papers. He is the original developer of the Analytic Element Method, AEM.

Organization: U of MN - College of Science and Engineering

Organization Description:
The College of Science and Engineering is uniquely positioned to provide the vision, leadership, and intellectual capital that underwrite progress in the 21st Century. Created in 1935, the College of Science and Engineering (formerly known as the Institute of Technology) brought together the University's programs in engineering, mining, architecture, and chemistry. Today, the college is ranked among the top engineering and science academic programs in the country. The college includes 12 academic departments offering a wide range of degree programs at the baccalaureate, master's, and doctoral levels.

Budget Summary

Category / Name	Subcategory or Type	Description	Purpose	Gen. Ineligible	% Benefits	# FTE	Classified Staff?	$ Amount
Personnel								
Otto Strack		Project manager			36.6%	0.66		$87,270
John Nieber		Co-PI			36.6%	0.34		$55,647
graduate student		Assist with program testing and running the design tool			46.28%	1.5		$121,083
							Sub Total	**$264,000**
Contracts and Services								
							Sub Total	-
Equipment, Tools, and Supplies								
							Sub Total	-
Capital Equipment								
							Sub Total	-
Acquisitions and Stewardship								
							Sub Total	-
Travel In Minnesota								
							Sub Total	-
Travel Outside Minnesota								
							Sub Total	-
Printing and Publication								

							Sub Total	**-**
Other Expenses								
							Sub Total	**-**
							Grand Total	**$264,000**

Classified Staff or Generally Ineligible Expenses

Category/Name	Subcategory or Type	Description	Justification Ineligible Expense or Classified Staff Request

Non ENRTF Funds

Category	Specific Source	Use	Status	Amount
State				
			State Sub Total	**-**
Non-State				
			Non State Sub Total	**-**
			Funds Total	**-**

Total Project Cost: $264,000

This amount accurately reflects total project cost?

Yes

Attachments

Required Attachments

Visual Component

File: 0c9129a1-aaf.pdf

Alternate Text for Visual Component

This visual illustrates the proposed design for subsurface irrigation as well existing subsurface drip irrigation and shows the difference between existing and new....

Supplemental Attachments

Capital Project Questionnaire, Budget Supplements, Support Letter, Photos, Media, Other

Title	File
approval from SPA, UMN	bdc25a6a-f92.pdf

Administrative Use

Does your project include restoration or acquisition of land rights?

No

Do you understand that travel expenses are only approved if they follow the "Commissioner's Plan" promulgated by the Commissioner of Management of Budget or, for University of Minnesota projects, the University of Minnesota plan?

N/A

Does your project have potential for royalties, copyrights, patents, sale of products and assets, or revenue generation?

No

Do you understand and acknowledge IP and revenue-return and sharing requirements in 116P.10?

N/A

Do you wish to request reinvestment of any revenues into your project instead of returning revenue to the ENRTF?

N/A

Does your project include original, hypothesis-driven research?

No

Does the organization have a fiscal agent for this project?

Yes, Sponsored Projects Administration

Does your project include the pre-design, design, construction, or renovation of a building, trail, campground, or other fixed capital asset costing $10,000 or more or large-scale stream or wetland restoration?

No

Do you propose using an appropriation from the Environment and Natural Resources Trust Fund to conduct a project that provides children's services (as defined in Minnesota Statutes section 299C.61 Subd.7 as "the provision of care, treatment, education, training, instruction, or recreation to children")?

No

Provide the name(s) and organization(s) of additional individuals assisting in the completion of this proposal:

Enoch Pan,CEGE grant submission administrator and John Nieber, co-PI

Do you understand that a named service contract does not constitute a funder-designated subrecipient or approval of a sole-source contract? In other words, a service contract entity is only approved if it has been selected according to the contracting rules identified in state law and policy for organizations that receive ENRTF funds through direct appropriations, or in the DNR's reimbursement manual for non-state organizations. These rules may include competitive bidding and prevailing wage requirements

N/A