Environment and Natural Resources Trust Fund

M.L. 2025 Approved Work Plan

General Information

ID Number: 2025-258

Staff Lead: Mike Campana

Date this document submitted to LCCMR: June 6, 2025

Project Title: Biofilm Mediated Destruction of PFAS in Groundwater

Project Budget: $1,336,000

Project Manager Information

Name: Seth Thompson

Organization: Freshwater Society

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Web Address: https://freshwater.org/

Project Reporting

Date Work Plan Approved by LCCMR: June 24, 2025

Reporting Schedule: March 1 / September 1 of each year.

Project Completion: June 30, 2028

Final Report Due Date: August 14, 2028

Legal Information

Legal Citation: M.L. 2025, First Special Session, Chp. 1, Art. 2, Sec. 2, Subd. 04t

Appropriation Language: $1,336,000 the first year is from the trust fund to the commissioner of natural resources for an agreement with Freshwater Society to develop biofilm treatment technology and demonstrate field-scale removal of per- and polyfluoroalkyl substances (PFAS) from contaminated groundwater. A fiscal management plan must be approved in the work plan before any trust fund money is spent.

Appropriation End Date: June 30, 2028

Narrative

Project Summary: Microbes control the attenuation and destruction of environmental contaminants. Biofilms form structures to facilitate biodegradation of contaminated groundwater. We design, develop, and grow biofilms capable of destroying PFAS.

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

Twenty years ago, per- and polyfluoroalkyl substances (PFAS) were discovered in surface water and groundwater in the eastern Twin Cities associated with former 3M disposal facilities. Today, Minnesota Department of Health estimates the drinking water supplies for 140,000+ Minnesotans are contaminated by PFAS, covering 150+ square miles. Minnesota Pollution Control Agency subsequently identified additional PFAS sources, including landfills, wastewater treatment facilities, and several dozen industries. Regulations continue to lower permissible levels in the environment.

Existing cleanup technologies for PFAS are limited to aboveground or point-source treatment after groundwater has been extracted at a centralized location. For instance, the City of Woodbury constructed a temporary facility to address PFAS-impacted groundwater, costing over $11 million. Other remedy technologies, such as drinking water treatment plants, concentrate PFAS through mechanical operations, or use adsorbents or resins to bind PFAS to an alternative medium. This is extremely expensive to implement due to intensive infrastructure costs, coupled with high energy inputs and residual waste products that still need to be properly managed. Little attention has been placed on field-scale bioremediation technologies to destroy PFAS, which would mitigate the need for point-of-contact treatment technologies. Freshwater and Bay West are uniquely qualified to tackle this challenge.

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.

Greater than 80% of all microbes (bacteria, fungi, and archaea) exist within a “biofilm”. Biofilms form and function via cell-to-cell communication and collaboration, developing when cells attach to surfaces where biodegradation occurs. Thus far, efforts to discover PFAS biodegradation pathways have focused on identifying individual species or enzymes, but Freshwater intends to use Bay West to identify and evaluate the multi-species synergies present in biofilm. Recent advancements in hydrogeomicrobiochemistry have shown mineralization of PFAS is possible, and we propose to identify, document, and replicate the destruction of PFAS compounds through focused biofilm implementation. Once that degradation is identified, our subcontractor Bay West, who specializes in bioremediation via biofilm, will develop this into an in-situ bioremediation strategy (ISBS). ISBS will replace the need for costly treatment methodologies requiring significant front-end capital and operational expenditures. Furthermore, ISBS are efficient and sustainable options to treat PFAS in place. This study will analyze various PFAS-impacted water sources to determine the diversity of microbes and associated biofilm constituents (nutrients, media, signaling) associated with PFAS destruction. When successful, this monumental study for Minnesota will mark the pathway worldwide for destroying PFAS in the ground via microbes and bioamendments that have proven effective by this study.

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?

After more than 20 years of knowingly living with toxic perfluorinated compounds in our biosphere, Minnesota is ready to address these prominent and widespread toxins, harmful to human health and the environment. Due to ubiquitous distribution of PFAS, bioremediation practices represent the technology capable of addressing statewide, broad contamination of soil, plants, surface water, groundwater, and air – our biosphere. Once demonstrated, bioremediation will begin the destructive treatment of PFAS contamination in the aquifers themselves, not relying on capture and concentration of high levels of pure, or nearly-pure compounds, and relying on expensive, intensive, and unsustainable high-energy sources for point-of-recovery treatment.

Project Location

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

Region(s): Metro

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

Statewide

When will the work impact occur?

During the Project and In the Future

Activities and Milestones

Activity 1: Workplan development and documentation of bench-scale biofilm procedures

Activity Budget: $215,000

Activity Description:
Bioremediation, the use of natural microorganisms to break down environmental pollutants, is the sole technology capable of addressing the vast groundwater plumes in Minnesota. Studies have identified microbes capable of surviving the presence of PFAS, but successful bioremediation programs depend on biofilm mediated biodegradation for all known classes of man-made chemicals, and PFAS are no different. Establishing microbial biofilms is critical to in-situ destruction of these compounds, which includes identifying and reproducing microbiome processes, while delivering nutrients necessary to facilitate growth. Establishing a functioning biofilm is vastly more complex than adding individual microorganisms to an aqueous solution under the premise they are individually essential for biodegradation. Discovering the biofilm genetic makeup is critical, and documenting each step of the microbiome viability and community structure is essential. To jumpstart this process, we will utilize Bay West and their unique biofilm experience to generate viable microorganisms present under natural conditions from existing PFAS sources underground. Identifying, isolating, and collecting microbes from existing sources include; PFAS impacted landfill leachate, indigenous microbes from PFAS-impacted aquifers, and directly isolating microbial growth on physical medium in nutrient-sufficient groundwater. This sourcing will form the backbone for biofilm microbes, and define nutrient needs.

Activity Milestones:

Description	Approximate Completion Date
Pilot Study Workplan completion and documentation of bench-scale biofilm procedures - Freshwater and Bay West	July 31, 2025
Identifying, sampling, analyzing PFAS sources and determine microbiome - Bay West and UMN	September 30, 2025
Demonstration of biofilm health, statistics, and bioamendment performance/adjustments - UMN	November 30, 2025
Perform, test, and confirm biofilm demonstration - Bay West and UMN	December 31, 2025

Activity 2: Demonstration: Site-specific field implementation of biofilm procedures and documenting destruction pathways for PFAS

Activity Budget: $300,000

Activity Description:
Freshwater will work with Bay West to lead the demonstration efforts. Bioengineered environments provide favorable conditions facilitating microbial growth, quorum sensing, and enabling interspecies gene- and energy-transfer to expedite destruction of pollutants. Augmenting these recovered microbes with essential nutrients catalyzes this process, driving biodegradation to complete destruction. Importantly, microbes need exposure to contaminants to induce and develop the metabolic pathways needed to digest and destroy the pollutant. In-situ sources will be collected from multiple operations, including: 1) air-driven recirculation system within a well to bring PFAS and microorganisms to the surface in a concentrate; 2) collected landfill leachate; and, 3) customized downwell bioamendment packages with physical media to foster biofilm growth. An inoculum will be prepared consisting of a diverse group of microorganisms and nutrients capable of forming a PFAS-degrading biofilm in groundwater. By partnering with laboratories capable of quantifying microorganism and biological community metagenomics, we will use these samples to characterize the organisms and identify PFAS destruction pathways. Evolution is immature with respect to the biodegradation of polyfluorinated compounds, this is relatively young chemistry with ill-defined microbial metabolic pathways, and thus fluorinated compounds pose a new challenge for microbes in bioremediation.

Activity Milestones:

Description	Approximate Completion Date
Install down-well foam fractionation unit to recover in situ PFAS + microorganisms - Bay West	January 31, 2026
Identify suitable sites for full-scale implementation\source material acquisition - Bay West	February 28, 2026
Inoculate and initiate bioamendments for field implementation - Bay West	April 30, 2026

Activity 3: Implementation: Site-selection and field implementation of biofilm processes to demonstrate and document the PFAS biodegradation process pathways

Activity Budget: $640,000

Activity Description:
A massive spread of PFAS compounds in Minnesota aquifers occurred through decades-long groundwater flow, transporting contaminants from their source, often with little retardation or natural attenuation. Left unchecked, these contaminants will outlive the chemists who developed them. The culminating testing phase of this project will be implementing biofilm-mediated techniques at PFAS-impacted field site(s). Minnesota has 'old PFAS' and 'new PFAS' sites. The former are shorter-chained molecules having undergone decades-long in-situ natural attenuation and partially broken down PFAS structures, the most recalcitrant PFAS to destroy, while the latter newer PFAS will generally be easier, at least initially, to bioremediate.

A fully-formed biofilm grows and sheds a genetic copy of the biofilm known as ultramicrobacteria (UMB), a billion-year-old survival mechanism storing the heritable biofilm genetic code. UMBs and the bioamendments represent the penultimate importance for technology transfer to other sites, world-wide. Each line of testing will generate a set of biofilm-mediated samples to assess the microbiome developed from the input of PFAS-tolerant microbes, the bioamendments stimulating that growth, and a metagenomic assay of the microbial community. This will be accompanied with laboratory assessment to document the complete destruction pathways for these PFAS. This has been the unexplored blueprint for PFAS destruction.

Activity Milestones:

Description	Approximate Completion Date
Attain regulatory permission, permitting, land access - Bay West and Freshwater	April 30, 2026
Field demonstration initiation - Bay West	May 31, 2026
Draft-Final Biofilm Mediated Destruction of PFAS in Groundwater Report - Bay West and Freshwater	April 30, 2027

Activity 4: Reporting and Project Communications

Activity Budget: $181,000

Activity Description:
Communication and outreach is integral to this study. Ongoing communication and outreach provides learning opportunities for state, county, and local officials in addition to academia and the general public. Freshwater will partner with the University of Minnesota, and world experts in proving and disseminating technology. This will provide learning opportunities to students and participants by both investing in higher level education opportunities for graduate students and interns from the Department of Earth and Environmental Sciences, Civil Engineering, Environmental, and Microbiology. Additionally, graduate and intern students will be involved through the University of Minnesota Geomicrobiology Laboratory to support our biofilm documentation efforts. Advanced assistance in hydrogeomicrobiochemistry principles will come through Dr. Santelli, Dr. Kang, and Bay West. Dr. Peacock will provide a unique understanding of microbiological communities through metagenomic assays. Dr. McLoughlin will support the efforts documenting the full destruction of PFAS throughout this study. Following completion, final reports detailing all

aspects of the project will be prepared and shared with MPCA and regulatory partners, community stakeholders, and the general public. These results will be publicly disseminated at relevant symposiums, conferences, seminars, and workshops, including publications and continued efforts to advance environmental education.

Activity Milestones:

Description	Approximate Completion Date
Draft-Final Biofilm Mediated Destruction of PFAS in Groundwater Report - Freshwater	May 31, 2027
Final Report Distribution - Freshwater	June 30, 2027
ONGOING: Update MPCA, partners and general public (as applicable) with general findings - Freshwater	December 31, 2027
ONGOING: Dissemination of bioremediation progress results via media and symposium/seminars - Freshwater	December 31, 2027
Peer Reviewed Publication based on work - UMN, Bay West, Freshwater	December 31, 2027

Project Partners and Collaborators

Name	Organization	Role	Receiving Funds
Kent Armstrong	TerraStryke Products LLC	Dual role as vendor supplier for bionutrients, and consultant in establishing and documenting biofilm growth.	Yes
Dr. Patrick McLoughlin	McLoughlin Environmental Science, LLC	Expert in geochemical sampling and analytical methods to obtain environmental data. Dr. McLoughlin builds integrated systems to collect data, assess and document the quality of the analyses that produced it, and present it in usable forms to data validators, electronic data specialists, and environmental project managers.	Yes
Dr. Aaron Peacock	Microbac	Expert in next generation sequencing (NGS) and analyzing nucleic acid based tests (PCR, qPCR, NGS). Dr. Peacock also provides subject matter expertise for client projects.	Yes
Dr. Cara Santelli	University of Minnesota	Expert Laboratory Director working with multidisciplinary science teams using multiple approaches from metagenomics, genomics, and transcriptomics to define microbial communities and molecular mechanisms associated with specific biogeochemical activities. This collaborator includes a Graduate Student from the Santelli Geomicrobiology Lab (individual TBD).	Yes
Andri Dahlmeier	MPCA	Teaming Partner – The MPCA is partnering with Bay West to provide PFAS impacted waste streams for bioremediation testing. Project reports will be provided to MPCA for communications and distribution.	No

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.
Freshwater and Bay West staff, will openly disseminate the objectives of this study at a groundwater conference (MGWA) in MN in November 2024. We will collect information and ideas generated from the audience. Once this study commences, Freshwater will openly and regularly disseminate progress on the study through local and regional conferences with a focus on PFAS issues (company website, newsletter, LinkedIn). Simultaneously, this study will hold informational meetings with MN state agencies (MPCA, MDH, MGS, UM, etc.), including interested municipalities, to update interested parties on the progress of this study. The goal of these informational meeting will be in transferring information to allow entities in planning and managing potential remediation options for their compliance with new federal regulations. As part of this study, there will be large databases generated which will be archived and available to the public, including machine-learning and AI mind mapping technologies. At the end of this study, the final report and databases generated will be used in the publication of at least one (1) peer-reviewed journal, and one (1) local\regional conference focused on PFAS issues, with the objective of sharing to all Minnesotans an accessible means to understand this study which was only made possible with help from the Environment and Natural Resources Trust Fund.

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?
This work will establish the pathways by which forever PFAS chemicals in the environment no longer last forever. The latter stages of this project is scaling up the technology application from laboratory and field trials. This includes identifying and developing lab and field scale cost estimates, and demonstrating effectiveness. Expanding the Project Team will incorporate hydrogeologists, engineers, and environmental experts, including those at the MPCA, forensic and commercial testing laboratories, university microbiology intern, and experts in regulatory oversight, bioremediation,

chemistry, biology, hydrogeology, and engineering to transpose this nature-based bioremediation process to community participants and the public.

Budget Summary

Category / Name	Subcategory or Type	Description	Purpose	Gen. Ineligible	% Benefits	# FTE	Classified Staff?	$ Amount
Personnel								
Michelle Stockness		Technical Lead for Freshwater - will serve as technical reviewer for reports, project scopes, and final products			20%	0.25		$45,000
Seth Thompson		Freshwater Project Lead - will oversee execution of the project			20%	0.63		$80,000
Project Coordinator - To be named		Provide direct project coordination including support in producing project dissemination materials and coordinating stakeholder engagement			15%	0.38		$35,000
Cathy Rucci		Responsible for all financial and contract processing for the project		X	20%	0.07		$13,000
							Sub Total	**$173,000**
Contracts and Services								
University Minnesota - Dr. Cara Santelli	Subaward	Subaward includes $160,000 in salary support for Santelli and a graduate student and $33,000 for project supplies and analysis costs. Dr. Santelli will work with the graduate student researcher to support, measure, and document biofilm development and contribute to data analysis and reporting efforts.				1.2		$193,000
Bay West	Service Contract	Lead the technical services of the project, including biofilm development and field testing of PFAS destruction. $650,000 for Bay West salaries, $50,000 for project supplies, $220,000 for commercial lab testing (sub-contracts managed by Bay West) and $30,000 for additional technical advising (sub-contracts managed by Bay West)				5		$950,000
							Sub Total	**$1,143,000**
Equipment, Tools, and Supplies								
							Sub Total	**-**

Capital Expenditures								
							Sub Total	**-**
Acquisitions and Stewardship								
							Sub Total	**-**
Travel In Minnesota								
	Conference Registration Miles/ Meals/ Lodging	Attendance at relevant Minnesota conferences to disseminate project findings. Freshwater staff will disseminate project results at 5 conferences over the course of the project period. We estimate total cost of attendance at $1,600 per person and budget for two people per conference	Dissemination of project findings are vital given the major public interest in PFAS remediation. Ensuring that relevant stakeholders are informed of project outcomes is key to the success of this investment.					$16,000
							Sub Total	**$16,000**
Travel Outside Minnesota								
							Sub Total	**-**
Printing and Publication								
	Publication	Publication of one open access peer-reviewed journal article	Publication of an open access peer-reviewed journal article will allow results from this investigation and pilot testing to be made available and accessible to citizens, stakeholders, and a broad community interested in alternative PFAS management and destruction technologies					$4,000
							Sub Total	**$4,000**
Other Expenses								
							Sub Total	**-**
							Grand Total	**$1,336,000**

Classified Staff or Generally Ineligible Expenses

Category/Name	Subcategory or Type	Description	Justification Ineligible Expense or Classified Staff Request
Personnel - Cathy Rucci		Responsible for all financial and contract processing for the project	Administrative support is generally ineligible, but we request support specifically for the staff time that will be needed to process the larger number of financial statements and contracts directly associated with this project. As a small non-profit, Freshwater runs administratively lean and completely absorbing this costs creates a financial burden.

Non ENRTF Funds

Category	Specific Source	Use	Status	$ Amount
State				
			State Sub Total	**-**
Non-State				
In-Kind	Unrecovered indirect costs for Freshwater	Per LCCMR expense allowability, Freshwater will not charge general overhead expenses associated with completing this work. We estimate this at 10% of the total modified direct costs (Freshwater costs + first $25,000 of subawards)	Pending	$25,000
			Non State Sub Total	**$25,000**
			Funds Total	**$25,000**

Total Project Cost: $1,361,000

This amount accurately reflects total project cost?

Yes

Attachments

Required Attachments

Visual Component

File: cb6a1c08-7a4.pdf

Alternate Text for Visual Component

One-page project summary...

Financial Capacity

Title	File
Audit Report	f93c5764-f6c.pdf
2023 Form 990	091a8309-cc3.pdf
Evidence of Good Standing	2fe30ca6-8f2.pdf

Board Resolution or Letter

Title	File
Board Resolution	3acd9a29-b1b.pdf

Supplemental Attachments

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

Title	File
Letter of Support - University of Minnesota	fdbd1e6b-541.pdf
Letter of Support - Microbac	a5b2839f-e1e.pdf
Letter of Support - MES	47c029e1-5ad.pdf
Letter of Support - SKB	3ab3d390-c30.pdf
Letter of Support - SSI	13ced068-1fd.pdf
Letter of Support - TerraStryke	ed3ad990-d64.pdf
Letters of Support - MPCA	57de30b7-76a.pdf
Letter of Commitment	8394998b-85c.pdf

Difference between Proposal and Work Plan

Describe changes from Proposal to Work Plan Stage

Adjusted work task scope and cost estimates to match recommended funding. Addressed each of the LCCMR comments at requested.

Additional Acknowledgements and Conditions:

The following are acknowledgements and conditions beyond those already included in the above workplan:

Do you understand and acknowledge the ENRTF repayment requirements if the use of capital equipment changes?

N/A

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?

Yes, I understand the Commissioner's Plan applies.

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?

No

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 project:

Kaitlin Larson, Jonna Spanier, Matt Schemmel - Bay West

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

Yes, I understand