Environment and Natural Resources Trust Fund

2025 Request for Proposal

General Information

Proposal ID: 2025-258

Proposal Title: Biofilm Mediated Destruction of PFAS in Groundwater

Project Manager Information

Name: Keith Rapp

Organization: Bay West LLC

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Email: krapp@baywest.com

Project Basic Information

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.

ENRTF Funds Requested: $1,699,000

Proposed Project Completion: December 31, 2027

LCCMR Funding Category: Water Resources (B)

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

Narrative

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

About 20 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 (MDH) estimates the drinking water supplies for 140,000+ Minnesotans are contaminated by PFAS, covering 150+ square miles. Minnesota Pollution Control Agency (MPCA) 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. Bay West is 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 Bay West intends to look at 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, Bay West is uniquely suited to 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 study will be monumental for Minnesota, and 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.

Activities and Milestones

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

Activity Budget: $569,000

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, Bay West will collect 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	July 31, 2025
Identifying, sampling, analyzing PFAS sources and determine microbiome	August 31, 2025
Intern demonstration of biofilm health, statistics, and bioamendment performance/adjustments	October 31, 2025
Perform, test, and confirm biofilm demonstration	December 31, 2025

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

Activity Budget: $430,000

Activity Description:
Bay West practitioners repeatedly develop biofilms in our in situ bioremediation projects. These 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. We will then prepare an inoculum 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 and operate down-well foam fractionation unit to recover in situ PFAS + microorganisms	December 31, 2025
Identify suitable sites for full-scale implementation\source material acquisition	January 31, 2026
Inoculate and initiate bioamendments for field implementation	February 28, 2026

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

Activity Budget: $500,000

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	May 31, 2026
Field demonstration initiation	June 30, 2026
Draft-Final Biofilm Mediated Destruction of PFAS in Groundwater Report	May 31, 2027
Final Report Distribution	June 30, 2027

Activity 4: Reporting and Project Communications

Activity Budget: $200,000

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. Bay West 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, Ms. Higgins, 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	May 31, 2027
Final Report Distribution	June 30, 2027
ONGOING: Update MPCA, partners and general public (as applicable) with general findings	December 31, 2027
ONGOING: Dissemination of bioremediation progress results via media and symposium/seminars	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.	Yes
Dr. Peter Kang	University of Minnesota	Dr. Kang is a geoscientist focusing on groundwater flow and contaminant transport in porous and fractured media. Leader of Kang Research Group, their focus combines theory, high-performance numerical simulations, machine learning, and laboratory experiments to understand how coupled processes (pore to field scale) improved understanding of groundwater and environmental applications.	Yes
Rebecca Higgins	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
TBD	TBD	Learning/Operational Partner – Provide intern to support system operation, data collection and interpretation.	Yes

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.

Project Manager and Organization Qualifications

Project Manager Name: Keith Rapp

Job Title: PG Senior Hydrogeologist

Provide description of the project manager's qualifications to manage the proposed project.

Mr. Rapp received his undergraduate degree in Geology from the University of Minnesota-Duluth, and graduate degree in Geology & Geophysics from Baylor University. Mr. Rapp has over 36 years of experience in hydrogeology and forensics, managing projects throughout his career. Mr. Rapp is an experienced solutions manager for environmental problems in demanding regulatory climates. Versed in management consulting, administration supervision and

oversight, project management, quality assurance/quality control, problem solving, technology identification and development, data interpretation, regulatory interfacing, expert testimony, permit writing, and complex negotiations in all aspects of corporate, industry and consulting environmental areas. Environmental management experience includes managing a broad array of soil and groundwater cleanup projects in the demanding regulatory climate of North America and Europe. Mr. Rapp has managed project investigation and reporting of soil and groundwater contamination sites for clients in the chemical and petrochemical industries, manufacturing, and state superfund sites. Skilled in the development of investigative programs utilizing varied drilling technologies and geophysical techniques. Responsibilities included developing strategic analytical sampling programs for hazardous waste sites, data interpretation, permitting, regulatory negotiations, and expert testimony. Mr. Rapp has successfully deployed multiple in situ bioremediation projects across numerous states in the US, and countries in the EU, which have all been successful.

Organization: Bay West LLC

Organization Description:
Headquartered in St. Paul, Bay West has 50 years of experience as a nationally recognized environmental consulting and remediation company. With over 100 personnel in the Twin Cities and surrounding areas, we are proud to help the State, city, and its community members solve some of their greatest environmental challenges.
Bay West has been working on PFAS-impacted media for the past decade as the awareness of PFAS contamination has grown locally and nationwide. Our engineering work with General Atomics to evaluate and establish destruction efficiencies and costs to destroy PFAS wastes leads the way to rapid deployment of PFAS management solutions. With our experience in various site environmental work and remediation system design and operation, we have readily incorporated how best to address and remediate PFAS within our scope of overall expertise and services. Our ability to navigate an ever-changing regulatory climate, coupled with the recent work in PFAS destruction technology research, makes us uniquely suited to spearhead PFAS remediation work in Minnesota.

Budget Summary

Category / Name	Subcategory or Type	Description	Purpose	Gen. Ineligible	% Benefits	# FTE	Classified Staff?	$ Amount
Personnel								
Project Management		Project management, team coordination, data management coordination, budget tracking, progress tracking (split between multiple staff, estimating 2-3 individuals)			70%	0.76		$149,700
Staff Professional		Field and science leads for operations, monitoring, sampling, and modifying lab testing, field operations, data reduction, and chemistry assemblies (split between multiple staff, estimating 3-5 individuals)			70%	2.4		$295,000
Geologist Support		Geoscience lead, data quality, database management, hydrogeomicrobiochemistry technical leader, project planning, permitting, and reporting lead (split between multiple staff, estimating 2-4 individuals)			70%	0.96		$216,000
Engineering Support		Engineering support and downwell equipment operations, data management, data quality, permitting, and onsite monitoring support (split between multiple staff, estimating 2-4 individuals)			70%	0.56		$118,300
Principal		Fiscal responsibility for sponsoring organization, project oversight, quality control, project delivery, and communications\education			70%	0.06		$15,600
Technician Support		Assisting staff professional, geologists, and engineering support			70%	0.52		$43,000
GIS Support		Mapping, data management, reporting production			70%	0.18		$18,900
Safety Professionals		Ensuring and documenting safe site conditions and field operations			70%	0.02		$4,800
Office Support		Project management, fiscal management, quality control, report production, communications and education			70%	0.38		$34,000
							Sub Total	**$895,300**
Contracts and Services								
Dr. Cara Santelli --	Sub award	Primary investigator and researcher for coordination and direction of interns, lab resources, and support\technical assistance in research				0		$40,000

Geomicrobiology Lab								
University Minnesota - Intern\Grad. Student	Sub award	Primary laboratory intern to support, measure, and document biofilm development, health, composition, data evaluation, and reporting				0		$117,000
University Minnesota	Sub award	Lab fees				0		$33,000
Dr. Pat McLoughlin - MES, Inc.	Sub award	Primary investigator and researcher for coordination and direction of test methods, lab resources, and support\technical assistance in research				0		$23,000
Dr. Aaron Peacock - Microbac	Sub award	Primary investigator and researcher analyzing microbes, nucleic acids (DNA), enzyme-linked immunosorbent assays, microscopy, analyzing next generation sequencing (NGS), including nucleic acid-based testing (PCR, qPCR, NGS) for this study				0		$23,000
Contract Laboratory - Microbac	Professional or Technical Service Contract	Commercial laboratory testing for metagenomic and microbial analysis, DNA, direct microscopy, and NGS needed to document PFAS degradation				0		$55,000
Kent Armstrong - TerraStryke	Sub award	Primary investigator and researcher as a world expert in biofilm development and health, including quorum sensing and analyzing for microbes				0		$11,000
Bioamendment vendor - TerraStryke	Professional or Technical Service Contract	Bioamendment vendor to supply specialized, proprietary, micro- and macro-nutrients essential in biofilm development				0		$25,000
Contract Laboratory - Eurofins	Professional or Technical Service Contract	Commercial laboratory testing for general water quality analyses, PFAS and precursor analyses, and confirmation PFAS degradation. Commercial laboratories will provide analytical testing, laboratory reports to support data management, and data quality reports				0		$358,700
Contract Laboratory - PACE\AECOM	Professional or Technical Service Contract	Commercial laboratory testing for general water quality analyses, quorum sensing, proteins, and ultraviolet absorbance. Commercial laboratories will provide analytical testing, laboratory reports to support data management, and data quality reports				0		$41,000
Specialty Systems Integrators	Professional or Technical	Vendor of ART-PFAS technology for removing and isolating PFAS from contaminated groundwater,				0		$45,000

	Service Contract	down-well, necessary to collect and identify archaea, fungi, and bacteria						
							Sub Total	**$771,700**
Equipment, Tools, and Supplies								
	Equipment	Water sampling equipment, meters, pumps, data loggers, sampling supplies, PPE, and miscellaneous equipment	General equipment needs					$22,000
							Sub Total	**$22,000**
Capital Expenditures								
							Sub Total	**-**
Acquisitions and Stewardship								
							Sub Total	**-**
Travel In Minnesota								
	Miles/ Meals/ Lodging	Amount includes mileage for round trip from Bay West offices in the Twin Cities to laboratories and MN field sites (Metro Counties) for deployment of bioamendments and field scale tests. Day trips only.	Bay West staff and partners will regularly visit the field implementation sites to observe and assist with equipment installation. During field implementation, staff will be collecting samples and monitoring the ART-SAFF system					$7,500
							Sub Total	**$7,500**
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,					$2,500

			stakeholders, and a broad community interested in alternative PFAS management and destruction technologies					
							Sub Total	**$2,500**
Other Expenses								
							Sub Total	**-**
							Grand Total	**$1,699,000**

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: $1,699,000

This amount accurately reflects total project cost?

Yes

Attachments

Required Attachments

Visual Component

File: ff7da2fc-be5.pdf

Alternate Text for Visual Component

NA...

Financial Capacity

Title	File
Financial Capacity Note	e2df0325-029.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

Administrative Use

Does your project include restoration or acquisition of land rights?

No

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 proposal:

Kaitlin Larson