



# Environment and Natural Resources Trust Fund

M.L. 2026 Final Work Plan

## General Information

**ID Number:** 2026-486

**Staff Lead:** Lisa Bigaouette

**Date this document submitted to LCCMR:** May 22, 2026

**Project Title:** Mitigating Short-Chain Forever Chemicals Toward a PFAS-Free Minnesota

**Project Budget:** \$299,000

## Project Manager Information

**Name:** Peter Bruggeman

**Organization:** U of MN - College of Science and Engineering

**Office Telephone:** (612) 626-8391

**Email:** pbruggem@umn.edu

**Web Address:** <https://cse.umn.edu/>

## Project Reporting

**Reporting Schedule:** April 1 / October 1 of each year.

**Project Completion:** June 30, 2029

**Final Report Due Date:** August 14, 2029

## Legal Information

**Legal Citation:** M.L. 2026, Chp. 104, Sec. 2, Subd. 04q

**Appropriation Language:** \$299,000 the second year is from the trust fund to the Board of Regents of the University of Minnesota to demonstrate, optimize, and provide an energy cost analysis of an enhanced plasma reactor to remove resistant short-chain per- and polyfluoroalkyl substances (PFAS) from wastewater and other point sources.

**Appropriation End Date:** June 30, 2029

## Narrative

**Project Summary:** The project addresses the remediation of short-chain PFAS that are irreversibly accumulating in water streams and are largely inadequately removed by currently implemented PFAS mitigation processes.

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

Contamination of water streams with per- and polyfluoroalkyl substances (PFAS), a large group of synthetic chemicals used in household and industrial products, are a global concern. Several PFAS chemicals have been measured in Minnesota water streams at concentrations sufficient to harmfully impact human health and the ecological environment. PFAS are also referred to as “forever chemicals” because they are not biodegradable and accumulate in the environment over time. Many reported PFAS of concern by the US Environmental Protection Agency, such as PFOA and PFOS, are long-chain molecules with eight or more carbon atoms that can be effectively removed from water streams with adsorbent material or membrane filtration technologies. However, there is an emerging concern about short-chain PFAS that are recently found to be irreversibly accumulating in water streams at concentrations an order of magnitude higher than PFOA. An example is trifluoroacetic acid (TFA), a nearly indestructible molecule and finds its origin in, for example, PFAS containing pesticides. TFA is attributed with reproductive toxicity and is by some researchers identified as a “planetary boundary threat with potential irreversible disruptive impacts on vital earth system processes”. Currently implemented PFAS mitigation processes are largely inadequate in removing short-chain PFAS such as TFA.

**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.**

The proposed project aims to create a disruptive technology enabled by non-thermal plasma generated at the liquid surface that can efficiently treat both short and long-chain PFAS contaminated water streams and dissociate the PFAS into harmless byproducts. The surfactant nature of long-chain PFAS such as PFOA and PFOS causes the accumulation of PFAS at the liquid surface resulting in its effective decomposition by the plasma-generated reactive species at the liquid surface. This technology is also able to decompose short-chain PFAS but at significantly lower rates due to the slow transport of these compounds to the liquid surface. Nonetheless, by adding a (non-toxic) surfactant to the water to which the short-chain PFAS can attach, their decomposition can be as effective as long-chain PFAS. This was recently shown for PFBS (a PFAS with 4 carbon atoms). We will demonstrate this surfactant enhanced plasma decomposition for a broad range of short-chain PFAS and develop a scaled-up prototype reactor for energy efficient PFAS decomposition enabled by intimate contact between the plasma and the water. The vision is that the technology can be scaled up to treat PFAS contaminated water in wastewater treatment plants or at point emission sources.

**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?**

Several PFAS chemicals have been measured in Minnesota water streams at concentrations sufficient to harmfully impact human health and the ecological environment. Minnesota will, starting 2032, put limitations on the use of PFAS in pesticides (an important source of short-chain PFAS) and has also extensive monitoring of PFAS including short-chain PFAS compounds. The development of a new degradation capability for PFAS that also effectively tackles short-chain PFAS will enhance Minnesota’s natural water resources and contribute to a more sustainable and cost effective protection of the environment.

## 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: Demonstration of proposed surfactant enhanced plasma decomposition for a broad range of short-chained PFAS

**Activity Budget:** \$100,000

#### Activity Description:

We hypothesize that a broad range of short-chain PFAS can electrostatically bind to cationic surfactants and is transported with the surfactant to the plasma-liquid interface. Activity 1 consists of assessing the enhancement of short-chain PFAS (including TFA, PFBA and PFHxS) decomposition by plasma upon the addition of different non-toxic surfactants. We will use hexadecyltrimethylammonium bromide (CTAB) as a reference surfactant as CTAB has recently been shown to be effective in increasing PFBS decomposition by Mededovic and co-workers. These experiments will be performed in plasma-liquid film and plasma-liquid jet reactors available at the High Temperature and Plasma Laboratory, directed by the PI. These reactors have very well-defined fluid flow characteristics that allow us to quantitatively assess the impact of the addition of surfactants on the decomposition rates. The analysis of the decomposition will be performed by nuclear magnetic resonance (NMR). Plasma can in principle decompose PFAS into water, CO<sub>2</sub> and fluorine but often unmineralized fragments remain in solution. Hence, we will also assess major byproducts and determine the total amount of fluoride formed with as key goal to close the fluorine mass balance. The quantitative results obtained in these measurements will be leveraged to build a scaled-up reactor in Activity 2.

#### Activity Milestones:

| Description   | Approximate Completion Date |
|---|-----------------------------|
| Determination of enhancement of PFBS decomposition upon addition of a range of surfactants. | December 31, 2026           |
| Assessment of plasma-enabled decomposition of a broad range of short-chain PFAS             | June 30, 2027               |
| Assessment of the selected surfactant on a broad range of short-chain PFAS                  | June 30, 2027               |

### Activity 2: Development of scaled-up prototype reactor

**Activity Budget:** \$75,000

#### Activity Description:

The reactor used in activity 1 operates at electrical powers of the order of 1 W and typically treats less than half a liter of water per hour. Activity 2 consists of scaling up this technology to a prototype reactor with a capacity to treat 0.5 to 1 liter water per minute. The efficiency of the reactor will critically depend on the innovative design of a water handling system that enables the intimate contact between plasma and the wastewater. We will explore a variety of approaches enabled by innovative multiphase reactor design and informed by extensive research over the last decade at the High Temperature and Plasma Laboratory. Studies by the PIs suggest that treatment times, as short as 10 milliseconds, are sufficient for (local) PFAS decomposition. This very fast decomposition is promising for scale up and enhancing process efficiency. As the detection of PFAS can be challenging, the preliminary optimization of the reactor, which will involve a large parametric study, will be performed with dye such as Rhodamine B as its decomposition can be easily measured even in situ by absorption. The outcome of this work will be a prototype reactor that will be optimized for PFAS decomposition

#### Activity Milestones:

| Description   | Approximate Completion Date |
|---|-----------------------------|
| Scaled-up prototype reactor   | December 31, 2027           |
| Attending and presenting results at Minnesota Water Resource Conference | December 31, 2027           |

### Activity 3: Optimization of prototype reactor with preliminary economic analysis

**Activity Budget:** \$124,000

**Activity Description:**

Research in Activity 3 will be focused on assessing the efficacy of plasma-enabled decomposition of PFAS starting from the preliminary optimized reactor conditions determined in Activity 2. We will measure the decomposition kinetics of both long-chain (PFOA and PFOS) and short-chain (PFBS, TFA, PFBA and PFHxS) with and without additional surfactant selected in activity 1. The decomposition kinetics dependence on key operation parameters including liquid residence time and PFAS concentration will be assessed. These investigations will allow us to further optimize the prototype system and establish energy cost and decomposition efficiency of the proposed technology. We will evaluate the product composition of the optimized plasma treatment to confirm that no toxic decomposition products remain and further optimize the treatment conditions if required. To assess the viability of the proposed technology, we will perform a preliminary economic analysis of the process using the measured energy cost and decomposition efficiency obtained in this activity. As plasma requires electricity to be generated, the developed technology can fully exploit renewable energy sources such as wind or solar energy.

**Activity Milestones:**

| Description   | Approximate Completion Date |
|---|-----------------------------|
| Optimization of the reactor and determining decomposition kinetics to determine scaling laws for scale up | June 30, 2028               |
| Assessment of the decomposition of short-chain PFAS chemicals and their kinetics                          | March 31, 2029              |
| Preliminary economic analysis of the proposed process with scale up assessment                            | June 30, 2029               |
| Publication in peer reviewed journal describing highlights of project                                     | June 30, 2029               |

## Project Partners and Collaborators

| Name        | Organization            | Role  | Receiving Funds |
|-------------|-------------------------|---|-----------------|
| Aditya Bhan | University of Minnesota | Professor Bhan is a Distinguished McKnight University Professor in Chemical Engineering and Materials Science at the University of Minnesota. He is an expert in chemical process and reactor engineering and will lead the effort on reactor design and analytics. | 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.**

We anticipate to report results in peer-reviewed publications and presentations of researcher and PI at technical meetings. The Environment and Natural Resources Trust Fund will be acknowledged through use of the trust fund logo or attribution language on project print and electronic media, publications, signage, and other communications per the ENRTF Acknowledgment Guidelines.

## 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?**

A likely outcome at the conclusion of the project is the establishment of a start-up company focused on technology scale up and testing in partnership with stakeholders. This will enable us to pursue a variety of funding sources including private capital and grants from federal agencies such as the National Science Foundation and the Advanced Research Projects Agency-Energy (ARPA-e). The PI has levered initial previous support from LCCMR to land a \$2.8M ARPA-e project for developing and scaling up plasma-enabled iron ore reduction. The proposed work will similarly position us to attract future funding while developing an out-of-the-box technology.

## Other ENRTF Appropriations Awarded in the Last Six Years

| Name  | Appropriation                                   | Amount Awarded |
|---|---|----------------|
| Environment-Friendly Decarbonizing of Steel Production with Hydrogen Plasma | M.L. 2023, , Chp. 60, Art. 2, Sec. 2, Subd. 07e | \$739,000      |

## Budget Summary

| Category / Name                       | Subcategory or Type                  | Description  | Purpose  | Gen. Ineligible | % Benefits | # FTE | Classified Staff? | \$ Amount        |
|---------------------------------------|--------------------------------------|--|--|-----------------|------------|-------|-------------------|------------------|
| <b>Personnel</b>                      |                                      |  |  |                 |            |       |                   |                  |
| Peter Bruggeman                       |                                      | Principal Investigator   |  |                 | 26.79%     | 0.09  |                   | \$39,032         |
| Aditya Bhan                           |                                      | Co-PI  |  |                 | 26.79%     | 0.09  |                   | \$40,165         |
| Graduate Research Assistant           |                                      | Researcher/Engineer  |  |                 | 43.01%     | 1.5   |                   | \$186,760        |
|                                       |                                      |  |  |                 |            |       | <b>Sub Total</b>  | <b>\$265,957</b> |
| <b>Contracts and Services</b>         |                                      |  |  |                 |            |       |                   |                  |
| University of Minnesota               | Internal services or fees (uncommon) | PFAS analysis in NMR and analytics facility at the University of Minnesota   |  |                 |            | -     |                   | \$9,000          |
|                                       |                                      |  |  |                 |            |       | <b>Sub Total</b>  | <b>\$9,000</b>   |
| <b>Equipment, Tools, and Supplies</b> |                                      |  |  |                 |            |       |                   |                  |
|                                       | Tools and Supplies                   | Laboratory supplies (e.g., glassware), gases, chemical reagents and solvents | The laboratory supplies, gases, chemical reagents and solvents are essential to conduct the proposed work. |                 |            |       |                   | \$13,543         |
|                                       | Tools and Supplies                   | Parts to construct scaled up reactor   | Parts needed to construct scaled-up reactor as described in Activity 2                                     |                 |            |       |                   | \$10,000         |
|                                       |                                      |  |  |                 |            |       | <b>Sub Total</b>  | <b>\$23,543</b>  |
| <b>Capital Equipment</b>              |                                      |  |  |                 |            |       |                   |                  |
|                                       |                                      |  |  |                 |            |       | <b>Sub Total</b>  | -                |
| <b>Acquisitions and Stewardship</b>   |                                      |  |  |                 |            |       |                   |                  |
|                                       |                                      |  |  |                 |            |       | <b>Sub Total</b>  | -                |

|                                 |   |  |   |  |  |  |                    |                  |
|---------------------------------|---|--|---|--|--|--|--------------------|------------------|
| <b>Travel In Minnesota</b>      |   |  |   |  |  |  |                    |                  |
|                                 | Conference Registration<br>Miles/ Meals/<br>Lodging |  | Attending and presenting results at<br>Minnesota Water Resource<br>Conference |  |  |  |                    | \$500            |
|                                 |   |  |   |  |  |  | <b>Sub Total</b>   | <b>\$500</b>     |
| <b>Travel Outside Minnesota</b> |   |  |   |  |  |  |                    |                  |
|                                 |   |  |   |  |  |  | <b>Sub Total</b>   | -                |
| <b>Printing and Publication</b> |   |  |   |  |  |  |                    |                  |
|                                 |   |  |   |  |  |  | <b>Sub Total</b>   | -                |
| <b>Other Expenses</b>           |   |  |   |  |  |  |                    |                  |
|                                 |   |  |   |  |  |  | <b>Sub Total</b>   | -                |
|                                 |   |  |   |  |  |  | <b>Grand Total</b> | <b>\$299,000</b> |

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        |
|------------------|--|--|----------------------------|------------------|
| <b>State</b>     |  |  |                            |                  |
|                  |  |  | <b>State Sub Total</b>     | -                |
| <b>Non-State</b> |  |  |                            |                  |
| In-Kind          | Unrecovered F&A calculated at 54% MTDC | Support of ME facilities where research will be conducted. | Secured                    | \$131,413        |
|                  |  |  | <b>Non State Sub Total</b> | <b>\$131,413</b> |
|                  |  |  | <b>Funds Total</b>         | <b>\$131,413</b> |

**Total Project Cost: \$430,413**

**This amount accurately reflects total project cost?**

Yes

## Attachments

### Required Attachments

#### *Visual Component*

File: [4428f405-afd.pdf](#)

#### *Alternate Text for Visual Component*

Mitigating short-chain forever chemicals for a PFAS-Free Minnesota: visualization of problem to solve and proposed solution....

### Supplemental Attachments

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

| Title                                  | File                              |
|--|-----------------------------------|
| authorization letter                   | <a href="#">692691aa-ac2.pdf</a>  |
| Research_addendum_PFAS_Bruggeman_Final | <a href="#">04ca013d-190.docx</a> |

### Difference between Proposal and Work Plan

#### *Describe changes from Proposal to Work Plan Stage*

We shifted \$500 from consumables to pay for the conference registration fee (Minnesota Water Resources Conference). We intend to publish in a journal that does not charge page charges so no additional budget is needed for this.

## 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 UMN Policy on travel applies.

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

Yes

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

Yes

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

No

**Does your project include original, hypothesis-driven research?**

Yes

**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 project:**

Alex Sullivan

**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