

Giant Mine Oversight Board Research Program

TERRE-NET 2022 (Year 4 Q2) Progress Report

Year 4 Q2 Progress Report

Remediation Strategies for the Long-term Management of Arsenic-trioxide-bearing Roaster Wastes at the Giant Mine, Northwest Territories

This report was prepared by Toward Environmentally Responsible Resource Extraction Network (TERRE-NET) personnel to provide an update through to the end of Year 4 Q2 (to September 30, 2022) of the main aspects of the TERRE-NET-GMOB research project and to identify any research and budget challenges experienced to date. The research projects reviewed herein include four GMOB funded projects (1, 3, 5, 6) and three NSERC-Alliance funded projects (2, 4, 7):

Project 1: Examination of arsenic trioxide dust composition and solubility

Project 2: Stability of iron arsenate phases

Project 3: Sulfidation of As_2O_3 to low-solubility arsenic sulfide (As_2S_3)

Project 4: Biogenic sulfide precipitation

Project 5: Leaching behaviour and geochemical stability of vitrified arsenical glass

Project 6: Incorporation of As_2O_3 into cemented-paste backfill

Project 7: Implementation and application of Sb isotope systems

The overall goals of the projects proposed within Phase 1 are to: provide an enhanced understanding of the physical and geochemical properties of the roaster waste; and screen for potentially viable remediation alternatives that may warrant additional research (*e.g.*, long-term laboratory experiments, pilot-scale trials).

Expenditures to end of Year 4 Q2 are briefly summarized in the report (including the NSERC-Alliance funded portions for Year 2 of that program). Combined TERRE-NET-GMOB and NSERC-Alliance funded projects will provide direct stipend support for the training of 19 highly-qualified personnel (HQP), including three MSc students, three PhD students, three post-doctoral fellows (PDFs), and five undergraduate co-op students. HQP will be supported by the TERRE-NET co-investigators and administrative and technical staff, and academic collaborators.

Project 1: Examination of arsenic trioxide dust composition and solubility

Investigators:

Joyce McBeth (University of Regina)
Matthew Lindsay (University of Saskatchewan)
Heather Jamieson (Queen's University)
Valerie Schoepfer (University of Saskatchewan)

1.1 Research update

Considerable progress has been achieved on all aspects of this project over the past year. This research focuses on improving understanding of the composition of arsenic trioxide roaster waste (ATRW) samples obtained from Giant Mine, and on assessing the solubility of these ATRW samples under a range of environmental conditions. Our recent efforts have focused on completing research objectives originally proposed for this project.

The first phase of this project (Project 1a) focused on determining the chemical forms and mineral associations of arsenic (As) and antimony (Sb) in ATRW samples using conventional and advanced techniques. We found that arsenolite (i.e., arsenic trioxide) is the principal mineral host of both As and Sb, along with minor associations with As- and Sb-bearing sulfides and oxides. We also observed quantitative substitution of Sb for As in arsenolite, which was previously speculated to decrease the solubility of ATRW. A journal article describing the results of this project was recently submitted to GMOB for review and a revised version will soon be submitted for publication.

The second phase of this project (Project 1b) examines micrometer-scale spatial relationships between As, Sb, and other elements (e.g., iron, calcium, sulfur), in the ATRW samples using synchrotron microprobe techniques. We have observed co-occurrence of As and Sb consistent with previous results from Project 1a. However, we noted associations between As and Sb with iron and calcium, which is inconsistent with Sb-substituted arsenolite. These results point to additional arsenic and antimony associations that may influence ATRW solubility. We have submitted a proposal for additional synchrotron beamtime to complete analytical aspects of this project in early 2023. A journal article describing the results of Project 1b will be completed before the end of 2023.

The third phase of this project (Project 1c) employs laboratory experiments to examine ATRW solubility under varied environmental conditions. Over the past six months, we have completed 180 of 216 individual experiments to assess the influences of temperature, ionic strength (i.e., salinity), and initial solution pH on the dissolution of ATRW samples. Consistent with previous studies, we have observed that ATRW solubility (i) is limited compared to pure arsenolite and (ii) varies widely among different ATRW samples. We attribute these differences to variations in the chemical and mineralogical characteristics of the ATRW samples observed in Projects 1a and 1b. Experimental and analytical work associated with this phase of the project will be completed in early 2023. Data analysis and interpretation will continue through mid-2023 and a journal article describing the results of Project 1c will be completed by the end of 2023.

1.2 Deviations from research plan

Dr. Valerie Schoepfer transitioned into the full-time PDF role for this project in May 2022. Since that time, we have seen excellent progress on all aspects of this project and expect to complete all proposed objectives during 2023.

1.3 Budget update

The total proposed budget for research in Year 4 is \$0 plus additional funds of \$111,215 carried over from Year 3 which is available for total GMOB funds of \$111,215 in Year 4. This amount includes \$88,972 for direct research costs plus 25% overhead (\$22,243) charged by the University of Saskatchewan (Table 1). Additional funds from the NSERC Alliance program (Year 2 of that program) in the amount of \$7,050 are also available to the project in Year 4.

Table 1. Summary of budget proposed and actuals for Year 4.

	Year 4 GMOB Budget	Year 3 GMOB C'fwd	Total available from GMOB Year 4	Y4 Q1 GMOB Actuals Apr1-Jun30	Y4 Q2 GMOB Actuals Jul1-Sep30	Y4 Q3 GMOB Actuals Oct1-Dec31	Y4 Q4 GMOB Actuals Jan1-Mar31	Year 4 GMOB Actuals Total	GMOB unspent Year 4	Year 2 Alliance Budget	Year 1 Alliance C'fwd	Total available from Alliance Year 2	Alliance Expenses Year 2	Alliance unspent Year 2	Total unspent GMOB + Alliance
Salaries and Benefits	\$ -	\$ 17,923	\$ 17,923	\$ 14,905	\$ 16,745	\$ -	\$ -	\$ 31,650	\$ (13,727)	\$ -	\$ -	\$ -	\$ -	\$ -	\$ (13,727)
a) PhD students	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
b) Master's students	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
c) Undergraduate students	\$ -	\$ 12,163	\$ 12,163	\$ 4,914	\$ 7,416	\$ -	\$ -	\$ 12,331	\$ (168)	\$ -	\$ -	\$ -	\$ -	\$ -	\$ (168)
d) Postdoctoral fellows	\$ -	\$ (5,490)	\$ (5,490)	\$ 9,990	\$ 9,329	\$ -	\$ -	\$ 19,319	\$ (24,809)	\$ -	\$ -	\$ -	\$ -	\$ -	\$ (24,809)
e) Technical/Professional Assistants	\$ -	\$ 11,250	\$ 11,250	\$ -	\$ -	\$ -	\$ -	\$ -	\$ 11,250	\$ -	\$ -	\$ -	\$ -	\$ -	\$ 11,250
Equipment	\$ -	\$ 47,303	\$ 47,303	\$ 225	\$ 837	\$ -	\$ -	\$ 1,062	\$ 46,240	\$ 3,050	\$ 4,000	\$ 7,050	\$ -	\$ 7,050	\$ 53,290
a) Purchase or rental	\$ -	\$ 4,768	\$ 4,768	\$ -	\$ 837	\$ -	\$ -	\$ 837	\$ 3,931	\$ -	\$ 4,000	\$ 4,000	\$ -	\$ 4,000	\$ 7,931
b) Operation and maintenance costs	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
c) User Fees	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
d) Analytical Costs	\$ -	\$ 42,535	\$ 42,535	\$ 225	\$ -	\$ -	\$ -	\$ 225	\$ 42,310	\$ 3,050	\$ -	\$ 3,050	\$ -	\$ 3,050	\$ 45,360
Materials and Supplies	\$ -	\$ 2,600	\$ 2,600	\$ 771	\$ 357	\$ -	\$ -	\$ 1,128	\$ 1,472	\$ -	\$ -	\$ -	\$ -	\$ -	\$ 1,472
a) Laboratory supplies, reagents	\$ -	\$ 2,600	\$ 2,600	\$ 771	\$ 357	\$ -	\$ -	\$ 1,128	\$ 1,472	\$ -	\$ -	\$ -	\$ -	\$ -	\$ 1,472
b) Machining costs	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
Travel	\$ -	\$ 21,147	\$ 21,147	\$ -	\$ -	\$ -	\$ -	\$ -	\$ 21,147	\$ -	\$ -	\$ -	\$ -	\$ -	\$ 21,147
a) Conferences and Workshops	\$ -	\$ 17,147	\$ 17,147	\$ -	\$ -	\$ -	\$ -	\$ -	\$ 17,147	\$ -	\$ -	\$ -	\$ -	\$ -	\$ 17,147
b) Field Work	\$ -	\$ 4,000	\$ 4,000	\$ -	\$ -	\$ -	\$ -	\$ -	\$ 4,000	\$ -	\$ -	\$ -	\$ -	\$ -	\$ 4,000
Dissemination	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
a) Publication costs	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
b) Communication costs (teleconference)	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
Subtotal	\$ -	\$ 88,972	\$ 88,972	\$ 15,901	\$ 17,939	\$ -	\$ -	\$ 33,839	\$ 55,133	\$ 3,050	\$ 4,000	\$ 7,050	\$ -	\$ 7,050	\$ 62,183
University Overhead (25%)	\$ -	\$ 22,243	\$ 22,243	\$ 3,975	\$ 4,485	\$ -	\$ -	\$ 8,460	\$ 13,783	\$ -	\$ -	\$ -	\$ -	\$ -	\$ 13,783
Grand Total	\$ -	\$ 111,215	\$ 111,215	\$ 19,876	\$ 22,423	\$ -	\$ -	\$ 42,299	\$ 68,916	\$ 3,050	\$ 4,000	\$ 7,050	\$ -	\$ 7,050	\$ 75,966

1.4 Deviations from budget

Primary deviations from the budget include a higher level of PDF salary disbursements due to the delayed issuance of Alliance funds – this is anticipated to be corrected in Year 5. The end date for this project has been revised to align with the NSERC Alliance portion of the research program (May 14, 2026).

Project 2: Stability of iron arsenate phases

Investigators:

Joyce McBeth (University of Regina)

Matthew Lindsay (University of Saskatchewan)

Heather Jamieson (Queen's University)

Valerie Schoepfer (University of Saskatchewan)

2.1 Research update

Initial progress has been made on this project over the past three months. This project examines the long-term stability of iron-arsenate phases subjected to abiotic (Project 2a) and biological (Project 2b) redox reactions under anoxic environmental conditions. Our progress to date has focused on laboratory synthesis of key iron-arsenate phases including scorodite, ferric arsenate, and arsenical ferrihydrite commonly produced during mine water treatment. Initial characterization of the synthetic phases was completed in December 2022, and abiotic experiments will be initiated in early 2023.

2.2 Deviations from research plan

Delays in student recruitment has resulted in deferment of the start of the biological experiments associated with this project; recruitment is ongoing, and it is anticipated that this portion of the project will be completed by the end of the program (i.e., there are no plans to change the project objectives).

2.3 Budget update

The total proposed budget for research in Year 4 is \$68,889 (Table 2). This amount is fully funded by the NSERC Alliance program, which is in Year 2.

Table 2. Summary of budget proposed and actuals for Year 4.

	Year 4 GMOB Budget	Year 3 GMOB C'fwd	Total available from GMOB Year 4	Y4 Q1 GMOB Actuals Apr1-Jun30	Y4 Q2 GMOB Actuals Jul1-Sep30	Y4 Q3 GMOB Actuals Oct1-Dec31	Y4 Q4 GMOB Actuals Jan1-Mar31	Year 4 GMOB Actuals Total	GMOB unspent Year 4	Year 2 Alliance Budget	Year 1 Alliance C'fwd	Total available from Alliance Year 2	Alliance Expenses Year 2	Alliance unspent Year 2	Total unspent GMOB + Alliance
Salaries and Benefits	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ 50,346	\$ -	\$ 50,346	\$ -	\$ 50,346	\$ 50,346
a) PhD students			\$ -					\$ -	\$ -		\$ -	\$ -		\$ -	\$ -
b) Master's students			\$ -					\$ -	\$ -	\$ 20,000	\$ -	\$ 20,000		\$ 20,000	\$ 20,000
c) Undergraduate students			\$ -					\$ -	\$ -		\$ -	\$ -		\$ -	\$ -
d) Postdoctoral fellows			\$ -					\$ -	\$ -	\$ 26,596	\$ -	\$ 26,596		\$ 26,596	\$ 26,596
e) Technical/Professional Assistants			\$ -					\$ -	\$ -	\$ 3,750	\$ -	\$ 3,750		\$ 3,750	\$ 3,750
Equipment	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ 13,280	\$ -	\$ 13,280	\$ -	\$ 13,280	\$ 13,280
a) Purchase or rental			\$ -					\$ -	\$ -		\$ -	\$ -		\$ -	\$ -
b) Operation and maintenance costs			\$ -					\$ -	\$ -		\$ -	\$ -		\$ -	\$ -
c) User Fees			\$ -					\$ -	\$ -		\$ -	\$ -		\$ -	\$ -
d) Analytical Costs			\$ -					\$ -	\$ -	\$ 13,280	\$ -	\$ 13,280		\$ 13,280	\$ 13,280
Materials and Supplies	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ 3,763	\$ -	\$ 3,763	\$ -	\$ 3,763	\$ 3,763
a) Laboratory supplies, reagents			\$ -					\$ -	\$ -	\$ 3,763	\$ -	\$ 3,763		\$ 3,763	\$ 3,763
b) Machining costs			\$ -					\$ -	\$ -		\$ -	\$ -		\$ -	\$ -
Travel	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ 1,500	\$ -	\$ 1,500	\$ -	\$ 1,500	\$ 1,500
a) Conferences and Workshops			\$ -					\$ -	\$ -	\$ 1,500	\$ -	\$ 1,500		\$ 1,500	\$ 1,500
b) Field Work			\$ -					\$ -	\$ -		\$ -	\$ -		\$ -	\$ -
Dissemination	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
a) Publication costs			\$ -					\$ -	\$ -		\$ -	\$ -		\$ -	\$ -
b) Communication costs (teleconference)			\$ -					\$ -	\$ -		\$ -	\$ -		\$ -	\$ -
Subtotal	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ 68,889	\$ -	\$ 68,889	\$ -	\$ 68,889	\$ 68,889
University Overhead N/A	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
Grand Total	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ 68,889	\$ -	\$ 68,889	\$ -	\$ 68,889	\$ 68,889

2.4 Deviations from budget

No spending has occurred on this budget to date due to delays in the release of Alliance funds. The end date for this project has been revised to align with the NSERC Alliance portion of the research program (May 14, 2026).

Project 3: Sulfidation of As_2O_3 to form low-solubility As_2S_3

Investigator:

Tom Al (University of Ottawa)

3.1 Research update

The purpose of this project is to explore methods to transform As_2O_3 -rich dust to a low-solubility As_2S_3 material – a process called sulfidation. The As_2S_3 is stable in an anaerobic environment such as deep in the mine.

Transformation of As_2O_3 to a low-solubility As_2S_3 material requires dissolution, or extraction, of the As_2O_3 in the Giant Mine dust prior to sulfidation. The recent focus of the research program has been to determine the optimal temperature, pressure and time required to fully extract the As_2O_3 from the waste by dissolution in water. These extractions have been conducted up to 220 °C (at corresponding pressures) and times ranging from 0.25 to 10 minutes. Initially, dust from sample B233 was used because it contains the highest levels of antimony and iron impurities and is therefore thought to be the most difficult to dissolve. Results indicate that the majority of the As_2O_3 in this sample can be extracted in ten minutes at 180 °C. Confirmation of these results using powder X-ray diffraction on the residue is ongoing. Testing with dust samples B235 and B212 is underway but results to date indicate that dissolution of As_2O_3 is incomplete for extractions conducted up to 7 minutes at 200 °C. Testing continues to longer times and higher temperatures.

The Giant Mine dusts are mixtures of As_2O_3 and other minerals that originate from the ore feed to the roaster. These other minerals form an insoluble residue that remains after extraction of the As_2O_3 , and there is residual arsenic associated with this residue. Work is underway to characterize the mineralogical hosts of the residual arsenic in the extraction residues in order to understand their stability in different disposal settings.

3.2 Deviations from research plan

There are no deviations from the research plan since the last report.

3.3 Budget update

The total proposed budget for research in Year 4 is \$3,028 plus additional funds from Year 3 of \$8,564 for a total available funds of \$11,592 in Year 4. This amount includes \$8,280 for direct research costs plus 40% overhead (\$3,312) charged by the University of Ottawa (Table 3). Additional funds from the NSERC Alliance program (Year 2 of that program) in the amount of \$84,500 are also available to the project in Year 4.

Table 3. Summary of budget proposed and actuals for Year 4.

	Year 4 GMOB Budget	Year 3 GMOB C'fwd	Total available from GMOB Year 4	Y4 Q1 GMOB Actuals Apr1-Jun30	Y4 Q2 GMOB Actuals Jul1-Sep30	Y4 Q3 GMOB Actuals Oct1-Dec31	Y4 Q4 GMOB Actuals Jan1-Mar31	Year 4 GMOB Actuals Total	GMOB unspent Year 4	Year 2 Alliance Budget	Year 1 Alliance C'fwd	Total available from Alliance Year 2	Alliance Expenses Year 2	Alliance unspent Year 2	Total unspent GMOB + Alliance
Salaries and Benefits	\$ -	\$ (12,866)	\$ (12,866)	\$ 7,430	\$ 5,548	\$ -	\$ -	\$ 12,978	\$ (25,844)	\$ 39,000	\$ 21,500	\$ 60,500	\$ -	\$ 60,500	\$ 34,656
a) PhD students	\$ -	\$ -	\$ -		\$ -	\$ -	\$ -	\$ -	\$ -	\$ 17,500	\$ -	\$ 17,500	\$ -	\$ 17,500	\$ 17,500
b) Master's students	\$ -	\$ 29,375	\$ 29,375		\$ -	\$ -	\$ -	\$ 29,375	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ 29,375
c) Undergraduate students	\$ -	\$ (8,722)	\$ (8,722)		\$ -	\$ -	\$ -	\$ (8,722)	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ (8,722)
d) Postdoctoral fellows	\$ -	\$ -	\$ -		\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
e) Technical/Professional Assistants	\$ -	\$ (33,519)	\$ (33,519)	\$ 7,430	\$ 5,548	\$ -	\$ -	\$ 12,978	\$ (46,497)	\$ 21,500	\$ 21,500	\$ 43,000	\$ -	\$ 43,000	\$ (3,497)
Equipment	\$ -	\$ (14,989)	\$ (14,989)	\$ -	\$ -	\$ -	\$ -	\$ -	\$ (14,989)	\$ 9,000	\$ 9,000	\$ 18,000	\$ -	\$ 18,000	\$ 3,011
a) Purchase or rental	\$ -	\$ (26,374)	\$ (26,374)		\$ -	\$ -	\$ -	\$ -	\$ (26,374)	\$ -	\$ -	\$ -	\$ -	\$ -	\$ (26,374)
b) Operation and maintenance costs	\$ -	\$ -	\$ -		\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
c) User Fees	\$ -	\$ 7,500	\$ 7,500		\$ -	\$ -	\$ -	\$ 7,500	\$ -	\$ 4,000	\$ 4,000	\$ 8,000	\$ -	\$ 8,000	\$ 15,500
d) Analytical Costs	\$ -	\$ 3,885	\$ 3,885		\$ -	\$ -	\$ -	\$ 3,885	\$ -	\$ 5,000	\$ 5,000	\$ 10,000	\$ -	\$ 10,000	\$ 13,885
Materials and Supplies	\$ -	\$ 17,137	\$ 17,137	\$ -	\$ -	\$ -	\$ -	\$ -	\$ 17,137	\$ 3,000	\$ 3,000	\$ 6,000	\$ -	\$ 6,000	\$ 23,137
a) Laboratory supplies, reagents	\$ -	\$ 11,137	\$ 11,137		\$ -	\$ -	\$ -	\$ 11,137	\$ -	\$ 3,000	\$ 3,000	\$ 6,000	\$ -	\$ 6,000	\$ 17,137
b) Machining costs	\$ -	\$ 6,000	\$ 6,000		\$ -	\$ -	\$ -	\$ 6,000	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ 6,000
Travel	\$ 2,163	\$ 13,124	\$ 15,287	\$ -	\$ -	\$ -	\$ -	\$ -	\$ 15,287	\$ -	\$ -	\$ -	\$ -	\$ -	\$ 15,287
a) Conferences and Workshops	\$ 2,163	\$ 13,124	\$ 15,287		\$ -	\$ -	\$ -	\$ 15,287	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ 15,287
b) Field Work	\$ -	\$ -	\$ -		\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
Dissemination	\$ -	\$ 3,711	\$ 3,711	\$ 209	\$ -	\$ -	\$ -	\$ 209	\$ 3,502	\$ -	\$ -	\$ -	\$ -	\$ -	\$ 3,502
a) Publication costs	\$ -	\$ 4,000	\$ 4,000		\$ -	\$ -	\$ -	\$ 4,000	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ 4,000
b) Communication costs (teleconference)	\$ -	\$ (289)	\$ (289)	\$ 209				\$ 209	\$ (498)	\$ -	\$ -	\$ -	\$ -	\$ -	\$ (498)
Subtotal	\$ 2,163	\$ 6,117	\$ 8,280	\$ 7,639	\$ 5,548	\$ -	\$ -	\$ 13,187	\$ (4,907)	\$ 51,000	\$ 33,500	\$ 84,500	\$ -	\$ 84,500	\$ 79,593
University Overhead (40%)	\$ 865	\$ 2,447	\$ 3,312	\$ 3,056	\$ 2,219	\$ -	\$ -	\$ 5,275	\$ (1,963)	\$ -	\$ -	\$ -	\$ -	\$ -	\$ (1,963)
Grand Total	\$ 3,028	\$ 8,564	\$ 11,592	\$ 10,695	\$ 7,767	\$ -	\$ -	\$ 18,462	\$ (6,870)	\$ 51,000	\$ 33,500	\$ 84,500	\$ -	\$ 84,500	\$ 77,630

3.4 Deviations from budget

This project is currently slightly overspent in Year 4 (GMOB funds) due to delays in the release of NSERC Alliance funds. The end date for this project has been revised to align with the NSERC Alliance portion of the research program (May 14, 2026).

Project 4: Biogenic sulfide precipitation

Investigators:

David Blowes (University of Waterloo)

Carol Ptacek (University of Waterloo)

4.1 Research update

The overall goal of this project is to evaluate the efficacy of biologically-mediated sulfate reduction and precipitation of As-bearing sulfides (e.g., FeAsS) using conventional and readily available liquid- and solid-phase industrial by-products as electron donors or carbon sources.

An MSc student (Hailey Jack, University of Waterloo) has been recruited and started on the project in September 2022. Work on the project has begun with a background literature review – the project is expected to proceed without delay.

4.2 Deviations from research plan

The start of this project has been deferred due to a delay in student recruitment.

4.3 Budget update

The total proposed budget for research in Year 4 is \$64,000 plus additional funds carried over from Year 3 of \$64,000 for total available funds of \$128,000 in Year 4 (Table 4). This amount is fully funded by the NSERC Alliance program, which is in Year 2.

Table 4. Summary of budget proposed and actuals for Year 4.

	Year 4 GMOB Budget	Year 3 GMOB C'fwd	Total available from GMOB Year 4	Y4 Q1 GMOB Actuals Apr1-Jun30	Y4 Q2 GMOB Actuals Jul1-Sep30	Y4 Q3 GMOB Actuals Oct1-Dec31	Y4 Q4 GMOB Actuals Jan1-Mar31	Year 4 GMOB Actuals Total	GMOB unspent Year 4	Year 2 Alliance Budget	Year 1 Alliance C'fwd	Total available from Alliance Year 2	Alliance Expenses Year 2	Alliance unspent Year 2	Total unspent GMOB + Alliance
Salaries and Benefits	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ 40,000	\$ 40,000	\$ 80,000	\$ -	\$ 80,000	\$ 80,000
a) PhD students	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ 20,000	\$ 20,000	\$ 40,000	\$ -	\$ 40,000	\$ 40,000
b) Master's students	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
c) Undergraduate students	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
d) Postdoctoral fellows	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
e) Technical/Professional Assistants	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ 20,000	\$ 20,000	\$ 40,000	\$ -	\$ 40,000	\$ 40,000
Equipment	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ 19,000	\$ 19,000	\$ 38,000	\$ -	\$ 38,000	\$ 38,000
a) Purchase or rental	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ 4,000	\$ 9,000	\$ 13,000	\$ -	\$ 13,000	\$ 13,000
b) Operation and maintenance costs	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
c) User Fees	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
d) Analytical Costs	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ 15,000	\$ 10,000	\$ 25,000	\$ -	\$ 25,000	\$ 25,000
Materials and Supplies	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ 2,000	\$ 5,000	\$ 7,000	\$ -	\$ 7,000	\$ 7,000
a) Laboratory supplies, reagents	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ 2,000	\$ 5,000	\$ 7,000	\$ -	\$ 7,000	\$ 7,000
b) Machining costs	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
Travel	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ 3,000	\$ -	\$ 3,000	\$ -	\$ 3,000	\$ 3,000
a) Conferences and Workshops	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ 2,000	\$ -	\$ 2,000	\$ -	\$ 2,000	\$ 2,000
b) Field Work	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ 1,000	\$ -	\$ 1,000	\$ -	\$ 1,000	\$ 1,000
Dissemination	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
a) Publication costs	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
b) Communication costs (teleconference)	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
Subtotal	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ 64,000	\$ 64,000	\$ 128,000	\$ -	\$ 128,000	\$ 128,000
University Overhead N/A	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
Grand Total	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ 64,000	\$ 64,000	\$ 128,000	\$ -	\$ 128,000	\$ 128,000

4.4 Deviations from budget

Underspending has occurred on this project due to a delay in student recruitment. It is expected that the spending will occur in Year 4.

Project 5: Geochemical and leaching characterization of vitrified arsenical glass

Investigators:

David Blowes (University of Waterloo)

Carol Ptacek (University of Waterloo)

5.1 Research update

The overall goals of this project include: 1) evaluate the physical and chemical characteristics of vitrified ATRW; 2) determine the leachability of the vitrified products under geochemically relevant conditions using selective extractions; and 3) evaluate the viability of long-term stability of vitrified ATRW under saturated-flow conditions.

Three vitrified products (GMOB-G5, GMOB-G10, and GMOB-G15) received from Dundee Sustainable Technologies were split and crushed. Both the uncrushed and crushed materials were then split for solid-phase characterization, non-sequential extractions and column experiments. The vitrified products have been characterized using pair distribution function, X-ray diffraction, Fourier-transform infrared spectroscopy, optical microscope, scanning electron microscope/energy dispersive spectroscopy, and X-ray absorption spectroscopy. Experimental work for the selective extraction study has been completed and a journal article related to characterizing the vitrified materials and leachability under different environmentally relevant conditions is in preparation.

Subsamples of uncrushed vitrified material were packed into two sets of acrylic columns. One set of the columns was conducted under anoxic conditions using synthetic Giant Mine groundwater as influent, and the second set was conducted under aerobic conditions with Great Slave Lake water, collected near Yellowknife, NT, as influent. The columns were conducted with a target flow rate of 0.5 pore volumes per day. Effluent from the columns was collected every two pore volumes for the first 10 pore volumes and every five pore volumes until 80 pore volumes; effluent was collected every 10 pore volumes thereafter. Aqueous and solid sample profiles along each column length were collected at selected intervals over the duration of the experiments. Aqueous samples were collected to measure pH, Eh and alkalinity (as $\text{CaCO}_3 \text{ mg L}^{-1}$) and for determination of concentrations of anions, trace metals and major cations. Collected solid samples were kept frozen for future analysis. One journal article related to the column experiments is currently in preparation.

5.2 Deviations from research plan

Additional characterization and chemical extractions were added to the research plan. Pair distribution function analysis provides structural information for amorphous materials. Grain-size analysis shows impacts of crushing on particle size distributions, and the shifts in particle-size distributions may further illustrate changes in reactivity and leachability of the vitrified products. Extractions targeting weakly-sorbed phases were modified following the procedure described by Wenzel et al. (2001). Extractions targeting residual phases were modified from the EPA method 3052 (EPA, 1996) to evaluate the leachability of the vitrified products under strong acidic conditions. These deviations provide a more comprehensive understanding of the vitrified products.

Wenzel, W. W., Kirchbaumer, N., Prohaska, T., Stingeder, G., Lombi, E., Adriano, D. C. (2001). Arsenic fractionation in soils using an improved sequential extraction procedure. *Analytica Chimica Acta*, 436(2), 309–323.

US EPA, 1996. Method 3052: Microwave assisted acid digestion of siliceous and organically based matrices.

5.3 Budget update

The total proposed budget for research in Year 4 is \$96,498 plus additional funds carried over from Year 3 of \$48,853 for total available funds of \$145,351 in Year 4. This amount includes \$111,809 for direct research costs plus 30% overhead (\$33,543) charged by the University of Waterloo (Table 5).

Table 5. Summary of budget proposed and actuals for Year 4.

	Year 4 GMOB Budget	Year 3 GMOB C'fwd	Total available from GMOB Year 4	Y4 Q1 GMOB Actuals Apr1-Jun30	Y4 Q2 GMOB Actuals Jul1-Sep30	Y4 Q3 GMOB Actuals Oct1-Dec31	Y4 Q4 GMOB Actuals Jan1-Mar31	Year 4 GMOB Actuals Total	GMOB unspent Year 4	Year 2 Alliance Budget	Year 1 Alliance C'fwd	Total available from Alliance Year 2	Alliance Expenses Year 2	Alliance unspent Year 2	Total unspent GMOB + Alliance
Salaries and Benefits	\$ 45,000	\$ 14,947	\$ 59,947	\$ 16,163	\$ 16,159	\$ -	\$ -	\$ 32,322	\$ 27,625	\$ -	\$ -	\$ -	\$ -	\$ -	\$ 27,625
a) PhD students	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
b) Master's students	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
c) Undergraduate students	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
d) Postdoctoral fellows	\$ 40,000	\$ 7,382	\$ 47,382	\$ 16,163	\$ 16,159	\$ -	\$ -	\$ 32,322	\$ 15,060	\$ -	\$ -	\$ -	\$ -	\$ -	\$ 15,060
e) Technical/Professional Assistants	\$ 5,000	\$ 7,566	\$ 12,566	\$ -	\$ -	\$ -	\$ -	\$ -	\$ 12,566	\$ -	\$ -	\$ -	\$ -	\$ -	\$ 12,566
Equipment	\$ 18,000	\$ 26,000	\$ 44,000	\$ 515	\$ 223	\$ -	\$ -	\$ 738	\$ 43,262	\$ -	\$ -	\$ -	\$ -	\$ -	\$ 43,262
a) Purchase or rental	\$ 2,000	\$ 4,000	\$ 6,000	\$ 255	\$ 223	\$ -	\$ -	\$ 478	\$ 5,522	\$ -	\$ -	\$ -	\$ -	\$ -	\$ 5,522
b) Operation and maintenance costs	\$ 500	\$ 1,000	\$ 1,500	\$ -	\$ -	\$ -	\$ -	\$ -	\$ 1,500	\$ -	\$ -	\$ -	\$ -	\$ -	\$ 1,500
c) User Fees	\$ 500	\$ 1,000	\$ 1,500	\$ -	\$ -	\$ -	\$ -	\$ -	\$ 1,500	\$ -	\$ -	\$ -	\$ -	\$ -	\$ 1,500
d) Analytical Costs	\$ 15,000	\$ 20,000	\$ 35,000	\$ 260	\$ -	\$ -	\$ -	\$ 260	\$ 34,740	\$ -	\$ -	\$ -	\$ -	\$ -	\$ 34,740
Materials and Supplies	\$ 5,000	\$ (11,326)	\$ (6,326)	\$ 1,124	\$ 9,142	\$ -	\$ -	\$ 10,266	\$ (16,592)	\$ -	\$ -	\$ -	\$ -	\$ -	\$ (16,592)
a) Laboratory supplies, reagents	\$ 5,000	\$ (11,326)	\$ (6,326)	\$ 1,124	\$ 9,142	\$ -	\$ -	\$ 10,266	\$ (16,592)	\$ -	\$ -	\$ -	\$ -	\$ -	\$ (16,592)
b) Machining costs	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
Travel	\$ 5,729	\$ 7,458	\$ 13,187	\$ -	\$ -	\$ -	\$ -	\$ -	\$ 13,187	\$ -	\$ -	\$ -	\$ -	\$ -	\$ 13,187
a) Conferences and Workshops	\$ 4,229	\$ 5,958	\$ 10,187	\$ -	\$ -	\$ -	\$ -	\$ -	\$ 10,187	\$ -	\$ -	\$ -	\$ -	\$ -	\$ 10,187
b) Field Work	\$ 1,500	\$ 1,500	\$ 3,000	\$ -	\$ -	\$ -	\$ -	\$ -	\$ 3,000	\$ -	\$ -	\$ -	\$ -	\$ -	\$ 3,000
Dissemination	\$ 500	\$ 500	\$ 1,000	\$ -	\$ -	\$ -	\$ -	\$ -	\$ 1,000	\$ -	\$ -	\$ -	\$ -	\$ -	\$ 1,000
a) Publication costs	\$ 500	\$ 500	\$ 1,000	\$ -	\$ -	\$ -	\$ -	\$ -	\$ 1,000	\$ -	\$ -	\$ -	\$ -	\$ -	\$ 1,000
b) Communication costs (teleconference)	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
Subtotal	\$ 74,229	\$ 37,580	\$ 111,809	\$ 17,802	\$ 25,524	\$ -	\$ -	\$ 43,327	\$ 68,482	\$ -	\$ -	\$ -	\$ -	\$ -	\$ 68,482
University Overhead (30%)	\$ 22,269	\$ 11,274	\$ 33,543	\$ 5,341	\$ 7,657	\$ -	\$ -	\$ 12,998	\$ 20,545	\$ -	\$ -	\$ -	\$ -	\$ -	\$ 20,545
Grand Total	\$ 96,498	\$ 48,853	\$ 145,351	\$ 23,143	\$ 33,182	\$ -	\$ -	\$ 56,325	\$ 89,026	\$ -	\$ -	\$ -	\$ -	\$ -	\$ 89,026

5.4 Deviations from budget

This project started later than anticipated due to delays in receiving vitrified material from Dundee; the project was started in March 2021. The end date for this project has been revised to align with the NSERC Alliance portion of the research program (May 14, 2026).

Project 6: Stabilization of As_2O_3 dust in cemented paste backfill

Investigators:

Isabelle Demers (UQAT)

Nick Beier (University of Alberta)

Mostafa Benzaazoua (UQAT; collaborator)

6.1 Research update

Cemented paste backfill (CPB) samples made with an inert material (silica), pure As_2O_3 and binders, as well as CPB samples made with Giant Mine tailings, ATRW and binders, were tested for strength after 7 days and 28 days of curing. A significant reduction in strength acquisition was observed in samples containing As_2O_3 , indicating lack of cement hydration and possibly minimal As stabilisation. Several binders and As_2O_3 contents were tested to select the most promising combinations for further testing. A series of tests were performed based on the central composite design of experiment procedure and identified binder and solid contents as the significant parameters affecting the strength of the CPB samples with Giant Mine tailings and ATRW. Unconfirmed compressive strength (UCS) over 400 kPa were obtained with 5% and more of general use (GU) cement as binder and over 74% solid content, while UCS over 200 kPa were achieved with a 50/50 mixture of GU cement and lime kiln dust for similar binder and solid contents. The environmental behaviour of the CPB is currently under investigation. Tank leaching tests are ongoing to assess the chemical stability of the CPB samples, and more specifically the As leaching rates.

Dissemination of this research is expected in 2023, with a conference presentation and article at the 25th International Conference on Paste, Thickened and Filtered Tailings in April and one to two journal articles to follow. The University of Alberta components of this project are scheduled to start in 2024.

6.2 Deviations from research plan

There are no deviations from the research plan since the last progress report.

6.3 Budget update

The total proposed budget for research in Year 4 is \$3,979 plus additional funds carried over from Year 3 of \$67,128 for total available funds of \$71,107 in Year 4. This amount includes \$61,832 for direct research costs plus 15% overhead (\$9,275) charged by UQAT (Table 6). Additional funds from the NSERC Alliance program (Year 2 of that program) in the amount of \$32,500 are also available to the project in Year 4.

Table 6. Summary of budget proposed and actuals for Year 4.

	Year 4 GMOB Budget	Year 3 GMOB C'fwd	Total available from GMOB Year 4	Y4 Q1 GMOB Actuals Apr1-Jun30	Y4 Q2 GMOB Actuals Jul1-Sep30	Y4 Q3 GMOB Actuals Oct1-Dec31	Y4 Q4 GMOB Actuals Jan1-Mar31	Year 4 GMOB Actuals Total	GMOB unspent Year 4	Year 2 Alliance Budget	Year 1 Alliance C'fwd	Total available from Alliance Year 2	Alliance Expenses Year 2	Alliance unspent Year 2	Total unspent GMOB + Alliance
Salaries and Benefits	\$ -	\$ 25,040	\$ 25,040	\$ 17,733	\$ 8,333	\$ -	\$ -	\$ 26,066	\$ (1,026)	\$ 13,000	\$ -	\$ 13,000	\$ -	\$ 13,000	\$ 11,974
a) PhD students	\$ -	\$ 20,140	\$ 20,140	\$ 8,333	\$ 8,333	\$ -	\$ -	\$ 16,666	\$ 3,474	\$ -	\$ -	\$ -	\$ -	\$ -	\$ 3,474
b) Master's students	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
c) Undergraduate students	\$ -	\$ -	\$ -	\$ 8,400	\$ -	\$ -	\$ -	\$ 8,400	\$ (8,400)	\$ 6,000	\$ -	\$ 6,000	\$ -	\$ 6,000	\$ (2,400)
d) Postdoctoral fellows	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
e) Technical/Professional Assistants	\$ -	\$ 4,900	\$ 4,900	\$ 1,000	\$ -	\$ -	\$ -	\$ 1,000	\$ 3,900	\$ 7,000	\$ -	\$ 7,000	\$ -	\$ 7,000	\$ 10,900
Equipment	\$ -	\$ 20,010	\$ 20,010	\$ 5,708	\$ 23	\$ -	\$ -	\$ 5,731	\$ 14,279	\$ 10,000	\$ 3,500	\$ 13,500	\$ -	\$ 13,500	\$ 27,779
a) Purchase or rental	\$ -	\$ (386)	\$ (386)	\$ 144	\$ 23	\$ -	\$ -	\$ 168	\$ (554)	\$ 2,000	\$ 2,000	\$ -	\$ -	\$ 2,000	\$ 1,446
b) Operation and maintenance costs	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
c) User Fees	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
d) Analytical Costs	\$ -	\$ 20,396	\$ 20,396	\$ 5,564	\$ -	\$ -	\$ -	\$ 5,564	\$ 14,832	\$ 10,000	\$ 1,500	\$ 11,500	\$ -	\$ 11,500	\$ 26,332
Materials and Supplies	\$ -	\$ (1,307)	\$ (1,307)	\$ -	\$ -	\$ -	\$ -	\$ -	\$ (1,307)	\$ 3,000	\$ 3,000	\$ 6,000	\$ -	\$ 6,000	\$ 4,693
a) Laboratory supplies, reagents	\$ -	\$ (1,307)	\$ (1,307)	\$ -	\$ -	\$ -	\$ -	\$ -	\$ (1,307)	\$ 3,000	\$ 3,000	\$ 6,000	\$ -	\$ 6,000	\$ 4,693
b) Machining costs	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
Travel	\$ 3,460	\$ 13,679	\$ 17,139	\$ 1,742	\$ -	\$ -	\$ -	\$ 1,742	\$ 15,397	\$ -	\$ -	\$ -	\$ -	\$ -	\$ 15,397
a) Conferences and Workshops	\$ 3,460	\$ 13,679	\$ 17,139	\$ 1,742	\$ -	\$ -	\$ -	\$ 1,742	\$ 15,397	\$ -	\$ -	\$ -	\$ -	\$ -	\$ 15,397
b) Field Work	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
Dissemination	\$ -	\$ 950	\$ 950	\$ -	\$ -	\$ -	\$ -	\$ -	\$ 950	\$ -	\$ -	\$ -	\$ -	\$ -	\$ 950
a) Publication costs	\$ -	\$ 950	\$ 950	\$ -	\$ -	\$ -	\$ -	\$ -	\$ 950	\$ -	\$ -	\$ -	\$ -	\$ -	\$ 950
b) Communication costs (teleconference)	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
Subtotal	\$ 3,460	\$ 58,372	\$ 61,832	\$ 25,183	\$ 8,356	\$ -	\$ -	\$ 33,540	\$ 28,292	\$ 26,000	\$ 6,500	\$ 32,500	\$ -	\$ 32,500	\$ 60,792
University Overhead (15%)	\$ 519	\$ 8,756	\$ 9,275	\$ 3,778	\$ 1,253	\$ -	\$ -	\$ 5,031	\$ 4,244	\$ -	\$ -	\$ -	\$ -	\$ -	\$ 4,244
Grand Total	\$ 3,979	\$ 67,128	\$ 71,107	\$ 28,961	\$ 9,610	\$ -	\$ -	\$ 38,571	\$ 32,536	\$ 26,000	\$ 6,500	\$ 32,500	\$ -	\$ 32,500	\$ 65,036

6.4 Deviations from budget

Underspending has occurred on this budget to date due to delays in the release of Alliance funds. The end date for this project has been revised to align with the NSERC Alliance portion of the research program (May 14, 2026).

Project 7: Implementation and application of Sb isotope systems

Investigators:

David Blowes (University of Waterloo)

Carol Ptacek (University of Waterloo)

7.1 Research update

The goal of this project is to assess whether antimony (Sb) stable isotopes can be used to: characterize sources of As and Sb across Giant Mine and the surrounding environment; and monitor reactions controlling As and Sb in ATRW. The stated objectives are: i) Implementation of the Sb isotope method using multicollector inductively coupled plasma mass spectrometry (MC-ICP-MS); ii) Application to mine site waters (surface/ground/tailings/effluent) and solids (ATRW); and iii) Application to laboratory experimental systems (stabilization products from Projects 2-6).

The use of Sb isotopes for environmental applications is an emerging field, with active research in this area starting in ~2020. As a result, the few papers published in the scientific literature to-date have mostly focused on analytical method development. Our method is being developed on the foundation of these papers (e.g., Ferrari et al., 2021), with additional optimizations for the challenges posed by Giant Mine-impacted samples (e.g., elevated and varied concentrations of As, Fe, and Sb). Method development will be ongoing for the entire project as new types of samples need to be analyzed. Current work is focused on optimizing Sb purification procedures using chemical reagents, standards, and synthetic mine waters to maximize Sb recovery. Purification and Sb isotope analysis of field-collected Giant Mine samples will begin in early 2023.

Small-scale field sampling of Giant Mine surface water and tailings/effluent occurred in September 2022. Samples were collected from nine existing CIRNAC Giant Mine Remediation Project (GMRP) surface water monitoring stations. Conventional water chemistry analyses of these samples were completed in November 2022: cations and trace metals (ICP-OES & ICP-MS), anions (IC), dissolved organic carbon (DOC), and water isotopes (^2H and ^{18}O). Sb isotope analysis of these samples will begin in early 2023. Planning is currently underway for a second field sampling campaign to occur in 2023 of additional GMRP surface water monitoring stations, as well as groundwater monitoring stations. Subsamples of ATRW for Sb isotope analysis will be collected from the other research groups actively working with ATRW in early 2023 (Projects 1, 3, 6).

Influent and effluent column water samples for Sb isotope analysis are currently being collected from Project 5 stabilization experiments, with plans to collect samples from Project 4 stabilization experiments once they begin in 2023. Discussions are also underway to acquire input and output samples for Sb isotope analysis from the experiments of the other ATRW stabilization research groups (Projects 2, 3, 6).

Ferrari, C., Resongles, E., Freydier, R., and C. Casiot. (2021). A single-step purification method for the precise determination of the antimony isotopic composition of environmental, geological and biological samples by HG-MC-ICP-MS. *Journal of Analytical Atomic Spectrometry* 36, 776–785.

7.2 Deviations from research plan

There have been extended analytical delays throughout 2022 due to multiple instances of COVID-19 related maintenance and repairs on critical instruments (X-Series & Element ICP-MS; Neptune MC-ICP-MS) which have affected trace metal analysis (for optimizing purification procedures) and isotope analysis (of field samples).

7.3 Budget update

The total proposed budget for research in Year 4 is \$91,257 plus additional funds carried over from Year 3 of \$23,425 for total available funds of \$114,682 in Year 4 (Table 7). This amount is fully funded by the NSERC Alliance program, which is in Year 2.

Table 7. Summary of budget proposed and actuals for Year 4.

	Year 4 GMOB Budget	Year 3 GMOB C'fwd	Total available from GMOB Year 4	Y4 Q1 GMOB Actuals Apr1-Jun30	Y4 Q2 GMOB Actuals Jul1-Sep30	Y4 Q3 GMOB Actuals Oct1-Dec31	Y4 Q4 GMOB Actuals Jan1-Mar31	Year 4 GMOB Actuals Total	GMOB unspent Year 4	Year 2 Alliance Budget	Year 1 Alliance C'fwd	Total available from Alliance Year 2	Alliance Expenses Year 2	Alliance unspent Year 2	Total unspent GMOB + Alliance
Salaries and Benefits	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ 64,500	\$ -	\$ 64,500	\$ 1,666	\$ 62,834	\$ 62,834
a) PhD students	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ 1,666	\$ (1,666)	\$ (1,666)
b) Master's students	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
c) Undergraduate students	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
d) Postdoctoral fellows	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ 64,500	\$ -	\$ 64,500	\$ -	\$ 64,500	\$ 64,500
e) Technical/Professional Assistants	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
Equipment	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ 15,000	\$ 14,604	\$ 29,604	\$ -	\$ 29,604	\$ 29,604
a) Purchase or rental	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ 10,000	\$ 10,000	\$ 20,000	\$ -	\$ 20,000	\$ 20,000
b) Operation and maintenance costs	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
c) User Fees	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
d) Analytical Costs	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ 5,000	\$ 4,604	\$ 9,604	\$ -	\$ 9,604	\$ 9,604
Materials and Supplies	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ 7,000	\$ 4,480	\$ 11,480	\$ 2,757	\$ 8,723	\$ 8,723
a) Laboratory supplies, reagents	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ 7,000	\$ 4,480	\$ 11,480	\$ 2,757	\$ 8,723	\$ 8,723
b) Machining costs	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
Travel	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ 4,757	\$ 4,341	\$ 9,098	\$ -	\$ 9,098	\$ 9,098
a) Conferences and Workshops	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ 2,000	\$ 4,341	\$ 6,341	\$ -	\$ 6,341	\$ 6,341
b) Field Work	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ 2,757	\$ -	\$ 2,757	\$ -	\$ 2,757	\$ 2,757
Dissemination	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
a) Publication costs	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
b) Communication costs (teleconference)	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
Subtotal	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ 91,257	\$ 23,425	\$ 114,682	\$ 4,423	\$ 110,259	\$ 110,259
University Overhead N/A	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
Grand Total	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ 91,257	\$ 23,425	\$ 114,682	\$ 4,423	\$ 110,259	\$ 110,259

7.4 Deviations from budget

This project is underspent to date due to delays in recruiting HQP; the PhD student currently working on the project is funded from other sources.

Administration

Investigators:

David Blowes (University of Waterloo)

Carol Ptacek (University of Waterloo)

8.1 Budget update

The total proposed budget for administration in Year 4 is \$53,301 plus additional funds carried over from Year 3 of \$92,430 for total available funds of \$145,731 in Year 4. This amount includes \$112,101 for direct administration costs plus 30% overhead (\$33,630) charged by the University of Waterloo (Table 8). Additional budget for administration from the NSERC Alliance program (Year 2) brings the total available Year 4 funds for administration to \$202,242 (including overhead).

Table 8. Summary of budget proposed and actuals for Year 4.

	Year 4 GMOB Budget	Year 3 GMOB C'wd	Total available from GMOB Year 4	Y4 Q1 GMOB Actuals Apr1-Jun30	Y4 Q2 GMOB Actuals Jul1-Sep30	Y4 Q3 GMOB Actuals Oct1-Dec31	Y4 Q4 GMOB Actuals Jan1-Mar31	Year 4 GMOB Actuals Total	GMOB unspent Year 4	Year 2 Alliance Budget	Year 1 Alliance C'wd	Total available from Alliance Year 2	Alliance Expenses Year 2	Alliance unspent Year 2	Total unspent GMOB + Alliance
Salaries and Benefits	\$ 33,949	\$ 57,492	\$ 91,441	\$ 7,676	\$ 13,099	\$ -	\$ -	\$ 20,775	\$ 70,666	\$ -	\$ -	\$ -	\$ 5,685	\$ (5,685)	\$ 64,981
a) PhD students	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
b) Master's students	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
c) Undergraduate students	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ 5,685	\$ (5,685)	\$ (5,685)
d) Postdoctoral fellows	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
e) Technical/Professional Assistants	\$ 33,949	\$ 57,492	\$ 91,441	\$ 7,676	\$ 13,099	\$ -	\$ -	\$ 20,775	\$ 70,666	\$ -	\$ -	\$ -	\$ -	\$ -	\$ 70,666
Equipment	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ 86,203	\$ 86,203	\$ -	\$ 86,203	\$ 86,203
a) Purchase or rental	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ 86,203	\$ 86,203	\$ -	\$ 86,203	\$ 86,203
b) Operation and maintenance costs	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
c) User Fees	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
d) Analytical Costs	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
Materials and Supplies	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
a) Laboratory supplies, reagents	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
b) Machining costs	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
Travel	\$ 6,052	\$ 11,608	\$ 17,660	\$ -	\$ -	\$ -	\$ -	\$ -	\$ 17,660	\$ 1,000	\$ -	\$ 1,000	\$ -	\$ 1,000	\$ 18,660
a) Conferences and Workshops	\$ 6,052	\$ 11,976	\$ 18,028	\$ -	\$ -	\$ -	\$ -	\$ -	\$ 18,028	\$ -	\$ -	\$ -	\$ -	\$ -	\$ 18,028
b) Field Work	\$ -	\$ (368)	\$ (368)	\$ -	\$ -	\$ -	\$ -	\$ -	\$ (368)	\$ 1,000	\$ -	\$ 1,000	\$ -	\$ 1,000	\$ 632
Dissemination	\$ 1,000	\$ 2,000	\$ 3,000	\$ -	\$ -	\$ -	\$ -	\$ -	\$ 3,000	\$ 2,000	\$ -	\$ 2,000	\$ -	\$ 2,000	\$ 5,000
a) Publication costs	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ 2,000	\$ -	\$ 2,000	\$ -	\$ 2,000	\$ 5,000
b) Communication costs (teleconference)	\$ 1,000	\$ 2,000	\$ 3,000	\$ -	\$ -	\$ -	\$ -	\$ -	\$ 3,000	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
Subtotal	\$ 41,001	\$ 71,100	\$ 112,101	\$ 7,676	\$ 13,099	\$ -	\$ -	\$ 20,775	\$ 91,326	\$ 3,000	\$ 86,203	\$ 89,203	\$ 5,685	\$ 83,518	\$ 174,844
University Overhead (30%)	\$ 12,300	\$ 21,330	\$ 33,630	\$ 2,303	\$ 3,930	\$ -	\$ -	\$ 6,232	\$ 27,398	\$ -	\$ -	\$ -	\$ -	\$ -	\$ 27,398
Grand Total	\$ 53,301	\$ 92,430	\$ 145,731	\$ 9,979	\$ 17,028	\$ -	\$ -	\$ 27,007	\$ 118,724	\$ 3,000	\$ 86,203	\$ 89,203	\$ 5,685	\$ 83,518	\$ 202,242

8.2 Deviations from budget

The administration portion of the project is actively incurring costs in Year 4 (for project administration) and it is expected that the current rate of spending on this account will continue throughout Year 4 and for the remainder of the program. The end date for the administration portion of the agreement has been revised to align with the NSERC Alliance portion of the research program (May 14, 2026).