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**Carbon Ore, Rare Earth, and Critical Minerals (CORE-CM) Assessment of San Juan  
River-Raton Coal Basin**

7th Quarterly Research Performance Progress Report  
Reporting Period: April 1, to July 31, 2023  
Project Performance Period: 10/01/2021 – 09/30/2023

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## 1. ACCOMPLISHMENTS

The objective of this project is to determine the rare earth elements (REE) and critical minerals (CM) resource potential in coal and related stratigraphic units in the San Juan and Raton basins, New Mexico. We will conduct the following tasks: (1) a basinal assessment for CM and REE potential, using state-of-the-art technologies to estimate basin-wide CM and REE resources in coal and related stratigraphic units; (2) identify, sample, and characterize coal waste stream products; (3) conduct bench tests to develop a basinal reuse of waste strategy; (4) illustrate the current status of the feedstock supply of REE and CM to understand the basinal REE industry's capital expenditures and obstacles to expanding REE-related business development; (5) develop a life-cycle analysis to establish pathways, process engineering, and design requirements to upgrade REE processing industry, (6) evaluate technology gaps, (7) establish a Center of Excellence and Training Center (COE) for coal ash beneficiation at San Juan County; and (8) create REE research-based activities that can be shared during the NMBGMR summer geology teacher workshop and assemble REE research-related articles for an REE-centered issue of *Lite*. This project will delineate favorable geologic terranes and priority areas containing potential REE and CM deposits for the DOE mandate, which is also a priority of the NMBGMR and state of NM.

### **A. Major goals and objectives**

The following are the major goals of this project as described in the approved Statement of Project Objectives (SOPO):

1. Identify and quantify the distribution of critical minerals (CM), including rare earth elements (REE), in coal beds and related stratigraphic units in the San Juan and Raton basins in New Mexico (including coal, coal refuse, ash, coal seam, interstitial clays/shales, volcanic ash beds, acid mine drainage, associated sludge samples, mine dumps, other nonfuel carbon-based products, process waters, etc.).
2. Identify possible sources of CM and REE in the basins.
3. Identify the coal mine and nonfuel carbon-based waste products that could contain CM and REE.
4. Characterize the CM and REE in these materials.
5. Determine the economic viability of extracting CM and REE from these materials
6. Test and develop new technologies in identifying and quantifying CM and REE in high-fidelity geologic models.

Table 1 describes the tasks and subtasks that will be undertaken to accomplish these goals and Table 2 provides a listing of the revised project milestones, along with anticipated delivery dates.

TABLE 1. List of tasks and subtasks

<b>Task 1.0 Project Management and Planning</b>
<b>Task 2.0 Basinal Assessment of CM and REE in the San Juan and Raton Basins</b> Subtask 2.1 Identification of Sampling Sites Subtask 2.2 Collection and Review of Existing Data Subtask 2.3 Develop a Sampling Plan Subtask 2.4 Collect Samples Subtask 2.5 Sample Characterization Subtask 2.5.1 Bulk Rock Characterization Subtask 2.5.2 Micro-scale Characterization Subtask 2.5.3 3D Multiscale Petrography Subtask 2.5.4 In situ LIBS/RAMAN Analyses Subtask 2.6 Application of Machine Learning techniques for basin-wide resource assessment
<b>Task 3.0 Basinal Strategies for Reuse of Waste Streams</b> Subtask 3.1 Waste Streams Sampling and Characterization Subtask 3.2 Coal Ash Subtask 3.3 Technology Development of Basinal Reuse Strategy
<b>Task 4.0 Basinal Strategies for Infrastructure, Industries and Businesses</b> Subtask 4.1 Infrastructure Investigation Subtask 4.2 Competitiveness and Challenge Subtask 4.3 Life-Cycle Analysis
<b>Task 5.0 Technology Assessment, Development and Field Testing</b> Subtask 5.1 Identify and Assess Existing and Novel Technologies Specific to the Resource Subtask 5.2 Develop Plan for Field Testing
<b>Task 6.0 Technology Innovation Centers</b> Subtask 6.1 SonoAsh Center of Excellence
<b>Task 7.0 Stakeholder Outreach and Education</b> Subtask 7.1 New Mexico State and Regional Education Subtask 7.2 Lessons Learned and Narratives Constructed Subtask 7.3 Publications Subtask 7.4 Training and Conferencing with SJC and Sonoash COE

TABLE 2. Revised List of Milestones (**bold=completed**)

Task/ Subtask	Milestone Title	Planned Completion	Verification method	Status
	Quarterly reports	Quarterly	Report every quarter	<b>1-7<sup>th</sup> quarters completed</b> (see <a href="https://geoinfo.nmt.edu/staff/mclemore/REEinCoalWeb.html">https://geoinfo.nmt.edu/staff/mclemore/REEinCoalWeb.html</a> )
	Year I interim report	Year 1	Submitted this report	<b>completed</b>
	Meeting with DOE manager	12/7/22, 4/11/23, 7/11/23	attend	<b>Presentation given</b>
<b>1.0</b>	<b>A: Project Kick-off meeting</b>	<b>10/15/21</b>	<b>Attend, report</b>	<b>Completed</b> (see <a href="https://geoinfo.nmt.edu/staff/mclemore/documents/CORE-CMprojectNMfinal.pdf">https://geoinfo.nmt.edu/staff/mclemore/documents/CORE-CMprojectNMfinal.pdf</a> )
2.1	B: Identification of Sampling Sites	Quarterly	Reports every quarter (quarterly reports), environmental questionnaire	<b>Ongoing</b> , planned in 2 phases Phase 1 ( <a href="https://geoinfo.nmt.edu/staff/mclemore/SampleLocations1_23.xlsx">https://geoinfo.nmt.edu/staff/mclemore/SampleLocations1_23.xlsx</a> ), environmental questionnaire completed and revision submitted
2.2	C: Collection and Review of Existing Data	2 <sup>nd</sup> quarter	Map, description	<b>Report completed</b> ( <a href="https://geoinfo.nmt.edu/staff/mclemore/documents/legacychemistryrpt23.pdf">https://geoinfo.nmt.edu/staff/mclemore/documents/legacychemistryrpt23.pdf</a> ), ongoing activity, <b>REE in produced waters</b> ( <a href="https://geoinfo.nmt.edu/staff/mclemore/ree_produced_waters_for_GIS.xlsx">https://geoinfo.nmt.edu/staff/mclemore/ree_produced_waters_for_GIS.xlsx</a> ) and <b>USGS coal chemistry</b> ( <a href="https://geoinfo.nmt.edu/staff/mclemore/REEcoal.mpk">https://geoinfo.nmt.edu/staff/mclemore/REEcoal.mpk</a> ) are on the project web site; summary of data and preliminary interpretations <a href="https://geoinfo.nmt.edu/staff/mclemore/documents/McLemoreGSA22Wed10-12-22.pdf">https://geoinfo.nmt.edu/staff/mclemore/documents/McLemoreGSA22Wed10-12-22.pdf</a>

2.3	<b>D: Sampling Plan</b>  Database	10/31/2021, progress report 2 <sup>nd</sup> quarter.  3/31/2022	<b>Sampling plan</b>  Database, web forms, reports.	<b>Sampling plan is completed</b> ( <a href="https://geoinfo.nmt.edu/staff/mclemore/documents/samplingplan_v3.pdf">https://geoinfo.nmt.edu/staff/mclemore/documents/samplingplan_v3.pdf</a> ). Database and data entry web pages are available and being updated.
2.4	E: Collect Samples	Quarterly	Report, database	Started sampling in April 2022 (see Table 3), permit to collect on Navajo Tribal Lands issued April 2023 and ended June 30, 2023
2.5	F: Characterization	Quarterly	Progress report quarterly, database	<b>Ongoing</b> once samples are collected, <b>samples submitted to laboratories for chemical analyses, chemical analyses received (see Attachment 3)</b> Chemical analyses at <a href="https://geoinfo.nmt.edu/staff/mclemore/NMTcoalChem_003.xlsx">https://geoinfo.nmt.edu/staff/mclemore/NMTcoalChem_003.xlsx</a> , preliminary report by Sandia <a href="https://geoinfo.nmt.edu/staff/mclemore/documents/Coal9_Petrography.pdf">https://geoinfo.nmt.edu/staff/mclemore/documents/Coal9_Petrography.pdf</a>
2.6	G: Application of Machine Learning techniques for Basin-wide Assessment	12/31/2022	Progress report quarterly, database, 1 <sup>st</sup> summary report completed	<b>Completed</b> , Submitted 8/9/2023
3.0	H: Sampling and Characterization of Waste Streams	Quarterly	Progress report quarterly, database	<b>Ongoing</b> , see 2.5, future activity
4.0	I: Results of Basinal Infrastructure, Industries and Business Assessment	03/31/2023	Progress report quarterly, database, publications	Future activity; 4.3 <b>Life cycle analysis completed (see below)</b> , Extraction techniques report completed <a href="https://geoinfo.nmt.edu/staff/mclemore/documents/January2023ExtractionTechnique.pdf">https://geoinfo.nmt.edu/staff/mclemore/documents/January2023ExtractionTechnique.pdf</a>

Accomplishments during 7<sup>th</sup> quarter

***Task 1.0 Project Management and Planning***

Project management activities during this quarter included the implementation of regular procedures including regular management and biweekly working group meetings. The team also has regular meetings of the New Mexico Bureau of Geology and Mineral Resources (NMBGMR) database group to develop the project database. Meetings with the DOE coordinator/manager have been held.

***Task 2.0 Basinal Assessment of CM and REE in the San Juan and Raton Basins***

***Status:***

***Subtask 2.1 Identification of Sampling Sites (COMPLETED)***

1. Sample sites include the coal fields and mines in the San Juan and Raton basins, shown in Figure 1. Potential sample sites listed [https://geoinfo.nmt.edu/staff/mclemore/SampleLocations1\\_23.xlsx](https://geoinfo.nmt.edu/staff/mclemore/SampleLocations1_23.xlsx).
2. Received permit from Navajo Tribe to sample on Tribal lands April-July 2023, sampling began in April and completed in June

***Subtask 2.2 Collection and Review of Existing Data (COMPLETED)***

Legacy chemistry data have been collected. See preliminary results in Geological Society of America presentation by McLemore (<https://geoinfo.nmt.edu/staff/mclemore/documents/McLemoreGSA22Wed10-12-22.pdf>), DOE workshop presentation (<https://geoinfo.nmt.edu/staff/mclemore/documents/McLemoreDOE22Tues10-25-22.pdf>), group presentation on geochemistry (11/15.22), and report (<https://geoinfo.nmt.edu/staff/mclemore/documents/legacychemistryrpt23.pdf>).

***Subtask 2.3 Develop a Sampling Plan (COMPLETED)***

The field sampling plan is completed and revised ([https://geoinfo.nmt.edu/staff/mclemore/documents/samplingplan\\_v5.pdf](https://geoinfo.nmt.edu/staff/mclemore/documents/samplingplan_v5.pdf)). Figure 1 shows the coal fields and mines in the area. Table 3 is a list of the coal fields.

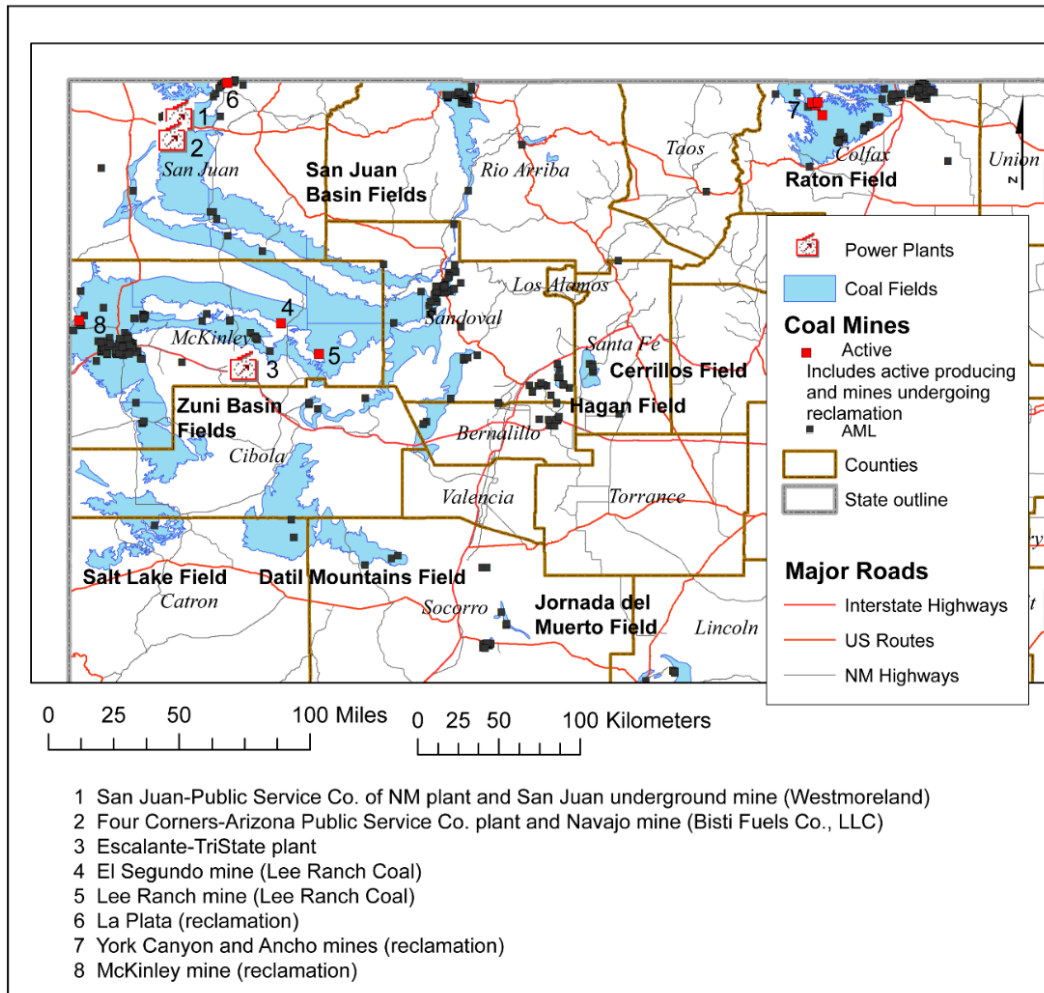


FIGURE 1. Coal fields, active mines, AML (abandoned mine lands) sites, and power plants in the San Juan and Raton Basins.

TABLE 3. Coal fields in the San Juan and Raton basins, studied in this project, delineated by Hoffman (1996, 2017). District Id is from the New Mexico Mines Database (McLemore, 2010a, 2017). Representative samples will be collected from each coal field. Each drill core sample will be identified by the hole number and depth. At least 3 samples will be collected from each coal field. Approximately 200 additional samples will be collected. Red=no analyses at this time

District id	District (coal field)	Year of Initial Production	Year of Last Production	Estimated Cumulative Production	Formation	Number of samples analyzed	Number of coal analyzed	Number of samples analyzed from legacy data	Number of samples to be analyzed
DIS257	Barker Creek		1905		Menefee				18
DIS150	Bisti	1980	1988	40,075,148	Fruitland	47	15		8



District id	District (coal field)	Year of Initial Production	Year of Last Production	Estimated Cumulative Production	Formation	Number of samples analyzed	Number of coal analyzed	Number of samples analyzed from legacy data	Number of samples to be analyzed
DIS208	Carthage	1861	1963		Crevasse Canyon, Tres Hermanos	2	2		
DIS259	Chaco Canyon	1905			Menefee				3
DIS260	Chacra Mesa		1945		Menefee	11	3		32
	Dakota				Dakota	4	4		2
DIS118	Crownpoint	1914	1951	20,758	Crevasse Canyon	10	8		3
DIS262	Datil	1917	1940	66,980	Crevasse Canyon, Tres Hermanos	1	1	1	
DIS155	Fruitland	1889	2001	3,137,957,050	Fruitland	67	46	63	1
DIS119	Gallup	1882	2001	121,522,629,885	Crevasse Canyon	13	8		34
DIS156	Hogback	1907	1971	301,237	Menefee				9
DIS264	Jornada del Muerto		1927		Crevasse Canyon	3	3		1
DIS174	La Ventana	1904	1983		Menefee	4	4		
DIS146	Monero	1882	1970	5,277,552	Menefee	15	13		5
DIS016	Mount Taylor	1952	1953	69,948	Crevasse Canyon	7	5		2
DIS157	Navajo	1963	9999	4,714,689,147	Fruitland	6	3	1	11
DIS258	Newcomb				Menefee				3
DIS021	Raton	1898	2002	954,470,032	Vermejo, Raton	27	11	30	2
DIS003	Rio Puerco	1937	1944	139,555	Crevasse Canyon				
DIS009	Salt Lake	1987	1987	100,000	Moreno Hill	2	1	13	
DIS121	San Mateo	1983	2001	954,470,032	Menefee	9	5	170	8
DIS261	Standing Rock	1952	1958		Menefee	4	1		5
DIS158	Star Lake				Fruitland	41	24		5
DIS263	Tierra Amarilla	1955	1955		Menefee				
DIS159	Toadlena				Menefee	4			12
DIS124	Zuni	1908	1926	16,010	Crevasse Canyon, Tres Hermanos			3	1
	coal ash					5		2	1
	beach placer sandstone					24		103	22
	uranium sandstone							23	
	Other samples					20			
	total samples					329	157	407	189

*Health and safety plan (COMPLETED)*

HASP is complete ([https://geoinfo.nmt.edu/staff/mclemore/documents/HASP\\_10.pdf](https://geoinfo.nmt.edu/staff/mclemore/documents/HASP_10.pdf)). NMT requires all projects to have a **Safe and Inclusive Working Environment Plan for Off-Campus or Off-Site Research**, which has been added to the HASP.

*Subtask 2.4 Collect Samples*

Sampling was delayed due to poor weather, vacation schedules, closures of Federal land because of fire danger, and students not available because of school schedule. We started sampling in April 2022.

We have logged 3162 ft of core (33 holes). We have collected 211 samples (Table 3; Attachment 3, <https://geoinfo.nmt.edu/staff/mclemore/Attachment3-NETLREE-SEDSampleDataNM.xlsx>).

Additional samples are being collected.

Photographs of drill core are at <https://photoarchive.nmt.edu/> (you need to search by coal and sample)

*Subtask 2.5 Sample Characterization*

Chemical analyses was delayed due to obtaining quotes and proper paperwork required by NM Tech (completed August 2022)

Samples have been analyzed for major and trace elements (see Attachment 3, [https://geoinfo.nmt.edu/staff/mclemore/NMTcoalChem\\_003.xlsx](https://geoinfo.nmt.edu/staff/mclemore/NMTcoalChem_003.xlsx)

Sandia is working on characterization (will submit in the future)

*Subtask 2.6 Application of Machine Learning techniques for basin-wide resource assessment*

Las Alamos is working on machine learning analyses (1<sup>st</sup> summary report submitted)

*Task 3.0 Basinal Strategies for Reuse of Waste Streams**Subtask 3.1 Waste Streams Sampling and Characterization*

There is no update on this subtask.

*Subtask 3.2 Coal Ash*

We have collected 8 coal ash samples from Generating Plants.

*Subtask 3.3 Technology Development of Basinal Reuse Strategy*

There is no update on this subtask.

*Task 4.0 Basinal Strategies for Infrastructure, Industries and Businesses**Subtask 4.1 Infrastructure Investigation*

There is no update on this subtask.

*Subtask 4.2 Competitiveness and Challenge*

There is no update on this subtask.

*Subtask 4.3 Life-Cycle Analysis (UPDATED AND COMPLETED)*

The project team is utilizing the cradle-to-grave concept, which would be adopted to set the boundary of energy and material flows for all the processes involved in the REE industry. Life-cycle analysis including energy and material analysis, environmental impact assessment, scalability assessment and detailed economic analysis shall be conducted to the current REE and CM supply chain and investigate the potential upgrading of the REE and CM process industry, in order to establish pathways toward net neutral carbon emission and the process engineering and design requirements to accomplish this. Typical REE production route is describe in Figure 2:

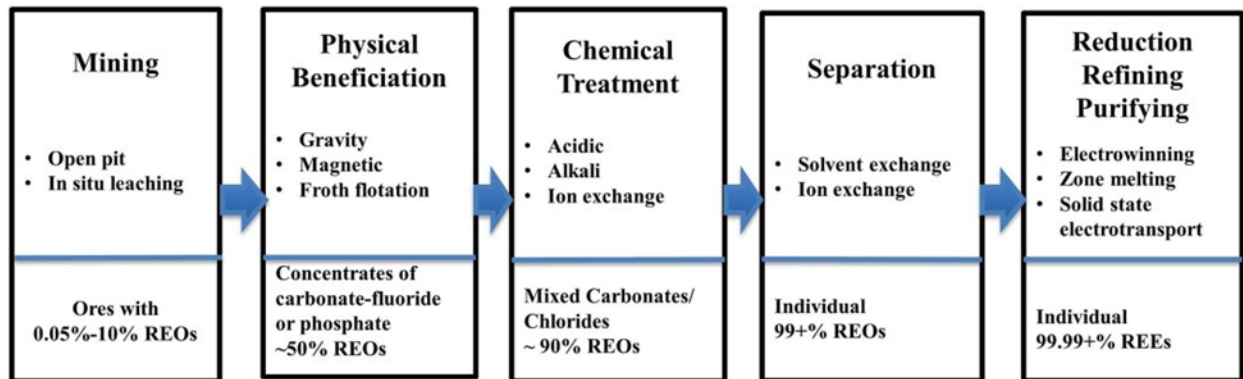


Figure 2. Generalize REE production flow chart

Proposed boundary for this task would be simplified as Figure 3.

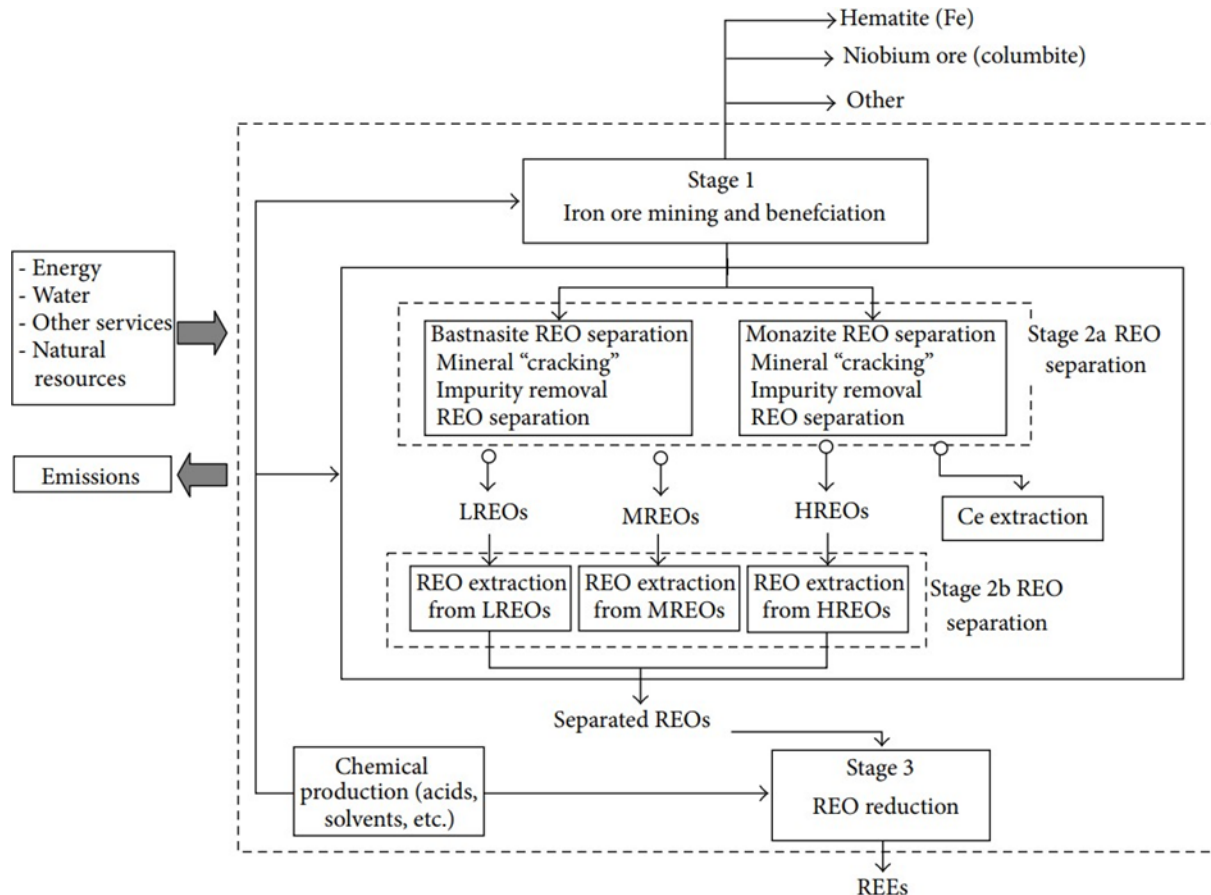


Figure 3. Simplified boundary. (To be modified with details of each unit processes for LCI)

### **Real Earth Element (REE)/Critical Mineral (CM) Extraction Technique**

The focus extraction technology is the utilization of supercritical CO<sub>2</sub> Chelator fluids to mine these minerals (Sandia National Laboratories). In this approach, the solvent dissolves CM and extracted selectively. Also the solvent enhances solution mining by being used to fracture ores (Mark J. et al). A detail assessment of the processes involved in this technique with respect to its green or carbon neutral importance in comparison to current techniques ought to be conducted.

### **Overview of Life Cycle Assessment (LCA)**

Calculating and evaluating all inputs and outputs of environmental stressors and products' potential impact on the environment, from raw material extraction and acquisition, manufacturing, transportation and distribution, use and maintenance, reuse and recycle, and all the way to disposal and waste management describes LCA. This study follows the ISO 14000 and frame work (Fig. 4).

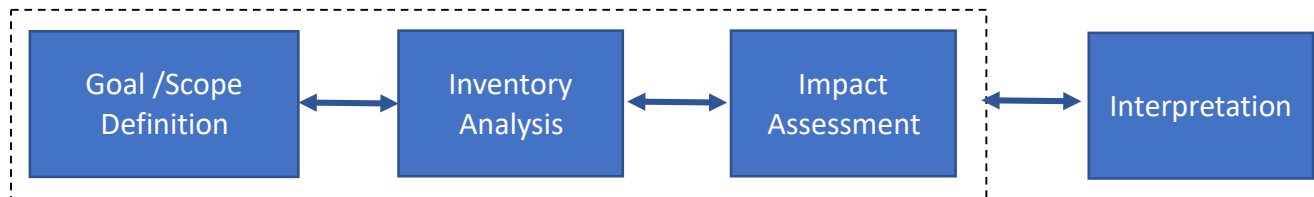


Figure 4. Life Cycle Assessment framework

### **Goal and scope**

Life-Cycle Analysis: Life-cycle analysis including energy and material analysis, environmental impact assessment, scalability assessment and detailed economic analysis shall be conducted to the current REE and CM supply chain and investigate the potential upgrading of the REE and CM process industry, in order to establish pathways toward net neutral carbon emission and the process engineering and design requirements to accomplish this.

### **Lifecycle Inventory Analysis (LCI)**

The LCI is a critical component as it is the data foundation of the LCA study. The approach adopted by ISO 14044 is to compile the inventory based on the inputs and outputs from each of the processes (referred to as unit processes) involved in a product's life cycle.

Figure 5, presents the key processes involved and hence a summary of the project boundary. Inventory of key units to be collected are based on this boundary.

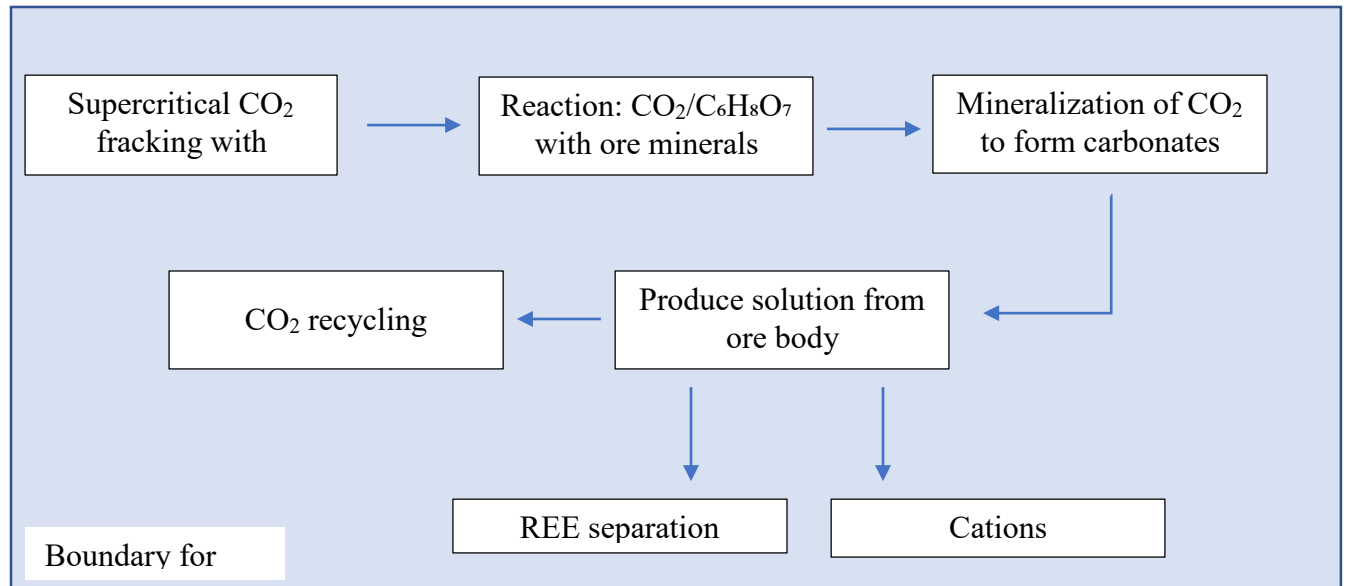


Figure 5. Summary of Key process steps involved/Boundary for LCA

### Life Cycle Impact assessment (LCIA)

The LCIA step of an LCA study is used to evaluate the significance of potential environmental impacts using inventory data, and providing information for the interpretation step. This study will focus on evaluating the impact of global warming through a midpoint assessment of measuring global warming potential. Hence the relative potency of different greenhouse gases such as CO<sub>2</sub>, N<sub>2</sub>O and methane and the results in kgCO<sub>2</sub> equivalent (Equations 1 and 2) and other environmental impacts.

$$Impact = \sum_{p \in P} CF_{ip} \cdot MassEmitted_p \quad \text{Equ. 1}$$

$$GWP[kgCO_{2eq}] = \sum_{p \in P} GWP_p \left[ \frac{kgCO_{2e}}{kg p} \right] \cdot MassEmitted_p [kg p] \quad \text{Equ. 2}$$

### Interpretation of Results

The last step in an LCA study is the interpretation of results. The findings from the LCI and LCIA are considered together. The results will be discussed and summarized in the form of conclusions and recommendations, and presented to decision makers. And this will be in line with the goals of the analysis.

### Other Environmental Impacts

TRACI Global Warming Air, Acidification Air, Eutrophication Water, Smog Air, all Ecotoxicity categories, and all Human Health categories. m<sup>3</sup> water consumed/ton ore produced. Extractability of toxins per EPA Method 1311.

### Selected References

Mark J. Rigali, Yifeng Wang, Yongliang Xiong, Green Mining of Critical Metals Using Supercritical CO<sub>2</sub>-H<sub>2</sub>O-Chelator Fluids Sandia National Laboratories (Albuquerque, NM); Guangping Xu

N. A. Azzolina, J. A. Hamling, W. D. Peck, C. D. Gorecki, D. V Nakles, and L. S. Melzer, "A Life Cycle Analysis of Incremental Oil Produced via CO2 EOR," *Energy Procedia*, vol. 114, pp. 6588–6596, 2017.

ISO 14041: Environmental Management - Life Cycle Assessment - Goal and Scope Definition and Inventory Analysis. 199

Navarro J and Zhao F (2014) Life-cycle assessment of the production of rare-earth elements for energy applications: a review. *Front. Energy Res.* 2:45. doi: 10.3389/fenrg.2014.00045

### ***Task 5.0 Technology Assessment, Development and Field Testing***

#### ***Subtask 5.1 Identify and Assess Existing and Novel Technologies Specific to the Resource***

There is no update on this subtask.

#### ***Subtask 5.2 Develop Plan for Field Testing***

There is no update on this subtask.

### ***Task 6.0 Technology Innovation Centers***

#### ***Subtask 6.1 SonoAsh Center of Excellence***

Memo written describing meetings with parties to establish COE.

### ***Task 7.0 Stakeholder Outreach and Education***

#### ***Subtask 7.1 New Mexico State and Regional Education***

A short summary of the project was written for Gold Pan

([https://nmt.edu/advancement/goldpan\\_archives/2022\\_Summer\\_GoldPan\\_Digital2.pdf](https://nmt.edu/advancement/goldpan_archives/2022_Summer_GoldPan_Digital2.pdf)), NMIMT Alumni Newsletter.

Another short summary of the project written for Lite Geology

[https://geoinfo.nmt.edu/publications/periodicals/litegeology/51/lg\\_v51.pdf](https://geoinfo.nmt.edu/publications/periodicals/litegeology/51/lg_v51.pdf).

The NMBGMR Rockin' Around New Mexico was in Socorro, NM July 5-8, 2023

Other outreach activities see [REE in Coal \(nmt.edu\)](https://www.nmt.edu/ree-in-coal)

#### ***Subtask 7.2 Lessons Learned and Narratives Constructed***

There is no update on this subtask.

#### ***Subtask 7.3 Publications and presentations***

See Section 2 below

#### ***Subtask 7.4 Training and Conferencing with SJC and Sonoash COE***

There is no update on this subtask.

## **2. PRODUCTS**

### **A. Publications, conference papers, and presentations**

*1<sup>st</sup> quarter*

Kickoff presentation October 15, 2021

(<https://geoinfo.nmt.edu/staff/mclemore/documents/CORE-CMprojectNMfinal.pdf>)

DOE Division of Critical Minerals Program Plan Rollout on December 8, 2021

([https://geoinfo.nmt.edu/staff/mclemore/documents/CORE-CMprojectNMDOEsummary12\\_21.pdf](https://geoinfo.nmt.edu/staff/mclemore/documents/CORE-CMprojectNMDOEsummary12_21.pdf))

*2<sup>nd</sup> quarter*

New Mexico Geological Society abstract: Badonie, M.N. and McLemore, V.T., 2022, REE in coalbeds in the San Juan-Raton coal basins (abstr.): New Mexico Geological Society, Spring Meeting, <https://nmgs.nmt.edu/meeting/abstracts/view.cfm?aid=2838>. Poster at <https://geoinfo.nmt.edu/staff/mclemore/documents/NMSG.Poster2022COPY2.pdf>.

*3<sup>rd</sup> quarter*

Rockin' 22 Critical Minerals presentation

(<https://geoinfo.nmt.edu/staff/mclemore/documents/McLemoreRockinCM22.pdf>)

Rockin' 22 Critical Minerals activities

(<https://geoinfo.nmt.edu/staff/mclemore/documents/Rockin22.pdf>)

*4<sup>th</sup> quarter*

New Mexico Mining Association abstract and presentation: REE in the coal and associated strata in the San Juan and Raton Basins, New Mexico, 2022, Megan Badonie, Jakob Newcomer, Devlon Shaver Advised by: Dr. Virginia T. McLemore, <https://geoinfo.nmt.edu/staff/mclemore/documents/NMAAPresentationNMMAFINAL2022.pdf>

McLemore, V.T., 2022, Rare Earth Elements (REE) in Late Cretaceous coal and beach-placer sandstone deposits in the San Juan Basin, New Mexico: Preliminary Observations (abstr.): Geological Society of America, Annual Conference, October, <https://gsa.confex.com/gsa/2022AM/meetingapp.cgi/Paper/378264>, presentation <https://geoinfo.nmt.edu/staff/mclemore/documents/McLemoreGSA22Wed10-12-22.pdf>

*5<sup>th</sup> quarter*

McLemore, V.T., 2022, Rare earth elements (REE) in Late Cretaceous coal and beach-placer sandstone deposits in the San Juan Basin, New Mexico: Preliminary results: presentation at the DOE National Energy Technology Laboratory Resource Sustainability Project Review Meeting, Oct. 25-27, 2022 <https://geoinfo.nmt.edu/staff/mclemore/documents/McLemoreDOE22Tues10-25-22.pdf>

*6<sup>th</sup> quarter*

Badonie, M., Newcomer, J., Shaver, S., and McLemore, V.T., 2023, REE in coal and associated strata in the San Juan and Raton Basins, New Mexico: Minexchange, 2023 SME Annual Conference Technical Program, preprint 23-055, 5 p., <https://geoinfo.nmt.edu/staff/mclemore/documents/23-055.pdf>

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- Badonie, M.N. and McLemore, V.T., 2023, Rare earth elements and critical minerals in coal and related strata in the San Juan Basin in northern New Mexico (abstr.): New Mexico Geological Society, Spring meeting, <https://nmgs.nmt.edu/meeting/abstracts/view.cfm?aid=2939>
- Lempke, J., Frey, B., Goehring, B., and McLemore, V.T., 2023, Rare earth elements in humates mined in the San Juan Basin (abstr.): New Mexico Geological Society, Spring meeting, <https://nmgs.nmt.edu/meeting/abstracts/view.cfm?aid=2954>
- McLemore, V.T. and Gysi, A., 2023, Critical minerals in New Mexico: Earth Matters, winter 2023, [https://geoinfo.nmt.edu/publications/periodicals/earthmatters/23/n1/em\\_v23\\_n1.pdf](https://geoinfo.nmt.edu/publications/periodicals/earthmatters/23/n1/em_v23_n1.pdf)

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- Owen, E.J. and McLemore, V.T., 2023, Distribution of REE in selected deposits in New Mexico: Forum on the Geology of Industrial Minerals, presentation, <https://geoinfo.nmt.edu/staff/mclemore/documents/ejo.FGIM23AustinDistributionofREEinselectedNMdeposits0.1.pdf>
- McLemore, V.T., 2023, Industrial minerals in the San Juan Basin, New Mexico: Forum on the Geology of Industrial Minerals, presentation, [https://geoinfo.nmt.edu/staff/mclemore/documents/fgim23-ppt\\_sm.pdf](https://geoinfo.nmt.edu/staff/mclemore/documents/fgim23-ppt_sm.pdf)
- Shaver, D., 2023, Coal mining history of New Mexico (abstr.): Mine History Association annual meeting, Socorro, NM, June 2023, <https://geoinfo.nmt.edu/staff/mclemore/documents/CoalMiningHistoryNewMexico.pdf>
- McLemore, V.T., 2023, Rare Earth Elements and Critical Minerals in Late Cretaceous Coal and Related Strata in the San Juan and Raton Basins, New Mexico: Lite Geology, v. 51, [https://geoinfo.nmt.edu/publications/periodicals/litegeology/51/lg\\_v51.pdf](https://geoinfo.nmt.edu/publications/periodicals/litegeology/51/lg_v51.pdf)
- Matt Powell, Guangping Xu, Mark J Rigali, Virginia McLemore, Shuya We<sup>2</sup> and Robert Happney, 2023, Microwave Digestion for Rare Earth Elements (REE) Quantification in Coal and Coal Ash (abstr.): Goldschmidt2023 conference, July, 2023

#### **B. Website(s) or other Internet site(s)**

See project web page at <https://geoinfo.nmt.edu/staff/mclemore/REEinCoalWeb.html>

#### **C. Technologies or techniques**

No update

#### **D. Inventions, patent applications, and/or licenses**

No update



## **E. Other products**

### *1<sup>st</sup> quarter*

- Sampling plan
- Health and safety plan  
([https://geoinfo.nmt.edu/staff/mclemore/documents/HASP\\_v2.pdf](https://geoinfo.nmt.edu/staff/mclemore/documents/HASP_v2.pdf))
- SOP17 Drillhole logging  
<https://geoinfo.nmt.edu/staff/mclemore/documents/SOP17DrillholeLoggingupdated.pdf>

### *3<sup>rd</sup> quarter*

- Revised sampling plan  
([https://geoinfo.nmt.edu/staff/mclemore/documents/samplingplan\\_v5.pdf](https://geoinfo.nmt.edu/staff/mclemore/documents/samplingplan_v5.pdf))
- REE in produced waters  
([https://geoinfo.nmt.edu/staff/mclemore/ree\\_produced\\_waters\\_for\\_GIS.xlsx](https://geoinfo.nmt.edu/staff/mclemore/ree_produced_waters_for_GIS.xlsx)) and USGS coal chemistry (<https://geoinfo.nmt.edu/staff/mclemore/REEcoal.mpk>)
- McLemore attended Mining and Metallurgical Society of America AML summit in Phoenix April 6-7, 2022
- Rockin' was held in Farmington July 5-8, 2022

### *6<sup>th</sup> quarter*

- Participated on the DOE working subgroups (Characterization, Infrastructure, Social Justice)
- Submitted request for extension until Dec. 2024
- Submitted request, budget, and work plan for \$500,000 extension ending Dec 2024

### *7<sup>th</sup> quarter*

- Attended DOE 2023 Carbon ore, rare earth, and critical minerals (CORE-CM) initiative workshop #2, June 2023
- Mining in New Mexico with emphasis on Critical Minerals, Leadership Academy, May 2023, <https://geoinfo.nmt.edu/staff/mclemore/documents/LeadershipMining2023.pdf>
- GSA Earth Scope—had two interns from 2-yr colleges for the summer (one will present on coal mine wastes)
- Rockin' was held in Socorro July 5-8, 2023
- Abstracts being written for presentation at Geological Society of America (Oct, 2023) and Society of Mining, Metallurgy, and Exploration (Feb, 2024) annual meetings

## **3. PARTICIPANTS & OTHER COLLABORATING ORGANIZATIONS**

### **A. Individuals involved in project**

#### *New Mexico Tech*

Dr. Navid Mojtabai (PI) is a professor and department chair in the Mineral Engineering Department at New Mexico Tech - Tasks 1, 3, 5, and 7.

Dr. Virginia McLemore (Co-PI) is the Principal Senior Economic Geologist for the NMBGMR - Tasks 1, 2, 3, 5 and 7.

Dr. Robert Balch (PM) is the Project manager for this project and is the Director of the PRRC – Task 1, 2, 4 and 7.

Dr. William Ampomah (Co-PI) is a Research Engineer and Section Head at PRRC – Task 1, 4, 5 and 7.

Dr. Sai Wang is a Research Associate at PRRC - Tasks 4.

Dr. William Chavez is a professor in the Mineral Engineering department at New Mexico Tech – Task 2 and 3.

Mr. Mark Leo-Russell is the NMBGMR database specialist - Task 2 and 3.

Mr. Mark Mansell: is the NMBGMR GIS specialist - Task 2.

Ms. Cynthia Connolly is the Education Outreach Manager at the NMBGMR – Task 7.

Dr. Shari Kelley is a senior field geologist and geophysicist at the NMBGMR – Task 2 and 7.

Mr. Christopher Armijo is the NMBGMR computer specialist - Task 1 and 2.

Mr. Brian Wheeler is the NMBGMR fleet manager - Tasks 2 and 3.

Ms. Gretchen Hoffman is the NMBGMR emeritus coal geologist - Task 2 and 3.

Mr. Evan Owen is Economic Geologist at NMBGMR- Task 2 and 3.

### ***Sandia National Laboratories(SANL)***

Dr. Jason Heath is a hydrogeologist at SANL. –Task 2 and 5.

Dr. Guangping Xu is an experimental geochemist at SANL - Tasks 2, 3 and 5.

Dr. Mark J Rigali

### ***San Juan College***

Dr. John Burris: is a Professor of Geology and Department Chair at San Juan College - Tasks 7.

Summer Begay

Craig J. Williams

### ***Los Alamos National Laboratory (LANL)***

Dr. Kirsten Sauer is a Scientist at LANL - Task 5.

Dr. Hakim Boukhalfa is a Senior Scientist at LANL – Task 5

Dr. Sam Clegg is Senior Scientist at LANL – Task 2

Dr. Brent Goehring

### ***SonoAsh***

Mr. Claudio Arato is the CTO of SonoAsh company - Task 3, 4, 5, 6 and 7.

Mr. Brad MacKenzie is the VP of SonoAsh company – Task 4 and 6

Bruce Sifton

## **B. Change in support levels of key persons**

Dr. Rajesh Pawar had shifted his responsibilities on this project to Dr. Kirsten Sauer.

Craig Williams and Summer Begay are now representing San Juan College.

Evan Owen added to project at NMBGMR to assist with Tasks

## **4. SPECIAL REPORTING REQUIREMENTS: Mandatory**

No update

**5. BUDGETARY INFORMATION: MANDATORY**

<b>Spend Plan by Fiscal Year Format</b>						
	<b>FY 2022</b>		<b>FY 2023</b>		<b>Total</b>	
	<b>DOE funds</b>	<b>Cost Share</b>	<b>DOE funds</b>	<b>Cost Share</b>	<b>DOE</b>	<b>Cost Share</b>
<b>NMIMT</b>	564,432	101,114	544,856	104,147	1,109,287	205,261
Los Alamos National Laboratory	93,750	-	93,750	-	187,500	-
Sandia National Laboratories	99,946	-	87,054	-	187,000	-
SonoAsh LLC	-	115,000	-	115,000	-	230,000
<b>Total (\$)</b>	<b>758,128</b>	<b>216,114</b>	<b>725,660</b>	<b>219,147</b>	<b>1,483,787</b>	<b>435,261</b>
<b>Total Cost Share %</b>		<b>22.2%</b>		<b>23.2%</b>		<b>22.7%</b>

Table for Actual Incurred Costs

Table for Remaining Balance

**6. REFERENCES**

## 7. APPENDICES

### APPENDIX 1. List of SOPs and plans

(see <https://geoinfo.nmt.edu/staff/mclemore/REEinCoalWeb.html> for copies as they are completed)

Number	Name	Description
HASP	Health and Safety Plan (HASP)	Health and safety plan for field and laboratory work ( <a href="https://geoinfo.nmt.edu/staff/mclemore/documents/HASP_v2.pdf">https://geoinfo.nmt.edu/staff/mclemore/documents/HASP_v2.pdf</a> )
FSP	Field Sampling Plan (FSP)	Field sampling plan ( <a href="https://geoinfo.nmt.edu/staff/mclemore/documents/samplingplan_v3.pdf">https://geoinfo.nmt.edu/staff/mclemore/documents/samplingplan_v3.pdf</a> )
SOP 1	Data management	entering, reporting, verification, and validation of data to the database
SOP 2	Photography	procedures taking photographs in the field and laboratory
SOP 3	GPS surveying	Procedures for use of handheld GPS surveying
SOP 4	Sampling outcrops, rock piles, and drill core	field procedures for taking surface solid samples
SOP 17	Drillhole logging	procedures for drilling, logging, and sampling of subsurface samples (solids) ( <a href="https://geoinfo.nmt.edu/staff/mclemore/documents/SOP17DrillholeLoggingupdated.pdf">https://geoinfo.nmt.edu/staff/mclemore/documents/SOP17DrillholeLoggingupdated.pdf</a> )
SOP 6	Soil paste pH and paste conductivity	laboratory procedures for soil paste pH and paste conductivity
SOP 7	Field measurements of water	field procedures for measuring water flow, pH, conductivity, alkalinity, temperature when collecting water samples
SOP 8	Surface water and seep sampling	field procedures for collecting samples of surface and seep water samples
SOP 9	Petrographic analysis	laboratory procedures for describing petrographic samples
SOP 10	Electron microprobe analyses	laboratory procedures use for analyses using the electron microprobe
SOP 12	X-ray diffraction (XRD) analyses	laboratory procedures for mineralogical analyses by x-ray diffraction (XRD)