IDENTIFICATION AND CHARACTERIZATION OF RARE EARTH ELEMENTS IN LARGE-SCALE MINE WASTES—TASK 4

DATA SUMMARY REPORT

YEAR 1 (2022–2023)

Terence E. Duaime, Jackson T. Quarles, and Matthew J. Vitale

prepared for Army Research Laboratory

MBMG
Montana Bureau of Mines and Geology

Front photo: Reclaimed open pit at the Zortman Mine, Zortman, MT. Photo by Matthew Vitale, August 2023.

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1.0 INTRODUCTION

The United States is reliant on foreign countries (e.g., China) for much of its rare earth element (REE) supply. The reliance on foreign countries for REEs is a major concern for the U.S. in both domestic use and military security. China is the largest producer of REEs and has set quotas on production and exports, both of which have the potential to affect the U.S. economy and defense network. The U.S. desire to move to a more "Green Energy" environment will only put more strain on REE supply. This task aims to identify REE occurrences in large-scale waste sources associated with past underground and open-pit mining and ore processing facilities throughout portions of Montana. Mine types include metallic, non-metallic, and coal. Programs to identify REE deposits throughout the U.S. are underway; however, exploration and mine development can take decades before resulting in an increase in U.S. resources and production. Recovery of REEs from abandoned/inactive sites would shorten the time necessary to add to the U.S. REE supply and production, as no new mine permitting would be required. Recovery of REEs from mine waste has a secondary benefit of aiding environmental cleanup and reducing waste sources.

This data summary report presents the results of aqueous and solid sample collection and analysis performed as part of a Cooperative Agreement titled "Materials Technology for Rare Earth Elements Processing (MT-REEP)." MT-REEP consists of several different tasks focused on sharing expertise with Montana Technological University, including Montana Bureau of Mines and Geology (MBMG) faculty and staff. The multiple research projects aim to demonstrate that REEs exist and can be produced economically—even from undesirable mining wastes—without environmental damage, thus reducing the Nation's dependence on foreign-based supply chains. Task 4 focuses on the collection of samples from a preliminary list of large-scale mining and ore processing sites throughout Montana. Throughout the year, additional sites were added as contact was made with various State and Federal agencies and private companies. The list currently consists of 21 sites. Table 1-1 contains the initial 13 sites, plus the added sites, while figure 1-1 shows the counties the sites are located within.

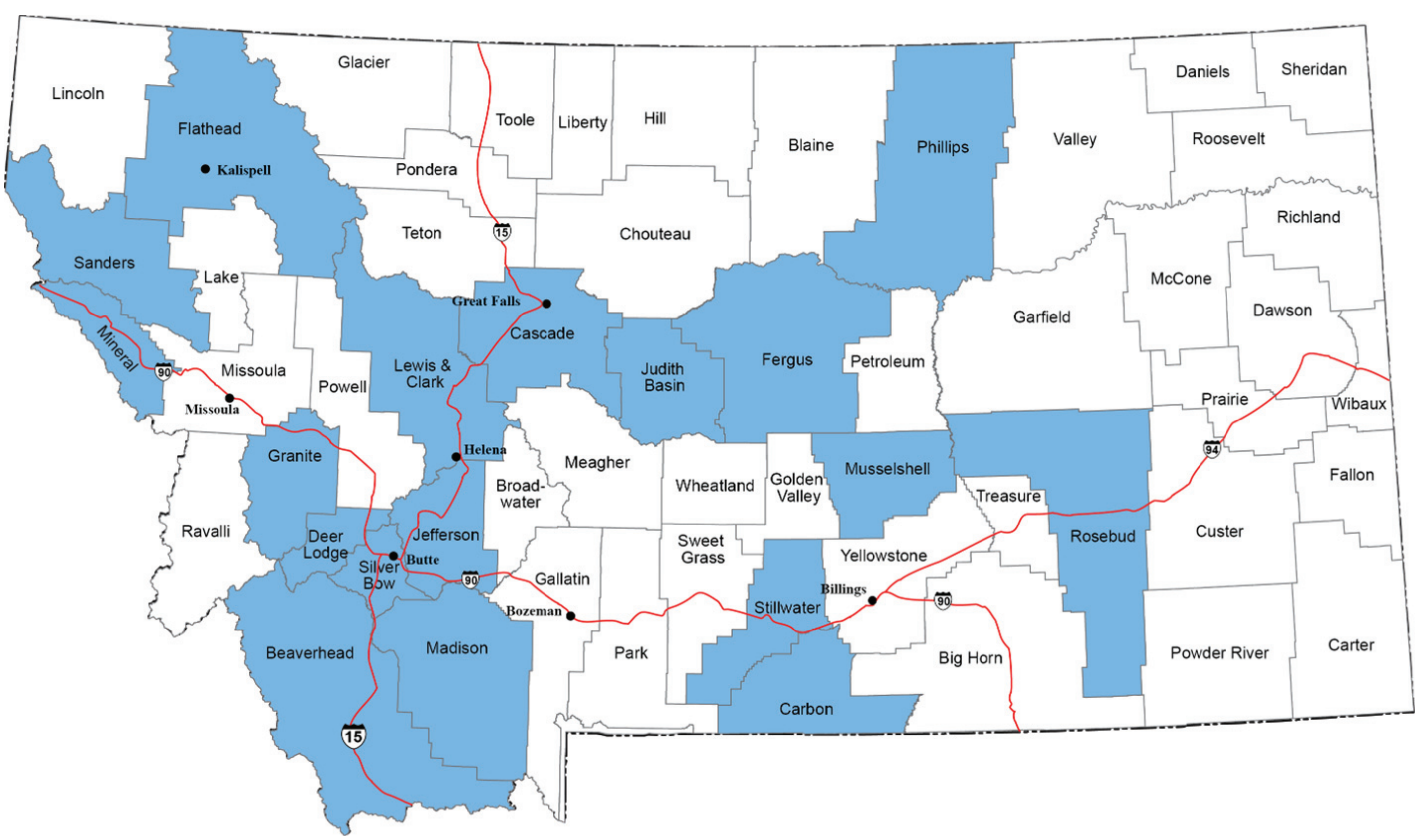

Figure 1-1. Location map showing counties where study/sampling areas are located throughout Montana.

Table 1-1. Potential study/resource areas–REE, MBMG Task 4.

1. **Butte Operations**
    a. Berkeley Pit
    b. Horseshoe Bend
    c. HsB WTP sludge
    d. Leach pads
    e. Waste dumps
    f. Yankee Doodle Tailings
2. **Anaconda Operations**
    a. Smelter Hill slag
    b. Smelter Hill tailings
    c. Opportunity Pond
3. Columbia Falls Aluminum Plant
    a. SPL ponds
    b. Waste pits
4. **Beal Mountain**
    a. Waste dump
    b. Tailings/leach pad
5. **Golden Sunlight Mine**
    a. Waste dump
    b. Tailings (?)
6. **Solvay/Stauffer**
    a. Tailings basin
    b. Waste pile
    c. Maiden Rock ore piles
7. Garrison/Phosphate Area Mines
    a. Waste dumps
8. **Phillipsburg Mining District**
    a. Waste dumps
    b. Tailings
    c. AMD sites
9. **Basin/Ten Mile Watersheds**
    a. AMD sites (Basin/Cataract Creeks)
    b. Luttrell Waste Repository
10. **Great Falls/Lewistown Coal Fields**
    a. Belt/Stockett/Sand Coulee AMD
    b. Waste/spoils piles
11. **Black Eagle Smelter/Great Falls**
    a. Waste dumps
    b. Tailings
    c. Seeps
12. Roundup/Red Lodge Coal Fields
    a. Waste/spoils piles
13. **Nye/Fishtail/Columbus Chrome**
    a. Waste piles
    b. Ore stock piles
    c. Columbus Smelter
14. **Zortman–Landusky**
    a. AMD
    b. Treated water
    c. Waste piles
15. Montana Tunnels
    a. AMD/seeps
    b. Waste piles
16. Thompson Falls–U.S. Minerals
    a. Waste Dumps
    b. Tailings
    c. AMD seeps
17. Kendall Mine/Lewistown
    a. Waste Dumps
    b. Tailings
    c. AMD seeps
18. Hog Heaven Mine/Kalispell area
    a. Waste Dumps
    b. Tailings
    c. AMD seeps
19. Carpenter/Snow Creek
    a. Waste Dumps
    b. Tailings
    c. Seeps
20. **Flat Creek Tailings**
    a. Waste dumps
    b. Tailings
21. **Barkers/Hughesville**
    a. Waste dumps
    b. Tailings
    c. AMD seeps

Note. Sites in bold indicate locations where samples were collected during year 1 activities.

Year 1 work focused on the following activities:

1. Perform a thorough literature search of existing information for each site and compile REE data.
2. Develop detailed field and laboratory quality assurance project plans (QAPP) and sampling and analysis plans to guide personnel to ensure high-quality data are collected and analytical data meet the Army Research Laboratory (ARL) program goals.
3. Initiate contact with property owners and regulatory agencies (i.e., USFS, EPA, and DEQ) for site access; and
4. Implement a reconnaissance/limited sampling program to collect opportunistic aqueous and solid samples for REE at sites located in southwest Montana.

This data summary report describes the sampling conducted for item 4 above. Sampling procedures followed those described in the project-specific QAPP developed under item 2 above. Many of the sites shown in table 1-1 are part of ongoing U.S. Environmental Protection Agency Superfund activities or other regulatory action; therefore, sampling and analysis procedures, along with safety procedures, were designed to be compatible with those governing Superfund sites.

Solid samples were submitted to ALS Laboratories and West Virginia University (WVU) for rare earth element analysis and the MBMG Analytical Laboratory for inorganic analysis for the dissolved and total recoverable fractions. Water-quality data from the MBMG lab are available from the MBMG Groundwater Information Center online at: Montana's Ground Water Information Center 2025.

2.0 YEAR 1 SAMPLING OBJECTIVES

Limited reconnaissance sampling was conducted during the first year of the project at sites where access was easily obtained and previous data suggested REE existed in waste material. Initial reconnaissance sampling entailed collecting an adequate number of solid and/or aqueous samples at specific sites to determine if REE concentrations merited more detailed sampling. Sample sites included acid mine drainage discharge, sludge from water treatment facilities, waste dumps, smelter wastes, and mill tailings.

Initial sampling results are being used to develop more detailed sampling plans at sites with elevated REE concentrations. Sites with total REE concentrations above 412 mg/kg in solids/sludge (concentration approximately two times that found in earth's crust; Balaram, 2019) and total REE concentrations above 499 µg/L in aqueous samples (value identified as having secondary recovery potential) are considered as sites with elevated concentrations. Sites were also evaluated on the ratio of the amount of critical REEs (i.e., neodymium, europium, terbium, dysprosium, erbium, and yttrium) in the REE sum to the amount of more abundant REEs, also known as the outlook coefficient (Coutl; Seredin and Dai, 2012). The higher the coefficient, the more promising the material is as a secondary source; sites with a coefficient of 0.7 or above are considered elevated for critical REEs.

3.0 BACKGROUND AND SAMPLE SITE DESCRIPTION

A total of 149 aqueous and 243 solid samples were collected from 12 sites during year 1 activities. A description of each sample site and summary of aqueous, sludge, and solid sample results showing average, minimum, maximum, and number of samples are presented below.

3.1 Butte Mining District

Butte, Montana is well known for its long mining history. Mining first began in the 1860s with placer gold deposits. Soon after, silver, copper, and zinc were found in quantity and began to be mined. Duaime and McGrath (2019) noted the existence of 517 underground mines on the Butte Hill, with depths reaching up to 1 mi; production of ore from these mines was prodigious, with more than 23 billion pounds of copper and 4.9 billion pounds of zinc produced from 1880 through 2017. Over 10,000 miles of underground workings (Duaime and others, 2002) were exhumed in search of these metals; several open pit mines (e.g., the Berkeley Pit) were operated as part of mining operations. In 1982 the mines closed and the water pumps dewatering them were turned off. Open pit mining ended in 1983, but resumed in 1986. The cessation of underground mine dewatering allowed heavy-metal-laden water to flood the abandoned workings and Berkeley Pit (fig. 3-1).

Figure 3-1. The Berkeley Pit and the Horseshoe Bend Water Treatment plant.

Initial sampling focused on the collection of aqueous samples from sites monitored as part of the Butte Mine Flooding Operable Unit–Long-Term Monitoring Program. Samples were collected from a combination of alluvial and bedrock monitoring wells, underground mines, and surface-water sites, including the Berkeley Pit. Solid samples were collected from ore being mined in the Continental Pit and processed ore from the site concentrator. In addition, sludge samples were collected and analyzed from the onsite Horseshoe Bend Water Treatment Plant (HsB). Other opportunistic samples (both solid and aqueous) were collected in the Butte area. In total, 110 samples were collected and analyzed for REE; the results are presented in figures 3-2 and 3-3 and tables 3-1 through 3-16.

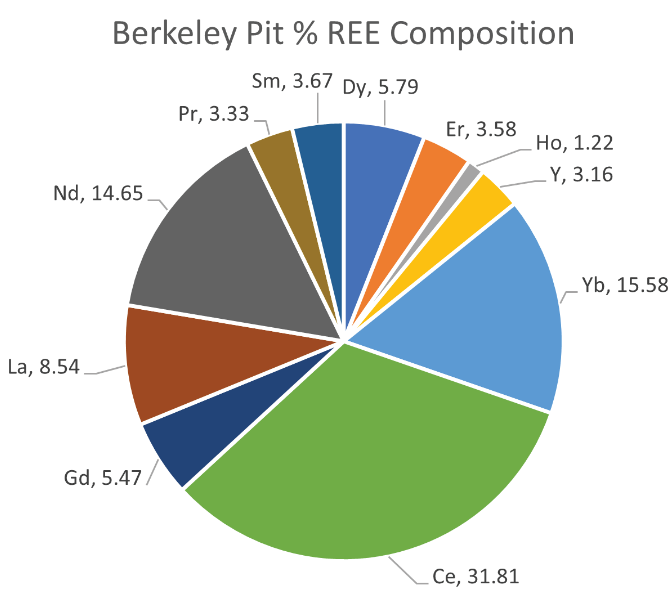

Figure 3-2. REE concentration percentages for every sample taken at the Berkeley Pit. Elements with less than 1% concentration were removed.

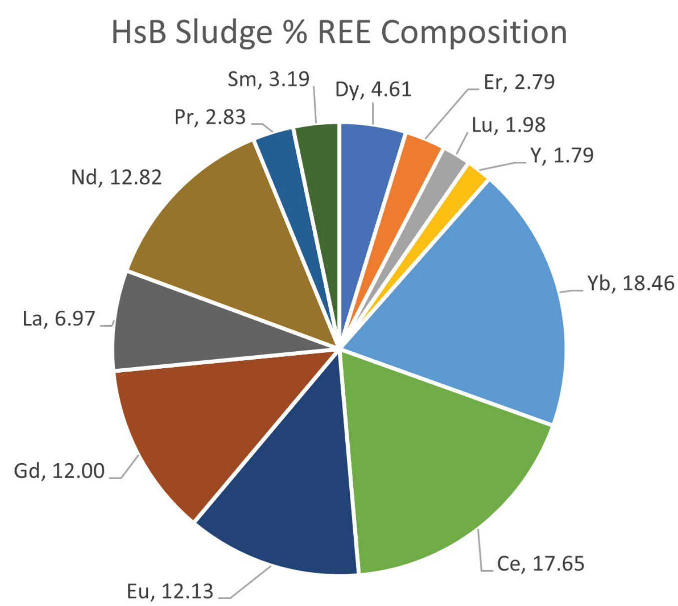

Figure 3-3. REE concentration percentages for every sludge sample taken at HsB. Elements with less than 1% concentration were removed.

Table 3-1. Butte operations, Butte mine flooding monitoring sites—rare earth element and germanium concentrations.

Butte Mineshafts Aqueous																	
Sample ID	Ge (µg/L)	Dy (µg/L)	Er (µg/L)	Ho (µg/L)	Lu (µg/L)	Tb (µg/L)	Tm (µg/L)	Y (µg/L)	Yb (µg/L)	Ce (µg/L)	Eu (µg/L)	Gd (µg/L)	La (µg/L)	Nd (µg/L)	Pr (µg/L)	Sm (µg/L)	Sc (µg/L)
AMC-5	<32.00	6.38	4.58	1.52	0.47	0.88	0.57	2.98	66.02	50.29	0.63	5.64	14.88	15.12	3.71	2.84	0.17
AMW-20	<32.00	4.63	2.91	1.01	0.32	0.71	0.34	1.98	46.23	60.24	0.58	4.70	29.59	14.23	4.03	2.51	0.15
Anselmo Dissolved	<32.00	0.01	0.01	<0.002	<0.002	<0.002	<0.002	0.01	0.58	0.08	<0.003	0.01	0.09	0.02	<0.003	<0.004	0.08
Anselmo Mine	NA	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.00	0.04	<0.02	<0.02	0.07	0.02	<0.02	<0.02	0.00
GM-1	<32.00	0.05	0.04	0.01	0.00	<0.002	0.00	0.03	0.89	1.01	0.00	0.05	0.74	0.20	0.06	0.01	0.10
Green Seep	<32.00	<0.004	<0.004	<0.002	<0.002	<0.002	<0.002	<0.004	<0.004	<0.008	<0.003	<0.003	<0.003	<0.008	<0.003	<0.004	0.07
Kelley Dissolved	<32.00	24.19	14.37	4.98	1.65	3.78	1.80	10.77	161.13	19.62	3.60	24.10	5.35	17.57	2.87	8.70	0.27
Kelley Mine	NA	25.18	14.60	5.38	1.69	4.02	1.90	11.15	0.00	21.36	3.79	24.35	5.99	19.09	3.16	9.33	0.00
LP-9	<32.00	504.64	329.25	107.34	44.55	76.25	46.61	299.41	2977.14	6376.91	74.38	475.06	1108.74	1547.90	374.87	329.53	11.13
LP-10	<32.00	0.15	0.11	0.04	0.02	0.02	0.02	0.10	1.57	0.37	0.02	0.16	0.08	0.32	0.06	0.08	0.08
LP-12	<32.00	0.01	0.01	0.00	0.00	0.00	0.00	0.01	0.09	0.02	<0.003	0.01	0.02	0.01	<0.003	<0.004	0.07
LP-13	<32.00	0.09	0.08	0.03	0.01	<0.002	0.01	0.06	2.06	0.07	<0.003	0.09	0.03	0.12	0.02	0.01	0.15
LP-14	<32.00	<0.004	<0.004	<0.002	<0.002	<0.002	<0.002	<0.004	0.10	<0.008	<0.003	<0.003	0.02	<0.008	<0.003	<0.004	0.10
LP-15	<32.00	0.01	<0.004	<0.002	<0.002	<0.002	<0.002	<0.004	0.27	0.02	<0.003	<0.003	0.03	<0.008	<0.003	<0.004	0.20
LP-16	<32.00	0.02	0.03	0.01	0.00	0.00	0.00	0.03	0.58	0.15	<0.003	0.02	0.13	0.05	0.01	<0.004	0.09
LP-17R	<32.00	10.39	7.89	2.54	0.95	1.45	1.03	5.94	99.71	62.29	1.07	8.80	9.34	17.46	3.86	3.71	0.13
Marget Ann	<32.00	<0.004	<0.004	<0.002	<0.002	<0.002	<0.002	<0.004	0.11	0.06	<0.003	<0.003	0.04	0.03	<0.003	<0.004	0.04
Ophir Dissolved	<32.00	0.03	0.02	<0.002	<0.002	<0.002	<0.002	0.02	0.44	0.32	<0.003	0.03	0.19	0.17	0.03	0.02	0.08
Ophir Mine	NA	0.04	0.03	<0.02	<0.02	<0.02	<0.02	0.03	0.00	0.33	<0.02	0.04	0.20	0.18	0.04	0.03	0.00
Orphan Boy Dissolved	<32.00	0.01	0.01	<0.002	<0.002	<0.002	<0.002	0.01	0.21	0.04	<0.003	<0.003	0.01	0.02	<0.003	<0.004	0.11
Orphan Boy Mine	NA	0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.00	0.06	<0.02	<0.02	0.03	0.03	<0.02	<0.02	0.00
Steward Dissolved	<32.00	2.83	1.73	0.61	0.16	0.43	0.20	1.08	26.65	1.70	0.40	3.05	0.77	1.63	0.24	0.86	0.17
Tech Well	<32.00	<0.004	<0.004	<0.002	<0.002	<0.002	<0.002	<0.004	0.10	<0.008	<0.003	<0.003	<0.003	<0.008	<0.003	<0.004	0.08
Travona Dissolved	<32.00	0.01	0.01	<0.002	<0.002	<0.002	<0.002	0.01	0.26	0.15	<0.003	0.01	0.10	0.06	0.01	<0.004	0.06
Travona Mine TR	<32.00	0.03	0.03	0.01	0.01	0.01	0.01	0.03	0.27	0.21	0.01	0.03	0.11	0.11	0.03	0.03	0.04
Well B	<32.00	<0.004	<0.004	<0.002	<0.002	<0.002	<0.002	0.00	0.05	0.03	<0.003	<0.003	0.01	<0.008	<0.003	<0.004	0.09
Well C	<32.00	0.28	0.23	0.07	0.02	0.01	0.03	0.14	4.28	<0.008	0.02	0.21	<0.003	0.05	<0.003	0.01	0.14
Well D-2	19.90	0.64	0.39	0.13	0.05	0.11	0.05	0.30	4.30	0.64	0.10	0.65	0.21	0.63	0.11	0.29	0.16
Well E	<32.00	<0.004	<0.004	<0.002	<0.002	<0.002	<0.002	<0.004	0.02	0.03	<0.003	<0.003	<0.003	<0.008	<0.003	<0.004	0.10
Well F	<32.00	<0.004	<0.004	<0.002	<0.002	<0.002	<0.002	<0.004	0.01	<0.008	<0.003	<0.003	<0.003	<0.008	<0.003	<0.004	0.08
Well G	<32.00	<0.004	<0.004	<0.002	<0.002	<0.002	<0.002	<0.004	0.02	<0.008	<0.003	<0.003	<0.003	<0.008	<0.003	<0.004	0.09

Note. Green elements represent heavy REE, Yellow represents light REE, and NA represents not analyzed.

Table 3-2. Butte operations, Butte mine flooding monitoring sites—rare earth element and germanium statistics.

Butte Mineshafts Aqueous Statistics					
Sample ID	Coutl	Total REE (µg/L)	Average REE	Minimum REE	Maximum REE
AMC-5	1.77	176.67	11.04	0.17	66.02
AMW-20	1.12	174.16	10.88	0.15	60.24
Anselmo Dissolved	0.00	0.88	0.10	0.01	0.58
Anselmo Mine	0.00	0.14	0.02	0.00	0.07
GM-1	0.00	3.19	0.21	0.00	1.01
Green Seep	0.00	0.07	0.07	0.07	0.07
Kelley Dissolved	8.01	304.73	19.05	0.27	161.13
Kelley Mine	2.20	150.97	8.88	0.00	25.18
LP-9	0.84	14,683.69	917.73	11.13	6376.91
LP-10	5.02	3.19	0.20	0.02	1.57
LP-12	0.00	0.24	0.02	0.00	0.09
LP-13	0.00	2.82	0.20	0.01	2.06
LP-14	0.00	0.22	0.07	0.02	0.10
LP-15	0.00	0.53	0.11	0.01	0.27
LP-16	0.00	1.13	0.08	0.00	0.58
LP-17R	2.07	236.54	14.78	0.13	99.71
Marget Ann	0.00	0.27	0.05	0.03	0.11
Ophir Dissolved	0.00	1.32	0.12	0.02	0.44
Ophir Mine	0.00	0.93	0.08	0.00	0.33
Orphan Boy Dissolved	0.00	0.40	0.05	0.01	0.21
Orphan Boy Mine	0.00	0.14	0.02	0.00	0.06
Steward Dissolved	12.64	42.50	2.66	0.16	26.65
Tech Well	0.00	0.19	0.09	0.08	0.10
Travona Dissolved	0.00	0.68	0.07	0.01	0.26
Travona Mine TR	1.96	0.95	0.06	0.01	0.27
Well B	0.00	0.17	0.03	0.00	0.09
Well C	0.00	5.48	0.42	0.01	4.28
Well D-2	7.07	28.64	1.68	0.05	19.90
Well E	0.00	0.14	0.05	0.02	0.10
Well F	0.00	0.09	0.04	0.01	0.08
Well G	0.00	0.11	0.06	0.02	0.09

Table 3-3. Butte operations, Butte mine flooding monitoring sites—rare earth element and germanium concentrations.

Butte Mineshafts Solids																	
Sample ID	Ge (mg/kg)	Dy (mg/kg)	Er (mg/kg)	Ho (mg/kg)	Lu (mg/kg)	Tb (mg/kg)	Tm (mg/kg)	Y (mg/kg)	Yb (mg/kg)	Ce (mg/kg)	Eu (mg/kg)	Gd (mg/kg)	La (mg/kg)	Nd (mg/kg)	Pr (mg/kg)	Sm (mg/kg)	Sc (mg/kg)
220-230 GM-1	1.6	3.66	2.32	0.79	0.38	0.65	0.37	22.7	2.32	72.4	1.2	4.33	37	27.9	8	5.12	14.4
330-340 GM-1	1.8	3.25	2.03	0.69	0.28	0.57	0.3	1.86	19.1	66.1	1.14	3.84	34.6	25.8	7.27	4.77	13.6
490-500 GM-1	1.7	3.69	2.18	0.74	0.31	0.61	0.32	2.1	21.3	74.7	1.1	4.29	38.8	29.3	8.2	5.21	14
610-620 GM-1	1.4	3.64	2.16	0.81	0.35	0.59	0.31	2.09	21.9	73.5	1.16	4.03	38.8	29.3	8.09	5.05	14.9
800-810 GM-1	1.2	3.54	2.18	0.72	0.35	0.63	0.33	2.1	21.3	58.3	1.22	3.98	31.1	26.2	6.78	4.44	15.3
Granite Mine	3.7	2.66	1.49	0.52	0.24	0.42	0.23	1.84	14.8	56.7	1.04	3.01	30.9	23.8	6.9	4.36	8
YDT-2014-001	1.6	3.61	2.16	0.77	0.36	0.6	0.34	2.24	20	67.3	1.11	3.88	37	24.8	7.33	4.52	13.5

Table 3-4. Butte operations, Butte mine flooding monitoring sites—rare earth element and germanium statistics.

Butte Mineshafts Solids Statistics					
Sample ID	Coutl	Total REE (mg/kg)	Average REE	Minimum REE	Maximum REE
220-230 GM-1	0.77	205.14	12.07	0.37	72.40
330-340 GM-1	0.75	187.00	11.00	0.28	66.10
490-500 GM-1	0.74	208.55	12.27	0.31	74.70
610-620 GM-1	0.76	208.08	12.24	0.31	73.50
800-810 GM-1	0.89	179.67	10.57	0.33	58.30
Granite Mine	0.74	160.61	9.45	0.23	56.70
YDT-2014-001	0.74	191.12	11.24	0.34	67.30

Table 3-5. Butte operations, Butte treatment lagoons—rare earth element and germanium statistics.

Butte Treatment Lagoon Solids (WVU) Statistics					
Sample ID	Coutl	Total REE (mg/kg)	Average REE	Minimum REE	Maximum REE
BTL-WTP#2	1.38	70.01	4.38	0.16	19.29
BTL-WTP#4	1.34	55.02	3.44	0.14	15.41

Table 3-6. Butte operations, Butte treatment lagoons—rare earth element and germanium statistics.

Butte Treatment Lagoon Solids (ALS) Statistics					
Sample ID	Coutl	Total REE (mg/kg)	Average REE	Minimum REE	Maximum REE
BTL-WTP#2	0.13	30.34	1.90	0.06	9.40
BTL-WTP#4	0.13	31.28	1.96	0.07	9.90

Table 3-7. Butte operations, Butte treatment lagoons—rare earth element and germanium concentrations.

Butte Treatment Lagoon Solids (WVU)																	
Sample ID	Ge (mg/kg)	Dy (mg/kg)	Er (mg/kg)	Ho (mg/kg)	Lu (mg/kg)	Tb (mg/kg)	Tm (mg/kg)	Y (mg/k	Yb (mg/kg)	Ce (mg/kg)	Eu (mg/kg)	Gd (mg/kg)	La (mg/kg)	Nd (mg/kg)	Pr (mg/kg)	Sm (mg/kg)	Sc (mg/kg)
BTL-WTP#2	<0.032	1.651	1.138	0.569	2.486	0.371	0.161	0.324	0.17	0.889	12.948	19.291	10.319	12.169	2.467	2.611	2.444
BTL-WTP#4	<0.032	1.662	1.096	0.352	1.831	0.361	0.158	0.288	0.142	0.837	12.881	15.409	8.568	6.433	1.624	1.599	1.775

Table 3-8. Butte operations, Butte treatment lagoons—rare earth element and germanium concentra-

Butte Treatment Lagoon Solids (ALS)																	
Sample ID	Ge (mg/kg)	Dy (mg/kg)	Er (mg/kg)	Ho (mg/kg)	Lu (mg/kg)	Tb (mg/kg)	Tm (mg/kg)	Y (mg/k	Yb (mg/kg)	Ce (mg/kg)	Eu (mg/kg)	Gd (mg/kg)	La (mg/kg)	Nd ((mg/kg	Pr (mg/kg)	Sm (mg/kg)	Sc (mg/kg)
BTL-WTP#2	<0.5	0.72	0.49	0.16	0.06	0.12	0.07	6.9	0.41	9.4	0.16	0.78	5.1	3.3	0.97	0.7	1
BTL-WTP#4	<0.5	0.79	0.46	0.17	0.07	0.14	0.07	6.6	0.45	9.9	0.14	0.89	5.2	3.8	1.02	0.58	1

Table 3-9. Butte operations, Montana Resources mill—rare earth element and germanium concentrations.

Montana Resources Mill Operations																	
Sample ID	Ge (mg/kg)	Dy (mg/kg)	Er (mg/kg)	Ho (mg/kg)	Lu (mg/kg)	Tb (mg/kg)	Tm (mg/kg)	Y (mg/kg)	Yb (mg/kg)	Ce (mg/kg)	Eu (mg/kg)	Gd (mg/kg)	La (mg/kg)	Nd (mg/kg)	Pr (mg/kg)	Sm (mg/kg)	Sc (mg/kg)
Copper Comp Jan-Mar 22	0.9	1.45	0.97	0.3	0.18	0.23	0.13	1.03	8.9	26.9	0.34	1.52	14	11.2	3.12	2.14	1.1
Copper Comp Apr-Jun 22	0.5	1.22	0.74	0.23	0.11	0.19	0.09	0.69	6.3	21	0.25	1.2	10.6	8.5	2.38	1.58	1
Copper Comp Jul-Sep 22	0.5	1.07	0.65	0.21	0.1	0.17	0.1	0.67	6.8	20.4	0.33	1.26	10	8.2	2.34	1.42	1.1
Copper Comp Jan 2023	<0.5	1.13	0.8	0.26	0.13	0.19	0.13	0.82	7.8	21.5	0.31	1.19	10.7	8.6	2.39	1.58	2
Copper Comp Feb 2023	0.5	1.19	0.74	0.25	0.11	0.19	0.12	0.75	7.9	20.6	0.29	1.19	10.2	8.9	2.34	1.48	1.3
Mill Feed Aug 22	1.5	3.58	2.21	0.7	0.29	0.65	0.3	2.15	19.3	72.8	1.13	3.95	37.8	28.6	8.11	5.08	10.6
Mill Feed Sept 22	1.3	3.16	1.88	0.67	0.3	0.56	0.28	1.79	19.1	69.6	0.97	3.67	35.8	28.4	7.62	4.71	12.3
Mill Feed Oct 22	1.6	3.75	2.25	0.72	0.35	0.6	0.32	2.07	20.3	70.7	0.97	4.19	36.8	27.1	7.77	4.95	12
Mill Feed Dec 22	1.3	3.69	2.14	0.69	0.39	0.59	0.29	2.07	19.6	70.7	0.92	4.01	37.8	27	7.89	4.99	11.5
Moly Comp Sept 22	<0.5	0.46	0.28	0.09	0.02	0.08	0.04	0.32	2.4	8.5	0.13	0.45	4.2	3.4	0.91	0.5	<1
Moly Comp Oct 22	<0.5	0.63	0.29	0.1	0.04	0.1	0.05	0.3	3.4	9.7	0.19	0.48	4.9	4.1	1.09	0.91	<1
Moly Comp Nov 22	<0.5	0.49	0.28	0.1	0.05	0.1	0.04	0.36	3.1	7.7	0.15	0.61	4	3.2	0.86	0.65	<1
Moly Comp Dec 22	<0.5	0.54	0.33	0.1	0.04	0.1	0.05	0.26	2.9	9.2	0.13	0.5	4.7	3.4	1.02	0.67	<1
Moly Comp Jan 2023	<0.5	0.52	0.3	0.1	0.04	0.07	0.05	0.31	3	7.2	0.1	0.48	3.8	3.1	0.81	0.62	<1
Moly Comp Feb 2023	<0.5	0.47	0.35	0.12	0.05	0.07	0.05	0.28	3.6	8	0.12	0.49	4.2	3.2	0.88	0.68	<1
Tailings Aug 22	1.6	3.25	2.19	0.75	0.27	0.56	0.32	2.24	17.7	69.4	0.94	4.05	37.2	25.9	7.79	4.91	10.1
Tailings Sept 22	1.4	3.24	2.01	0.72	0.33	0.56	0.29	2.1	18.6	71.8	0.98	4.17	37.2	27.9	7.99	4.67	12.7
Tailings Oct 22	1.3	3.27	2.15	0.69	0.34	0.59	0.26	1.99	18.6	68.3	0.9	3.86	36.7	25.6	7.65	4.55	11.7
Tailings Nov 22	1.4	3.65	2.1	0.72	0.32	0.58	0.3	2.16	18.4	71.5	0.97	4.23	37.7	26.5	7.97	4.73	11
Tailings Dec 22	1.4	3.71	2.01	0.75	0.29	0.62	0.29	2.01	18.9	68.2	1.09	4.12	36.4	27	7.78	4.95	11.1
Total Tail Jan 2023	1.5	3	1.84	0.67	0.35	0.52	0.25	1.88	17.4	59.6	0.89	3.33	30.1	24.1	6.7	4.32	13
Total Tail Feb 2023	1.4	3.68	1.99	0.71	0.32	0.63	0.32	2.16	21.3	65.6	1.11	3.92	33.1	26.5	7.24	4.48	9.4

Table 3-10. Butte operations, Horseshoe Bend Water Treatment Plant—rare earth element and germanium concentrations.

HsB Aqueous																	
Sample ID	Ge (µg/L)	Dy (µg/L)	Er (µg/L)	Ho (µg/L)	Lu (µg/L)	Tb (µg/L)	Tm (µg/L)	Y (µg/L)	Yb (µg/L)	Ce (µg/L)	Eu (µg/L)	Gd (µg/L)	La (µg/L)	Nd (µg/L)	Pr (µg/L)	Sm (µg/L)	Sc (µg/L)
1st Stage Sludge Decant-HsB-Tot. Rec.	<32.00	0.121	0.061	0.018	<0.002	0.014	<0.002	0.026	1.316	2.743	0.02	0.197	1.808	0.828	0.202	0.128	0.045
2nd Stage Sludge Decant-HsB-Tot. Rec.	<32.00	<0.004	<0.004	<0.002	<0.002	<0.002	<0.002	<0.004	<0.004	<0.008	<0.003	<0.003	<0.003	<0.008	<0.003	<0.004	<0.037
HsB	<32.00	62.192	38.983	12.796	5.278	9.501	5.366	34.967	351.652	304.768	9.815	57.277	80.776	164.058	35.823	41.847	6.322
HsB 5/23/2023	<32.00	70.658	44.369	14.906	6.04	10.788	6.134	39.584	394.23	319.955	11.212	65.509	85.25	189.414	38.503	47.197	7.078
HsB Dissolved	<32.00	65.868	41.076	13.601	5.4	9.992	5.614	36.281	393.659	309.867	10.636	62.445	82.742	180.573	36.669	45.389	8.782
HsB Plant Influent, BP	<32.00	217.099	133.113	43.687	17.519	33.42	18.192	121.43	1283.2	1228.24	35.928	207.669	324.773	573.827	126.198	141.993	27.55
HsB-total recov	NA	89.656	55.09	17.878	7.392	13.544	10.206	67.85	486.803	450.468	18.768	86.212	115.53	340.352	70.865	62.242	14.876
HsB-total recov	NA	117.358	72.801	23.945	9.892	17.746	7.702	51.119	671.703	576.174	14.387	108.924	143.197	269.398	54.407	79.622	9.417
HsB-WTR Stage 1 Diss	23.10	0.233	0.115	0.049	<0.002	0.047	0.013	0.043	1.901	8.953	0.064	0.437	5.574	2.301	0.635	0.289	0.061
HsB-WTR Stage 1-Tot. Recov	22.20	0.438	0.246	0.093	0.025	0.08	0.032	0.174	3.06	9.876	0.102	0.627	5.723	2.71	0.741	0.47	0.109
HsB-WTR Stage 1-Tot. Recov, Jan. Comp	16.70	2.439	1.433	0.488	0.183	0.396	0.196	1.232	15.251	24.439	0.45	2.614	10.981	8.826	2.098	1.785	0.352
HsB-WTR Stage 2 Diss	26.80	<0.004	<0.004	<0.002	<0.002	<0.002	<0.002	<0.004	<0.004	<0.008	<0.003	<0.003	<0.003	<0.008	<0.003	<0.004	<0.037
HsB-WTR Stage 2 Tot. Recov	29.40	<0.004	<0.004	0.002	<0.002	<0.002	<0.002	<0.004	0.053	0.102	<0.003	<0.003	0.051	0.037	<0.003	<0.004	<0.037

Table 3-11. Butte operations, Montana Resources mill—Rare earth element and germanium statistics.

Montana Resources Mill Operations Statistics					
Sample ID	Coutl	Total REE	Average REE	Minimum REE	Maximum REE
Copper Comp Jan-Mar 22	0.81	74.41	4.38	0.13	26.90
Copper Comp Apr-Jun 22	0.78	56.58	3.33	0.09	21.00
Copper Comp Jul-Sep 22	0.80	55.32	3.25	0.10	20.40
Copper Comp Jan 2023	0.82	59.53	3.72	0.13	21.50
Copper Comp Feb 2023	0.88	58.05	3.41	0.11	20.60
Mill Feed Aug 22	0.73	198.75	11.69	0.29	72.80
Mill Feed Sept 22	0.74	192.11	11.30	0.28	69.60
Mill Feed Oct 22	0.74	196.44	11.56	0.32	70.70
Mill Feed Dec 22	0.73	195.57	11.50	0.29	70.70
Moly Comp Sept 22	0.75	21.78	1.45	0.02	8.50
Moly Comp Oct 22	0.85	26.28	1.75	0.04	9.70
Moly Comp Nov 22	0.89	21.69	1.45	0.04	7.70
Moly Comp Dec 22	0.77	23.94	1.60	0.04	9.20
Moly Comp Jan 2023	0.92	20.50	1.37	0.04	7.20
Moly Comp Feb 2023	0.92	22.56	1.50	0.05	8.00
Tailings Aug 22	0.69	189.17	11.13	0.27	69.40
Tailings Sept 22	0.71	196.66	11.57	0.29	71.80
Tailings Oct 22	0.71	188.45	11.09	0.26	68.30
Tailings Nov 22	0.70	194.23	11.43	0.30	71.50
Tailings Dec 22	0.75	190.62	11.21	0.29	68.20
Total Tail Jan 2023	0.76	169.45	9.97	0.25	59.60
Total Tail Feb 2023	0.80	183.86	10.82	0.32	65.60

Table 3-12. Butte operations, Horseshoe Bend Water Treatment Plant—rare earth element and germanium statistics.

HsB Aqueous Statistics					
Sample ID	Coutl	Total REE (μg/L)	Average REE	Minimum REE	Maximum REE
1st Stage Sludge Decant-HsB-Tot. Rec.	0.00	7.53	0.54	0.01	2.74
2nd Stage Sludge Decant-HsB-Tot. Rec.	0.00	0.00	0.00	0.00	0.00
HsB	1.94	1,221.42	76.34	5.28	351.65
HsB 5/23/2023	2.08	1,350.83	84.43	6.04	394.23
HsB Dissolved	2.10	1,308.59	81.79	5.40	393.66
HsB Plant Influent, BP	1.74	4,533.83	283.36	17.52	1283.20
HsB-total recov	2.00	1,907.73	119.23	7.39	486.80
HsB-total recov	1.92	2,227.79	139.24	7.70	671.70
HsB-WTR Stage 1 Diss	0.00	43.82	2.74	0.01	23.10
HsB-WTR Stage 1-Tot. Recov	0.66	46.71	2.75	0.03	22.20
HsB-WTR Stage 1-Tot. Recov, Jan. Comp	1.14	89.86	5.29	0.18	24.44
HsB-WTR Stage 2 Diss	0.00	26.80	26.80	26.80	26.80
HsB-WTR Stage 2 Tot. Recov	0.00	29.65	4.94	0.00	29.40

Table 3-13. Butte operations, Horseshoe Bend Water Treatment Plant sludge—rare earth element and germanium concentrations.

HsB Sludge																	
Sample ID	Ge (mg/kg)	Dy (mg/kg)	Er (mg/kg)	Ho (mg/kg)	Lu (mg/kg)	Tb (mg/kg)	Tm (mg/kg)	Y (mg/kg	Yb (mg/kg)	Ce (mg/kg)	Eu (mg/kg)	Gd (mg/kg)	La (mg/kg)	Nd (mg/kg)	Pr (mg/kg)	Sm (mg/kg)	Sc (mg/kg)
HsB-Stage 1	<0.5	0.7	0.36	0.16	0.05	0.12	0.07	0.43	6.1	11.2	0.18	0.82	6.1	4.1	0.95	0.75	0.6
HsB Stage 2	0.6	31	18.8	6.76	2.42	5.2	2.76	17.4	213	187.5	5.51	31.4	52.3	90.5	20.4	22.9	4.4
HsB-WTP-Stage1, BP, Jan 23	<0.5	32.8	19.55	6.96	2.82	5.22	2.74	17.7	208	191.5	5.52	30.9	49.1	86	19.95	21.8	4.5
HsB-WTP-Stage 1 Feb 23	<0.5	29.7	17.9	6.25	2.5	4.69	2.67	16.15	197	176.5	5.19	27.4	47.5	81.2	18.4	20.3	4.1
HsB 1st stage clarifier, HsB	<0.032	20.932	13.029	3.227	19.122	4.29	1.853	3.119	1.811	12.172	112.699	101.543	26.149	50.41	11.347	13.14	2.972
HsB 1st stage clarifier, HsB 5/23/2023	<0.032	42.146	25.415	6.721	40.465	8.381	3.304	6.333	3.391	22.755	284.469	216.956	56.469	124.8	25.537	29.814	5.518

Table 3-14. Butte operations, Berkeley Pit—rare earth element and germanium concentrations.

Berkeley Pit																	
Sample ID	Ge (µg/L)	Dy (µg/L)	Er (µg/L)	Ho (µg/L)	Lu (µg/L)	Tb (µg/L)	Tm (µg/L)	Y (µg/L)	Yb (µg/L)	Ce (µg/L)	Eu (µg/L)	Gd (µg/L)	La (µg/L)	Nd (µg/L)	Pr (µg/L)	Sm (µg/L)	Sc (µg/L)
BP-4 ft, Diss.	NA	208.86	130.79	43.67	18.15	33.47	18.62	114.43	NA	1279.31	35.09	204.97	343.65	565.21	131.14	136.13	NA
BP-4 ft, Tot. Recov.	<32.00	263.17	161.54	56.54	23.22	41.06	23.71	147.19	1100.79	1223.62	40.25	241.62	332.33	579.94	132.2	155.08	24.78
BP-4 REE dissolved	<32.00	263.17	161.54	56.54	23.22	41.06	23.71	147.19	1100.79	1223.62	40.25	241.62	332.33	579.94	132.2	155.08	24.78
BP-4 REE total recov	<32.00	207.34	126.98	44.33	17.71	32.6	18.37	113.24	1031.7	1099.71	32.99	195.16	302.25	548.48	116.26	129.43	21.81
BP-26 ft, Diss.	NA	216.45	137.2	46	18.2	35.55	19.2	119.15	NA	1370.55	36.2	209.35	366.05	587.65	140.55	145.2	NA
BP-26 ft, Tot. Recov.	NA	219.18	137.69	46.28	18.68	35.61	19.49	119.83	NA	1346.76	36.25	210.89	361.8	585.51	138.56	142.51	NA
BP-150 ft, Diss.	NA	216.6	132.35	45.15	17.95	34.25	18.6	117.55	NA	1329.3	36.45	204.95	352.6	577.7	137.55	142.95	NA
BP-150 ft, Tot. Recov.	NA	216.4	137.75	45.15	18.8	34.95	19.45	117.3	NA	1336.35	35.45	210.65	355.95	578.45	137.05	141.3	NA
BP-166 ft	NA	248.18	152.99	50.3	20.56	37.4	21.14	137.67	1440.83	1353.59	40.51	239.52	357.08	649.29	139.05	161.07	32.17
BP-373 REE dissolved	<32.00	250.79	155.4	54.46	22.29	39.1	22.83	141.44	1015.65	1133.13	38.02	228.44	302.61	589.86	123.77	146.97	24.49
BP-373 REE total recov	<32.00	133.84	81.521	28.9	11.71	21.09	11.89	74.081	592.987	647.621	20.87	122.94	173.8	309.81	70.715	80.303	13.88
BP-394-Tot. Rec.	<32.00	244.55	148.72	50.72	20.08	37.47	20.44	128.7	1370.28	1283.46	39.22	227.72	350.15	606.63	135.96	156.92	29.93
BP-398-Tot. Rec.	<32.00	245.2	149.33	50.03	19.68	37.58	20	126.64	1427.74	1252.14	39.05	227.32	334.58	598	132.99	157.06	27.11
BP-820 ft, Diss.	NA	219.4	132.3	45.9	17.45	33.55	18.65	118.45	NA	1301.1	36.7	206.95	350.3	581.5	133.3	143.8	NA
BP-820 ft, Tot. Recov.	NA	222.31	141.29	46.46	18.79	35.84	19.89	120.81	NA	1356.56	36.48	214.14	363.2	596.12	139.72	145.41	NA

Table 3-15. Butte operations, Horseshoe Bend Water Treatment Plant sludge—rare earth element and germanium statistics.

HsB Sludge Statistics					
Sample ID	Coutl	Total REE (mg/kg)	Average REE	Minimum REE	Maximum REE
HsB-Stage 1	0.97	32.69	2.04	0.05	11.20
HsB Stage 2	1.68	712.85	41.93	0.60	213.00
HsB-WTP-Stage1, BP, Jan 23	1.61	705.06	44.07	2.74	208.00
HsB-WTP-Stage1 Feb 23	1.64	657.45	41.09	2.50	197.00
HsB 1st stage clarifier, HsB	1.86	397.82	24.86	1.81	112.70
HsB 1st stage clarifier, HsB 5/23/2023	2.11	902.47	56.40	3.30	284.47

Table 3-16. Butte operations, Berkeley Pit—rare earth element and germanium statistics.

Berkeley Pit Statistics					
Sample ID	Coutl	Total REE (µg/L)	Average REE	Minimum REE	Maximum REE
BP-4 ft, Diss.	0.72	3,263.49	233.11	18.15	1279.31
BP-4 ft,Tot. Recov.	0.72	4,547.04	284.19	23.22	1223.62
BP-4 REE dissolved	1.65	4,547.04	284.19	23.22	1223.62
BP-4 REE total recov	1.65	4,038.35	252.40	17.71	1099.71
BP-26 ft, Diss.	0.70	3,447.30	246.24	18.20	1370.55
BP-26 ft, Tot. Recov.	0.71	3,419.04	244.22	18.68	1346.76
BP-150 ft, Diss.	0.71	3,363.95	240.28	17.95	1329.30
BP-150 ft, Tot. Recov.	0.71	3,385.00	241.79	18.80	1336.35
BP-166 ft	1.78	5,081.34	317.58	20.56	1440.83
BP-373 REE dissolved	1.69	4,289.24	268.08	22.29	1133.13
BP-373 REE total recov	1.66	2,395.95	149.75	11.71	647.62
BP-394-Tot. Rec.	1.78	4,850.96	303.19	20.08	1370.28
BP-398-Tot. Rec.	1.86	4,844.43	302.78	19.68	1427.74
BP-820 ft, Diss.	0.73	3,339.35	238.53	17.45	1301.10
BP-820 ft, Tot. Recov.	0.72	3,457.03	246.93	18.79	1356.56

3.2 Anaconda Operations

The town of Anaconda, Montana was founded by Marcus Daly on June 25, 1883 for the purpose of constructing a smelter to process ore being mined in Butte, 26 mi to the east (fig. 3-4, Morris, 1997). The mining company [Anaconda Copper Mining Company (ACM)] operated by Daly and his partners began construction of the first concentrator and smelter on the north side of Warm Springs Creek in 1883; the facility was put into operation in 1884 as the Upper Works. As ore production increased from ACM mines in Butte, Daly built an additional smelter in 1897, which became known as the Lower Works. Byproducts of the smelting process were slimes, slag, tailings, and airborne emissions of gases from the smelter stack. Tailings were sluiced to a series of ponds north of the town of Opportunity (which became known as the Opportunity Ponds), and beginning in 1947, to two ponds just below the concentrator, known as the Anaconda Ponds (Shovers and others, 1991). The Anaconda Smelter continued to operate until its closure in 1980.

The Anaconda Smelter Superfund site was a big target for this project due to its ease of access and large scale. An estimated 25 million cubic yards of slag now cover the area around the smelter. Most of the waste piles are capped with topsoil, and samples were taken as more were being covered. A preliminary set of eight samples was taken from random points across the uncapped piles. These samples were sent to ALS for assay (fig. 3-5, tables 3-17, 3-18).

The Opportunity Ponds are also nearby and are a repository for 130 million cubic yards of tailings and other wastes from the smelter. Atlantic Richfield (AR) and its contractors provided splits of soil borings taken from various locations across the ponds. From these borings, 13 samples were sent to ALS for assay (tables 3-19, 3-20).

Figure 3-4. An aerial view of the Anaconda Smelter and operations, as well as a pile of the black slag.

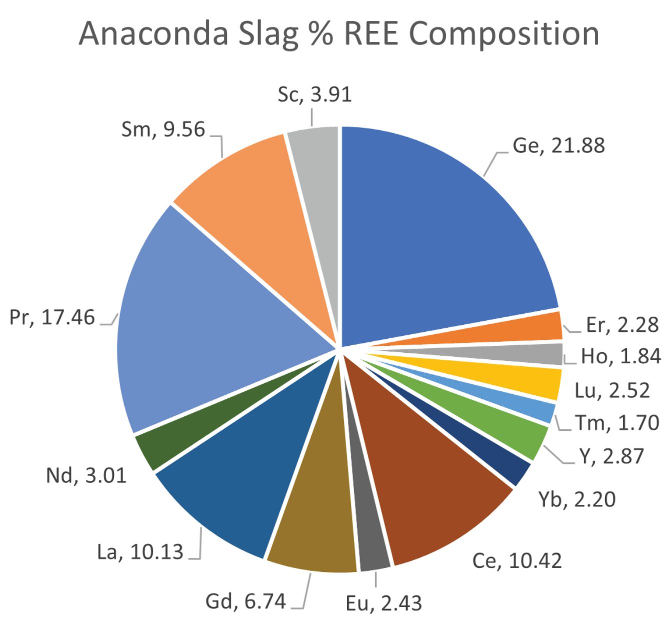

Figure 3-5. REE concentration percentages for every sample taken at the Anaconda slag piles. Elements with less than 1% concentration were removed.

Table 3-17. Anaconda operations, Anaconda slag—rare earth element and germanium concentrations.

Anaconada Slag																	
Sample ID	Ge (mg/kg)	Dy (mg/kg)	Er (mg/kg)	Ho (mg/kg)	Lu (mg/kg)	Tb (mg/kg)	Tm (mg/kg)	Y (mg/kg)	Yb (mg/kg)	Ce (mg/kg)	Eu (mg/kg)	Gd (mg/kg)	La (mg/kg)	Nd (mg/kg)	Pr (mg/kg)	Sm (mg/kg)	Sc (mg/kg)
AR-Slag 1	50.1	2.65	1.6	0.55	0.21	0.44	0.22	1.41	16.2	45.6	0.8	2.91	27.5	19.5	5.04	3.45	6
AR-Slag 2	42.1	1.52	1.45	16.4	0.23	0.53	0.42	0.24	2.3	3.65	5.17	19.7	25.9	0.73	45.6	2.75	6.5
AR-Slag 3	88.3	0.21	2.19	1.18	12.8	0.2	0.37	0.45	1.18	17	4.48	3.19	2.47	0.67	21.1	40	6.1
AR-Slag 4	14.5	1.64	0.23	0.42	0.56	0.22	1.47	16.9	2.71	3.37	4.65	16.5	20.6	0.76	39.6	2.83	5.5
AR-Slag 5	12.5	0.46	2.54	1.49	0.22	0.21	1.51	15.2	0.54	34.2	0.68	3.19	4.03	14.6	2.81	17.6	5
AR-Slag 6	9.4	2.47	1.54	1.45	14.4	0.21	0.52	0.46	0.25	3.33	4.31	17.3	19.6	0.77	36.3	2.62	5.2
AR-Slag 7	21.9	0.31	19.6	1.76	3.49	0.29	0.58	0.73	2.16	23.4	5.96	4.06	3.53	0.93	28.2	51	9
AR-Slag 8	43	1.61	0.23	0.44	0.6	0.21	16.8	1.62	2.94	3.66	5.26	20	26.8	0.79	46.2	2.86	7.1

Table 3-18. Anaconda operations, Anaconda slag—rare earth element and germanium statistics.

Anaconda Slag Statistics					
Sample ID	Coutl	Total REE (mg/kg)	Average REE	Minimum REE	Maximum REE
AR-Slag 1	0.86	184.18	10.83	0.21	50.10
AR-Slag 2	0.85	175.19	10.31	0.23	45.60
AR-Slag 3	0.81	201.89	11.88	0.20	88.30
AR-Slag 4	0.92	132.46	7.79	0.22	39.60
AR-Slag 5	0.95	116.78	6.87	0.21	34.20
AR-Slag 6	0.95	120.13	7.07	0.21	36.30
AR-Slag 7	0.93	176.90	10.41	0.29	51.00
AR-Slag 8	0.87	180.12	10.60	0.21	46.20

Table 3-19. Anaconda operations, Opportunity ponds—rare earth element and germanium statistics.

Opportunity Ponds Statistics					
Sample ID	Coutl	Total REE (mg/kg)	Average REE	Minimum REE	Maximum REE
BH-01 2.5-3	0.74	208.50	12.26	0.22	72.90
BH-05 10.5-11.0	0.78	181.46	10.67	0.27	61.90
BH-05 11-12	0.84	139.35	8.20	0.25	41.10
BH-07 7.5-8.0	0.84	185.85	10.93	0.21	54.70
BH-08 11.5-12.0	0.74	134.51	7.91	0.15	44.90
BH-08 12.5-13	0.85	127.21	7.48	0.19	37.50
BH-08 13.0-14.0	0.87	120.34	7.08	0.18	36.60
BH-11 5.0-7.0	0.81	127.71	7.51	0.20	43.80
BH-11 7.5-9.0	0.76	198.73	11.69	0.24	69.20
BH-13 11.0-11.5	0.80	224.09	13.18	0.30	76.00
BH-13 11.5-12	0.77	186.23	10.95	0.26	64.70
BH-15 15-16.2	0.73	106.71	6.28	0.14	36.30
BH-17 11-12	0.78	149.38	8.79	0.23	50.30
BH-21 0-5	0.89	166.92	9.82	0.24	55.40
BH-21 5-10	0.87	171.48	10.09	0.21	53.70
BH-21 10-15	0.84	155.68	9.16	0.22	50.10
BH-21 15-20	0.89	139.83	8.23	0.21	43.00
BH-21 20-25	0.81	128.30	7.55	0.22	41.40
BH-21 25-27	0.81	162.91	9.58	0.21	53.20

Table 3-20. Anaconda operations, Opportunity ponds—rare earth element and germanium concentrations.

Opportunity Ponds																	
Sample ID	Ge (mg/kg)	Dy (mg/kg)	Er (mg/kg)	Ho (mg/kg)	Lu (mg/kg)	Tb (mg/kg)	Tm (mg/kg)	Y (mg/kg)	Yb (mg/kg)	Ce (mg/kg)	Eu (mg/kg)	Gd (mg/kg)	La (mg/kg)	Nd (mg/kg)	Pr (mg/kg)	Sm (mg/kg)	Sc (mg/kg)
BH-01 2.5-3	3.7	3.05	1.52	0.57	0.26	0.54	0.22	1.6	15.5	72.9	1.2	4.23	37.4	34	8.96	5.85	17
BH-05 10.5-11.0	3.6	3.41	1.73	0.62	0.27	0.58	0.28	1.8	17.1	61.9	1.14	3.69	31.7	26.7	7.27	5.17	14.5
BH-05 11-12	15.8	2.26	1.43	0.51	0.26	0.41	0.25	1.54	14	41.1	0.67	2.59	22	17.7	4.8	3.33	10.7
BH-07 7.5-8.0	14.1	2.44	1.35	0.48	0.21	0.43	0.21	1.4	16.8	54.7	0.86	3.09	38.5	26.2	7.36	4.22	13.5
BH-08 11.5-12.0	7	2.01	1.12	0.4	0.22	0.39	0.15	1.14	11.6	44.9	0.62	2.3	23	18.7	5.26	3.4	12.3
BH-08 12.5-13	14.1	2.22	1.28	0.46	0.22	0.4	0.19	1.33	12.6	37.5	0.76	2.41	18.6	16.5	4.53	3.41	10.7
BH-08 13.0-14.0	9.8	1.98	1.18	0.38	0.2	0.38	0.18	1.23	12.2	36.6	0.75	2.44	18.5	16.9	4.34	3.08	10.2
BH-11 5.0-7.0	4.6	2.22	1.3	0.47	0.22	0.39	0.2	1.26	14.2	43.8	0.66	2.57	22.4	18.6	4.92	3.2	6.7
BH-11 7.5-9.0	3.3	3.37	1.75	0.66	0.27	0.61	0.24	1.57	17.6	69.2	1.01	4.01	34.1	30	7.78	5.56	17.7
BH-13 11.0-11.5	4.5	3.96	2.02	0.74	0.39	0.67	0.3	2.12	21.4	76	1.31	4.76	37.3	34	8.92	6.2	19.5
BH-13 11.5-12	3.7	2.86	1.78	0.61	0.26	0.49	0.28	1.6	17.7	64.7	0.94	3.26	32.3	28	7.51	4.84	15.4
BH-15 15-16.2	4.6	1.46	0.84	0.34	0.17	0.26	0.14	0.99	9.5	36.3	0.47	1.66	19.1	15.3	4.23	2.55	8.8
BH-17 11-12	2.9	2.62	1.42	0.44	0.24	0.44	0.23	1.51	14.4	50.3	0.89	3.11	25.7	21.5	5.89	3.99	13.8
BH-21 0-5	2.3	3.05	1.76	0.65	0.24	0.55	0.28	1.56	19.1	55.4	0.98	3.82	27.9	26.1	6.94	4.89	11.4
BH-21 5-10	6	2.77	1.62	0.55	0.21	0.49	0.23	1.52	18.7	53.7	1.02	3.65	31	24.3	6.86	4.56	14.3
BH-21 10-15	4.9	2.46	1.42	0.51	0.22	0.39	0.22	1.54	16.9	50.1	0.85	3.09	28.1	22.3	6.11	4.17	12.4
BH-21 15-20	4.4	2.23	1.34	0.5	0.21	0.44	0.22	1.46	16	43	0.72	2.78	25.1	19.7	5.58	3.85	12.3
BH-21 20-25	5.6	2.25	1.14	0.41	0.23	0.36	0.22	1.28	13	41.4	0.8	2.62	21.9	17.7	4.78	3.21	11.4
BH-21 25-27	7.5	2.77	1.7	0.55	0.26	0.49	0.21	1.55	16.6	53.2	0.88	3.19	27	22.7	6.09	4.02	14.2

3.3 Beal Mountain Mine

The Beal Mountain Mine is located at the headwaters of German Gulch Creek in the Pioneer Mountains, in Silver Bow County, Montana (fig. 3-6). The mine began extracting gold and silver ore in 1988. The mine consisted of two open pits, and since its closure in 1999 has left behind several waste rock piles and a large heap leach pad. The heap leach pad covers approximately 77 acres and stores an estimated 14,807,100 tons of spent ore (Tetra Tech, 2010). The waste rock piles have since been covered to prevent the generation of acid mine drainage. The leach pad has been covered but still generates drainage that is treated at an onsite water treatment plant. Due to the varied forms of mine waste and its water treatment plant, the site was targeted for rare earth element sampling. Several samples have been collected from the water treatment plant, including aqueous and sludge samples. MBMG field crew collected three samples from the water treatment plant, and one sample from a drain designed to catch water from a waste rock pile. The sampling was conducted on August 2nd, 2023. Data from collected samples are in figures 3-7 and 3-8, and tables 3-21 through 3-24.

Figure 3-6. Inside the Beal Mountain Water Treatment plant.

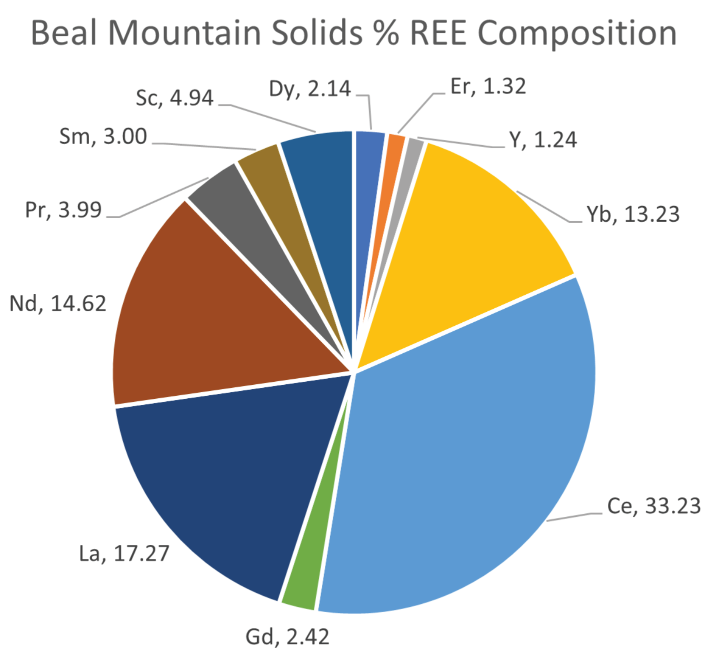

Figure 3-7. REE concentration percentages for every solid sample taken at Beal Mountain. Elements with less than 1% concentration were removed.

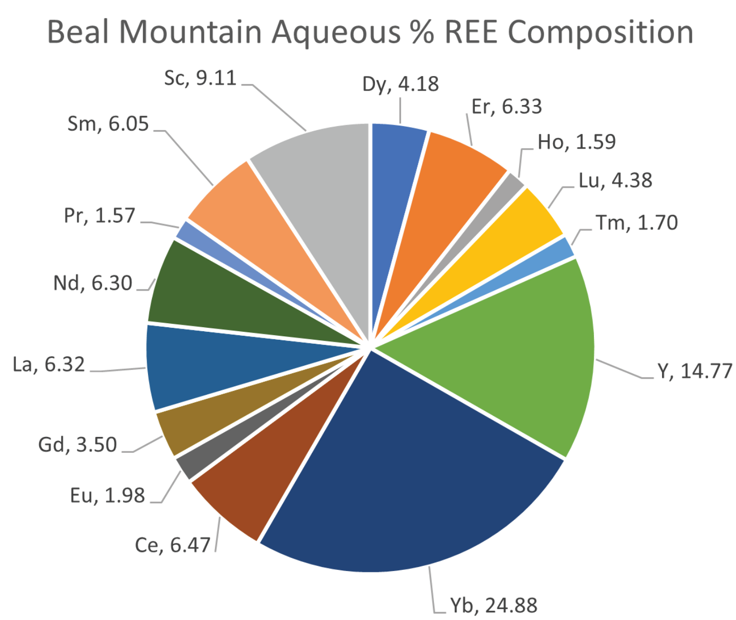

Figure 3-8. REE concentration percentages for every aqueous sample taken at Beal Mountain. Elements with less than 1% concentration were removed.

Table 3-21. Beal Mountain, aqueous samples—rare earth element and germanium concentrations.

Beal Mountain (Aqueous)																	
Sample ID	Ge (µg/L)	Dy (µg/L)	Er (µg/L)	Ho (µg/L)	Lu (µg/L)	Tb (µg/L)	Tm (µg/L)	Y (µg/L)	Yb (µg/L)	Ce (µg/L)	Eu (µg/L)	Gd (µg/L)	La (µg/L)	Nd (µg/L)	Pr (µg/L)	Sm (µg/L)	Sc (µg/L)
Beal Effluent-Diss	<32.00	<0.004	<0.004	<0.002	<0.002	<0.002	<0.002	<0.004	<0.004	<0.008	<0.003	<0.003	<0.003	<0.008	<0.003	<0.004	<0.037
Beal Effluent-TR	<32.00	<0.004	<0.004	<0.002	<0.002	<0.002	<0.002	<0.004	<0.004	<0.008	<0.003	<0.003	<0.003	<0.008	<0.003	<0.004	<0.037
Beal Influent-Diss	<32.00	0.119	0.148	0.041	0.111	0.028	0.043	0.366	0.485	0.13	0.063	0.092	0.091	0.152	0.04	0.194	0.169
Beal Influent-TR	<32.00	0.105	0.169	0.046	0.11	0.025	0.048	0.348	0.547	0.148	0.065	0.11	0.093	0.141	0.041	0.171	0.146
Beal Reject-Diss	<32.00	0.188	0.305	0.077	0.219	0.038	0.086	0.763	1.106	0.269	0.076	0.152	0.132	0.254	0.052	0.276	0.324
Beal Reject-Tot. Rec.	<32.00	0.176	0.313	0.067	0.223	0.033	0.079	0.762	1.099	0.257	0.076	0.121	0.128	0.177	0.047	0.225	0.355
Horizontal Drain-HD-9, Diss	<32.00	<0.004	<0.004	<0.002	0.002	<0.002	<0.002	<0.004	<0.004	<0.008	<0.003	<0.003	<0.003	<0.008	<0.003	<0.004	0.095
Horizontal Drain-HD-9, TR	<32.00	<0.004	<0.004	<0.002	0.002	<0.002	<0.002	<0.004	0.005	<0.008	<0.003	<0.003	<0.003	<0.008	<0.003	<0.004	0.092
Horizontal Drain-HD-9, TR	<32.00	<0.004	<0.004	<0.002	<0.002	<0.002	<0.002	<0.004	<0.004	<0.008	<0.003	<0.003	<0.003	<0.008	<0.003	<0.004	0.119
Waste Rock Drain-Diss	<32.00	0.019	0.012	0.004	<0.002	0.002	<0.002	0.007	0.266	0.057	0.006	0.022	0.271	0.1	0.027	0.014	0.053
Waste Rock Drain-TR	<32.00	0.034	0.024	0.009	0.005	0.007	0.004	0.018	0.306	0.131	0.017	0.039	0.254	0.141	0.034	0.047	0.043

Table 3-22. Beal Mountain, aqueous samples—rare earth element and germanium statistics.

Beal Mountain (Aqueous) Statistics					
Sample ID	Coutl	Total REE (µg/L)	Average REE	Minimum REE	Maximum REE
Beal Effluent-Diss	0.00	0.00	0.00	0.00	0.00
Beal Effluent-TR	2.99	0.00	0.00	0.00	0.00
Beal Influent-Diss	3.06	2.27	0.14	0.03	0.49
Beal Influent-TR	2.99	2.31	0.14	0.03	0.55
Beal Reject-Diss	3.02	4.32	0.27	0.04	1.11
Beal Reject-Tot. Rec.	2.99	4.14	0.26	0.03	1.10
Horizontal Drain-HD-9, Diss	0.00	0.10	0.05	0.00	0.10
Horizontal Drain-HD-9, TR	0.00	0.10	0.03	0.00	0.09
Horizontal Drain-HD-9, TR	0.00	0.12	0.12	0.12	0.12
Waste Rock Drain-Diss	0.00	0.86	0.06	0.00	0.27
Waste Rock Drain-TR	3.55	1.11	0.07	0.00	0.31

Table 3-23. Beal Mountain, solid samples—rare earth element and germanium statistics.

Beal Mountain Mine (Solids) Statistics					
Sample ID	Coutl	Total REE (mg/kg)	Average REE	Minimum REE	Maximum REE
Beal Spent Ore A	0.94	166.19	9.78	0.32	54.80
Beal Spent Ore B	0.89	177.80	10.46	0.33	59.50

Table 3-24. Beal Mountain, solid samples—rare earth element and germanium concentrations.

Beal Mountain Mine (Solids)																	
Sample ID	Ge (mg/kg)	Dy (mg/kg)	Er (mg/kg)	Ho (mg/kg)	Lu (mg/kg)	Tb (mg/kg)	Tm (mg/kg)	Y (mg/kg)	Yb (mg/kg)	Ce (mg/kg)	Eu (mg/kg)	Gd (mg/kg)	La (mg/kg)	Nd (mg/kg)	Pr (mg/kg)	Sm (mg/kg)	Sc (mg/kg)
Beal Spent Ore A	1.4	3.67	2.26	0.74	0.35	0.64	0.32	2.14	22.8	54.8	0.9	4.03	28.1	24.5	6.57	4.97	8
Beal Spent Ore B	1.5	3.68	2.29	0.76	0.33	0.64	0.35	2.14	22.7	59.5	1.02	4.29	31.3	25.8	7.15	5.35	9

3.4 Golden Sunlight Mine

The Golden Sunlight mine sits just northeast of Whitehall, Montana (fig. 3-9) and is owned by the Barrick Gold Corporation (Barrick Gold Corporation, 2022). Mine operations began in 1975, with open pit operations shutting down in 2019. In its 40 yr of production, Golden Sunlight extracted over 3 million oz of gold and generated 23 million tons of tailings. In 2022 a new flotation plant was constructed and is currently reprocessing 2 million tons of tailings a year. Their current tailings reserve and the tailings from the new flotation plant were sampled on January 18, 2023 (fig. 3-10, tables 3-25, 3-26).

Figure 3-9. The pit at the Golden Sunlight Mine.

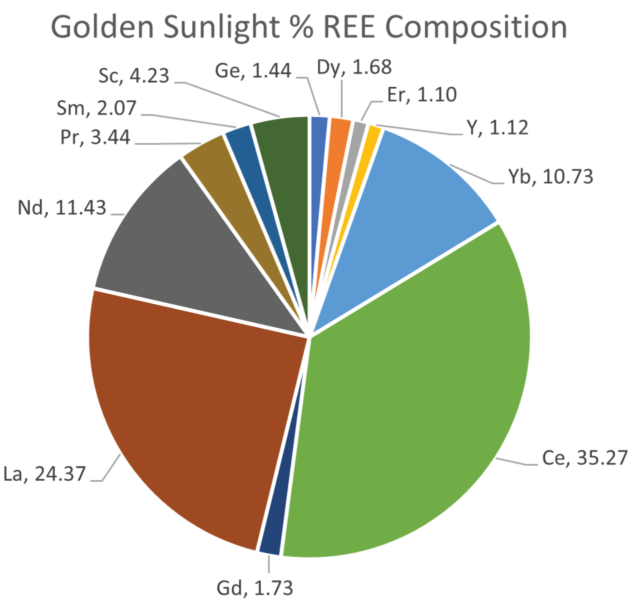

Figure 3-10. REE concentration percentages for every sample taken at Golden Sunlight, including germanium. Elements with less than 1% concentration were removed.

Table 3-25. Golden Sunlight—rare earth element and germanium statistics.

Golden Sunlight Statistics					
Sample ID	Coutl	Total REE (mg/kg)	Average REE	Minimum REE	Maximum REE
GS-Feed-1	0.68	289.70	17.04	0.42	102.50
GS-Feed-2	0.69	279.66	16.45	0.44	98.50
GS-Tailings-1	0.70	279.55	16.44	0.41	98.40
GS-Tailings-2	0.69	269.60	15.86	0.41	95.10

Table 3-26. Golden Sunlight—rare earth element and germanium concentrations.

Golden Sunlight																	
Sample ID	Ge (mg/kg)	Dy (mg/kg)	Er (mg/kg)	Ho (mg/kg)	Lu (mg/kg)	Tb (mg/kg)	Tm (mg/kg)	Y (mg/kg)	Yb (mg/kg)	Ce (mg/kg)	Eu (mg/kg)	Gd (mg/kg)	La (mg/kg)	Nd (mg/kg)	Pr (mg/kg)	Sm (mg/kg)	Sc (mg/kg)
GS-Feed-1	4	4.97	3.03	1.04	0.46	0.84	0.42	3.16	30.9	102.5	1.24	4.77	71.4	32.6	10.2	5.67	12.5
GS-Feed-2	4.2	4.8	2.99	1.06	0.44	0.7	0.44	3.16	29.9	98.5	1.33	5.1	69.3	31.9	9.42	5.82	10.6
GS-Tailings-1	3.9	4.39	3.38	1	0.46	0.67	0.41	3.11	30.3	98.4	1.33	4.84	67.2	32.8	9.77	5.89	11.7
GS-Tailings-2	4	4.65	2.95	1	0.51	0.7	0.41	3.06	28.9	95.1	1.17	4.59	64.7	30.5	9.08	5.78	12.5

3.5 Solvay Phosphate Plant

The Solvay plant was constructed in 1950 as a facility to produce elemental phosphorus (EPA, 2018). The plant was built on a 1.25-mi^2 site just outside of Ramsay, Montana. When Solvay closed its doors in 1997, a 500,000-gal tank of phosphorus sludge was left behind. Cleanup of the site began in 2004, with a facility to process the leftover sludge being constructed in 2020. The new facility operated using the Mud Still process and as of 2022 was still actively recovering phosphorus.

AR purchased some of the slag material and transported it offsite, where the MBMG collected samples on January 13, 2023. Six samples were collected (fig. 3-11, tables 3-27, 3-28).

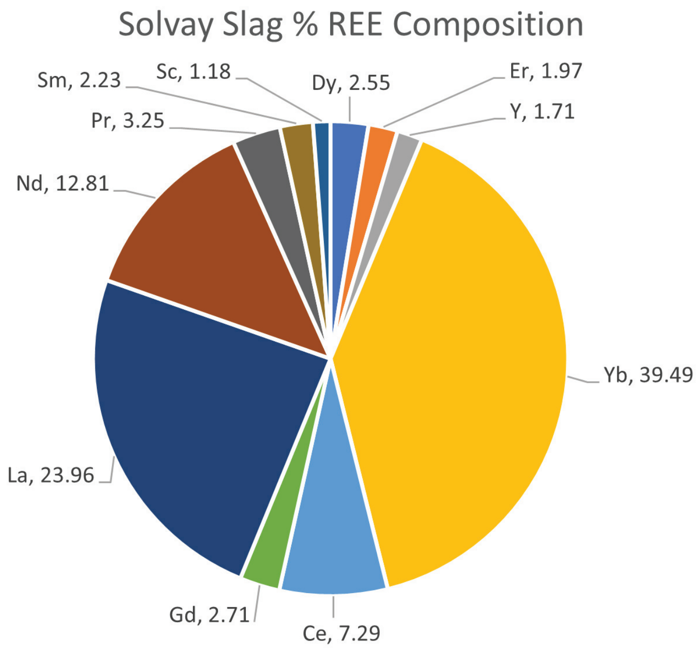

Figure 3-11. REE concentration percentages for every sample taken at the Solvay slag piles. Elements with less than 1% concentration were removed.

Table 3-27. Solvay/Stauffer, Solvay slag—rare earth element and germanium statistics.

Solvay Slag Statistics					
Sample ID	Coutl	Total REE (mg/kg)	Average REE	Minimum REE	Maximum REE
Solvay Slag #1	5.57	693.39	40.79	0.50	269.00
Solvay Slag #2	5.70	722.22	45.14	1.86	283.00
Solvay Slag #3	5.66	718.93	44.93	1.95	280.00
Solvay Slag #4	5.68	730.20	45.64	1.92	285.00
Solvay Slag #5	5.71	702.09	41.30	0.70	274.00
Solvay Slag #6	5.67	710.28	44.39	1.82	278.00

Table 3-28. Solvay/Stauffer, Solvay slag—rare earth element and germanium concentrations.

Solvay Slag																	
Sample ID	Ge (mg/kg)	Dy (mg/kg)	Er (mg/kg)	Ho (mg/kg)	Lu (mg/kg)	Tb (mg/kg)	Tm (mg/kg)	Y (mg/kg)	Yb (mg/kg)	Ce (mg/kg)	Eu (mg/kg)	Gd (mg/kg)	La (mg/kg)	Nd (mg/kg)	Pr (mg/kg)	Sm (mg/kg)	Sc (mg/kg)
Solvay Slag #1	0.5	17.45	13.25	4.38	1.86	2.58	1.74	12.4	269	50.4	3.48	18.2	164	88.5	22	15.25	8.4
Solvay Slag #2	<0.5	17.85	14.2	4.48	1.92	2.66	1.86	11.9	283	52.2	3.35	18.55	172	91.6	23.3	15.45	7.9
Solvay Slag #3	<0.5	18.3	14.1	4.62	1.95	2.74	1.98	12.35	280	51.6	3.24	19.15	170	91.8	22.8	15.8	8.5
Solvay Slag #4	<0.5	18.3	13.75	4.67	1.96	2.86	1.92	12.1	285	52.5	3.44	20.2	173	92.1	23.6	16.2	8.6
Solvay Slag #5	0.7	18	14.05	4.42	1.9	2.63	1.88	11.7	274	50.3	3.51	18.55	165	88.4	22.9	15.95	8.2
Solvay Slag #6	<0.5	17.75	13.85	4.62	1.9	2.64	1.82	11.95	278	51	3.35	19.7	168.5	88.8	22.7	15.4	8.3

3.6 Philipsburg Mining District

The Philipsburg mining district began in the 1860s after quartz was discovered in the area. In the 1880s, rich veins of silver were also discovered and began a renewed rush (Phillipsburg, 2024). In addition to silver and zinc, battery grade manganese dioxide was also mined. The Philipsburg area is home to dozens of mining claims, including the prominent Granite Mountain and Speckled Trout mines. Philipsburg remained a relatively active mining community until the 1980s, when declining prices caused a majority of mines to shut down. On July 13, 2023, 37 samples were collected from around the mining district and sent to both WVU and ALS laboratories for assay. The assay results can be found in figure 3-12 and tables 3-29 through 3-34.

Table 3-29. Philipsburg mining district, Philipsburg Area solids (WVU)—rare earth element and germanium statistics.

Philipsburg Area Solids (WVU) Statistics					
Sample ID	Coutl	Total REE (mg/kg)	Average REE	Minimum REE	Maximum REE
2% Mine 1	0.98	39.10	2.44	0.07	12.33
2% Mine 2	0.75	72.94	4.56	0.12	27.57
2% Mine 3	0.80	32.16	2.01	0.06	11.49
Cadgie Taylor Mine 1	1.47	32.66	1.92	0.10	7.48
Cadgie Taylor Mine 2	1.01	40.17	2.51	0.11	12.38
Cadgie Taylor Mine 3	1.15	33.87	2.12	0.07	9.52
Cadgie Taylor Mine 4	1.35	26.13	1.63	0.07	6.80
Mountain Boy Mine 1	0.99	74.94	4.41	0.09	41.61
Mountain Boy Mine 2	1.75	24.29	1.52	0.07	4.69
Porter Mine 1	1.10	23.00	1.35	0.02	5.38
Porter Mine 2	1.28	13.87	0.87	0.02	3.44
Porter Mine 3	1.23	45.80	2.69	0.02	26.59
Shapleigh Mine 1	0.93	26.51	1.66	0.04	7.91
Shapleigh Mine 2	0.67	33.99	2.12	0.08	13.43
Shapleigh Mine 3	1.06	39.42	2.46	0.07	11.72
Shapleigh Mine 4	1.19	28.39	1.77	0.05	7.20

Table 30. Philipsburg mining district, Philipsburg area solids (WVU)—rare earth element and germanium concentrations.

Philipsburg Area Solids (WVU)																	
Sample ID	Ge (mg/kg)	Dy (mg/kg)	Er (mg/kg)	Ho (mg/kg)	Lu (mg/kg)	Tb (mg/kg)	Tm (mg/kg)	Y (mg/k)	Yb (mg/kg)	Ce (mg/kg)	Eu (mg/kg)	Gd (mg/kg)	La (mg/kg)	Nd (mg/kg)	Pr (mg/kg)	Sm (mg/kg)	Sc (mg/kg)
2% Mine 1	<0.032	1.061	0.603	0.348	1.113	0.217	0.073	0.146	0.091	0.542	5.387	12.328	6.064	5.445	1.438	1.232	3.016
2% Mine 2	<0.032	1.833	1.002	0.661	2.046	0.336	0.12	0.297	0.119	0.787	5.911	27.565	13.564	11.856	2.988	2.048	1.807
2% Mine 3	<0.032	0.833	0.45	0.407	0.873	0.157	0.056	0.106	0.061	0.423	3.346	11.485	5.388	4.599	1.205	1.073	1.699
Cadgie Taylor Mine 1	0.991	1.1	0.759	0.303	1.088	0.226	0.111	0.146	0.102	0.759	6.208	7.481	3.052	4.244	0.988	1.059	4.043
Cadgie Taylor Mine 2	<0.032	1.264	0.751	0.54	1.519	0.251	0.113	0.177	0.111	0.697	4.844	12.381	4.812	6.161	1.477	1.474	3.596
Cadgie Taylor Mine 3	<0.032	1.011	0.588	0.182	1.049	0.2	0.072	0.14	0.081	0.514	5.888	9.518	3.569	4.112	0.969	0.921	5.052
Cadgie Taylor Mine 4	<0.032	0.954	0.55	0.244	0.907	0.172	0.067	0.113	0.075	0.53	4.737	6.802	3.091	3.729	0.948	0.772	2.438
Mountain Boy Mine 1	41.607	1.147	0.749	1.206	1.12	0.238	0.094	0.177	0.092	0.664	2.493	10.354	5.525	5.556	1.3	1.187	1.429
Mountain Boy Mine 2	<0.032	1.035	0.552	0.263	0.993	0.2	0.066	0.148	0.074	0.448	4.511	4.689	2.219	3.049	0.714	0.797	4.527
Porter Mine 1	5.383	0.482	0.251	0.105	0.424	0.089	0.023	0.056	0.029	0.194	2.609	4.89	2.466	2.243	0.678	0.492	2.585
Porter Mine 2	<0.032	0.377	0.197	0.089	0.333	0.065	0.021	0.025	0.028	0.175	2.476	3.438	1.538	1.616	0.426	0.392	2.673
Porter Mine 3	26.591	0.456	0.197	0.151	0.676	0.075	0.018	0.053	0.031	0.193	2.583	4.927	2.479	2.997	0.775	0.713	2.886
Shapleigh Mine 1	<0.032	0.661	0.366	0.102	0.474	0.115	0.041	0.067	0.046	0.309	3.951	7.912	3.293	2.726	0.717	0.494	5.24
Shapleigh Mine 2	<0.032	0.867	0.542	0.91	0.943	0.17	0.077	0.114	0.076	0.494	1.841	13.426	5.063	5.217	1.283	0.981	1.981
Shapleigh Mine 3	<0.032	0.939	0.586	0.362	1.299	0.205	0.065	0.138	0.077	0.5	4.614	11.721	5.324	6.698	1.587	1.47	3.83
Shapleigh Mine 4	<0.032	0.882	0.438	0.169	0.782	0.164	0.045	0.104	0.059	0.343	4.598	7.196	3.15	3.109	0.861	0.71	5.778

Table 3-31. Philipsburg mining district, Philipsburg area solids (ALS)—rare earth element and germanium concentrations.

Philipsburg Area Solids (ALS)																	
Sample ID	Ge (mg/kg)	Dy (mg/kg)	Er (mg/kg)	Ho (mg/kg)	Lu (mg/kg)	Tb (mg/kg)	Tm (mg/kg)	Y (mg/kg	Yb (mg/kg)	Ce (mg/kg)	Eu (mg/kg)	Gd (mg/kg)	La (mg/kg)	Nd (mg/kg)	Pr (mg/kg)	Sm (mg/kg)	Sc (mg/kg)
2% Mine 1	5.5	0.5	0.32	0.1	0.04	0.09	0.03	0.26	3.1	8.2	0.11	0.6	4.5	3.5	0.92	0.68	<1
2% Mine 2	14.2	0.6	0.26	0.14	0.04	0.1	0.05	0.32	3.5	13.6	0.18	0.66	6.4	5.6	1.45	1.18	<1
2% Mine 3	8.5	0.42	0.21	0.07	0.04	0.06	0.03	0.2	2.1	7.1	0.12	0.43	3.7	3.1	0.77	0.5	<1
Algonquin 1	3.5	2.6	1.58	0.55	0.27	0.43	0.25	1.7	15.8	46.8	0.78	3.14	22.5	20.5	5.41	4.07	5
Algonquin 2	0.5	1.73	0.98	0.33	0.14	0.25	0.16	1.12	10.5	26	0.37	1.63	13.2	11.2	3.12	2.21	2
Antinoli Tailings Hole 1	2.3	1.66	0.96	0.32	0.16	0.29	0.16	10.1	1.12	22.1	0.6	1.86	12.9	11.9	3.37	2.28	2
Antinoli Tailings Hole 2	2.5	2.01	1.36	0.48	0.22	0.33	0.22	12.6	1.38	27.4	0.83	2.49	16	14	3.85	3.14	2
Antinoli Tailings Hole 3	3	2.05	1.12	0.41	0.18	0.32	0.23	10.8	1.2	26	0.72	2.24	15.2	13.6	3.59	2.19	2
Antinoli Tailings Hole 4	2.3	2.38	1.46	0.51	0.25	0.42	0.24	14.9	1.55	36.1	0.81	2.67	20.5	17.8	4.88	3.6	4
Antinoli Tailings Hole 5	2.9	2.44	1.42	0.52	0.21	0.38	0.23	14.4	1.42	34.5	1.01	2.56	19.1	16.8	4.64	3.63	5
Antinoli Tailings Hole 6	2.7	2.59	1.58	0.53	0.25	0.42	0.26	15	1.66	46.9	0.96	2.94	26.4	21.5	5.79	4.24	5
Antinoli Tailings Hole 7	2.7	2.23	1.3	0.46	0.23	0.38	0.19	13.8	1.31	30	0.81	2.24	17.3	15.1	4.2	3.05	3
Antinoli Tailings Hole 8	2.6	2.36	1.42	0.52	0.25	0.39	0.2	13.9	1.45	36.5	0.78	2.64	20.1	16.8	4.83	3.01	7
Antinoli Tailings Hole 9	2.5	2.21	1.26	0.45	0.23	0.35	0.21	12	1.42	25.5	0.76	2.2	14.2	13.2	3.71	2.8	2
Antinoli Tailings Hole 10	3.1	2.8	1.64	0.57	0.23	0.5	0.24	17.9	1.69	42.4	1.05	3.11	23.3	19.4	5.39	4.03	4
Cadgie Taylor Mine 1	0.6	0.63	0.39	0.14	0.07	0.1	0.08	0.42	4.3	4.2	0.09	0.55	2	2.5	0.53	0.52	2
Cadgie Taylor Mine 2	0.9	0.71	0.49	0.16	0.06	0.13	0.07	0.45	4.5	5.9	0.15	0.64	2.7	3	0.69	0.91	2
Cadgie Taylor Mine 3	<0.5	0.56	0.34	0.1	0.06	0.08	0.04	0.35	3.4	5.6	0.13	0.52	2.4	2.6	0.65	0.64	2
Cadgie Taylor Mine 4	<0.5	0.36	0.18	0.08	0.03	0.05	0.03	0.26	2.2	3.2	0.09	0.35	1.6	1.5	0.37	0.43	1
Granite Mine	3.7	2.66	1.49	0.52	0.24	0.42	0.23	1.84	14.8	56.7	1.04	3.01	30.9	23.8	6.9	4.36	8
Manganese Mill 1	4.6	2.9	1.64	0.61	0.26	0.52	0.28	1.74	17.6	48.2	1.03	3.13	25.5	21.1	6.23	4.23	7
Manganese Mill 2	4.8	2.62	1.52	0.6	0.25	0.43	0.25	1.56	16.5	41.5	0.78	2.68	21.4	17.4	5.13	3.3	6
Mountain Boy Mine 1	0.9	0.5	0.31	0.1	0.05	0.09	0.05	0.26	3.5	4.5	0.13	0.46	2.5	2.3	0.48	0.56	1
Mountain Boy Mine 2	1.8	0.41	0.22	0.07	0.04	0.04	0.04	0.24	2	2.9	0.06	0.35	1.4	1.4	0.34	0.36	1
Porter Mine 1	<0.5	0.23	0.12	0.04	0.01	0.03	0.02	0.13	1.1	3.5	0.06	0.19	1.9	1.4	0.37	0.34	1
Porter Mine 2	1.3	0.2	0.13	0.04	0.02	0.02	0.01	0.12	1	2.3	0.03	0.18	1.2	1.1	0.23	0.22	1
Porter Mine 3	0.6	0.14	0.08	0.03	0.01	0.02	0.01	0.1	0.9	2.1	0.02	0.24	1.1	0.9	0.23	0.28	<1
Shapleigh Mine 1	5.7	0.39	0.22	0.09	0.04	0.08	0.04	0.26	2.5	5.3	0.11	0.43	2.7	2.4	0.7	0.56	1
Shapleigh Mine 2	0.7	0.17	0.11	0.03	0.01	0.03	0.02	0.12	0.9	2.7	0.04	0.18	1.5	1.2	0.35	0.28	1
Shapleigh Mine 3	4.2	0.45	0.31	0.1	0.05	0.07	0.03	0.26	2.6	5.7	0.11	0.45	2	2.7	0.66	0.58	1
Shapleigh Mine 4	1.2	0.49	0.24	0.1	0.03	0.07	0.03	0.23	2.8	5.3	0.1	0.45	2.2	2.7	0.61	0.64	2
Silver Mill 1	3.6	2.43	1.48	0.53	0.25	0.44	0.24	1.56	14.4	39.9	0.64	2.84	20	17	4.68	3.25	4
Silver Mill 2	4	1.55	0.97	0.32	0.15	0.28	0.18	1.06	9.6	28	0.37	2.04	14.6	12	3.35	2.42	3
Speckled Trout 1	6.9	2.36	1.3	0.5	0.2	0.44	0.21	1.46	13	43.3	0.78	2.68	22.9	18.3	5.19	3.78	6
Speckled Trout 2	14.6	3.52	2.02	0.74	0.28	0.6	0.32	2	19	58.3	1.07	3.78	27.5	25	7.09	4.82	5
Speckled Trout 3	0.7	1.31	0.8	0.27	0.16	0.19	0.15	1.01	7.7	21.8	0.3	1.23	11	8.8	2.52	1.79	2
Speckled Trout 4	12.5	1.9	0.91	0.39	0.18	0.33	0.18	1.11	9.4	44.3	0.56	2.28	21.2	16.4	5.12	3.37	4

Table 3-32. Philipsburg mining district, Philipsburg area solids (ALS)—rare earth element and germanium statistics.

Philipsburg Area Solids (ALS) Statistics					
Sample ID	Coutl	Total REE (mg/kg)	Average REE	Minimum REE	Maximum REE
2% Mine 1	0.88	28.45	1.78	0.03	8.20
2% Mine 2	0.72	48.28	3.02	0.04	14.20
2% Mine 3	0.81	27.35	1.71	0.03	8.50
Algonquin 1	0.84	134.88	7.93	0.25	46.80
Algonquin 2	0.90	75.44	4.44	0.14	26.00
Antinoli Tailings Hole 1	3.32	74.08	4.36	0.16	22.10
Antinoli Tailings Hole 2	3.15	90.81	5.34	0.22	27.40
Antinoli Tailings Hole 3	3.55	84.85	4.99	0.18	26.00
Antinoli Tailings Hole 4	2.96	114.37	6.73	0.24	36.10
Antinoli Tailings Hole 5	1.61	111.16	6.54	0.21	34.50
Antinoli Tailings Hole 6	1.45	138.72	8.16	0.25	46.90
Antinoli Tailings Hole 7	3.08	98.30	5.78	0.19	30.00
Antinoli Tailings Hole 8	1.65	114.75	6.75	0.20	36.50
Antinoli Tailings Hole 9	4.52	85.00	5.00	0.21	25.50
Antinoli Tailings Hole 10	1.86	131.35	7.73	0.23	42.40
Cadgie Taylor Mine 1	1.63	19.12	1.12	0.07	4.30
Cadgie Taylor Mine 2	1.35	23.46	1.38	0.06	5.90
Cadgie Taylor Mine 3	1.16	19.47	1.22	0.04	5.60
Cadgie Taylor Mine 4	1.22	11.73	0.73	0.03	3.20
Granite Mine	0.74	160.61	9.45	0.23	56.70
Manganese Mill 1	0.88	146.57	8.62	0.26	48.20
Manganese Mill 2	0.89	126.72	7.45	0.25	41.50
Mountain Boy Mine 1	1.38	17.69	1.04	0.05	4.50
Mountain Boy Mine 2	1.26	12.67	0.75	0.04	2.90
Porter Mine 1	0.79	10.44	0.65	0.01	3.50
Porter Mine 2	1.00	9.10	0.54	0.01	2.30
Porter Mine 3	0.92	6.76	0.42	0.01	2.10
Shapleigh Mine 1	0.99	22.52	1.32	0.04	5.70
Shapleigh Mine 2	0.85	9.34	0.55	0.01	2.70
Shapleigh Mine 3	1.02	21.27	1.25	0.03	5.70
Shapleigh Mine 4	1.12	19.19	1.13	0.03	5.30
Silver Mill 1	0.86	117.24	6.90	0.24	39.90
Silver Mill 2	0.83	83.89	4.93	0.15	28.00
Speckled Trout 1	0.79	129.30	7.61	0.20	43.30
Speckled Trout 2	0.83	175.64	10.33	0.28	58.30
Speckled Trout 3	0.82	61.73	3.63	0.15	21.80
Speckled Trout 4	0.64	124.13	7.30	0.18	44.30

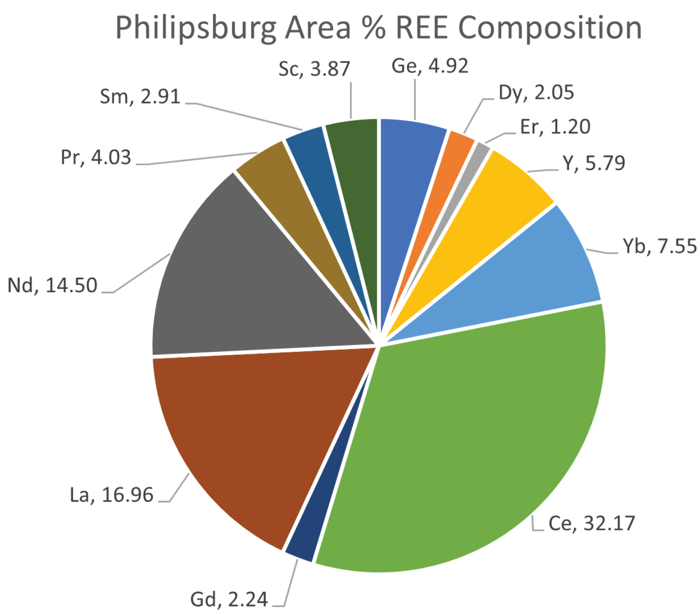

Figure 3-12. REE concentration percentages for every sample taken in the Philipsburg area. Elements with less than 1% concentration were removed.

Table 3-33. Philipsburg mining district, Ted Antonioli—rare earth element and germanium statistics.

Ted Antolonli Philipsburg Sites Statistics					
Sample ID	Coutl	Total REE (mg/kg)	Average REE	Minimum REE	Maximum REE
BJ-1	0.47	343.52	20.21	0.33	154.00
B1	0.81	67.36	3.96	0.11	22.30
ER-1	0.82	35.34	2.08	0.05	11.90
ER-2	0.80	38.88	2.29	0.05	13.50
ER-3	0.91	23.57	1.47	0.03	7.80
Marjae Mine	0.48	138.50	8.15	0.13	58.30
Mayflower Mine	1.53	66.77	3.93	0.10	16.40

Table 3-34. Philipsburg mining district, Ted Antonioli—rare earth element and germanium concentrations.

Sample ID	Ge (mg/kg)	Dy (mg/kg)	Er (mg/kg)	Ho (mg/kg)	Lu (mg/kg)	Tb (mg/kg)	Tm (mg/kg)	Y (mg/kg)	Yb (mg/kg)	Ce (mg/kg)	Eu (mg/kg)	Gd (mg/kg)	La (mg/kg)	Nd (mg/kg)	Pr (mg/kg)	Sm (mg/kg)	Sc (mg/kg)
BJ-1	1.1	3.76	2.15	0.75	0.33	0.64	0.33	2.22	24.2	154	1.13	4.57	80.2	41.8	13.6	6.37	6.37
B1	2	1.21	0.83	0.26	0.12	0.17	0.11	0.82	7.2	22.3	0.27	1.38	12	9.5	2.64	1.55	5
ER-1	0.6	0.66	0.42	0.15	0.05	0.12	0.06	0.36	4.1	11.9	0.28	0.75	6.9	4.7	1.4	0.89	2
ER-2	0.5	0.79	0.42	0.16	0.05	0.13	0.05	0.42	4.5	13.5	0.42	0.96	7.2	5.1	1.49	1.19	2
ER-3	<0.5	0.49	0.26	0.1	0.03	0.09	0.03	0.28	2.9	7.8	0.28	0.54	4.6	3.5	0.95	0.72	1
Marjae Mine	2.1	1.39	0.77	0.28	0.13	0.3	0.13	0.89	8.2	58.3	0.75	1.97	34.6	17.3	5.44	2.95	3
Mayflower Mine	0.8	1.29	0.81	0.32	0.1	0.21	0.1	0.65	13.5	15.6	0.53	1.72	16.4	9.4	2.5	1.84	1

3.7 Basin Mining District

The Basin mining district is located in Jefferson County, Montana and encompasses a 77-mi^2 area around the town of Basin. Mining started in the 1870s and continued through the 1960s (EPA, 2017a). Contamination of the watershed by mine wastes resulted in a Superfund listing in 1999. With mines such as the Crystal and the Bullion within the district already being monitored by the MBMG, the area was an easy addition to the ARL project. Three water samples were collected from the area; assay results are presented in tables 3-35 and 3-36.

Table 3-35. Basin/Ten Mile watersheds, Crystal and Bullion mines—rare earth element and germanium statistics.

Crystal & Bullion Mines Statistics					
Sample ID	CoutI	Total REE	Average REE	Minimum REE	Maximum REE
Crystal Mine Dissolved	1.55	26.89	1.68	0.09	7.12
Crystal Mine TR	1.56	22.19	1.39	0.07	5.90
Upper Bullion Dissolved	1.59	126.22	7.89	0.51	33.27
Upper Bullion TR	1.62	165.44	10.34	0.65	43.53
Lower Bullion TR	1.75	161.75	10.11	0.51	41.02

Table 3-36. Basin/Ten Mile watersheds, Crystal and Bullion mines—rare earth element and germanium concentrations.

Crystal & Bullion Mines																	
Sample ID	Ge (µg/L)	Dy (µg/L)	Er (µg/L)	Ho (µg/L)	Lu (µg/L)	Tb (µg/L)	Tm (µg/L)	Y (µg/L)	Yb (µg/L)	Ce (µg/L)	Eu (µg/L)	Gd (µg/L)	La (µg/L)	Nd (µg/L)	Pr (µg/L)	Sm (µg/L)	Sc (µg/L)
Crystal Mine Dissolved	<32.00	1.128	0.741	0.259	0.1	0.178	0.11	0.689	6.465	7.118	0.103	1.038	4.143	3.166	0.834	0.732	0.085
Crystal Mine TR	<32.00	0.871	0.578	0.198	0.077	0.134	0.084	0.528	5.613	5.895	0.083	0.827	3.459	2.505	0.69	0.586	0.065
Upper Bullion Dissolved	<32.00	5.352	3.462	1.173	0.509	0.849	0.521	3.352	26.88	33.27	0.846	5.31	14.2	19.05	4.491	4.339	2.612
Upper Bullion TR	<32.00	6.795	4.395	1.494	0.646	1.084	0.661	4.215	36.69	43.53	1.054	6.783	18.43	24.82	5.841	5.584	3.411
Lower Bullion TR	<32.00	5.906	3.753	1.217	0.51	0.912	0.53	3.529	40.39	41.02	0.926	6.134	18.38	23.69	5.456	5.263	4.138

3.8 Black Eagle Smelter

The Black Eagle Smelter, also known as the AMC Smelter and Refinery, is a 427-acre superfund site located in Black Eagle across the Missouri River from Great Falls, Montana. Construction of the first smelter was completed in 1893 by the Boston and Montana Consolidated Copper and Silver Mining Company. Primary products from the smelter and mill included copper, zinc, arsenic, and cadmium. In 1910 the Anaconda Copper Mining Company acquired the property. Zinc smelting and refining activates continued until the early 1970s. In 1977 AR purchased the Anaconda Copper Mining Company and continued to refine copper and zinc onsite until the plant's closure in 1980 (EPA, 2017d). Eighty years of operations generated millions of tons of slag and tailings, many of which were dumped into the Missouri River until 1915, when waste started being deposited onsite. The smokestacks ejected lead, arsenic, and other metals, depositing them on the site and the surrounding neighborhoods. In 2011 the EPA placed the AMC Smelter and Refinery on the Superfund National Priority list (EPA, 2017d).

The Black Eagle Smelter site was identified as an area of interest for rare earth element sampling by the MBMG, and sampling was conducted in March 2023. Groundwater samples were collected from wells at various depths across the site with the assistance of AR's contractor Woodard & Curran. Several groundwater seeps on the site were targeted, but were frozen. A second sampling effort in May 2023 collected samples from the seeps, along with some additional wells of interest. Data from collected samples are shown in tables 3-37 and 3-38.

Table 3-37. Black Eagle Smelter/Great Falls—rare earth element and germanium statistics.

Black Eagle Statistics					
Sample ID	Coutl	Total REE (µg/L)	Average REE	Minimum REE	Maximum REE
BH-02Am	3.71	87.08	5.44	0.11	57.90
BH-02Am-TR	9.22	97.19	6.07	0.15	62.18
BH-02 AM	8.00	89.70	5.61	0.06	39.04
BH-02 AM-TR.	9.71	107.20	6.70	0.05	43.00
BH-04s	5.73	182.70	11.42	0.20	89.26
BH-04s-TR	4.65	213.29	13.33	0.23	99.22
BH-08d	0.00	1.68	0.14	0.00	0.92
BH-08d-TR	0.00	1.82	0.15	0.00	0.99
BH-09S	7.53	7.12	0.45	0.01	3.84
BH-09S-TR	7.21	7.30	0.46	0.00	3.90
BH-12d	0.00	2.41	0.16	0.00	1.24
BH-12d-TR	0.00	2.99	0.20	0.00	1.55
BH-04	4.67	161.86	10.12	0.07	86.73
BH-04-TR	3.71	176.75	11.05	0.27	87.60
BH-18s	0.00	0.60	0.05	0.00	0.42
BH-18s-TR	0.00	0.59	0.05	0.00	0.40
EDS	0.00	5.05	0.34	0.00	2.82
EDS-TR	2.84	10.56	0.66	0.01	3.76
FED Seep B	0.00	0.06	0.03	0.02	0.04
FED Seep B-TR	0.00	0.46	0.05	0.00	0.14
FED Seep C	0.00	0.18	0.09	0.08	0.10
FED Seep C-TR	0.00	0.77	0.08	0.01	0.18
MW-11	0.00	0.83	0.07	0.00	0.41
MW-11-TR	0.00	0.89	0.07	0.00	0.42
NBS	0.00	0.12	0.06	0.05	0.07
NBS- TR	0.00	0.60	0.07	0.01	0.19
P-11	4.32	13.73	0.86	0.02	7.17
P-11-TR	4.17	13.06	0.82	0.02	6.69
PS-07	4.61	90.94	5.68	0.26	36.83
PS-07-TR	4.62	91.74	5.73	0.25	36.92
PS-07	4.57	85.08	5.32	0.21	35.33
PS-07-TR.	4.61	85.72	5.36	0.22	35.69
PS-08	0.00	0.40	0.10	0.01	0.26
PS-08-TR	0.00	0.45	0.07	0.00	0.24
PS-11	4.40	11.69	0.73	0.02	6.11
PS-11-TR	4.11	12.90	0.81	0.02	6.51
PS-18	0.00	0.80	0.07	0.01	0.34
PS-18-TR	0.00	1.13	0.09	0.00	0.41
PS-18	0.00	0.79	0.09	0.01	0.40
PS-18-TR.	0.00	0.84	0.09	0.01	0.41

Table 3-38. Black Eagle Smelter/Great Falls—rare earth element and germanium concentrations.

Black Eagle																
Sample ID	Ge (µg/L)	Dy (µg/L)	Er (µg/L)	Ho (µg/L)	Lu (µg/L)	Tb (µg/L)	Tm (µg/L)	Y (µg/L)	Yb (µg/L)	Ce (µg/L)	Eu (µg/L)	Gd (µg/L)	La (µg/L)	Nd (µg/L)	Pr (µg/L)	Sm (µg/L)	Sc (µg/L)
BH-02Am	<32.00	3.477	2.643	0.882	0.225	0.442	0.295	1.604	57.896	6.093	0.353	2.809	4.06	4.3	0.854	1.043	0.107
BH-02Am-TR	<32.00	3.783	2.836	0.954	0.242	0.52	0.31	1.736	62.181	7.904	0.429	3.161	5.02	5.561	1.068	1.342	0.145
BH-02 AM	32.00	2.154	1.564	0.475	0.06	0.184	0.082	0.847	39.039	4.149	0.192	1.77	2.795	3.149	0.497	0.746	<0.037
BH-02 AM-TR.	43.00	2.273	1.625	0.487	0.053	0.205	0.107	0.9	40.802	6.312	0.22	1.908	3.835	3.891	0.72	0.86	<0.037
BH-04s	33.00	4.562	3.126	1.061	0.2	0.572	0.262	1.707	89.256	17.594	0.721	4.727	10.041	11.335	2.375	2.164	<0.037
BH-04s-TR	35.00	5.22	3.604	1.196	0.227	0.713	0.306	1.928	99.219	25.045	0.902	5.718	13.005	14.844	3.24	3.119	<0.037
BH-08d	<32.00	0.027	0.021	0.006	<0.002	0.003	<0.002	0.019	0.329	0.921	<0.003	0.03	0.117	0.094	0.02	<0.004	0.093
BH-08d-TR	<32.00	0.033	0.024	0.006	<0.002	0.002	<0.002	0.018	0.337	0.99	<0.003	0.033	0.144	0.121	0.026	<0.004	0.09
BH-09S	<32.00	0.219	0.134	0.042	0.005	0.021	0.008	0.087	3.836	0.589	0.025	0.23	0.964	0.613	0.13	0.097	0.123
BH-09S-TR	<32.00	0.213	0.148	0.044	0.004	0.021	0.008	0.079	3.895	0.629	0.027	0.242	0.992	0.632	0.134	0.112	0.115
BH-12d	<32.00	0.042	0.035	0.01	0.003	0.004	0.005	0.032	0.569	1.236	<0.003	0.045	0.155	0.159	0.029	0.008	0.079
BH-12d-TR	<32.00	0.055	0.036	0.012	0.003	0.007	0.005	0.035	0.646	1.547	<0.003	0.06	0.209	0.204	0.043	0.019	0.109
BH-04	<32.00	5.357	3.574	1.224	0.295	0.822	0.367	1.909	86.731	22.091	0.967	5.916	11.929	14.524	3.049	3.035	0.067
BH-04-TR	<32.00	5.297	3.661	1.308	0.267	0.846	0.387	2.024	87.6	29.138	1.043	6.292	14.494	16.796	3.694	3.528	0.371
BH-18s	<32.00	0.017	0.018	0.004	<0.002	<0.002	0.003	0.024	0.416	0.012	<0.003	0.008	0.013	0.015	<0.003	<0.004	0.066
BH-18s-TR	<32.00	0.017	0.02	0.005	<0.002	<0.002	0.002	0.028	0.4	0.015	<0.003	0.009	0.018	0.019	<0.003	<0.004	0.061
EDS	<32.00	0.111	0.077	0.02	<0.002	0.01	0.002	0.046	2.817	0.455	0.013	0.11	0.894	0.32	0.071	0.046	0.06
EDS-TR	<32.00	0.296	0.166	0.056	0.01	0.043	0.013	0.109	3.763	1.874	0.073	0.369	1.56	1.215	0.272	0.271	0.473
FED Seep B	<32.00	<0.004	<0.004	<0.002	<0.002	<0.002	<0.002	<0.004	0.023	<0.008	<0.003	<0.003	<0.003	<0.008	<0.003	<0.004	0.041
FED Seep B-TR	<32.00	0.005	<0.004	<0.002	<0.002	<0.002	<0.002	<0.004	0.092	0.144	<0.003	0.011	0.072	0.075	0.009	0.004	0.046
FED Seep C	<32.00	<0.004	<0.004	<0.002	<0.002	<0.002	<0.002	<0.004	0.079	<0.008	<0.003	<0.003	<0.003	<0.008	<0.003	<0.004	0.096
FED Seep C-TR	<32.00	0.016	0.006	<0.002	<0.002	<0.002	<0.002	<0.004	0.166	0.184	<0.003	0.027	0.091	0.148	0.025	0.024	0.082
MW-11	<32.00	0.023	0.021	0.006	<0.002	0.002	<0.002	0.017	0.412	0.029	<0.003	0.021	0.108	0.075	0.015	<0.004	0.104
MW-11-TR	<32.00	0.027	0.02	0.006	<0.002	0.003	0.002	0.016	0.42	0.035	<0.003	0.024	0.119	0.089	0.016	<0.004	0.11
NBS	<32.00	<0.004	<0.004	<0.002	<0.002	<0.002	<0.002	<0.004	0.051	<0.008	<0.003	<0.003	<0.003	<0.008	<0.003	<0.004	0.073
NBS- TR	<32.00	0.011	<0.004	<0.002	<0.002	<0.002	<0.002	<0.004	0.187	0.134	<0.003	0.015	0.058	0.071	0.008	0.01	0.107
P-11	<32.00	0.315	0.236	0.073	0.018	0.033	0.015	0.153	7.169	1.887	0.032	0.308	2.234	0.819	0.186	0.124	0.126
P-11-TR	<32.00	0.304	0.239	0.077	0.018	0.036	0.017	0.147	6.689	1.837	0.033	0.319	2.075	0.83	0.185	0.131	0.12
PS-07	<32.00	5.113	2.828	1.047	0.285	0.848	0.333	1.893	36.833	11.131	1.212	6.233	5.196	12.132	1.996	3.594	0.263
PS-07-TR	<32.00	5.282	2.874	1.05	0.285	0.868	0.333	1.882	36.924	11.198	1.242	6.313	5.285	12.266	1.993	3.702	0.247
PS-07	<32.00	4.72	2.599	0.961	0.259	0.772	0.293	1.679	35.325	10.64	1.095	5.621	4.901	10.97	1.821	3.21	0.211
PS-07-TR.	<32.00	4.81	2.642	0.99	0.259	0.785	0.299	1.717	35.692	10.621	1.117	5.646	4.725	11.035	1.854	3.311	0.218
PS-08	<32.00	<0.004	<0.002	<0.002	<0.002	<0.002	<0.002	<0.004	0.092	0.031	<0.003	<0.003	0.014	<0.008	<0.003	<0.004	0.261
PS-08-TR	<32.00	<0.004	<0.004	<0.002	<0.002	<0.002	<0.002	<0.004	0.105	0.044	<0.003	<0.003	0.036	0.02	0.003	<0.004	0.239
PS-11	<32.00	0.244	0.197	0.066	0.021	0.034	0.021	0.131	6.114	1.546	0.028	0.255	1.977	0.653	0.165	0.079	0.154
PS-11-TR	<32.00	0.29	0.234	0.076	0.024	0.037	0.025	0.154	6.505	1.799	0.034	0.313	2.178	0.799	0.194	0.101	0.14
PS-18	<32.00	0.016	0.012	0.005	<0.002	<0.002	<0.002	0.012	0.338	0.107	<0.003	0.009	0.07	0.043	0.011	<0.004	0.179
PS-18-TR	<32.00	0.027	0.02	0.006	<0.002	0.003	0.002	0.015	0.405	0.214	<0.003	0.025	0.125	0.096	0.019	<0.004	0.169
PS-18	<32.00	0.013	0.008	<0.002	<0.002	<0.002	<0.002	0.007	0.4	0.105	<0.003	0.008	0.068	0.042	<0.003	<0.004	0.136
PS-18-TR.	<32.00	0.019	0.012	<0.002	<0.002	<0.002	<0.002	0.009	0.406	0.122	<0.003	0.012	0.079	0.059	<0.003	<0.004	0.121

3.9 Columbus/Stillwater Mine Smelter

Two ore types from the Stillwater Complex, located south of Columbus near the town of Nye, have been shipped to Columbus for processing. Chromite ore was processed and shipped to a site near the rail line from the late 1950s to early 1960s; ore containing platinum group metals from both the Stillwater Mine and the East Boulder Mine was sent to the Stillwater smelting complex in Columbus for processing beginning in 1990 (Sibanye, 2024).

3.9.1 Columbus/Mouat

Columbus is home to the 4.5-acre Mouat Industries Superfund cleanup site. Mouat Industries processed chromite ore from the Stillwater Mining Complex from 1957 to 1962 (EPA, 2017c). The mine waste, containing sodium chromate and sodium dichromate, leached into the soil and groundwater. Sodium dichromate spills also occurred as part of facility operations, further contaminating the site. Cleanup began in 1990 and was completed in 2008. Groundwater samples were collected on July 19, 2023 (tables 3-39, 3-40.

3.9.2 Stillwater Mine Smelter

Columbus, Montana is home to the Columbus metallurgical complex, which is a smelting and refining facility for the Stillwater mine (fig. 3-13). The facility has been processing platinum group elements (PGMs) since its opening in 1990, with over 1 million oz being produced in 2022 (Stillwater, 2024). The site receives ore from the East Boulder and the Stillwater mines, both located on the JM-Reef. With the high REE content in the JM-Reef and the large amount of ore being processed, this site was an optimal reconnaissance sampling location. Samples were taken on June 13, 2023 from the incoming concentrate as well as the slag that is produced as waste. Assay results of the Stillwater smelter samples and Mouat samples can be found in figure 3-14 and tables 3-41 and 3-42.

Figure 3-13. The inside of the Sibanye–Stillwater Columbus smelter concentrate receiving area.

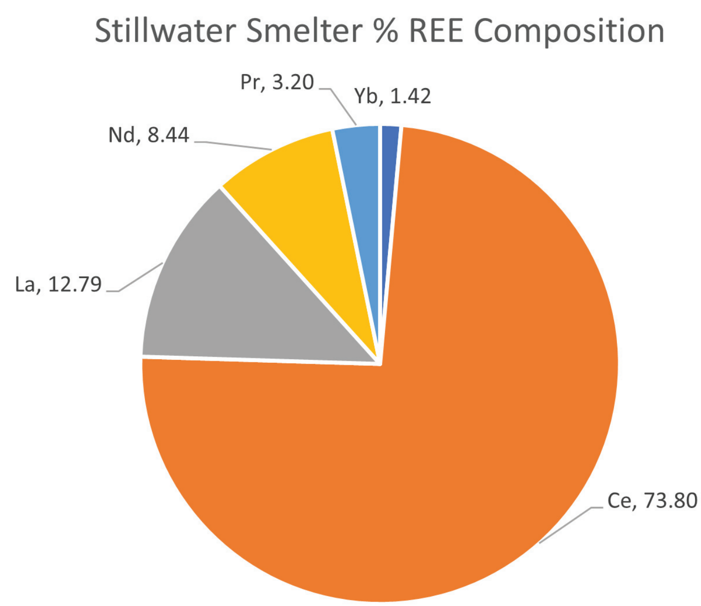

Figure 3-14. REE concentration percentages for every solid sample taken from the Stillwater smelter. Elements with less than 1% concentration were removed.

Table 3-39. Columbus/MOAUT monitoring wells—rare earth element and germanium statistics.

MOAUT Statistics					
Sample ID	Coutl	Total REE (µg/L)	Average REE	Minimum REE	Maximum REE
MO-9	0.00	0.28	0.06	0.01	0.15
MO-25	0.00	0.15	0.07	0.01	0.14
MO-26	0.00	0.21	0.10	0.04	0.17
RMIS-2	0.00	0.22	0.07	0.01	0.14

Table 3-40. Columbus/MOAUT monitoring wells—rare earth element and germanium concentrations.

MOAUT																	
Sample ID	Ge (µg/L)	Dy (µg/L)	Er (µg/L)	Ho (µg/L)	Lu (µg/L)	Tb (µg/L)	Tm (µg/L)	Y (µg/L)	Yb (µg/L)	Ce (µg/L)	Eu (µg/L)	Gd (µg/L)	La (µg/L)	Nd (µg/L)	Pr (µg/L)	Sm (µg/L)	Sc (µg/L)
MO-9	<32.00	<0.004	<0.004	<0.002	<0.002	<0.002	<0.002	<0.004	0.044	0.062	<0.003	<0.003	0.012	0.009	<0.003	<0.004	0.149
MO-25	<32.00	<0.004	<0.004	<0.002	<0.002	<0.002	<0.002	<0.004	0.006	<0.008	<0.003	<0.003	<0.003	<0.008	<0.003	<0.004	0.142
MO-26	<32.00	<0.004	<0.004	<0.002	<0.002	<0.002	<0.002	<0.004	0.037	<0.008	<0.003	<0.003	<0.003	<0.008	<0.003	<0.004	0.168
RMIS-2	<32.00	<0.004	<0.004	<0.002	<0.002	<0.002	<0.002	<0.004	0.069	<0.008	<0.003	<0.003	0.011	<0.008	<0.003	<0.004	0.141

Table 3-41. Nye/Fishtail/Columbus Chrome, Stillwater Smelter—rare earth element and germanium statistics.

Stillwater Smelter																	
Sample ID	Ge (mg/kg)	Dy (mg/kg)	Er (mg/kg)	Ho (mg/kg)	Lu (mg/kg)	Tb (mg/kg)	Tm (mg/kg)	Y (mg/kg)	Yb (mg/kg)	Ce (mg/kg)	Eu (mg/kg)	Gd (mg/kg)	La (mg/kg)	Nd (mg/kg)	Pr (mg/kg)	Sm (mg/kg)	Sc (mg/kg)
Slag-Stillwater Mine	2.4	0.7	0.39	0.15	0.08	0.33	0.06	0.58	109	5880	0.19	0.6	1025	673	255	3.19	6
Stillwater Mill Conc.	1	0.41	0.32	0.08	0.06	0.07	0.04	0.33	13.9	518	0.13	0.29	84.1	58.6	22.1	0.43	13

Table 3-42. Nye/Fishtail/Columbus Chrome, Stillwater Smelter—rare earth element and germanium statistics.

Stillwater Smelter Statistics					
Sample ID	Coutl	Total REE (mg/kg)	Average REE	Minimum REE	Maximum REE
Slag-Stillwater Mine	0.13	7,956.67	468.04	0.06	5880.00
Stillwater Mill Conc.	0.14	712.86	41.93	0.04	518.00

3.10 Zortman–Landusky

The Zortman and Landusky mines are two open pit mining operations encompassing 1,200 acres within the Little Rocky Mountains (fig. 3-15, Mitchell, 2004). The area has been mined since 1890, when rich gold and silver veins were discovered. Mining ceased in 1998 and the cleanup efforts began to try and stop the pollution of groundwater and surface water to the Fort Belknap reservation and surrounding areas. In 1999 the plant operator went bankrupt, and the cleanup fell to the State and Federal governments. Sampling included 18 samples: 3 from waste piles and 15 aqueous and sludge samples from the water treatment plants. These samples were sent to ALS and WVU for assay; the results are presented in figures 3-16 and 3-17 and tables 3-43 through 3-48.

Figure 3-15. The discharge from the Zortman–Landusky bioplant.

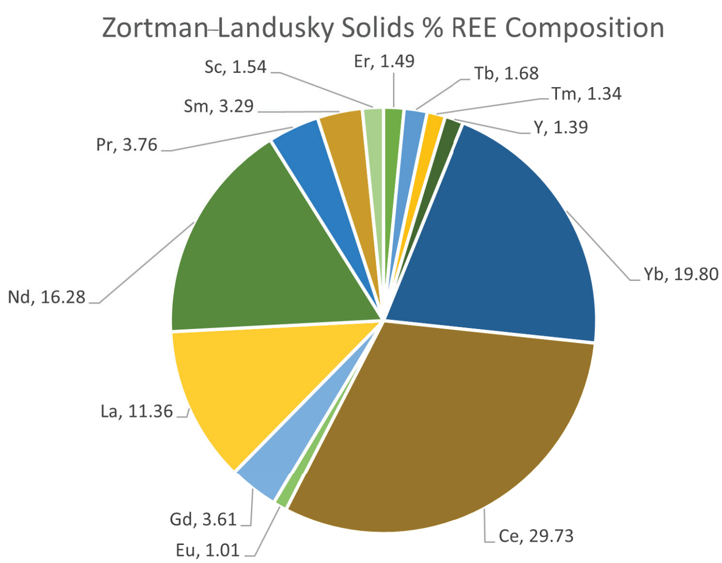

Figure 3-16. REE concentration percentages for every solid sample taken at Zortman–Landusky that was analyzed by ALS. Elements with less than 1% concentration were removed.

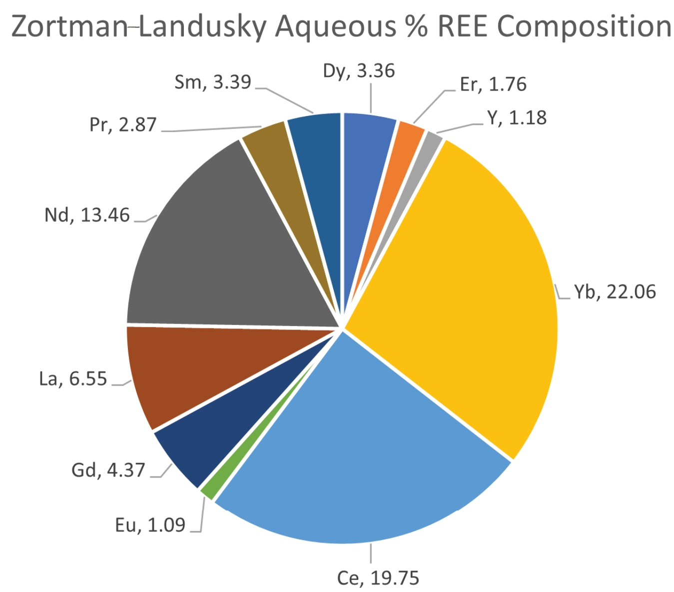

Figure 3-17. REE concentration percentages for every aqueous sample taken at Zortman–Landusky. Elements with less than 1% concentration were removed.

Table 3-43. Zortman–Landusky, aqueous samples—Rare earth element and germanium statistics.

Zortman-Landusky Aqueous Statistics					
Sample ID	Coutl	Total REE (µg/L)	Average REE	Minimum REE	Maximum REE
BioPlant Influent	2.25	3,984.94	249.06	8.62	1166.02
BioPlant Discharge	0.00	5.32	0.38	0.00	1.99
BioPlant Sludge Decant	0.96	159.92	10.00	0.10	59.04
Landusky WTP Influent	2.47	564.39	35.27	1.40	154.37
Landusky WTP Effluent	0.00	1.62	0.12	0.00	0.49
Landusky WTP Sludge Decant	2.44	5.38	0.36	0.01	1.52
Swift Influent	2.11	825.41	51.59	0.92	247.13
Swift Effluent	0.00	0.81	0.06	0.00	0.23
Swift Sludge Decant	0.00	0.06	0.01	0.01	0.02
Zortman WTP Influent	1.31	935.97	58.50	1.37	280.07
Zortman WTP Effluent	1.28	3.22	0.21	0.01	0.91

Table 3-44. Zortman–Landusky, aqueous samples—rare earth element and germanium concentrations.

Zortman-Landusky Aqueous																
Sample ID	Ge (µg/L)	Dy (µg/L)	Er (µg/L)	Ho (µg/L)	Lu (µg/L)	Tb (µg/L)	Tm (µg/L)	Y (µg/L)	Yb (µg/L)	Ce (µg/L)	Eu (µg/L)	Gd (µg/L)	La (µg/L)	Nd (µg/L)	Pr (µg/L)	Sm (µg/L)	Sc (µg/L)
BioPlant Influent	<32.00	180.862	93.198	33.89	8.618	31.631	10.809	60.561	1166.02	917.603	58.712	234.317	206.69	656.667	136.892	178.139	10.328
BioPlant Discharge	<32.00	0.061	0.031	0.012	<0.002	<0.002	0.003	0.013	0.81	1.986	0.022	0.126	1.162	0.772	0.19	0.081	0.046
BioPlant Sludge Decant	<32.00	3.005	1.379	0.541	0.104	0.57	0.143	0.767	25.943	59.038	1.267	5.463	25.671	25.509	6.116	4.238	0.167
Landusky WTP Influent	<32.00	24.379	13.226	4.611	1.431	4.206	1.67	10.095	154.365	115.029	8.252	30.894	50.1	99.099	19.899	25.737	1.401
Landusky WTP Effluent	<32.00	0.059	0.032	0.011	<0.002	<0.002	0.003	0.023	0.492	0.34	0.019	0.076	0.179	0.269	0.058	0.06	<0.037
Landusky WTP Sludge Decant	<32.00	0.219	0.117	0.043	0.013	0.012	0.015	0.088	1.52	1.108	0.074	0.284	0.52	0.938	0.189	0.24	<0.037
Swift Influent	<32.00	31.186	18.338	6.471	1.818	5.238	2.156	11.729	247.127	191.844	9.119	40.41	92.176	116.413	24.737	25.724	0.921
Swift Effluent	<32.00	0.02	0.011	0.004	<0.002	<0.002	<0.002	0.006	0.228	0.203	0.005	0.03	0.115	0.104	0.024	0.017	0.045
Swift Sludge Decant	<32.00	<0.004	<0.004	<0.002	<0.002	<0.002	<0.002	<0.004	0.013	0.021	<0.003	<0.003	0.012	0.01	<0.003	<0.004	<0.037
Zortman WTP Influent	<32.00	26.611	13.545	4.859	1.369	4.713	1.673	10.007	154.624	280.073	9.435	35.605	142.975	168.908	39.936	34.724	6.909
Zortman WTP Effluent	<32.00	0.1	0.051	0.021	0.008	<0.002	0.009	0.037	0.494	0.906	0.043	0.135	0.553	0.521	0.131	0.161	0.052

Table 3-45. Zortman–Landusky, solids samples (WVU)—rare earth element and germanium concentrations.

Zortman-Landusky Solids (WVU)																
Sample ID	Ge (mg/kg)	Dy (mg/kg)	Er (mg/kg)	Ho (mg/kg)	Lu (mg/kg)	Tb (mg/kg)	Tm (mg/kg)	Y (mg/k)	Yb (mg/kg)	Ce (mg/kg)	Eu (mg/kg)	Gd (mg/kg)	La (mg/kg)	Nd (mg/kg)	Pr (mg/kg)	Sm (mg/kg)	Sc (mg/kg)
BioPlant Carbon	19.689	7.751	4.167	2.591	11.19	1.569	0.511	1.246	0.534	3.086	51.695	215.371	71.69	51.518	13.073	10.173	19.773
BioPlant Sludge	<0.032	190.518	96.531	66.669	255.272	39.011	9.547	34.672	12.345	69.012	1349.64	796.354	289.068	835.452	154.983	196.58	17.904
L-83	16.147	53.899	28.708	18.785	71.584	10.58	3.158	9.698	3.658	21.458	342.031	378.504	183.769	254.102	55.604	62.427	10.139
L-91 Vent	<0.032	3.628	2.207	1.397	5.426	0.747	0.339	0.47	0.324	1.907	18.678	289.59	58.228	28.64	6.805	5.751	14.342
Landusky WTP Sludge	23.812	102.148	53.668	35.41	133.97	19.62	5.721	18.043	6.672	38.329	705.258	559.029	250.103	432.125	87.549	113.822	6.068
Swift Sludge	<0.032	49.542	29.358	14.933	68.253	10.668	2.93	8.541	3.5	18.366	438.41	403.507	190.621	207.52	43.627	44.732	2.839
Zortman WTP Sludge	<0.032	89.822	45.3	31.457	122.892	16.658	4.807	16.127	5.731	32.938	554.936	1040.42	505.944	579.1	140.527	120.449	38.259

Table 3-46. Zortman–Landusky, solids samples (WVU)—rare earth element and germanium statistics.

Zortman-Landusky Solids (WVU) Statistics					
Sample ID	Coutl	Total REE (mg/kg)	Average REE	Minimum REE	Maximum REE
BioPlant Carbon	0.54	485.63	28.57	0.51	215.37
BioPlant Sludge	2.78	4,413.56	275.85	9.55	1349.64
L-83	1.69	1,524.25	89.66	3.16	378.50
L-91 Vent	0.19	438.48	27.40	0.32	289.59
Landusky WTP Sludge	2.14	2,591.35	152.43	5.72	705.26
Swift Sludge	1.70	1,537.35	96.08	2.84	438.41
Zortman WTP Sludge	1.20	3,345.37	209.09	4.81	1040.42

Table 3-47. Zortman–Landusky, solids samples (ALS)—rare earth element and germanium statistics.

Zortman-Landusky Solids (ALS) Statistics					
Sample ID	Coutl	Total REE (mg/kg)	Average REE	Minimum REE	Maximum REE
BioPlant Carbon	0.93	159.54	9.97	0.20	54.70
L-83	1.68	504.66	29.69	0.97	127.00
L-91-Vent	0.78	72.83	4.28	0.14	25.70
Landusky WTP Sludge	2.22	1,880.39	110.61	1.30	513.00
Swift Sludge	1.92	449.39	26.43	0.33	281.00
Zortman WTP Sludge	1.15	2,010.35	118.26	0.70	643.00
ZL-Slag (12' deep Alabama pit)	1.21	143.71	8.98	0.18	45.30
ZL-Sludge-1	1.03	1,070.13	62.95	1.30	373.00
ZL-Sludge-2	0.88	863.48	53.97	0.60	317.00
ZL-Sludge-3	0.79	786.60	46.27	0.50	324.00

Table 3-48. Zortman–Landusky, solids samples (ALS)—rare earth element and germanium concentrations.

Zortman-Landusky Solids (ALS)																	
Sample ID	Ge (mg/kg)	Dy (mg/kg)	Er (mg/kg)	Ho (mg/kg)	Lu (mg/kg)	Tb (mg/kg)	Tm (mg/kg)	Y (mg/k	Yb (mg/kg)	Ce (mg/kg)	Eu (mg/kg)	Gd (mg/kg)	La (mg/kg)	Nd (mg/kg)	Pr (mg/kg)	Sm (mg/kg)	Sc (mg/kg)
BioPlant Carbon	<0.5	3.28	1.65	0.69	0.2	0.59	0.28	1.56	23.1	54.7	1.24	4.53	27.3	23.5	6.26	4.66	6
L-83	2	17.2	9.05	3.44	0.97	3.08	1.18	7.55	115.5	127	5.89	20.9	63.3	85.2	19.6	19.8	3
L-91-Vent	1.7	1.28	0.74	0.27	0.14	0.22	0.14	0.94	7.7	25.7	0.58	1.19	14.6	10.7	3.01	1.92	2
Landusky WTP Sludge	1.3	79	41.7	15.65	4.66	14	5.48	34	513	392	26.5	97.4	171	329	68.1	84.6	3
Swift Sludge	1.5	3.68	2.29	0.76	0.33	0.64	2.38	13.4	281	59.5	1.02	4.29	31.3	25.8	7.15	5.35	9
Zortman WTP Sludge	0.7	53	26.1	10.3	2.89	9.81	3.45	21.4	322	643	18.9	70	304	353	89	71.8	11
ZL-Slag (12' deep Alabama pit)	<0.5	3.46	1.76	0.72	0.18	0.64	0.22	1.29	28	45.3	1.13	5	19.8	22.9	5.35	4.46	3.5
ZL-Sludge-1	1.3	27.6	14.4	5.52	1.76	5.05	1.95	11.5	169	373	10.05	35.3	126.5	180.5	42.2	39.1	25.4
ZL-Sludge-2	0.6	20.5	10.85	4.12	1.48	96.4	89.6	9.78	12	317	7.95	25.6	74.8	134	29.9	<0.5	28.9
ZL-Sludge-3	0.5	17.75	9.76	3.61	1.37	3.25	1.48	8.64	101	324	7.14	22.4	69.7	128	28.1	29.4	30.5

3.11 Flat Creek

The Flat Creek–Iron Mountain mine is located near Superior, Montana in Mineral County. The mine operated for 27 years, with stints from 1909 to 1930 and 1947 to 1953. During the mine's operation it produced 7,535,084 lbs of zinc, 5,385,741 lbs of lead, 5,274 lbs of copper, and 389,355 fine oz of silver (Mineral Independent, 2016). The mine was originally operated by The Iron Mountain Mine and Mill, with ownership switching to ASARCO. In the year 2000, heavy rains following a 9,000-acre forest fire caused mine waste and tailings to flow into Flat Creek. Following the contamination of Flat Creek, ASARCO filed for bankruptcy in 2009 and the site was added to the Superfund list, with cleanup beginning in 2013. On June 22, 2023, 21 solid samples were collected and sent to ALS for assay (fig. 3-18). The assay results can be found in tables 3-49 and 3-50. Figure 3-19 shows REE percentages based on the average of concentrations for all 21 samples collected.

Figure 3-18. Reclamation of the contaminated soil in Flat Creek, Superior, Montana.

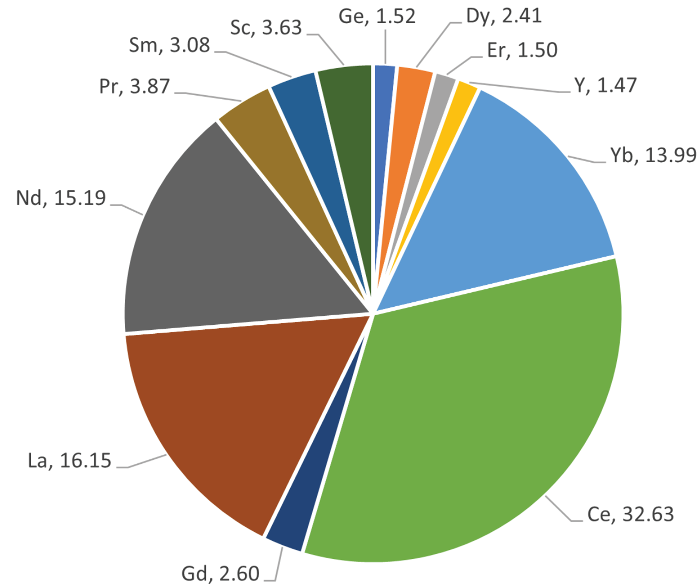

Figure 3-19. REE concentration percentages for every sample taken at Flat Creek, including germanium. Elements with less than 1% concentration were removed.

Table 3-49. Flat Creek tailings—rare earth element and germanium statistics.

Flat Creek Statistics					
Sample ID	Coutl	Total REE (mg/kg)	Average REE	Minimum REE	Maximum REE
#1 FC Unit #16	0.98	220.32	12.96	0.48	72.20
#2 FC Unit #16	0.95	191.16	11.24	0.43	62.80
#3 FC Unit #16	0.92	182.87	10.76	0.40	61.00
#4 FC Unit #16	0.93	185.41	10.91	0.42	61.50
#5 FC Rep	0.94	190.06	11.18	0.41	62.60
#6 FC Rep	1.06	204.82	12.05	0.48	62.10
#7 FC Rep	0.93	204.11	12.01	0.41	68.10
#8 FC Rep	0.96	210.96	12.41	0.46	70.00
#9 FC Rep	0.94	216.21	12.72	0.47	71.40
#10 FC Rep	0.88	212.69	12.51	0.42	72.40
#11 FC Rep	1.00	211.30	12.43	0.54	67.30
#12 FC WRD Adit	0.98	188.72	11.10	0.41	60.10
#13 FC WRD Adit	1.01	190.88	11.23	0.46	61.10
#14 FC WRD Adit	1.01	180.24	10.60	0.40	57.90
#15 FC WRD Adit	1.01	239.19	14.07	0.54	77.50
#16 FC WRD Adit	1.02	191.64	11.27	0.43	61.00
#17 FC WT	1.05	174.79	10.28	0.36	55.40
#18 FC WT	0.96	176.71	10.39	0.35	58.50
#19 FC WT	0.96	203.14	11.95	0.39	68.40
#20 FC WT	0.97	191.70	11.28	0.37	63.10

Table 3-50. Flat Creek tailings—rare earth element and germanium concentrations.

Flat Creek																	
Sample ID	Ge (mg/kg)	Dy (mg/kg)	Er (mg/kg)	Ho (mg/kg)	Lu (mg/kg)	Tb (mg/kg)	Tm (mg/kg)	Y (mg/kg)	Yb (mg/kg)	Ce (mg/kg)	Eu (mg/kg)	Gd (mg/kg)	La (mg/kg)	Nd (mg/kg)	Pr (mg/kg)	Sm (mg/kg)	Sc (mg/kg)
#1 FC Unit #16	2.8	5.58	3.36	1.14	0.48	0.83	0.5	3.52	32.3	72.2	1.06	5.33	35.9	32.8	8.37	7.15	7
#2 FC Unit #16	3.6	4.49	2.97	1	0.43	0.82	0.44	2.74	26.8	62.8	0.93	4.84	31.8	28.1	7.29	6.11	6
#3 FC Unit #16	2.7	4.15	2.72	0.88	0.4	0.71	0.46	2.54	23.1	61	1.18	4.69	30.8	28.2	7.18	6.16	6
#4 FC Unit #16	3.6	4.42	2.85	0.88	0.46	0.7	0.42	2.72	24.6	61.5	1.15	4.36	30.6	27.9	7.32	5.93	6
#5 FC Rep	2.8	4.53	2.79	0.88	0.42	0.7	0.41	2.75	24.9	62.6	0.97	4.96	31.7	29.3	7.49	5.86	7
#6 FC Rep	3	5.42	3.4	1.1	0.48	0.86	0.53	3.29	31	62.1	1.24	5.56	31	29.9	7.49	6.45	12
#7 FC Rep	3.2	4.65	2.89	0.93	0.44	0.82	0.41	2.85	27.1	68.1	0.92	4.99	34.6	31	7.83	6.38	7
#8 FC Rep	2.5	4.84	3.23	0.96	0.46	0.79	0.52	2.86	29.5	70	1.08	5.38	34.7	32.3	8.13	6.71	7
#9 FC Rep	2.8	5.24	3.28	1.06	0.52	0.8	0.47	3.16	29.4	71.4	1.08	5.19	37.1	32.5	8.3	6.91	7
#10 FC Rep	2.9	4.58	2.94	0.97	0.42	0.78	0.46	3.1	26.8	72.4	1.05	5.07	35.7	32.2	8.41	6.91	8
#11 FC Rep	3.3	5.5	3.21	1.13	0.55	0.87	0.54	3.35	31.7	67.3	0.97	5.52	34.3	30.5	8.06	6.5	8
#12 FC WRD Adit	4.9	4.55	2.74	1	0.43	0.83	0.41	2.84	27.5	60.1	1.3	5.12	29.1	29.4	7.28	5.22	6
#13 FC WRD Adit	4.1	4.35	2.86	0.93	0.5	0.74	0.46	2.97	26.2	61.1	1.46	5.26	29.9	29	7.52	5.53	8
#14 FC WRD Adit	2.5	4.52	2.82	1	0.47	0.78	0.4	2.82	27.1	57.9	0.88	4.96	28	26.9	7	5.19	7
#15 FC WRD Adit	2.5	5.97	3.61	1.32	0.54	0.99	0.54	3.74	36	77.5	1	6.51	37.8	36.5	9.5	7.17	8
#16 FC WRD Adit	4	4.96	2.99	1.02	0.45	0.81	0.43	2.98	27.8	61	1.04	5.13	29.7	29.7	7.19	5.44	7
#17 FC WT	3.3	4.5	2.67	0.9	0.36	0.75	0.42	2.59	25.6	55.4	1.9	5.06	27.2	27	6.79	5.35	5
#18 FC WT	1.2	4.22	2.49	0.91	0.35	0.74	0.35	2.41	24.5	58.5	1.01	4.7	27.1	27.3	6.87	5.06	9
#19 FC WT	2.4	4.66	2.78	1	0.39	0.81	0.39	2.55	26.4	68.4	2.06	5.7	33.2	32.8	8.05	6.55	5
#20 FC WT	2	4.56	2.88	0.96	0.43	0.75	0.37	2.64	26.5	63.1	1.24	4.99	30.6	29.4	7.51	5.77	8

3.12 Neihart Mining District (Barkers/Hughesville)

The Neihart mining district, located in the Little Belt Mountains, encompasses 9,000 acres around Neihart, MT (Barkers/Hughesville; fig. 3-20). Mining initially began in the 1890s with the discovery of silver and lead rich ores. Over $17 million of silver and other minerals were extracted from 96 known mines until the end of mining in the area in 1945 (Western Mining History, 2024a). Acid drainage from the mines polluted nearby creeks and groundwater. This site was added to the Superfund list in September 2001. The excessive amount of mine waste made it a target for the ARL project; EPA and U.S. Forest Service helped with site access. On September 25, 2023, 24 solid samples and 7 aqueous samples were collected from the district. The samples were sent to WVU and ALS for assay. The assay results can be found in tables 3-51 through 3-54. Figures 3-21 and 3-22 show the average REE concentration for solid and aqueous samples, respectively.

Figure 3-20. A large waste rock dump on the mountains near Neihart, Montana.

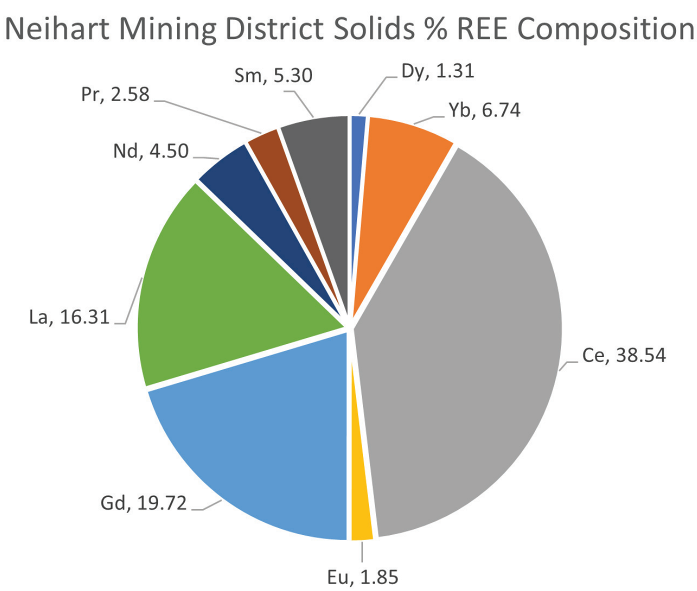

Figure 3-21. REE concentration percentages for every solid sample taken in the Neihart Mining District. Elements with less than 1% concentration were removed.

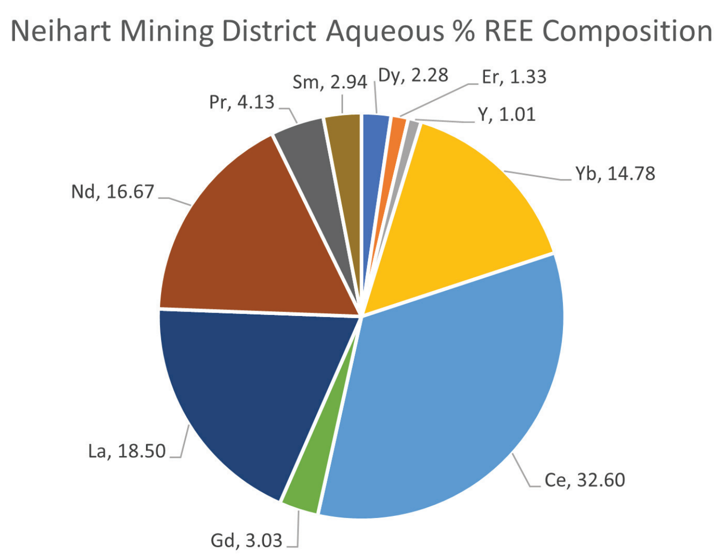

Figure 3-22. REE concentration percentages for every aqueous sample taken in the Neihart Mining District. Elements with less than 1% concentration were removed.

Table 3-51. Barkers/Hughesville, aqueous samples—rare earth element and germanium concentrations.

Neihart Mining District Aqueous																	
Sample ID	Ge (µg/L)	Dy (µg/L)	Er (µg/L)	Ho (µg/L)	Lu (µg/L)	Tb (µg/L)	Tm (µg/L)	Y (µg/L)	Yb (µg/L)	Ce (µg/L)	Eu (µg/L)	Gd (µg/L)	La (µg/L)	Nd (µg/L)	Pr (µg/L)	Sm (µg/L)	Sc (µg/L)
Broadwater Mine	<32.00	0.005	0.005	<0.002	<0.002	<0.002	<0.002	<0.004	0.207	0.041	<0.003	0.006	0.057	0.01	0.004	<0.004	0.049
Broadwater Mine-TR	<32.00	0.006	0.006	<0.002	<0.002	<0.002	<0.002	<0.004	0.208	0.035	<0.003	0.005	0.059	0.022	0.005	<0.004	<0.037
Compromise Shaft	<32.00	0.01	0.007	0.003	<0.002	<0.002	<0.002	0.005	0.222	0.089	<0.003	0.009	0.09	0.03	0.005	<0.004	0.049
Compromise Shaft-TR	<32.00	0.029	0.022	0.007	0.002	0.004	0.002	0.014	0.417	0.216	0.007	0.032	0.163	0.097	0.022	0.014	<0.037
Dacotah Mine	<32.00	1.608	0.879	0.322	0.097	0.272	0.105	0.626	10.7	9.82	0.575	1.944	3.983	7.2	1.452	1.607	0.75
Dacotah Mine-TR	<32.00	1.682	0.945	0.335	0.097	0.29	0.112	0.666	11.4	10.271	0.615	2.077	4.117	7.462	1.541	1.679	0.646
Florence Mine	<32.00	<0.004	<0.004	<0.002	<0.002	<0.002	<0.002	<0.004	0.033	0.043	<0.003	0.004	0.023	0.014	0.004	<0.004	<0.037
Florence Mine-TR	<32.00	0.006	<0.004	<0.002	<0.002	<0.002	<0.002	<0.004	0.047	0.072	<0.003	0.007	0.041	0.033	0.008	0.006	<0.037
Lower Rebellion	<32.00	0.605	0.325	0.13	0.062	0.128	0.057	0.246	3.218	2.604	0.255	0.78	1.944	2.105	0.48	0.775	0.073
Lower Rebellion-TR	<32.00	0.273	0.138	0.053	0.013	0.049	0.016	0.085	2.348	2.036	0.095	0.43	1.654	1.333	0.323	0.278	0.038
Silver Dyke Adit	<32.00	10.89	6.406	2.204	0.739	1.857	0.801	4.89	76.62	167.41	3.425	14.25	91.927	77.993	19.82	13.38	1.096
Silver Dyke Adit-TR	<32.00	14.49	8.595	2.875	1.017	2.519	1.069	6.647	87.49	235.95	5.064	19.7	139.6	122.1	30.5	20.53	7.277
Upper Rebelloin	<32.00	0.115	0.061	0.021	0.007	0.021	0.008	0.045	0.86	0.821	0.048	0.191	0.425	0.496	0.105	0.119	0.038
Upper Rebelloin-TR	<32.00	0.427	0.205	0.076	0.025	0.082	0.026	0.177	1.977	2.521	0.206	0.681	0.959	1.889	0.394	0.604	0.538

Table 3-52. Barkers/Hughesville, aqueous samples—rare earth element and germanium statistics.

Neihart Mining District Aqueous Statistics					
Sample ID	Coutl	Total REE (µg/L)	Average REE	Minimum REE	Maximum REE
Broadwater Mine	0.00	0.38	0.04	0.00	0.21
Broadwater Mine-TR	0.00	0.35	0.04	0.01	0.21
Compromise Shaft	0.00	0.52	0.05	0.00	0.22
Compromise Shaft-TR	2.54	1.05	0.07	0.00	0.42
Dacotah Mine	2.05	41.94	2.62	0.10	10.70
Dacotah Mine-TR	2.07	43.94	2.75	0.10	11.40
Florence Mine	0.00	0.12	0.02	0.00	0.04
Florence Mine-TR	0.00	0.22	0.03	0.01	0.07
Lower Rebellion	2.33	13.79	0.86	0.06	3.22
Lower Rebellion-TR	2.00	9.16	0.57	0.01	2.35
Silver Dyke Adit	1.04	493.72	30.86	0.74	167.41
Silver Dyke Adit-TR	1.00	705.41	44.09	1.02	235.95
Upper Rebelloin	1.87	3.38	0.21	0.01	0.86
Upper Rebelloin-TR	1.81	10.79	0.67	0.03	2.52

Table 3-53. Barkers/Hughesville, solids samples—rare earth element and germanium statistics.

Neihart Mining District Solids Statistics					
Sample ID	Coutl	Total REE (mg/kg)	Average REE	Minimum REE	Maximum REE
Big Seven	0.56	233.37	13.73	0.15	96.80
Broadwater Mine 1	0.78	229.31	13.49	0.27	83.00
Broadwater Mine 2	0.85	192.80	11.34	0.26	66.10
Compromise Shaft	0.86	220.59	12.98	0.30	74.80
Dacotah #1 - Charlie Bennett	0.71	179.04	10.53	0.14	65.40
Dacotah #2 - Charlie Bennett	0.85	226.52	13.32	0.22	78.60
Dacotah #3 - Charlie Bennett	0.76	202.10	11.89	0.22	73.80
Florence Mine - Charlie Bennett	0.63	213.73	12.57	0.18	84.50
Jig Tailings	0.61	198.37	11.67	0.17	78.00
Lower Carpenter Creek Tailings N	0.59	312.03	18.35	0.23	124.00
Lower Carpenter Creek Tailings S	0.63	269.64	15.86	0.27	105.00
Lower Carpenter Creek Tailings W	0.60	247.94	14.58	0.22	97.90
Lower Rebellion 1 of 2	0.73	240.12	14.12	0.27	89.90
Lower Rebellion 2 of 2	0.73	286.28	16.84	0.34	107.50
Neiheart Tailing S - Charlie Bennett	0.63	187.33	11.02	0.17	74.20
Neiheart Tailings N - Charlie Bennett	0.74	211.20	12.42	0.24	78.50
Ripple	0.69	219.79	12.93	0.26	85.00
Silver Dyke Glory Hole	0.52	205.42	12.08	0.17	86.40
Silver Dyke N 2	0.48	277.45	16.32	0.14	118.50
Silver Dyke N1	0.52	256.78	15.10	0.17	105.50
Silver Dyke S1	0.56	177.68	10.45	0.11	69.90
Silver Dyke SW1	0.64	289.43	17.03	0.26	110.50
Upper Carpenter Creek Tailings N	0.62	231.23	13.60	0.23	89.50
Upper Carpenter Creek Tailings S	0.64	289.72	17.04	0.25	111.50
Upper Rebellion	0.67	235.79	13.87	0.22	93.30

Table 3-54. Barkers/Hughesville, solids samples—rare earth element and germanium concentrations.

Neihart Mining District Solids																	
Sample ID	Ge (mg/kg)	Dy (mg/kg)	Er (mg/kg)	Ho (mg/kg)	Lu (mg/kg)	Tb (mg/kg)	Tm (mg/kg)	Y (mg/kg)	Yb (mg/kg)	Ce (mg/kg)	Eu (mg/kg)	Gd (mg/kg)	La (mg/kg)	Nd (mg/kg)	Pr (mg/kg)	Sm (mg/kg)	Sc (mg/kg)
Big Seven	1.7	2.22	1.17	0.43	0.15	0.41	0.16	1.11	11.4	96.8	1.17	3.37	47	39	11.1	6.18	10
Broadwater Mine 1	1.2	3.85	1.89	0.74	0.27	0.7	0.29	1.66	18.9	83	1.76	5.05	39.8	39.9	10.55	6.75	13
Broadwater Mine 2	1.3	3.45	1.9	0.67	0.26	0.59	0.27	1.67	18.5	66.1	1.36	4.3	31.8	32.6	8.47	5.56	14
Compromise Shaft	1.5	3.76	1.93	0.73	0.3	0.69	0.3	1.82	19.5	74.8	1.87	5.12	35.2	38.9	9.75	6.42	18
Dacotah #1 - Charlie Bennett	1.4	1.85	1.08	0.36	0.15	0.39	0.14	0.87	9.1	65.4	1.4	3.25	31.1	34	8.55	5	15
Dacotah #2 - Charlie Bennett	1.2	3.52	1.74	0.69	0.22	0.64	0.23	1.37	17.9	78.6	1.91	5.3	35.3	43.3	10.75	6.85	17
Dacotah #3 - Charlie Bennett	1.2	2.99	1.52	0.59	0.22	0.58	0.22	1.26	14.8	73.8	1.63	4.36	33.9	36.6	9.34	6.09	13
Florence Mine - Charlie Bennett	1.2	2.81	1.26	0.51	0.18	0.53	0.19	1.15	13.7	84.5	1.37	4.34	40.5	34.8	9.61	6.08	11
Jig Tailings	1.1	2.4	1.29	0.47	0.19	0.45	0.17	1.19	12.9	78	1.18	3.37	41.2	30.2	8.71	4.55	11
Lower Carpenter Creek Tailings N	1.1	3.49	1.62	0.68	0.23	0.66	0.25	1.39	17.4	124	1.89	5.28	69.6	49.1	13.95	7.39	14
Lower Carpenter Creek Tailings S	1.2	3.43	1.81	0.7	0.28	0.64	0.27	1.68	18.1	105	1.57	4.88	57.3	42.7	11.85	6.23	12
Lower Carpenter Creek Tailings W	1.2	2.84	1.62	0.57	0.23	0.55	0.22	1.38	15.6	97.9	1.43	4.19	53.9	37.8	10.8	5.71	12
Lower Rebellion 1 of 2	1.3	4.01	2	0.77	0.27	0.7	0.29	1.72	20.2	89.9	1.52	5.07	42.3	39.2	10.65	7.22	13
Lower Rebellion 2 of 2	1.3	4.48	2.42	0.89	0.34	0.82	0.34	2.13	23.8	107.5	1.92	6.2	53.3	47.9	13.15	7.79	12
Neiheart Tailing S - Charlie Bennett	2.4	2.45	1.33	0.49	0.17	0.47	0.19	1.12	12	74.2	0.98	3.23	35.5	30.5	8.41	4.89	9
Neiheart Tailings N - Charlie Bennett	2.3	3.72	2	0.7	0.24	0.68	0.25	1.65	18.2	78.5	1.44	4.81	37.6	34.2	9.43	6.48	9
Ripple	1.4	2.97	1.72	0.64	0.26	0.52	0.26	1.6	17.6	85	0.93	3.22	41.5	36.9	10.25	5.02	10
Silver Dyke Glory Hole	1.2	2.1	1.19	0.4	0.17	0.42	0.17	1.17	11.3	86.4	1.07	3.18	46	29.6	8.64	4.41	8
Silver Dyke N 2	1.1	2.41	1.16	0.45	0.14	0.5	0.15	0.98	13	118.5	1.28	3.94	68.1	39.1	12	5.64	9
Silver Dyke N1	1.1	2.3	1.04	0.45	0.19	0.44	0.17	1	12	105.5	1.34	3.55	62.3	38.8	11.2	5.4	10
Silver Dyke S1	1	1.79	0.76	0.32	0.11	0.35	0.12	0.72	8.5	69.9	1.05	2.69	38.8	27.6	7.88	4.09	12
Silver Dyke SW1	1	3.86	1.92	0.72	0.26	0.68	0.29	1.75	18.8	110.5	1.79	5.1	59.2	45.7	12.85	7.01	18
Upper Carpenter Creek Tailings N	1.2	2.87	1.64	0.58	0.27	0.55	0.23	1.45	14.9	89.5	1.38	4.11	48.2	35.5	10.35	5.5	13
Upper Carpenter Creek Tailings S	1.1	3.72	1.76	0.74	0.25	0.69	0.26	1.67	18.3	111.5	1.92	5.35	59.7	47.2	13.1	7.46	15
Upper Rebellion	1.4	3.09	1.71	0.61	0.22	0.59	0.23	1.42	16.6	93.3	1.24	4.48	41.3	40.6	11.25	6.75	11

4.0 SUMMARY

Task 4 year 1 field activities focused on the collection and analysis of solid and aqueous samples based on the initial site list and sites added throughout the year. Samples were collected at 12 of the 23 sites, with a total of 392 samples collected. Much of the sampling occurred at sites with active Superfund and other mine closure monitoring activities; however, some sampling occurred at active mine operations (e.g., Montana Resources active Butte mining operations).

Sample results showed REE present in all of the samples collected; however, concentrations vary considerably between sites and waste sources (figs. 3-23–3-26). REE concentrations were higher in surface-water and groundwater sites where pH values were less than or equal to 4.0. Sludge and solid samples with the highest REE concentrations were from sites treating acid mine water with lime, which concentrated REEs contained in the waste sludge.

Reconnaissance sampling will continue during year 2 of the study, and that data combined with year 1 results will be used to identify sites with elevated REE concentrations for further, more detailed sampling.

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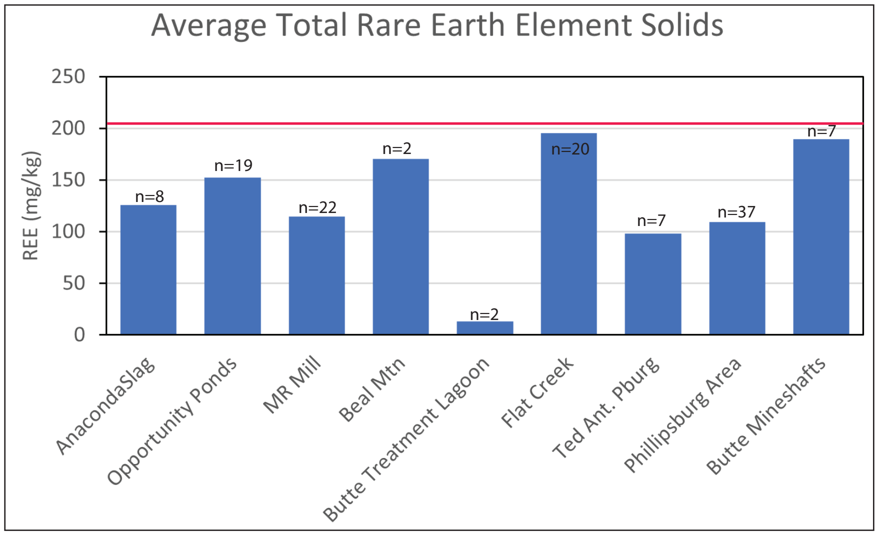

Figure 3-23. Average total REE concentrations per solid sample site for samples below 200 mg/kg. The red line represents the average REE concentration in Earth's crust, which is about 206 mg/kg.

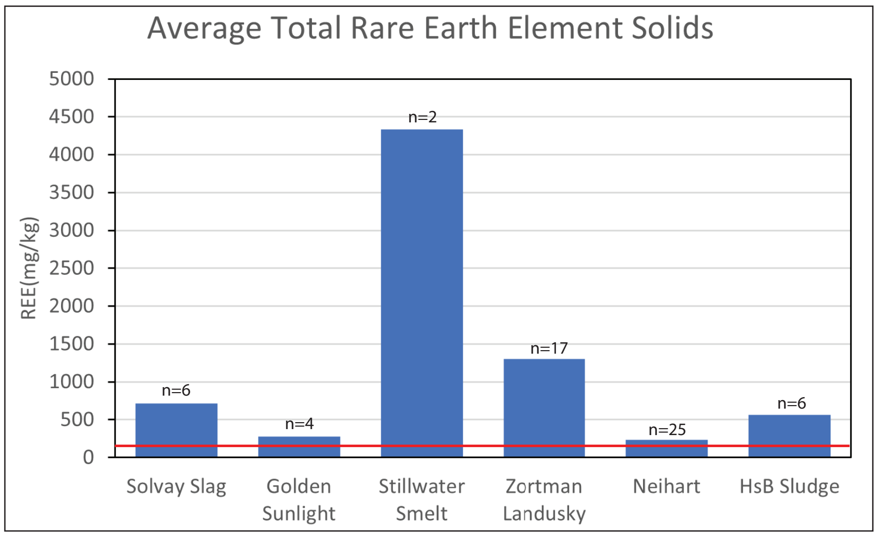

Figure 3-24. Average total REE concentrations per solid sample site for samples below 200 mg/kg. The red line represents the average REE concentration in Earth's crust, which is about 206 mg/kg.

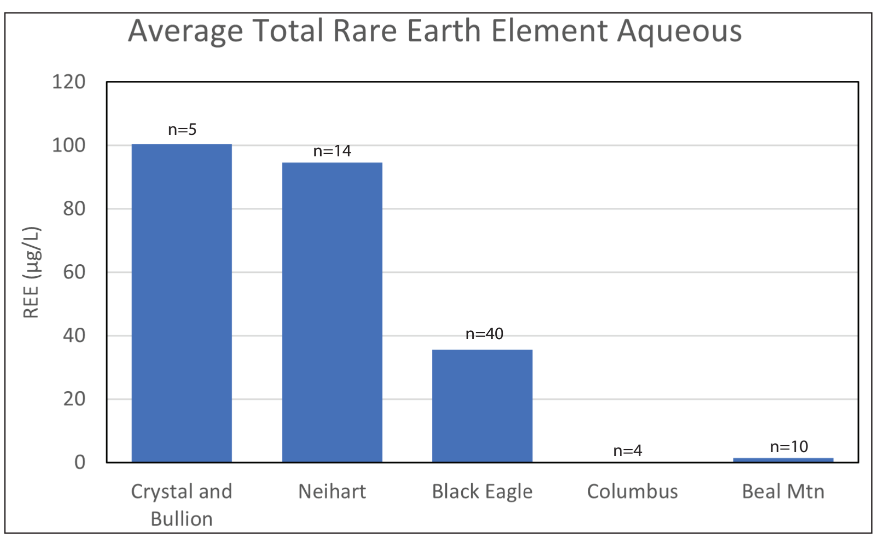

Figure 3-25. Average total REE concentrations per aqueous sample site below 100 µg/L.

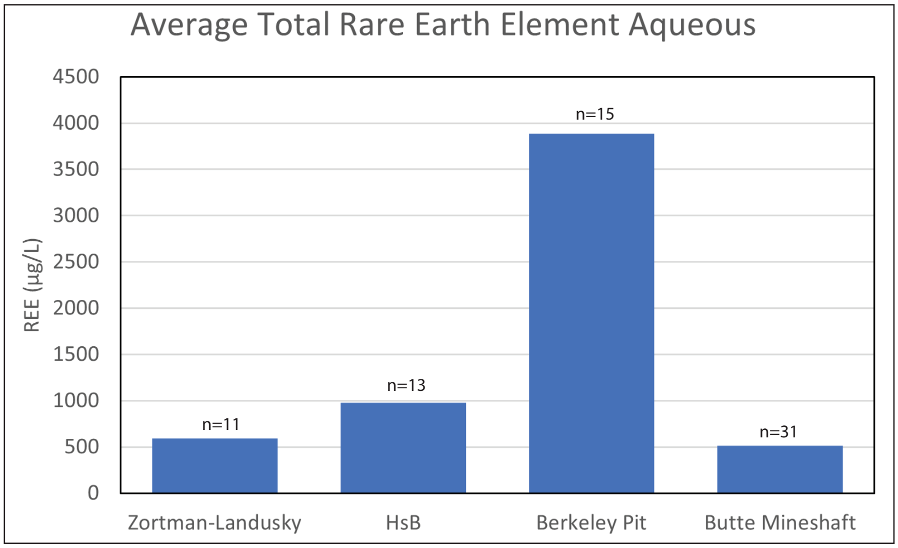

Figure 3-26. Average total REE concentrations per aqueous sample site above 100 µg/L.

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