CORE-CM PROJECT—SAN JUAN RIVER-RATON BASINS, NEW MEXICO
FIELD SAMPLING PLAN

Prepared by the Characterization Team

November 2021

1.0 INTRODUCTION

In order to evaluate REE in coal and associated stratigraphic units in the San Juan and Raton basins, a variety of field sampling methods of solid and water are required. This Field Sampling Plan describes the field sampling and analyses that will be conducted as part of studies for the CORE-CM Project. The field sampling program will be carefully planned to meet the Data Quality Objectives (DQOs), minimize cost, and minimize the potential conflicts between the numerous investigations. Appendix 1 is a list of SOPs. Appendix 2 includes forms used during the sampling program. All of this information is in the Project Database. The specific fields and data collected have been determined by various PIs to be important to characterize the samples. A SQS database will be designed to store, manage, and interpret data.

2.0 REE SAMPLING PROGRAM METHODOLOGY

Representative samples will be collected from each coal field. Clay, black shales, and other stratigraphic units above and below coal seams will be sampled as appropriate. Samples on Federal land do not require any permission for access and will be given higher priority for sampling. Coal waste and by-products will be sampled from active and inactive coal mines. The New Mexico State Land Office has granted permission to sample on state land and a permit is pending. Permission before sampling on private (including active coal mines and power plants) or Tribal lands will be obtained before sampling.

Five types of samples will be collected:

1) Drill core of coal deposits
2) Stratigraphic profile of outcrops with coal seams
3) Samples of waste products from operating active mines, preparation plants, power plants and disposal sites (active and inactive)
4) Samples from Abandoned Mine Lands (AML) sites
5) Samples of water draining from mines and waste storage sites (including process waters), where available (Separate SOP will be written to collect water samples)

3.0 DATA QUALITY OBJECTIVES

The proposed field investigation will focus on the following objectives:

1) Basinal Assessment of CORE-CM Resources

a) identify and quantify the distribution of REE and CM in coal beds and related stratigraphic units in the San Juan and Raton basins
b) identify and characterize the sources of REE and CM

2) Basinal Strategies for Reuse of Waste Streams
3) Basinal Strategies for Infrastructure, Industries and Businesses
   a) evaluate the basinal industry infrastructure and determine the economic viability of industrial upgrading
4) Technology Assessment, Development, and Field Testing
5) Technology Innovation Center
6) Stakeholder Outreach and Education

To meet these DQOs, the Characterization Team will implement this field sampling program. This sampling plan provides the detail sampling procedures to accomplish the work plan.

3.0 STUDY AREA

The study area includes the San Juan and Raton Basins in San Juan, Rio Arriba, Sandoval, McKinley, Cibola, Catron, Socorro, and Colfax Counties (Fig. 1, 2, Table 1). Field samples and drill core will be collected (Fig. 1, 2).

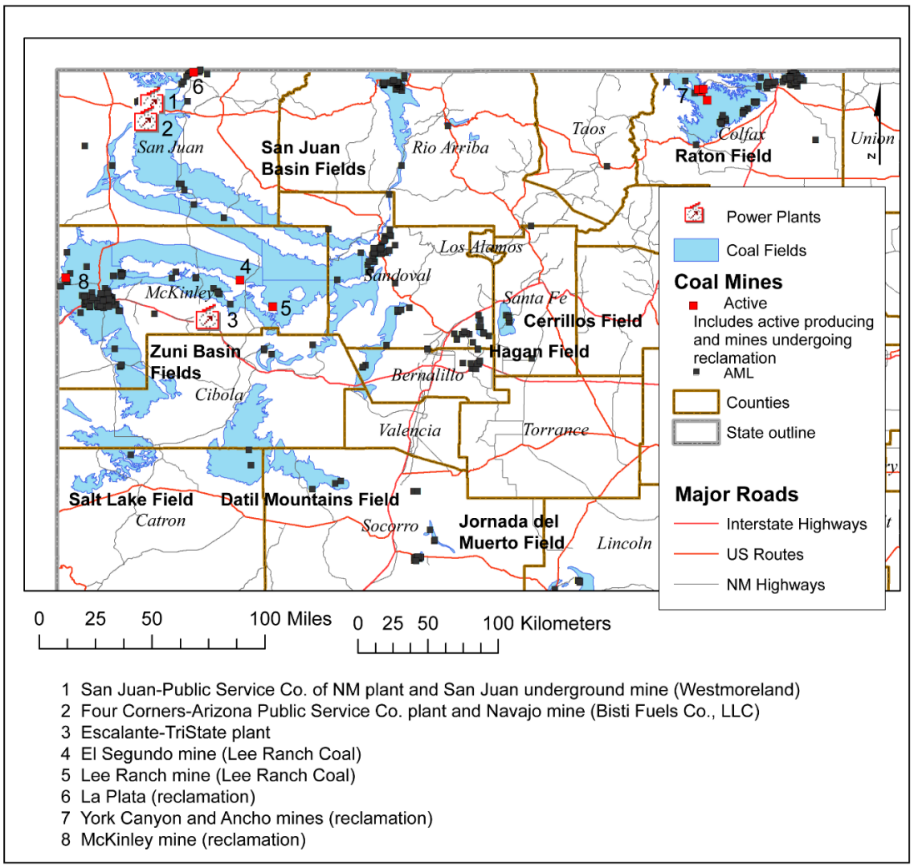


FIGURE 1. Coal fields, active mines, AML (abandoned mine lands) sites, and power plants in the San Juan and Raton Basins.

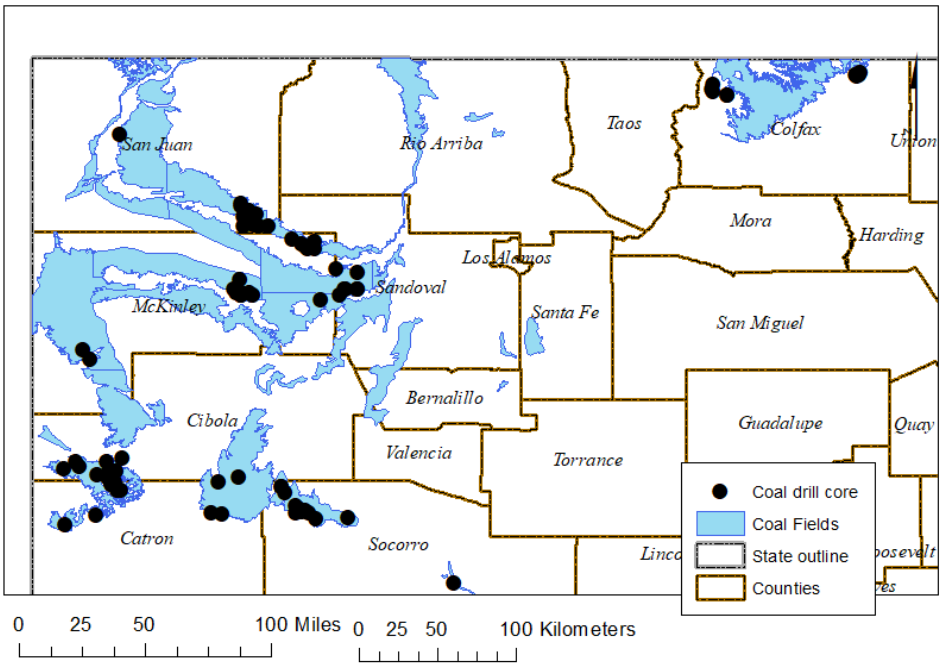


FIGURE 2. Coal fields and drill core in the San Juan and Raton Basins stored at the NMBGMR core facility.

TABLE 1. Coal fields in the San Juan and Raton basins, studied in this project, delineated by Hoffman (1996, 2017). District Id is from the New Mexico Mines Database (McLemore, 2010a, 2017). Representative samples will be collected from each coal field. Each field sample will be prefixed with an abbreviation representing each coal district. Each drill core sample will be identified by the hole number and depth. At least 3 samples will be collected from each coal field. Approximately 130 samples will be collected each year.

District id	District	Year of Discovery	Year of Initial Production	Year of Last Production	Estimated Cumulative Production	Formation	Prefix used for sample id
DIS257	Barker Creek coal field	1882		1905		Menefee	BAR
DIS150	Bisti coal field	1961	1980	1988	$40,075,148.00	Fruitland	BIS
DIS259	Chaco Canyon Coal Field	1905	1905			Menefee	CHACO
DIS260	Chacra Mesa coal field	1922		1945		Menefee	CHACA
DIS174	La Ventana	1884	1904	1983		Menefee	LAV
DIS118	Crownpoint coal field	1905	1914	1951	$20,758.00	Crevasse Canyon	CRWN
DIS155	Fruitland coal field	1889	1889	2001	$3,137,957,050	Fruitland	FRUIT
DIS119	Gallup coal field	1881	1882	2001	$121,522,629,885	Crevasse Canyon	GALL

District id	District	Year of Discovery	Year of Initial Production	Year of Last Production	Estimated Cumulative Production	Formation	Prefix used for sample id
DIS156	Hogback coal field	1907	1907	1971	$301,237.00	Menefee	HOG
DIS146	Monero coal field	1882	1882	1970	$5,277,552.00	Menefee	MON
DIS016	Mount Taylor coal field	1936	1952	1953	$69,948.00	Crevasse Canyon	TAY
DIS157	Navajo coal field	1933	1963	9999	$4,714,689,147	Fruitland	NAV
DIS258	Newcomb coal field	1955				Menefee	NEW
DIS021	Raton coal field	1820	1898	2002	$954,470,032.00	Vermejo, Raton	RAT
DIS003	Rio Puerco coal field	1901	1937	1944	$139,555.00	Crevasse Canyon	RIO
DIS009	Salt Lake coal field	1980	1987	1987	$100,000.00	Moreno Hill	SALT
DIS121	San Mateo coal field	1905	1983	2001	$1,678,742,326	Menefee	MAT
DIS261	Standing Rock coal field	1934	1952	1958		Menefee	STND
DIS158	Star Lake coal field	1907			$0.00	Fruitland	STAR
DIS263	Tierra Amarilla coal field	1935	1955	1955		Menefee	AMAR
DIS159	Toadlena	1950			$0.00	Menefee	TOAD
DIS124	Zuni coal field	1916	1908	1926	$16,010.00	Crevasse Canyon	ZUNI

4.0 INVESTIGATION APPROACH

The field characterization investigation has been designed to collect data to:

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

To accomplish these objectives requires a Basinal Resource assessment of the San Juan and Raton basins as described below. The following tasks will be performed:

1) identify the stratigraphic units and coal mine waste products including coal, coal refuse, ash, coal seam, interstitial clays/shales, volcanic ash beds, acid mine drainage, associated sludge samples, mine dumps, other nonfuel carbon-based products, process waters, etc. that contain potential economic concentrations of CM and REE (Fig. 1, 2),
2) their location within the San Juan and Raton basins (Fig. 1)
3) estimate the quantity of each material contained within the San Juan and Raton basins. maps with locations of mines and exploration sites, mine features, waste and rock piles and areas of disturbance (using existing coal resource estimates as determined by the NMBGMR and USGS)

These tasks and supporting activities are described in this field sampling plan (FSP) and supporting SOPs.

5.0 RESPONSIBILITIES AND QUALIFICATIONS

The Senior Characterization Team members will supervise the sampling activities.

The Team Leader and Characterization Team will have the overall responsibility for implementing this sampling field plan. They will be responsible for assigning appropriate staff to implement this sampling field plan and for ensuring that the procedures are followed.

All personnel performing these procedures are required to have the appropriate health and safety training (see HASP). In addition, all personnel are required to have a complete understanding of the procedures described within this sampling field plan, and receive specific training regarding these procedures, if necessary.

All staff and assay laboratory staff are responsible for reporting deviations from this sampling field plan to the Team Leader.

6.0 PERMIT REQUIREMENTS AND NOTIFICATION

State Land Office permit is pending

7.0 LIST OF EQUIPMENT

See SOPs for list of equipment.

8.0 RELATED STANDARD OPERATING PROCEDURES

The procedures set forth in this plan are intended for use with the SOPs listed in Appendix 1.

9.0 FIELD ACTIVITIES

This section describes field activities that will be performed for the project and consist of the following activities:

1) Premobilization and site reconnaissance
2) Sample site selection
3) Surveying
4) Characterization sampling
5) Water sampling and determination of hydrologic conditions
6) Quality control and quality assurance procedures

Instructions for implementing these tasks are given in standard operating procedures (SOPs), which are included with this FSP. Any identified deviations from this FSP or SOPs will be documented and the Team Leader and Principle Investigators will be informed.

Premobilization and site reconnaissance
One or more reconnaissance trips may be needed to identify sampling sites and address any potential safety issues. All trips must be scheduled with Virginia McLemore.

Drill core
Drill core stored at the NMBGMR will be logged and photographed. NMBGMR has drill core of coal deposits from 146 locations scattered throughout San Juan and Raton basins (Fig. 2). Holes will be selected on the basis of coal field, completeness of the core, core description, radioactivity (measure of elevated REE), and use of LANL LIBS/RAMAN instrument. Personnel from LANL will use the LIBS/RAMAN instrument to determine mineralogical and chemical analyses of the core. Samples will be selected for laboratory analyses to compare to the instrument analyses. We will sample the coal seams and layers above and below the coal seams.

Field Sample Site Selection and Marking
Topographic and geologic maps will be imported into ArcGis along with land ownership databases. Sample sites will be selected using ArcGis and these maps on the basis of:

1) Safe access and sampling (no landslides or other disturbed slopes)
2) Active mines and power plants (Fig. 1)
3) AML sites (Fig. 1)
4) Outcropping coal seams with exposed units above and below the coal seam
5) Near known coal mines (coals are likely to be thick enough to mine)
6) On Federal or State land
7) Coals known to have uranium concentrations (McLemore, 1983)
8) Accessible (roads nearby)
9) Other criteria (such as near faults where fluids flow to potentially enrich coals with REE, near dikes or other intrusions where REE could be sourced, near known clay beds)
10) Coal wastes from active, reclamation, and AML sites
    a) Fly ash, bottom ash
    b) Waste rock piles (dumps)
    c) AMD (acid mine drainage)
    d) Processing waters

Selected sample locations will be marked with aluminum tags. Photographs will be taken (SOP 4).

We will have two phases of sampling. Representative samples will be collected from the coal fields. LANL will then select phase 2 sample sites using machine learning techniques (LANL) to select sites to "fill in the gaps" for a complete basin assessment

Surveying
Conventional use of handheld GPS survey techniques will be used to locate samples; elevations will be taken from topographic maps. SOP 3 describes the procedures for GPS surveying.

SAMPLING
Different sampling strategies will be employed based upon the purpose of each sampling task. Field geologists with experience in the regional stratigraphy and in the recognition of altered and weathered rocks perform the sampling. The types of samples to be collected include:

1) Drill core of coal deposits (Fig. 2)
2) Stratigraphic profile of outcrops with coal seams (Fig. 1)
3) Samples of waste products from operating active mines, preparation plants, power plants or owning the disposal sites (active and inactive) (Fig. 1)
4) Samples from Abandoned Mine Lands (AML) sites (Fig. 1)
5) Samples of water draining from mines and waste storage sites, where available (SOP 7)

All of the coal fields and major lithologic units using outcrop localities (overburden, waste rock piles, underlying rocks, and other country rocks), drill core, and waste rock piles, will be sampled as appropriate. SOP 5 describes the procedures for sampling outcrops, rock piles, and drill core (solid samples).

A standardized protocol will be followed after each sample is taken (SOP 2). At each site, a select, grab, or bulk sample of rock or other material is collected for petrographic study and geochemical analyses that is representative of the DQO being addressed. Radioactive readings will be taken using a scintollometer (REE locally are found in areas of higher radioactivity). A hand specimen also is collected for thin section and archived. Each sample is collected in a separate bag or bucket, assigned a unique number (field id), and logged on a field description form (Appendix 2). Selected sample sites are marked in the field and a digital photograph (SOP 3, Appendix 2) is taken at all localities. Photographs provide visual record of the sample site; the photograph form identifies site specifics, provides basic location and other data about the photograph (SOP 3). Location information by GPS, type of sample, and field and laboratory petrographic descriptions will be collected (Appendix 2). Each sample will be clearly identified. Geologic observations are recorded on the field description form and each site is located on a map. A global positioning system (GPS) reading is recorded as well (SOP 3). Hand specimen description provides a record of what was collected, aids in petrographic description, and provides information on sample for the labs (high S may be treated differently than low S) (Appendix 2). The hand specimen description is the preliminary data required to determine what samples need specific detailed analyses to meet the DQOs. NMBGMR will archive all samples for potential future studies.

The samples are transported from the field to NMBGMR, where each sample is prepared for analyses. Samples will be cut and chips will be sent for preparation of polished thin sections. The prepared samples are then sent to a laboratory for chemical analyses. NMBGMR standards are submitted blind to the commercial laboratory with each sample batch to assure analytical quality.

Petrographic analysis and mineral identification are important in differentiating various rock units, determining rank and intensity of alteration, determining chemistry of alternating fluids, describing cementation, and determination of paragenesis of mineralization, alteration, and cementation. Alteration rank is based upon the mineral assemblages, which infers temperature, pressure, and permeability conditions at the time of formation. Petrography will be performed using standard petrographic and reflected ore microscopy techniques (Appendix 2). Mineral concentrations will be estimated using standard charts and data. Estimates of both primary and alteration minerals will be determined, cementation described, and the alteration intensity will be determined from the concentration of alteration minerals. Forms are in the database. Digital photographs will be taken (SOP 3).

Sampling Procedure

1) Collect samples of all of the major lithologic units using outcrop localities (ArcGis and geologic maps), drill core (Fig. 2), and AML waste rock piles (Fig. 1). The numbering system we will use will be a letter abbreviation that represent the coal field (Table 1) followed by sequential numbers. For example, STAR1 is the sample #1 collected from the Star Lake coal field. Samples of clay, shale, weathering profiles should be collected wherever possible and given unique sample numbers. Location data is entered into **waypoint form** (Appendix 2).
2) Record geologic observations on the **sample description form** (Appendix 2).
3) Record site description on the **sample description form** (Appendix 2).
4) Locate each site on a topographic map and take a GPS reading (NAD 27, UTM) and enter on the **waypoint form (SOP 3)** (Appendix 2)**.**
5) Photograph sample site (information recorded on **photograph form,** SOP 4, (Appendix 2). The numbering system for the photograph will be the field identification number, followed by P1 sequentially, Ros1-P1. Photographs will be taken at highest resolution as jpeg or tif files and stored in separate folders corresponding to their image type.
6) Archive hand sample prior to sample preparation.
7) All data are entered into the project database.

Surface water and seep sampling

Should any surface water or seeps be encountered in or near the rock piles, sampling could occur according to SOP 7.

10.0 ANALYTICAL ACTIVITIES

This section describes analytical activities that will be performed for the Project and consist of the following activities:

1) Sample preparation
2) Bulk mineral identification
3) Geochemical and statistical analyses
4) Quality control and quality assurance procedures

Sample preparation and analysis (solid)

1) Hand samples will be sawed in half, photographed and archived.

2) Solid samples cut for thin sections (information recorded on **sample preparation form,** Appendix 2, SOP 8).
3) Polished thin sections of selected samples will be prepared by a commercial laboratory.
4) Polished probe sections of selected samples for microprobe analysis will be prepared by NMIMT lab and examined for mineralogy (**petrographic description form,** SOP 24, Appendix 2,).
5) Photograph taken of thin sections (information recorded on **photograph form,** SOP 4, Appendix 2,).
6) Selected thin sections and other samples for electron microprobe study (SOP 26).
7) Samples analyzed for bulk mineralogy using XRD and recorded in **mineralogy table** (SOP 27).

Bulk mineral identification by XRD
Bulk mineral identification can be used to identify minerals present in quantities greater than approximately 3%. Altered, unaltered, and mineralized samples, including select samples of cement, will be powdered and analyzed by X-ray diffraction (XRD).

Chemical analyses
Chemical analyses of solids (ICP, XRF, other, SOP 30, 31, 28) provide detailed concentrations of abundance of specific elements that directly relate to mineralogy and water quality. Chemical analyses of water samples provide information on pore water chemistry and relates to the sequence of alteration SOP 30, 31).
1. Solid samples analyzed for major and trace elements using XRF, ICP, and other methods
2. Water samples analyzed for major and trace elements using ICP and other methods

Paste pH and conductivity
Paste pH and paste conductivity (SOP 11) are used to evaluate the geochemical behavior of mine rock materials subject to weathering under field conditions and to estimate the pH and conductivity of the pore water resulting from dissolution of secondary mineral phases on the surfaces of oxidized rock particles.

Electron microbe
Electron microprobe analyses (SOP 26) provide mineral identification, specific mineral chemistry, relationships between the minerals, provide information on how minerals are altering, and what new minerals forming at a microscopic level. Probe analysis can identify rims around sulfide minerals that could inhibit alteration of the mineral.

Criteria for selection: after petrographic analysis, clay mineralogy

11.0 QUALITY CONTROL AND QUALITY ASSURANCE PROCEDURES

Procedure—A standardized protocol will be followed after each sample is taken and chain of custody and request for analyses will be completed. Location data by GPS, type of sample, and field and laboratory petrographic descriptions will be collected. Each sample will be clearly identified. The samples will be transported from the field to NMBMMR. The samples will be sent to a laboratory for analyses.

For each batch of 25 samples, 1 set of duplicate samples with different sample_id numbers will be run. NMBGMR internal standards will be submitted blind to the laboratory with each sample batch of 25 samples to assure analytical quality. NMBGMR will archive a split of all samples for future studies.

Accuracy and precision of data—The accuracy of the data is how close the measured value is to the true value. Analyzing certified standards as unknown samples and comparing with known certified values monitors accuracy. The precision of an analysis is the repeatability of a measurement. Precision is monitored by multiple analyses of many sample duplicates and internal standards. Estimates of accuracy and precision will be determined. Errors due to accuracy will be determined by multiple analyses of commercial standards for which accepted values are known. Errors due to precision will be determined by multiple analyses of selected sample splits, as well as multiple analyses of standard samples. There are numerous reasons why duplicate samples and/standards do not always agree. Some samples, such as rhyolite and andesite, grind into powder more easily than other samples, such as stream-sediment and rock pile samples. Fusion techniques required for XRF analyses vary from lab to lab and may also differ between different personnel that could result in variations between sample pairs. Analytical error is higher for analyses with concentrations close to the detection limit. In addition, mine samples and alluvium, such as the Capulin standard (CAP-MLJ-0001), are very heterogeneous and difficult to completely homogenize.

Another problem encountered with mine samples, is the variability of sample collection. Only trained geologists will collect the AML samples using the exact procedures to avoid variations between sample collectors. In addition, three samples will be collected at two separate sites by one sampler to estimate sample heterogeneity and assigned different field_id numbers.

12.0 DATA MANAGEMENT

Data for the Project will be obtained from a combination of sources, including field and laboratory measurements. The process of collecting and managing data is a coordinated effort (described in SOP 1) and will be conducted by project staff and laboratories working closely together. Laboratory data will be provided, when appropriate, in electronic form, in addition to the required hard-copy analytical data package. Data quality will be examined (SOP 1) before results are presented or used in subsequent activities. The laboratory will confirm sample receipt, sample condition, and required analyses. All pertinent information about each sample will be recorded.

13.0 SAMPLING SCHEDULE

Preliminary field reconnaissance December 2021.

14.0 ANALYSES SCHEDULE

As samples are collected, sample preparation and analyses will occur.

15.0 FIELD DOCUMENTATION

Forms will be used to record field and laboratory data (Appendix 3). These forms include:

1) Sample description form
2) Photograph form
3) Drill log

All forms that are completed by hand and all field forms will be archived in a binder in Socorro for future reference. Data will be immediately entered into the database. Copies of the database forms after completion also will be stored in binders.

Geologic observations and site description are recorded on the **sample description form**. Each site is located on a topographic map and a GPS reading taken (NAD 27, UTM) (SOP 3) and entered on the **sample description form.**

Photographs are taken of sample site (SOP 4; information recorded on **photograph form**). Photographs will be taken at the highest resolution as jpeg or tif and stored in separate folders corresponding to their image type.

Sample Archival and Disposal

All solid samples will be collected and archived at NMBGMR for potential future evaluation. Groundwater, surface water, and microbe sample aliquots will not be archived as a part of the study for future analysis or consideration. Any water sample volume not consumed during sample analysis will be disposed of by the laboratories as described in the laboratory QAM, and in accordance with all applicable rules and regulations.

18.0 HEALTH AND SAFETY

The site health and safety plan (HASP) will be followed by all contractors and subcontractors working on the site. It is the policy of New Mexico Tech to provide a safe and healthful work place for all employees, subcontractors, and clients in compliance with MSHA requirements. Telephone contacts are in Appendix 2.

Safety shall take precedence over expediency or short cuts. It is a condition of employment that all employees and subcontractors work safely and follow established safety rules and procedures. All injuries, vehicle accidents, and incidents with potential for injury or loss will be investigated. Appropriate corrective measures will be taken to prevent recurrence, and to continually improve the safety of the work place. Molycorp has a mandatory drug testing program that all personnel working on the property must follow.

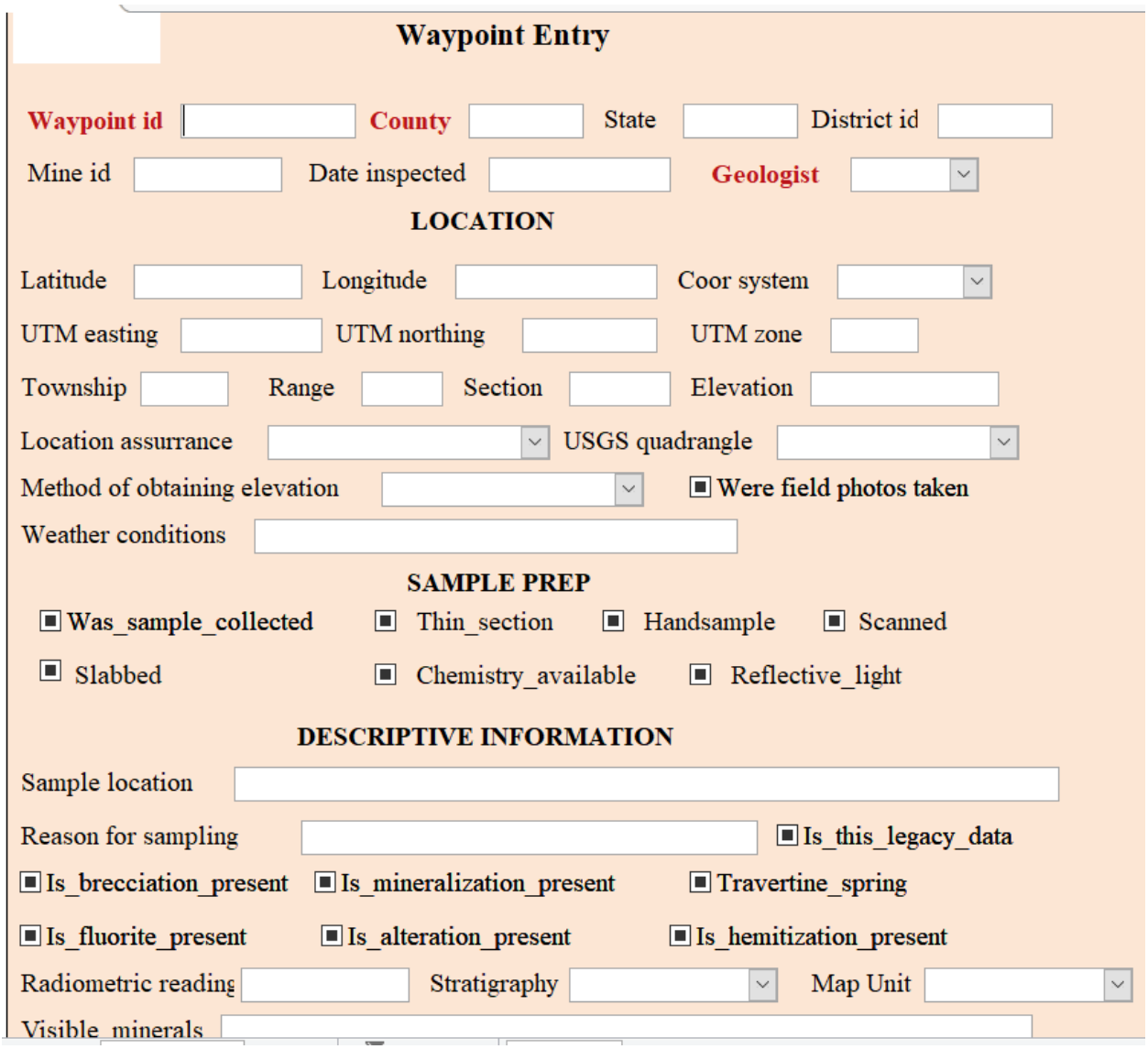
19.0 REFERENCES

APPENDIX 1. List of SOPs and plans

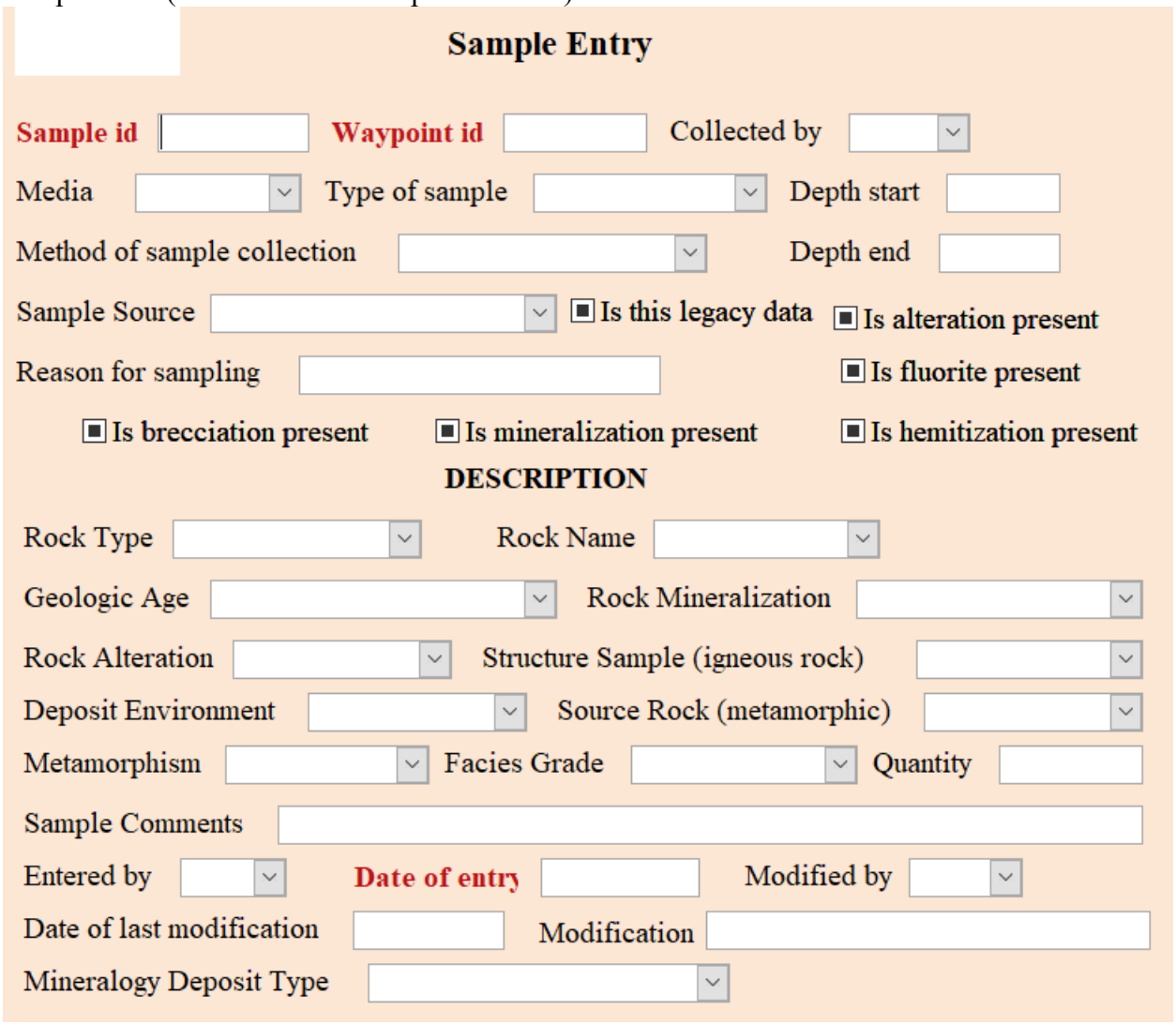
Number	Name	Description
HASP	Health and Safety Plan (HASP)	Health and safety plan for field and laboratory work
FSP	Field Sampling Plan (FSP)	Field sampling plan
SOP 1	Data management	entering, reporting, verification, and validation of data to the database
SOP 2	Photography	procedures taking photographs in the field and laboratory
SOP 3	GPS surveying	Procedures for use of handheld GPS surveying
SOP 4	Sampling outcrops, rock piles, and drill core	field procedures for taking surface solid samples
SOP 5	Drill logging and sampling of subsurface	field procedures for drilling, logging, and sampling of subsurface samples (solids)
SOP 6	Soil paste pH and paste conductivity	laboratory procedures for soil paste pH and paste conductivity
SOP 7	Field measurements of water	field procedures for measuring water flow, pH, conductivity, alkalinity, temperature when collecting water samples
SOP 8	Surface water and seep sampling	field procedures for collecting samples of surface and seep water samples
SOP 9	Petrographic analysis	laboratory procedures for describing petrographic samples
SOP 10	Electron microprobe analyses	laboratory procedures use for analyses using the electron microprobe
SOP 12	X-ray diffraction (XRD) analyses	laboratory procedures for mineralogical analyses by x-ray diffraction (XRD)

APPENDIX 2. Data entry forms (note these are not the final data entry forms, additional data will be added when the database is completely designed). All field specified in DOE DE-FOA-0002364 REE Researcher Database Template and NETL REE-SED Sample Data Needs 2020-07-17, i.e. DOE attachments 2 and 3 will be incorporated into the project database and these forms)

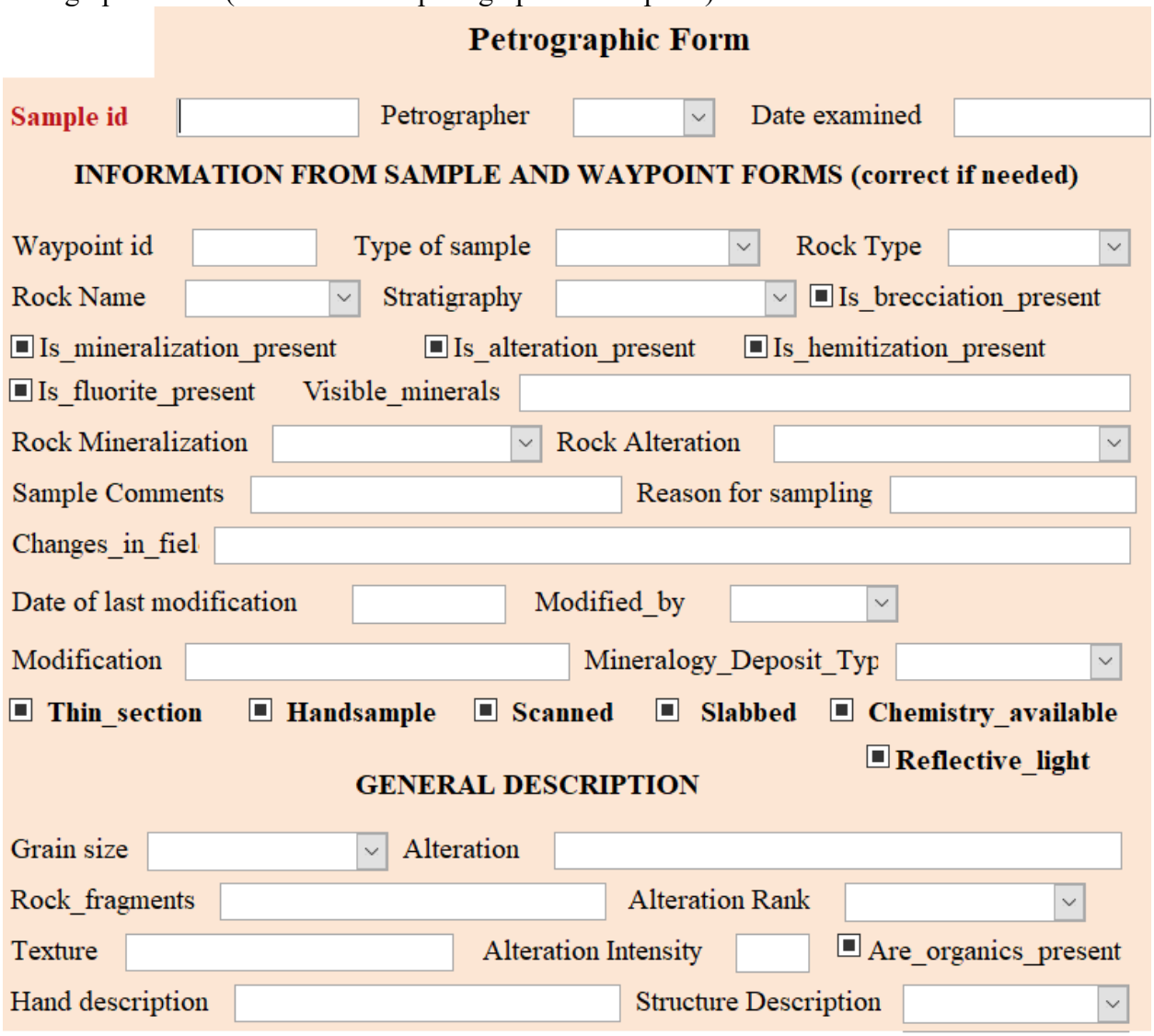
Waypoint form (sample location information)



Sample form (information on sample collected)



Petrographic form (information on petrographic description)



Petrographic Form

Sample id | Petrographer | Date examined

INFORMATION FROM SAMPLE AND WAYPOINT FORMS (correct if needed)

Waypoint id | Type of sample | Rock Type

Rock Name | Stratigraphy | Is_brecciation_present

Is_mineralization_present | Is_alteration_present | Is_hemitization_present

Is_fluorite_present | Visible_minerals

Rock Mineralization | Rock Alteration

Sample Comments | Reason for sampling

Changes_in_fiel

Date of last modification | Modified_by

Modification | Mineralogy_Deposit_Typ

Thin_section | **Handsample** | **Scanned** | **Slabbed** | **Chemistry_available** | **Reflective_light**

GENERAL DESCRIPTION

Grain size | Alteration

Rock_fragments | Alteration Rank

Texture | Alteration Intensity | Are_organics_present

Hand description | Structure Description

Photographs