

COLORADO MINED LAND RECLAMATION DIVISION

COAL SECTION

Guidelines for the Collection of Baseline Water Quality and Overburden Geochemistry Data

This document presents the guidelines of the Mined Land Reclamation Division for the collection of baseline water quality and overburden geochemistry data. The information contained within is to be used by potential coal mine operators to plan hydrologic baseline studies in anticipation of permit application submittal. These guidelines are not intended to carry the authority of regulations. They do, however, represent the Division's interpretation of portions of the Regulations and conformance with them should provide much of the information required by law. The guidelines are intended to provide a planning tool from which potential applicants may begin developing a baseline data-collection program. The specific data-gathering requirements will be worked out with each applicant on an individual basis. The guidelines are intended to allow for a great deal of flexibility in data-gathering. This should accommodate the variety of hydrologic and geochemical conditions found throughout coal mining areas in the State.

The purpose of a baseline data-collection program is to characterize the pre-mining environment. Once collected, the data may be used to help evaluate the potential hydrologic impacts that may occur as a result of coal mining. From there, a monitoring plan can be developed which would document any changes that occur. It is the intent of the Division to cause the documentation of mining-related hydrologic system changes to be accomplished. The basis for this intention derives from the statutory requirements regarding the topics of probable hydrologic consequences and cumulative hydrologic impact.

Before initiating a baseline data-collection program, the potential applicant should meet with the Division to discuss the proposed mine plan. The data-collection requirements will then be developed based upon the existing knowledge of the potential mining area and the proposed mining and reclamation plan. The applicant should review the various sections of the guidelines and determine which provisions are applicable to the particular mining situation. For example, the justification (Table 6) for requiring the analysis of chloride is that "chloride is a major component of chemical dust suppressants ...". Therefore, if the applicant does not intend to use chloride-based dust suppressants at the mine, the analysis of chloride would probably not be required in baseline studies. Only after consultation with the Division should the potential applicant begin collecting the required baseline information. In most cases, a year's worth of hydrologic data-collection will be required to meet the seasonal variation requirements of the Regulations. More stringent data-collection may be required for operations that have the potential to impact alluvial valley floors.

After the baseline data-collection requirements are met, a hydrologic monitoring program should be developed. This is usually accomplished during the permit application review process. The applicant should meet with the Division to discuss the baseline data collected and the applicant's assessment of "Probable Hydrologic Consequences". Every effort will be made to tailor the monitoring program specifically toward the potential impacts identified in the permit review process. Data-collection requirements for the monitoring program may be increased or decreased from the baseline requirements depending on the potential impacts identified.

Each of the chemical parameters listed in the guideline have been researched and justified for conditions commonly encountered in Colorado. Numerous publications and mining applications were reviewed to provide the justifications. A listing of all the references reviewed is available at the Division office in Denver. The majority of the available data is taken from studies done in northwest Colorado. Little data exists for coal mining areas in other regions of the State. Variations in the baseline data-collection requirements may be necessary as data are accumulated in these areas. Each chemical parameter was examined in terms of solubility and occurrence in Colorado coal mine discharge waters. The attenuation effects of the alkaline environment on water chemistry were taken into account. Hydrology monitoring reports provided in various publications and mining files were reviewed to note actual mining-related water chemistry changes.

Tables 1-3 present the suggested chemical parameters and procedures to be used when collecting baseline water quality and overburden geochemistry information. Tables 4 and 5 present the suggested methods of laboratory analysis to be used for the various chemical parameters. Table 6 provides the justifications for the individual chemical parameters. If questions or comments arise, the potential applicant is directed to contact the Division.

These guidelines were issued September 16, 1982

TABLE 1. - GROUND WATER

A. Suggested Water Quality Parameters *

pH (field)	Nitrate-Nitrite
Conductivity at 25°C (field)	Phosphate (PO ₄ ⁻³ as P)
Temperature (field)	Sodium (Na ⁺)
Total Dissolved Solids	Sulfate (SO ₄ ⁻²)
Bicarbonate (HCO ₃ ⁻)	Arsenic (As) Cadmium (Cd)
Calcium (Ca ⁺²)	Iron (Fe)
Carbonate (CO ₃ ⁻²) **	Manganese (Mn)
Chloride (Cl ⁻)	Mercury (Hg)
Magnesium (Mg ⁺²)	Selenium (Se)
Ammonia (NH ₃)	Zinc (Zn)

* Dissolved species concentration only.

** First sampling only.

B. Suggested Baseline Monitoring Frequency

1. Bedrock Aquifers ***

- a. Measure field water quality parameters monthly (pH, conductivity, and temperature). Record elevation of the water level in the well at time of sampling.
- b. Sample water for complete chemical analysis semi-annually.

2. Alluvial Aquifers ***

- a. Measure field water quality parameters monthly (pH, conductivity, and temperature). Record elevation of the water level in the well at time of sampling.
- b. Sample water for complete chemical analysis quarterly.

*** Aquifers monitored and monitoring locations will be dealt with on an individual basis. Consult the Division early in the mine-planning stage for specific requirements.

TABLE 2. SURFACE WATER (includes streams, springs, and seeps)

A. Suggested Water Quality Parameters *

pH (field)	Phosphate (PO_4^{-3} as P)
Conductivity at 25°C (field)	Sodium (Na^+)
Temperature (field)	Sulfate (SO_4^-)
Dissolved Oxygen (field) **	Aluminum (Al)
Total Suspended Solids **	Arsenic (As)
Total Dissolved Solids	Cadmium (Cd)
Oil and Grease **	Copper (Cu)
Sodium Adsorption Ratio	Iron (Fe)
Bicarbonate (HCO_3^-)	Lead (Pb)
Calcium (Ca^{+2})	Manganese (Mn)
Chloride (Cl^-)	Mercury (Hg)
Magnesium (Mg^{+2})	Molybdenum (Mo)
Nitrate-Nitrite	Selenium (Se)
	Zinc (Zn)

* Total species concentration (dissolved and suspended).

** Not necessary for springs and seeps.

TABLE 2. (page 2)

B. Suggested Baseline Monitoring Frequency

1. Perennial Streams ***
 - a. Measure field water quality parameters monthly (pH, conductivity, and temperature).
 - b. Sample water for complete chemical analysis quarterly, especially during high and low flow periods. Record flow at time of sampling.
 - c. Install a continuous recording device to monitor flow. Report monthly minimum, maximum, and mean flows.
2. Ephemeral Streams ***
 - a. Sample water for complete chemical analysis twice a year; once during snowmelt, and once during a storm event. Record flow at time of sampling.
 - b. Install crest stage recorders. Flow measurement frequency will be dealt with on an individual basis. Consult the Division before initiating baseline studies.
3. Intermittent Streams ***
 - a. Sample frequency will be dealt with on an individual basis. Consult the Division before initiating baseline studies. Record flow at time of sampling.
 - b. Determine duration of flow season and seasonal peak flow.
4. Springs and Seeps ***
 - a. Measure field water quality parameters monthly (pH, conductivity, and temperature). Record flow at time of sampling.
 - b. Sample water for complete chemical analysis quarterly. Record flow at time of sampling.

*** Monitoring locations will be dealt with on an individual basis. Consult the Division early in the mine-planning stage for specific requirements.

TABLE 3. OVERBURDEN - ROOF AND FLOOR

A. Suggested Chemical Parameters

pH	Sulfur
Electrical Conductivity	% pyritic sulfur
Total Combustible Solids	% sulfate sulfur
Lithologic Classification	% organic sulfur
Textural Analysis	Total sulfur
% sand	Arsenic (As)
% silt	Boron (B)
% clay	Cadmium (Cd)
Saturation Percentage	Copper (Cu)
Sodium Adsorption Ratio (SAR)	Iron (Fe)
Calcium (Ca ⁺²)	Lead (Pb)
Magnesium (Mg ⁺²)	Manganese (Mn)
Nitrate-Nitrite	Mercury (Hg)
Sodium (Na ⁺)	Molybdenum (Mo)
	Selenium (Se)
	Zinc (Zn)

TABLE 3. (page 2)

B. Suggested Sampling Procedures *

1. Overburden - Surface Mines **

- a. Drill hole spacing should be approximately one hole per square mile. A minimum of three drill holes should be sampled (this may require a closer drill hole spacing for smaller mines).
- b. Drill hole depth should be down to and including the strata immediately underlying the coal seam. Drill holes should be located to maximize overburden thickness.
- c. Generally, each individual stratum should be sampled. For thinly bedded strata (interbedded strata with individual beds less than four (4) feet thick), samples may be composited in 4-foot intervals. All carbonaceous units (coals and carbonaceous shales) in excess of one foot should be sampled. Composite sampling may be done when an individual stratum exhibits uniform color, lithology and mineralogy.

2. Roof, Floor, Interburden and Coal - Underground Mines

- a. Drill hole spacing should be approximately one hole per square mile. A minimum of three drill holes should be sampled (this may require a closer drill hole spacing for smaller mines).
- b. For each coal seam to be mined, the following samples should be analyzed; a composite sample from the first ten (10) feet of strata overlying the coal seam, a composite sample from the first five (5) feet of the stratum underlying the coal seam, a sample of the coal seam, and samples of interburden, partings, splits, etc.

* Consult the Division early in the mine-planning stage for drill hole locations and other specific requirements.

TABLE 4. WATER QUALITY - SUGGESTED METHODS OF ANALYSIS *

<u>Chemical Parameter</u>	<u>Sampled Units</u>	<u>Medium **</u>	<u>Method of Analysis ***</u>
pH (field)	pH Units	G,S	Field pH meter
Specific Conductance (field)	uhmo/cm at 25°C	G,S	Wheatstone Bridge (Specific Conductance Meter)
Temperature (field)	°C	S	Field thermometer
Total Dissolved Solids	mg/l	G,S	Filtrate evaporation; calculation
Total Suspended Solids	mg/l	S	Glass fiber filtration 103°-105°
Oil and Grease	mg/l	S	Liquid-liquid extraction with trifluoroethane
Sodium Adsorption Ratio	--	S	Calculation
Dissolved Oxygen (field)	mg/l	S	Membrane electrode
Bicarbonate (HCO ₃ ⁻)	mg/l	G,S	Titration; electrometric; manual or automated method -methyl orange atomic absorption
Calcium (Ca ⁺²)	mg/l	G,S	EDTA titration
Carbonate (CO ₃ ⁻)	mg/l	G	Titration; electrometric; manual or method -methyl orange
Chloride (Cl ⁻)	mg/l	G,S	Silver nitrate; mercuric nitrate; automated colorimetric-ferricyanide
Magnesium (Mg ⁺²)	mg/l	G,S	Atomic absorption; gravimetric
Ammonia (NH ₃)	mg/l	G	Automated colorimetric phenate; distillation
Nitrate-Nitrite	mg/l	G,S	Automated (cadmium reduction); automated (hydrazine reduction)
Phosphate (PO ₄ ⁻³ as P)	mg/l	G,S	Direct single reagent; automated single reagent or stannous chloride
Sodium (Na ⁺)	mg/l	G,S	Flame photometric; atomic absorption
Sulfate (SO ₄ ⁻)	mg/l	G,S	Gravimetric; turbidimetric; automated colorimetric - barium chloranilate
Aluminum (Al)	mg/l	S	Atomic absorption

<u>Chemical Parameter</u>	<u>Units</u>	<u>Sampled Medium **</u>	<u>Method of Analysis ***</u>
Arsenic (As)	mg/l	G,S	Atomic absorption
Cadmium (Cd)	mg/l	G,S	Atomic absorption
Copper (Cu)	mg/l	S	Atomic absorption
Iron (Fe)	mg/l	G,S	Atomic absorption
Lead (Pb)	mg/l	S	Atomic absorption
Manganese (Mn)	mg/l	G,S	Atomic absorption
Mercury (Hg)	mg/l	G,S	Flameless atomic absorption
Molybdenum (Mo)	mg/l	S	Atomic absorption
Selenium (Se)	mg/l	G,S	Atomic absorption
Zinc (Zn)	mg/l	G,S	Atomic absorption

* Additional methods may be substituted with prior approval from the Division.

** G = ground water; dissolved species concentration only
S = surface water (includes springs); total species concentration
(dissolved and suspended)

*** References which describe these methods:

American Public Health Association; American Water Works Association; and, Water Pollution Control Federation, 1979, Standard methods for the examination of water and waste water; 14th edition, American Public Health Association, 1015 18th Street, Washington, D.C. 20036, 1193 p.

American Society for Testing and Materials, 1980, Water: Part 31, Annual Book of ASTM Standards, American Society for Testing and Materials, 1916 Race Street, Philadelphia, Pennsylvania, 19103, 1401 p.

Brown, E.; Skaugstad, M. W.; and Fishman, M. J., 1979, Methods for collection and analysis for water samples for dissolved minerals and gasses: Book 5, Chap. A1, Techniques of Water-Resources Investigations of the United States Geological Survey, U.S.G.S., Publications Sales and Inquiries Office, Federal Office Building, Denver, Colorado.

TABLE 4. (page 3)

U.S. Environmental Protection Agency, 1979, Methods for chemical analysis of water and wastes: EPA-600/4-79-020, Environmental Monitoring and Support Laboratory, Cincinnati, Ohio 45268.

All of these references are available for inspection at the Division office: 1313 Sherman Street, Room 423, Denver, Colorado 80203.

TABLE 5. OVERBURDEN GEOCHEMISTRY - SUGGESTED METHODS OF ANALYSIS *

<u>Chemical Parameter</u>	<u>Units</u>	<u>Methods of Analysis **</u>
pH (paste)	pH units	Saturated paste
Electrical Conductivity	umhos/cm	Saturated paste extract
Total Combustible Solids	ppm	Dry ash; D 3174-73
Lithologic Classification	--	Visual observation
Textural Analysis		
% sand	%	Sieve analysis
% silt	%	Hydrometer
% clay	%	Hydrometer
Saturation Percentage	%	Saturated paste
Sodium Adsorption Ratio	--	Saturated paste extract
Calcium (Ca ⁺²)	ppm	Saturated paste extract
Magnesium (Mg ⁺²)	ppm	Saturated paste extract
Nitrate-Nitrite	ppm	Saturated paste extract
Sodium (Na ⁺)	ppm	Saturated paste extract
Sulfur		
% Pyritic Sulfur	%	D 2492-79
% Sulfate Sulfur	%	D 2492-79
% Organic Sulfur	%	D 2492-79
Total Sulfur	ppm	D 3177-75
Arsenic (As)	ppm	AB-DTPA/ Ammonium Bicarbonate
Boron (B)	ppm	Saturated paste extract
Iron (Fe)	ppm	AB-DTPA; DTPA
Lead (Pb)	ppm	AB-DTPA; DTPA
Manganese (Mn)	ppm	AB-DTPA; DTPA
Mercury (Hg)	ppm	Acid extract
Molybdenum (Mo)	ppm	AB-DTPA; Ammonium oxilate
Selenium (Se)	ppm	AB-DTPA; Hot water extract
Zinc (Zn)	ppm	AB-DTPA; DTPA

* Additional methods may be substituted with prior approval from the Division.

** References which describe these methods:

ASTM, 1980, Gaseous fuels; coal and coke; atmospheric analysis: annual book of ASTM standards, part 26, ASTM, 1916 Race Street, Philadelphia, Pennsylvania 19103.

TABLE 5. (page 2)

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TABLE 6. CHEMICAL PARAMETER JUSTIFICATIONS

<u>Chemical Parameter</u>	<u>Justification</u>
<u>Miscellaneous:</u>	
pH	a characteristic of water needed to assess the solubility ranges of the chemical parameters; a characteristic of rock needed to assess acid-base forming potential; effluent limitations of Rule 4.05.2 (7).
Electrical Conductivity	an indicator of the general quality of water; an indicator of the salinity hazard associated rock materials.
Temperature	a characteristic of water needed to assess solubility ranges of the chemical parameters.
Dissolved Oxygen	an essential element for aquatic life; increases in major ion concentrations that may occur as a result of mining in the western U.S. (Everett, 1979) may affect the natural chemical oxygen demand, potentially causing oxygen depletion in a stream.
Total Suspended Solids	an indicator of suspended sediment in a stream; effluent limitations from Rule 4.05.2 (7); suspended sediment could act as a transport mechanism for toxic-heavy metals.
Total Dissolved Solids	an indicator of the general quality of water; concentrations may increase in waters near surface mines in the western U.S. (Everett, 1979).
Total Combustible Solids	an indicator of the fire hazard potential of underground mine refuse rock and coal processing wastes.
Oil and Grease	an indicator of oil and grease leakage into surface waters.
Lithologic Classification	an indicator of general rock texture and type.
Textural Analysis	an indicator of textural variability; needed to
% sand	assess erosiveness and suitability of rock
% silt	material to be used as a plant growth medium;
% clay	an indicator of the infiltration and water retention properties of spoils material.

TABLE 6. (page 2)

Saturation Percentage	an indicator of the general plant growth medium potential of rock materials; an indicator of the water holding capacity, expected percolation rate, and clay swelling capacity of rock materials; used to evaluate the accuracy of reported SAR values.
Sodium Adsorption Ratio (SAR)	an indicator of the irrigation potential of water; an indicator of the dispersing character of the clay fraction of rock materials; an indicator of the infiltration capacity of rock materials.

Major Ions:

Ammonia (NH ₃)	a major component of ammonium-nitrate explosives commonly used at surface mines in the western U.S.
Bicarbonate (HCO ₃ ⁻)	a predominant anion in mine drainage at the Edna Mine, concentration increased above background levels (Skogerboe, et al., 1979); needed to evaluate ion balances.
Calcium (Ca ⁺²)	a predominant cation in mine drainage at the Edna Mine, concentration increased above background levels (Skogerboe, et al., 1979); concentrations may increase in waters near surface mines in the western U.S. (Everett, 1979); needed to evaluate ion balances; needed to calculate SAR.
Carbonate (CO ₃ ⁻)	an indicator of proper monitor well completion and reliability of ground water quality data.
Chloride (Cl ⁻)	a major component of chemical dust suppressants commonly used at coal mines in the western U.S.
Magnesium (Mg ⁺²)	a predominant cation in mine drainage at the Edna Mine, concentration increased above background levels (Skogerboe, et al., 1979); concentrations may increase in waters near surface mines in the western U.S. (Everett, 1979); needed to evaluate ion balances; needed to calculate SAR.

TABLE 6. (page 3)

Nitrate-Nitrite	a major component of ammonium-nitrate explosives commonly used at surface mines in the western U.S.; an indicator of spoils material suitability as a plant growth medium; a common constituent of fertilizers spread on reclaimed areas.
Phosphate (PO_4 as P) ⁻³	a common constituent of fertilizers spread on reclaimed areas.
Sodium (Na^+)	a predominant cation in mine drainage at the Edna Mine, concentration increased above background levels (McWhorter, et al., 1975); concentrations may increase in waters near surface mines in the western U.S. (Everett, 1979); needed to evaluate ion balances; needed to calculate SAR.
Sulfate (SO_4) ⁻	a predominant anion in mine drainage at the Edna Mine, concentration increased above background levels (McWhorter, et al., 1975); concentrations may increase in waters near surface mines in the western U.S. (Everett, 1979); needed to evaluate ion balances.
Sulfur % pyritic sulfur % sulfate sulfur % organic sulfur total sulfur	an indicator of the acid-base forming potential of spoils or refuse rock: % pyritic sulfur is an indicator of acid-forming potential; % sulfate sulfur is an indicator of base-forming potential; % organic sulfur is an indicator of the potential for spontaneous combustion of a mine's refuse pile.

Trace Elements

Aluminum (Al)	a major component of clays: may become attached to suspended colloids; aluminum bound to clay colloids may clog gills in fish, resulting in suffocation (Willingham, 1982).
Arsenic (As)	concentration reported to increase in mine spoils water at the Edna Mine (Skogerboe, et al., 1979); concentrations may increase in waters near surface mines in the western U.S. (Everett, 1979); likely to have a higher than average concentration in coal and associated shales (NAS, 1977); may be a pollutant associated with fly ash disposal in surface mines in the western U.S. (Everett, 1979)

TABLE 6. (page 4)

Boron (B)	an indicator of the usefulness of spoils and refuse rock as a plant growth medium (Bingham, 1973); concentrations may increase in waters near surface mines in the western U.S. (Everett, 1979).
Cadmium (Cd)	concentrations may increase in waters near surface mines in the western U.S. (Everett, 1979); may be a pollutant associated with fly ash disposal in surface mines in the western U.S. (Everett, 1979).
Copper (Cu)	concentrations may increase in waters near surface mines in the western U.S. (Everett, 1979); may be a pollutant associated with fly ash disposal in surface mines in the western U.S. (Everett, 1979); change in Cu:Mo ratio could cause molybdenosis in livestock.
Iron (Fe)	increased concentration reported in mine spoils water at the Edna Mine (Skogerboe, et al., 1979); concentrations may increase in waters near surface mines in the western U.S. (Everett, 1979); effluent limitations from Rule 4.05.2 (7).
Lead (Pb)	commonly exceeds drinking water, livestock, and aquatic life water quality standards in the Yampa River (Melancon, 1980); increased concentration reported in mine drainage in Colstrip, Montana (Van Voast, et al., 1977).
Manganese (Mn)	increased concentration reported in mine spoils water at the Edna Mine (Skogerboe, et al., 1979); concentrations may increase in waters near surface mines in the western U.S. (Everett, 1979); effluent limitations from Rule 4.05.2 (7).
Mercury	increased concentration reported in mine spoils water at the Edna Mine (Skogerboe, et al., 1979); commonly exceeds water quality standards in the Yampa River (Steele, et al., 1978); may be a pollutant associated with fly ash disposal in surface mines in the western U.S. (Everett, 1979).
Molybdenum (Mo)	increased concentration reported in mine effluent at the Empire Energy Mine (Empire Energy, 1981); may be a pollutant associated with fly ash disposal at surface mines in the western U.S. (Everett, 1979); change in Cu:Mo ratio could cause molybdenosis in livestock.

TABLE 6. (page 5)

Selenium (Se)

increased concentration reported in spoils water at the Edna Mine (Skogerboe, et al., 1979); may be a pollutant associated with fly ash disposal at surface mines in the western U.S. (Everett, 1979); coal commonly has a higher than average selenium concentration (NAS, 1976); the most highly seleniferous sediments in the U.S. were deposited during the Cretaceous Period (NAS, 1976), most coal-bearing strata in Colorado were deposited during the Cretaceous Period; selenium concentrations in coals and associated black shales are usually much higher than average (Latkin, 1973); at a pH of about 8 (common in Colorado coal environments), selenite may be oxidized to the soluble selenate ion (Latkin, 1973); harmful to livestock if in excessive concentrations.

Zinc (Zn)

increased concentration reported in spoils water at the Edna Mine (Skogerboe, et al., 1979); concentrations may increase in waters near surface mines in the western U.S. (Everett, 1979); may be a pollutant associated with fly ash disposal at surface mines in the western U.S. (Everett, 1979).

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