PERMITTING HYDROLOGY

A Technical Reference Document for Determination of Probable Hydrologic Consequences (PHC) and Cumulative Hydrologic Impact Assessments (CHIA)

BASELINE DATA

Prepared by
the Office of Surface Mining

May 2002

United States Department of the Interior

OFFICE OF SURFACE MINING
Reclamation and Enforcement
Washington, D.C. 20240

IN REPLY REFER TO:

MAY 17

MESSAGE FROM THE DIRECTOR

As the Director of the Office of Surface Mining (OSM), I look forward to working on issues affecting the regulation of coal mining and reclamation activities across the United States. Although there are regional differences in climate, topography, geology and hydrology that singularly and collectively need to be considered in the coal mining permitting process, the control of adverse environmental impacts associated with coal mining starts with the permitting process. I recognize the importance of the permitting process as the first step in balancing the Nation's need for coal as an energy source and controlling environmental impacts to the hydrologic balance.

It is within this context that I am pleased to make available a technical reference document prepared by OSM, entitled *Permitting Hydrology, A Technical Reference Document for Determination of Probable Hydrologic Consequences (PHC) and Cumulative Hydrologic Impact Assessments (CHIA) – Baseline Data*. This document covers a wide range of topics, including: potential hydrologic impacts; baseline information; quality assurance/quality control procedures; technical software and data management; national data bases and regional examples of baseline information summarized from an eastern site, a mid-continent site and a western site.

This technical reference document was prepared in order to provide coal mining regulatory authorities and others with a tool for their use during the permitting process. I encourage you to use this document appropriate to your needs. However, as a reference document, its use is discretionary, and not a requirement.

Sincerely,

Jeffrey D. Jarrett, Director
Office of Surface Mining

Attachment

FOREWORD

Permitting Hydrology,
A Technical Reference Document for Determination of
Probable Hydrologic Consequences (PHC) and
Cumulative Hydrologic Impact Assessments (CHIA),
Baseline Data

This PHC/CHIA technical reference document provides a technically sound approach for obtaining geologic and hydrologic information to be used in the review and preparation of coal mine permit applications. The document represents a snapshot in time - thus; it is subject to revision at some future date. While we believe the document represents a sound technical, good-science approach for permit reviewers, CHIA preparers and policy makers, it does not have the power of regulation, and we are not requiring its use by regulatory authorities (RAs). As we discuss in the introduction , the requirements for both PHC and CHIA are set forth as performance standards in the Surface Mining Control and Reclamation Act (SMCRA). Regulators choose how best to meet those standards. They may choose to follow the guidance in this document, or they may adopt an alternative combination of specifications, verifications and controls for hydrologic and geologic baseline data. Whatever approach is chosen, it must provide a framework for technically and scientifically sound and supported hydrologic impact analyses, and it must ensure the hydrologic performance standards of SMCRA are met.

Although this document describes a sound technical approach for meeting baseline requirements for PHCs and CHIAs, there will be cases in which either more or less baseline data are appropriate to characterize an individual site. It may be prudent on the part of the RA to consider the need to justify significant departures from the data and data-related procedures in this document or from established procedures that are no less effective as those in this document.

TABLE OF CONTENTS

FIGURES

TABLES

DEFINITIONS OF ACRONYMS AND UNITS

ABA – Acid base accounting

ADPS – USGS Automated Data Processing System

ADTI – Acid Drainage Technology Initiative

AMC – Antecedent moisture condition

AMD – Acid mine drainage

AOC – Approximate original contour

APPX – Applications Excellence (database) Software

ASTM – American Society for Testing and Materials

AVF – Alluvial valley floor

AWUDS – USGS Aggregate Water-Use Data System, a part of WUDS

BLM – U.S. Bureau of Land Management

CCB – Coal-combustion byproducts

CEC – Cation exchange capacity

CFR – U.S. Code of Federal Regulations

CHIA – Cumulative hydrologic impact assessment

CIA – Cumulative impact area

DECS – U.S. Department of Energy Coal Sample

DOGM – Utah Division of Oil, Gas and Mining

DQO – EPA's Data Quality Objectives

EA – Exchangeable acidity

EC –	Electrical conductivity
EIS –	Environmental impact statement
EPA –	U.S. Environmental Protection Agency
EPT –	EPA Total taxa and particular taxa diversity
ESP –	Exchangeable sodium percentage
FES –	Final environmental statement, equivalent to a final EIS
GOES –	Geostationary Operational Environmental Satellite
GPS –	Global positioning system
GWSI –	USGS Ground-Water Site Inventory
HEC –	U.S. Army Corps of Engineers Hydrologic Engineering Center
IBI –	EPA Index of Biological Integrity
IC –	Inorganic carbonates
ID –	Pipe inside diameter
meq/L –	Milliequivalents per liter
mg/L –	Milligrams per liter
mL –	Milliliters or 0.001 liters
mm –	Millimeters or 0.001 meters
MPA –	Maximum potential acidity
MUSLE –	Modified Universal Soil Loss Equation computer application
μ*mhos/cm* –	Micromhos per centimeter at 25° C, equivalent to microsiemens per centimeter at 25° C (μS/cm)
NABA –	Net Acid Base Account

NCRDS – USGS National Coal Resources Data System

NNP – Net neutralization potential

NP – Neutralization potential

NRCS – U.S. Natural Resources Conservation Service

NWIS – USGS National Water Information System

OSM – U.S. Office of Surface Mining Reclamation and Enforcement

PA – Potential acidity

PHC – Probable hydrologic consequences determination

QA/QC – Quality Assurance/Quality Control

PAP – SMCRA permit application package

PSOC – Pennsylvania State Office of Coal Research

PVC – Polyvinyl chloride plastic

RA – Regulatory authority

RUSLE – Revised Universal Soil Loss Equation computer application

SAR – Sodium adsorption ratio

SDPS – Surface Deformation Prediction System computer application

SMCRA – Surface Mining Control and Reclamation Act of 1977, Public Law 95-87, 30 U.S.C. 1201, *et seq.*

TR-55 – NRCS (previously Soil Conservation Service) Technical Release Number 55

STORET – EPA STOrage and RETrieval of parametric data

SWUDS – USGS Site-Specific Water-Use Data System, a part of WUDS

TDS – Total dissolved solids

TIPS – OSM's Technical Information Processing System

TSS – Total suspended solids

TVA – Tennessee Valley Authority

U.S.C. – U.S. Code

USDA – U.S. Department of Agriculture

USGS – U.S. Geological Survey

USDI – U.S. Department of the Interior

UTM – Universal Transverse Mercator global coordinate system

WAN – Wide area (computer) network

WRD – USGS Water Resources Division

WUDS – USGS Water-Use Data System

INTRODUCTION

The mission of the Office of Surface Mining (OSM) is to carry out the requirements of the Surface Mining Control and Reclamation Act (SMCRA) in cooperation with States and Tribes in order to ensure that:

- Coal mines are permitted and operated in a manner that protects citizens and the environment.

- The land is restored to beneficial use following mining.

Coal mining has the potential to adversely affect the hydrologic balance. SMCRA requires that these adverse impacts be minimized and not cause an unacceptable degree of damage to the hydrologic balance. A permit application for coal mining must contain:

- Baseline geologic and hydrologic information.

- A determination of probable hydrologic consequences (PHC) within the permit and adjacent areas resulting solely from the proposed operation.

- A hydrologic reclamation plan.

- Ground- and surface-water monitoring plans.

The PHC predictions of impacts for all mines in a designated area are the main source of input for the development of the cumulative hydrologic impact assessment (CHIA) prepared by the RA. The CHIA is an assessment of the incremental hydrologic impacts of the proposed operation in combination with the impacts of all other existing and anticipated mining within a defined cumulative impact area. The written finding by the RA that the proposed operation is designed to prevent off-site material damage to the hydrologic balance is based on the CHIA. This material damage finding must be made before a SMCRA permit can be issued.

Although requirements for both PHC and CHIA exist in SMCRA and the permanent program regulations, they are rather general performance-type standards in that they identify hydrologic objectives but do not prescribe exact methodologies for their accomplishment. As such, RA's have ample flexibility to set forth the combination of specifications, verifications and controls needed to produce a technically-sound hydrologic impact analysis and, ultimately, supportable permitting decisions. The reasonable procedural support for the PHC and CHIA would thus include:

- Quality assurance for hydrologic and geologic baseline data.

- Selection of appropriate analytical tools and methodologies.

- Selection of appropriate monitoring stations, parameters and frequencies.

Purpose And Scope

The purpose of this document is to provide new, updated guidance to assist in the review and preparation of the PHC and CHIA hydrologic and geologic portions of coal mine permit applications. This document is intended to promote effective and economic collection of existing and new hydrologic and geologic data to meet the requirements of SMCRA and the permanent program regulation. Adequate data are needed to ensure that reasonable and technically-supportable PHC's and CHIA's are prepared. The technical reference document is intended also to provide a national framework under which more detailed regional or State-specific documents can be developed, if appropriate. Discussions on the following topics are included in the Baseline document:

- Hydrologic impacts of different types of coal mining.

- Baseline geology and overburden requirements including a discussion of acid mine drainage (AMD).

- Baseline information for ground- and surface-water quantity and quality.

- Baseline information for CHIA.

- Quality assurance and quality control (QA/QC) procedures for data collection and analysis.

- Sources of hydrologic and geologic information including national and State/Tribal databases.

- The utility of OSM's Technical Information Processing System (TIPS) to present, characterize and analyze baseline hydrologic and geologic information.

- Examples of baseline information summarized from planned or actual permits representing differing regional settings.

This Baseline technical reference document focuses on baseline data needed to represent ambient conditions at the site prior to starting a proposed mining operation, and is the first part of a two-part independent series. This document is written from the perspective of the permanent program Federal rules. States have approved regulatory programs that are the same or as effective as the Federal rules.

The analysis and prediction document, which will deal with methodologies that can be used to analyze the baseline data and predict hydrologic impacts from a proposed mining operation will be developed separately. The purpose of both of these two documents is to assist the RAs in the review of PHCs and the preparation of CHIAs so that technically-supportable hydrologic impact analyses and permit findings can be developed.

This document and the analysis and prediction document, if completed, will replace the earlier guidance by OSM (OSM, 1997, 1985a, 1985b, and 1985c).

CHAPTER I
HYDROLOGIC IMPACTS OF MINING

Coal mining and reclamation operations alter the equilibrium of ground- and surface-water flow systems. The type and degree of hydrologic impacts vary with the size of the operation, the method of mining, and the manner in which the site is reclaimed. For example, a small contour surface mine would have different impacts on the hydrologic system than would a large longwall underground mine. Also, on a mine-specific basis, impacts will differ during the various stages of mining and reclamation. Therefore, the proposed mining method and type of reclamation must be taken into consideration when developing plans for the collection of baseline data. The following is a brief general discussion of different types of mining and mining-related activities and typical impacts. This discussion is included for reference.

A. Surface Coal Mining Operations

Surface coal mining operations break up the overlying rocks (overburden) to remove the coal. The reclaimed spoil (e.g., fragmented overburden) will have higher ground-water storage capacity and higher transmissive properties than in the original rock. These differences will alter ground-water flow in the reclaimed spoil and may affect neighboring aquifers that are hydraulically connected to the disturbed zone. As defined by the Federal regulations, *aquifer* means a zone, stratum, or group of strata that can store and transmit water in sufficient quantities for a specific use. Removal of water from the mine pit during mining may, at least temporarily, reduce the amount of water available to both up- and down-gradient wells in the immediate vicinity of the pit.

The breaking and crushing of overburden rock in the surface mining process creates an abundance of fresh, rock surfaces. These freshly broken rock surfaces may impart high levels of total dissolved solids impart to percolating water. The oxidation and hydrolysis of minerals in the spoil material could result in the production of acid or toxic drainage containing elevated concentrations of metals and sulfate. The quality of underlying or down-gradient aquifers can be affected by recharge to the ground-water system infiltrating improperly handled or amended spoil. Spoil-water discharges and seeps that develop in backfill areas can also pollute surface-water bodies.

Surface mining alters basic watershed characteristics such as area, slope and vegetative cover resulting in changes to runoff and infiltration. Stream-flow characteristics, especially during critical periods such as peak flow, can be affected by alterations in channel geometry or gradient, changes in the composition of channel material or the amount of water contributed by impoundments. During mining the open pit, spoil banks and sediment ponds tend to detain runoff. This usually lowers the peak flow of streams. However, the removal of vegetation, the construction of roads and the removal of ponds can increase the peak flows of streams.

The surface mining method itself also influences impacts. The effects on ambient hydrologic conditions of particular types of surface mining are discussed below.

The **area mining** method is commonly used to mine coal in flat to moderately rolling terrain. In this mining method, the overburden is excavated down to the coal seam and the mining area is enlarged horizontally to expose and remove the coal. These mines are usually large and operate for many years.

Area mines often occur in close proximity to streams, ponds, lakes and other surface-water bodies. Streams are sometimes relocated, either temporarily or permanently, as a result of the surface coal mining activity. When a large area is disturbed, surface-water courses must be re-routed or otherwise disturbed, and some surface-water flow changes will occur. The magnitude of the effect upon the surface-water system in large part is a function of the size of the mine and, hence, the amount of disturbed area created with different hydraulic properties.

Area surface mines can impact the underlying ground-water system. The effect will be most distinctly observed in shallow, unconfined aquifers that are directly recharged by infiltration from the surface. Subtle changes in the hydraulic characteristics of the surficial material can result in either more, or less, water reaching these aquifers. While operations conducted in compliance with existing mining regulations are required to minimize hydrologic impacts and to restore approximate pre-mining recharge capacity, large area mines could impose a moderate impact on underlying aquifers. The degree of impact to ground-water will be a function of the size of the disturbed area, the depth of coal seam, the local hydrogeology, and the nature of the backfill material.

The **contour mining** method is typically used in the mountainous terrain of the eastern U.S. where coal seams are exposed in outcrops on hillsides and mountainsides. The mining operation usually consists of one or two cuts that start at a coal outcrop and follow that outcrop along the hillside. These mines occupy a little more area on the hillside than the coal itself, and disturb a small area relative to the surrounding undisturbed area.

Although contour mines occupy narrow bands that are small relative to the surrounding undisturbed areas, impacts to the shallow ground-water system can be large through interception of the local stress-relief fracture system. This is because the stress-relief fracture system tends to extend 100 feet beneath the ground surface. Shallow wells located immediately down-slope from the mined area are often completed in this fracture system. Other potential hydrologic impacts are increased sediment load, principally during the active mining phase, and chemical contamination, principally from acid-or toxic-forming materials, both during mining (short term) and after reclamation (long term).

The **block-cut mining** method incorporates contour mining and area mining and is used predominantly in the eastern and midwestern states. Large cuts are made along the contour and all spoil material is hauled back to the previous cut. Impacts tend to be larger than contour mining because block-cut mining disturbs larger areas or blocks and material from the initial box cut must be stored until the end of mining.

Mining in the mountains generally refers to three types of mining operations: (1) mountaintop removal mining operations in which all or a large portion of a coal seam or seams running through the upper fraction of a mountain or ridge are removed and the land is reclaimed to support the approved postmining land use requirements with a variance from approximate original contour (AOC); (2) multiple seam mining in which all or a large portion of the coal seams running through the upper fraction of a mountain or ridge are removed and the land is reclaimed to AOC; and (3) steep slope mining in which the surface mining occurs in areas having topography with natural slopes greater than 20 degrees and the land is reclaimed with or without an AOC variance. The spoil that is not returned to the mined area for any of these three mining activities is placed in fills in adjoining valleys.

Mining in the mountains can impact surface water by altering peak and baseflow characteristics resulting from changes in both topography and drainage patterns, and it can alter the chemical content of the baseflow contribution. Peak flows during mining (worst case when revegetated steep slopes are bare) typically are higher than ambient conditions at the toe of the valley fills; but the flow is usually attenuated through the use of sediment structures downstream. Peak flows after mining and reclamation are typically less because the gentle slopes and higher infiltration rates contribute to reduced surface runoff. Reduced runoff rates in turn decrease peak flows. This also translates into higher baseflow rates as a result of the increased ground-water discharge from the backfilled areas and valley fills. In fact, the increases in baseflow may preserve streams that might otherwise dry up completely during the low flow season. The higher baseflow rates of the more mineralized ground water (higher dissolved solids, sulfates, metals) change the chemistry of the stream. Increases in suspended solids may also occur.

Mining in the mountains can impact ground water by altering recharge characteristics and flow patterns. In steep slope areas, ground water is typically conveyed through stress-relief fracture systems from ridge tops to valley bottoms. Mining in the recharge area of these fracture systems could result in less water available in the stress-relief systems at the base of the ridgeduring active mining. The recharge is re-directed into the mine backfills and valley fills where it may discharge and sustain surface-water flow during dry weather conditions. Water quality is highly variable depending on the geochemical characteristics of the overburden. Movement of water from these spoil systems into underlying water-bearing zones can cause increases in sulfates, metals and total dissolved solids.

B. Underground Coal Mining Operations

The process of underground coal mining results in the removal of coal under broad areas. The most common impact associated with underground mining is subsidence. The potential for subsidence depends on the thickness of the coal seams mined, the geometry of the mine, the thickness and strength characteristics of the overlying strata, the mining method and the percent of coal extracted.

Subsidence can alter the hydrologic balance and affect both ground- and surface-water flow. If subsidence cracks extend to the surface, surface flow can be diverted into underground mine workings, surface flow paths can be rerouted and ground-water recharge capacity may be increased. Depending on integrity of the coal barriers between mines, there can be a direct hydrologic interconnection between adjacent mines. However, recently and actively operating mines better maintain coal barrier integrity, which greatly impedes ground-water movement between adjacent mines. Subsidence potholes and the general lowering of the ground surface may also change the normal drainage pattern causing local surface flooding. It is important to note that the area of hydrologic impacts can extend beyond the subsided area.

Fracturing of rock strata can also affect the ground-water hydrologic system. If the confining strata below an aquifer fractures, this could cause the aquifer to drain and its potentiometric surface to drop. As a result, wells could go dry and springs fed by ground-water discharge could be reduced or dry up entirely. Fractures created in the rock strata may also result in intermixing of poor quality ground water with potable ground water.

Underground mining may cause ground- and surface-water contamination. Surface water can be degraded by discharges from subsurface workings containing water with acid or toxic characteristics and elevated concentrations of metals and sulfate. Flow of degraded surface water to the ground-water system from fractures extending to the surface can result in increased mineralization of ground water. Underground mining may dewater overlying water-bearing zones and impacts may extend beyond the local surface-water drainage divide. This can result in interbasin transfer of water and gaining or losing streams. Also, pumpage of excess water from active workings can contribute to stream channel erosion and an increase in suspended solids.

After mining, the mine workings can flood and raise the water table. Effects vary with topographic location. Below-drainage mines flood completely; above-drainage mines may only flood partially. Above-drainage mines can also have outcrop barrier seepage and may be susceptible to blowouts. Methane and other gases such as hydrogen sulfide and carbon monoxide can migrate into wells from below-drainage underground mines leading to serious problems. Partially flooded workings may allow the circulation of air which induces the production of acid mine drainage.

The method of underground mining can also influence impacts. The two major underground mining methods are room and pillar and longwall. The permit area for underground mines can include either the face-up area (the area where the initial development of the mine and mine entry takes place) and in some cases the shadow area (the area overlying the coal seam or seams that will be extracted). In either case, baseline data collection must reflect the existing ground and surface-water resources and the impact that the proposed mining can have on the hydrology and existing water use.

Room and pillar mining in its basic form consists of driving entries, rooms and crosscuts into the coal seam to extract coal. Pillars of coal are left to support the overburden or for haulage and ventilation. This procedure is called “development” mining. To increase extraction of coal where the conditions allow, development mining is followed by “pillar recovery” or “retreat mining”where the pillars are systematically extracted in part or completely.

The principal hydrologic impacts associated with room and pillar mining would be the interception of fractures and the effects of subsidence on overlying water-bearing zones. Both ground- and surface-water systems could be affected from change in recharge capacity and mixing of surface and ground water. The magnitude of the impacts depend on extraction ratio, depth of cover, overburden characteristics and areal extent of mining. Subsidence impacts from room and pillar mining, even without pillar recovery, can occur for years after mining has ceased.

Longwall mining is a high-extraction mining method that maximizes the recovery of coal resources. The coal is systematically removed in parallel panels ranging in size from 500-1,200 feet wide to 4,000 to 15,000 feet in length. The mine roof above the extracted coal collapses and subsidence occurs. As the overburden continues to collapse, effects of subsidence progress above the areas where coal is extracted. Ninety percent of the surface subsidence caused by longwall mining occurs within 4 to 6 weeks of coal extraction.

The hydrologic impacts to surface water during longwall mining may include loss of surface water because of leakage through fractures created by subsidence that intersect the stream channels and changes in drainage patterns due to ground settlement. These changes may be of short or long duration. In other areas, water pumped from the underground mine workings during mining can increase surface-water flow. Fractures resulting from subsidence may also allow ground water from overlying aquifers or surface water to leak into the mine workings.

The hydrologic impacts to ground water may include dewatering of local aquifers caused by pumping from the mine and a resulting cone of depression. Longwall mining may also suppress water tables by disrupting confining layers beneath aquifer zones or by increasing the transmissive properties of water-bearing units from new fractures and enlarged preexisting fractures caused by subsidence.

As in room and pillar mining, the magnitude of the hydrologic impacts depends on extraction ratio, depth of cover, overburden characteristics and areal extent of mining. Because of the higher extraction ratio and removal of large continuous panels, longwall mining can result in extensive subsurface fracturing of rock strata which can alter and/or hydraulically connect aquifers.

C. Special Categories of Mining/Mining-Related Activities

Special categories of mining and some mining-related activities can have hydrologic impacts that need to be evaluated and addressed as part of the permitting process. Appropriate planning and continued maintenance are necessary in order to minimize the impacts from these activities.

Steep slope mining is surface coal mining operations on pre-mining slopes greater than 20 degrees. Under specific circumstances the regulatory authority may issue a permit for steep slope mining which includes a variance from the requirement to restore disturbed lands to their approximate original contour (See permanent program regulations at 785.15 and 785.16). The hydrologic impacts of steep slope surface coal mines are similar to those of mountaintop removal and multiple-seam contour mining.

Augering is considered to be a special category of surface mining and is used when the overburden gets too thick to be removed economically. Large-diameter, evenly-spaced holes are horizontally drilled from the highwall up to 400 feet into the coal bed by an auger. The auger head breaks up the coal and brings it to the outcrop face. The major hydrologic impact from augering can result from improperly sealed auger holes discharging water containing acid-or toxic-forming material. Also, improperly sealed auger holes can act as zones of rapid ground-water movement and thus dewater the surrounding area or adjacent flooded underground mines.

Highwall mining is a variation of auger mining that allows for the complete removal of the coal seam along the face. As a result, impacts are greater and more widespread than augering.

In situ processing activities are activities conducted in connection with in-place distillation, retorting, leaching or other physical or chemical processing of coal and includes such operations as in situ gasification, slurry mining and borehole mining. In situ processing uses some type of borehole or well. Hydrologic impacts can result from: discharge of process recovery fluids from the open-hole portion of the borehole or annular space between the wall of the borehole and the casing into geologic zones or intervals. Process recovery fluid must be prevented from moving vertically into overlying and underlying aquifers and horizontally beyond the area identified in the permit.

Remining means conducting surface coal mining and reclamation operations which affect previously mined lands (i.e., lands affected prior to August 3, 1977, and not reclaimed to SMCRA standards). With modern mining technologies, many previously mined areas can yield additional coal through remining or, in some cases, during reclamation of abandoned mine sites. Sites that lend themselves to remining include: coal refuse piles, abandoned underground mining operations, abandoned highwalls and subsidence areas. Many remining sites contain environmental problems such as AMD discharges or excessive sediment discharge to streams. While most mining activities create some hydrologic impacts, remining has a high potential to improve ambient environmental conditions.

Roads are key to both surface mining and underground mining operations. They are classified according to use as either primary or ancillary. The design and construction, location, maintenance and reclamation of roads can have hydrologic impacts that need to be evaluated and addressed. Poorly designed or maintained access and haul roads can affect surface water as the result of increased erosion and sediment load to streams. Improperly located roads can increase the possibility of downstream flooding. Haulroads across mine spoil can cause linear areas of highly compacted and less transmissive material. This in turn can impact ground-water flow patterns and the final water table adjacent to the roads.

Support facilities, such as tipples, refuse piles and processing plants can have unique effects on the ground and surface water. Coal and coal-waste products may have significant quantities of acid or toxic material that can create water quality problems. Erosion of coal and refuse piles is a concern also. Appropriate planning and continued maintenance are necessary in order to minimize impacts.

D. Coal Exploration

Coal exploration involves field gathering of coal and overburden quality and quantity data or environmental data in order to establish conditions prior to mining. Exploration operations that substantially disturb the surface can result in a range of hydrologic impacts similar to those identified for surface mines. However, most exploration operations are typically smaller in size, of shorter duration and can be more readily designed and modified to avoid or minimize impacts. As a consequence, coal exploration operations would have lower overall impacts on hydrologic systems than those expected from surface mines.

CHAPTER II
BASELINE INFORMATION

A. Determining the Ground-water and Surface-water Baseline Collection Area

Baseline hydrologic data must be collected for both the permit and adjacent area. Many states have a set distance that is used in all cases to define the area outside of the permit area for which baseline data must be collected (e.g., one-half mile, 1,000 feet). Care must be used in determining and applying a set distance for all operations although it may be important to routinely require inventories of structures such as cisterns, wells and other water systems within one-half mile of the permit area for surface operations at which blasting will take place. A water system inventory is necessary because of the applicant's requirement to conduct pre-blast surveys at the request of any resident or property owner located within one-half mile of the permit area.

OSM believes that in some cases it may be more important to determine this distance on a case-by-case basis than to use a prescribed distance to assure that all pertinent information is obtained. This would usually involve a consultation between the RA and the applicant to discuss areas to sample based on several considerations related to the site and proposed mining. The advantage to this is that the applicant has a better chance of meeting the baseline requirements when the permit is eventually submitted. This should also enable the applicant to avoid sampling areas that are not hydrologically connected (and therefore no hydrologic impacts are anticipated) or duplicating data in areas where sampling has already been done by other entities. Some preliminary hydrologic information may need to be collected prior to the consultation. However, in practice, OSM realizes that a pre-baseline collection consultation will not always be possible.

The goal in baseline collection is to characterize the hydrology, hydrologic balance, and identify any water resource or water use that could be affected by the proposed operation. In this regard, it is important to review permit data from similar adjacent operations. Such operations will have actual data on the type and extent of impacts that can be used to determine the baseline collection area for the proposed mine. Information received from prior citizen complaints, aquatic surveys, and other sources also can be of assistance.

In some instances, it may also be appropriate to identify and characterize potential hydrologic impacts from non-mining sources that could occur in the permit and adjacent areas. These sources may include, for example, coal-bed methane development, timber harvesting, or large public or commercial water users. It may be advantageous to know about these non-mining sources to distinguish between coal mining impacts and non-mining impacts after the permit is issued.

1. Considerations for Delineating the Area for Ground-water Baseline Data Collection

For defining the area for collecting ground-water baseline data, a primary consideration would be the type of mining and associated types and degree of impacts to be expected. In this context, the extent of water level drawdown expected by the mining operation would be a major factor. Baseline data should be collected for the areas where this drawdown is expected over the life of the operation. Usually, disturbance to a shallow unconfined aquifer will have a smaller area of drawdown than a confined aquifer. This area can be estimated by using analytical drawdown calculations involving the depth and area of mining and the estimated hydraulic conductivity of the water- bearing strata. The distance to known or expected ground-water recharge or discharge areas is also important as is the identification/location of any boundaries such as outcrops, streams or faults that may effect ground-water recharge or discharge.

A ground-water use inventory should be conducted within and beyond the estimated mine drawdown area. This inventory may be used to determine whether the estimated mine drawdown area intercepts the recharge area of adjacent ground-water users. An inventory of springs and seeps is also an important consideration as these features reflect the locations of natural sources of ground-water discharge. The inventory area may extend a short or long distance from the mine drawdown area. Distance depends on the aquifer characteristics and magnitude of current and anticipated ground-water pumping in the area. Aquifers and other water-bearing strata which are located above or below the proposed surface or underground operation and which may be hydrologically connected to the coal or overburden/underburden to be disturbed need to be considered for baseline characterization.

Another major consideration is the proposed mining effects on ground-water quality. Estimates should be made of the type and concentration of pollutants expected from the proposed operation and the direction and magnitude of ground-water movement during and after mining. For example, if sulfate or TDS are expected to significantly increase, the ground-water user inventory and baseline data collection may need to extend to the closest public or domestic wells downgradient from the mine. If significant increases in trace metal concentrations are expected, the baseline data collection may need to extend to the nearest ground-water discharge area such as a stream or lake.

Fractures should also be considered in defining the limits of the baseline collection area. In areas where ground-water movement is controlled by fractures, the fracture zone(s) may limit the spread of the cone of depression. However fracture zones can also carry pollutants significant distances if the fractures are interconnected and the zone is highly transmissive. For stress relief fracture areas in steep valleys, the baseline area may only need to extend to the lateral boundaries of the fracture zone. It is often difficult to get complete baseline information for these areas because most wells, even observation wells, may only intercept a portion of the fracture system. In addition, it is important to choose the appropriate analytical tools to determine well yield and, as needed, hydraulic properties of bedrock aquifers where storage and movement are controlled by fractures because many of the common techniques for quantifying aquifer properties have limitations when applied to fractured bedrock systems. If the mine is large and impacts are expected to be significant, the water use inventory area may need to extend through the valley bottom to the downstream point where the fracture system discharges.

2. Considerations for Delineating the Area for Surface-water Baseline Data Collection

Determining the surface-water baseline data collection area is usually done after the ground-water baseline area has been determined. This sequence often eliminates the need to sample some streams that may be close to the proposed mining operation but which are not hydrologically connected to the mine (i.e., not reasonably expected to be impacted by virtue of the pre-application ground- water assumptions and estimates).

A first step is to look at a map with the location of all streams, water bodies, conveyance structures and possible surface-water users in the region including withdrawals from alluvial aquifers that can induce surface water flow to the well. This “region” should include and extend past the ground-water baseline collection area and include streams that are one or two stream orders higher than the receiving stream within the proposed permit and adjacent area. It may be advisable to have a map showing the location of the nearest major water user such as a public water system in case a catastrophic, unanticipated event were to occur during the operation. This information should be readily available from existing published maps or GIS databases.

Once a regional map has been obtained, the RA and applicant should try to establish those surface-water systems hydrologically connected to the ground-water baseline area and surface water runoff watershed. This is done by considering the ground-water recharge and discharge areas, direction and magnitude of ground water movement, and location of discharge structures, etc. Once surface-water systems that could be affected by mining are identified, the next task is to determine how far downstream the baseline area needs to extend.

Since hydrologic systems are often very complex and mining impacts difficult to predict with total precision, the inventory should err on the conservative side. The applicant may need to inventory all water users included in the next higher order drainage or even higher depending on circumstances. In this regard, it would be important to review existing information on threatened and endangered fish and associated aquatic species and their critical habitat because of their sensitivity to changes in surface-water quality or seasonal flow patterns.

The baseline collection area commonly becomes some subset of the larger surface-water inventory area based on simple mass balance (dilution) calculations estimated for a worst case discharge rate, worst-case mine water quality, and typical ambient water quality and quantity of the receiving stream. Calculations may need to be conducted for both high and low flows.

Downstream baseline sampling should extend to a point where the estimated stream quality and quantity would be diluted by other streams to ambient conditions. If this distance is too large and impractical, it may be reduced by fine tuning of mass balance calculations based on more refined assumptions.

The estimated stream water quality should also be compared with water-use standards (e.g. domestic, irrigation, livestock) and receiving stream standards as set by the appropriate state or Federal Clean Water Act authority. The baseline collection area should include all downstream segments of the receiving stream to the point where the potential impact would not result in exceeding these governing water quality standards.

B. Baseline Information for PHC

Baseline information describes site-specific conditions prior to mining and is the foundation on which permitting decisions are based. It provides a starting point from which to make predictions required in the PHC determination, and from which to compare potential hydrologic changes caused by mining. The Federal regulations require the applicant to obtain sufficient baseline surface-water, ground-water, geologic and overburden information to make a PHC determination, and to develop a hydrologic reclamation plan and surface- and ground-water monitoring plans for their proposed mining operation. In turn, the RA uses the PHC information to prepare the CHIA for the designated cumulative impact area (CIA). The regulations outline specific requirements for each of these determinations, assessments and plans in order to address a wide range of hydrologic concerns, including:

- Flooding and streamflow changes.
- Seasonal variation in flow and quality.
- Sediment yield and drainage control.
- Total suspended solids.
- Total dissolved solids.
- Toxic and acid drainage.
- Water availability and water use.
- Restoration of recharge capacity
- Disturbance to the hydrologic balance.

- Material damage prevention.

- Compliance with federal and state water-quality laws.

Specific hydrologic issues and concerns for individual permitting situations will vary. These issues and concerns need to be identified early in the permitting process in order to ensure sufficient baseline data are collected to characterize, evaluate and remediate them in the PHC. There are many activities that affect the hydrologic balance not related to coal. Some of these activities may produce significant impacts. In some cases a coal mining operation may be proposed in an area where the effects of mining will overlap those of non-SMCRA regulated activities. For example logging, coal-bed methane extraction, in-situ mine, municipal or other large water users, and agricultural activities may have significant hydrologic impacts on surface and ground water. Therefore, it may be necessary to collect information in order to evaluate the effect of these non-SMCRA activities when characterizing the ambient hydrologic condition and when projecting the effects and relative contribution of these activities when evaluating the hydrologic impacts of the proposed operation. In these situations, we encourage coordination and cooperation in data collection with agencies having interests or responsibilities in these non-SMCRA activities.

The number of sites, the frequency of sampling, and the parameters analysed will also vary for different mining scenarios. For example, a tipple or haulroad permit will generally require less intensive sampling than a mountaintop operation or a large area mine.

The gathering of baseline data to describe ambient conditions prior to mining is different from hydrologic monitoring data required during the mining operation and reclamation activities. The two hydrologic data activities are linked to different regulatory requirements, although the baseline data sites may also serve as monitoring sites for evaluating surface and ground-water impacts. Thus, some or all of the baseline sites will very likely be included as part of the ground- and surface-water monitoring plans.

Baseline information is needed to describe the hydrology, geology and overburden characteristics of the proposed permit and adjacent areas. Information is also needed on the chemical and other properties of any potentially acid-forming or toxic materials that will be imported or disposed of within the permit are, such as, coal combustion by-products (CCBs), and coal slurry or refuse.

Assembly of the necessary baseline information for the PHC determination by the applicant should be approached as a two-step process. First, existing information should be assembled and evaluated for usefulness and adequacy. The accuracy of the information and its applicability to the sites should also be assessed. On the basis of this initial evaluation, a plan should be developed for filling any additional data needs. This typically involves field sampling and analysis by the applicant.

This chapter discusses baseline information for the PHCs and CHIAs. Examples of baseline study plans for mining environments in the eastern, midwestern and western U.S. have been provided. It is important to note that the geographic setting, hydrologic concerns and size of coal mines vary. Also, many states have specific baseline data requirements and/or hydrologic resource protection obligations. Consequently, baseline data needs will differ and each permitting situation must be evaluated accordingly.

1. Geology

Conducting a thorough baseline geologic investigation requires several key steps to adequately describe local conditions. Available information must be reviewed, sampling sites must be appropriately located, and sufficient samples and data collected in order to define the local geologic conditions and characterize the overburden.

a. Regulatory Requirements

Permanent program requirements governing geologic information are summarized below. The Federal regulatory citation is included in parentheses.

(1) Geologic Information (30 CFR 780.22)

Each application shall include geological information in sufficient detail to assist in determining:

- The probable hydrologic consequences of the operation upon the quality and quantity of surface and ground water in the permit and adjacent areas, including the extent to which surface- and ground-water monitoring is necessary.

- All potentially acid- or toxic-forming strata down to and including the stratum immediately below the lowest coal seam to be mined.

- Whether reclamation can be accomplished and whether the proposed operation has been designed to prevent material damage to the hydrologic balance outside the permit area.

Geologic information shall include, at a minimum, the following:

- A description of the geology of the proposed permit and adjacent areas down to and including the deeper of either the stratum immediately below the lowest coal seam to be mined or any aquifer below the lowest coal seam to be mined which may be adversely impacted by mining.

- Analyses of samples collected from test borings; drill cores; or fresh unweathered, uncontaminated samples from rock outcrops from the permit area. The analyses of the geologic core samples will result in the following:

  - Logs showing the lithologic characteristics, including the physical properties and thickness of each stratum.

  - Chemical analyses to identify those strata that may contain acid- or toxic forming or alkalinity- producing materials and to determine their content.

  - Chemical analyses of the coal seam for acid- or toxic-forming materials, including sulfur and pyritic sulfur.

(2) Definition of Acid-forming Materials (30 CFR 701.5)

Acid-forming materials are those earthen materials that contain sulfide minerals or other materials which, if exposed to air, water, or weathering processes, form acids that may create acid drainage.

(3) Definition of Toxic-forming Materials (30 CFR 701.5)

Toxic-forming materials are those earth materials or wastes which, if acted upon by air, water, weathering, or microbiological processes, are likely to produce chemical or physical conditions in soils or water that are detrimental to biota or uses of water. The OSM definition differs from the definition used by the Environmental Protection Agency (EPA).

(4) Cross sections, maps, and plans (30 CFR 779.25)

This regulation identifies specific geologic information required in cross sections, maps, and plans that are included in the permit application. The required information is outlined in the section on maps and cross sections of this chapter.

(5) Hydrologic-balance protection (30 CFR 816.41)

Surface- and ground water shall be protected by handling earth material in a manner that minimizes the formation of acidic or toxic drainage by identifying and burying and/or treating, when necessary, materials which may adversely affect water quality.

(6) Backfilling and Grading: General Requirements (30 CFR 816.102 (f))

Acid- and toxic-forming materials exposed, used, or produced during mining shall be adequately covered with nontoxic material, or treated, to control the impact on surface and ground water.

b. Existing Information and Resource Inventories

An evaluation of existing geologic data in the permit and adjacent areas may provide an applicant all or part of the information necessary to meet the regulatory requirements for geology and overburden. The information may be available from the following sources:

- Geologic maps published by state Geological Surveys or organizational units.

- Geologic maps published by the U.S. Geological Survey (USGS).

- Soil survey information published by the U.S. Natural Resources Conservation Service (NRCS).

- Logs of exploratory holes maintained by state RAs or other state agencies.

- Published geologic literature.

- Orphan highwalls and active mining operations in the same geologic formations within one-half mile for detailed data or two miles for generalized statements. Observations and data from such areas will also lend credence to the interpretation of areal geology.

- Data bases such as the National Coal Resources Data System of the USGS, the Pennsylvania State Coal Database and other state data bases.

- Monitoring data from active mines in the area.

Data bases and web sites that provide information which may be useful in preparing geologic descriptions for permit applications are identified in Appendices A and B.

c. Geologic Description and Information

Certain geologic information is required as part of the permit application in order to adequately characterize the mine site and adjacent area. Due to local variations in the chemical and physical makeup of rocks, a geologic description must be provided which is site-specific and representative of the permit and adjacent areas. In addition, a generalized regional geologic description is necessary to adequately describe the geologic setting of the adjacent area. The geologic description must include the areal and structural geology of the area. It must also include a description of the lithology and stratigraphy commonly obtained from test borings, drill cores, or fresh, unweathered, uncontaminated samples from rock outcrops. Chemical analyses of overburden and coal strata are also required as part of the drilling program. Geologic information on lithology, stratigraphy and structure is depicted on maps and cross-sections.

Geologic data is closely inter-related to hydrologic baseline data. Structural data will help determine how the mining operation may affect the local ground- and surface-water systems and where to place water monitoring points. Overburden data will give an indication of potential postmining water quality in addition to determining what special handling techniques may be necessary in the mining plan.

d. Geologic Setting, Mineralogy and Weathering Processes

When exposed to near-surface conditions, spoils derived from deeply buried strata may undergo significant changes that affect their suitability for reclamation applications. The changes associated with spoil weathering that may negatively affect the exposed overburden include the oxidation of pyrite to create acid conditions that result in AMD and the release of salts that may accumulate in high concentrations hazardous to biota.

Geologic factors play a major role in the kind of water produced by a surface coal mine The two most important groups of minerals, in terms of postmining water quality impacts, are carbonates and sulfides. Weathering of carbonates produces alkalinity, and weathering of sulfides produces acidity. Major ions produced by these reactions are calcium, sulfate, and iron. The leaching of other ions also contributes to the composition of mine drainage, especially under low pH conditions. Some of these ions include manganese, magnesium and aluminum. The presence and predominance of sulfide minerals versus carbonate minerals in the rocks are based on the depositional environment. Rocks formed from the deposition of sediments in a marine environment frequently contain high-sulfur zones or layers– but they can also have calcareous zones. Rocks formed in brackish environments tend to have high sulfur and lack calcareous minerals. Rocks formed in marginally brackish (paralic) environments frequently have less sulfur than their marine and brackish counterparts. Truly freshwater sediments tend to have calcareous minerals.

Coal mine drainage can be acidic or alkaline and, depending on concentration, may seriously degrade the aquatic habitat and the quality of water supplies because of toxicity, corrosion, and incrustation. Acidic mine drainage, in which mineral acidity exceeds alkalinity, typically contains elevated concentrations of sulfate (SO_4), iron (Fe), manganese (Mn), aluminum (Al) and other ions. AMD results from the interactions of certain sulfide minerals with oxygen, water, and bacteria. The iron disulfide minerals pyrite (FeS_2) and, less commonly, marcasite (FeS_2), are the principal sulfur-bearing minerals in bituminous coal. Pyrrhotite (FeS), arsenopyrite (FeAsS), chalcopyrite ($CuFeS_2$) and other sulfide minerals containing Fe, copper (Cu), arsenic (As), antimony (Sb), bismuth (Bi), selenium (Se) and molybdenum (Mo) also can produce acidic solutions upon oxidation, but these minerals are uncommon in coal beds. Because of its wide distribution in coal and overburden rocks, especially in shales of marine and brackish water origin, pyrite is recognized as the major source of acidic drainage in the eastern U.S. Pyrite oxidation can be rapid upon exposure of freshly broken rock that is exposed by mining to humid air or aerated water, particularly above the water table. The following equation represents the oxidation of pyrite:

$$FeS_2(s) + 7/2\ O_2 + H_2O = Fe^{+2} + 2\ SO_4^{-2} + 2\ H^+$$

The pyrite or marcasite is oxidized releasing ferrous iron, sulfate and hydrogen ions. (Hydrogen ions cause low pH /acid conditions.) Ferrous iron can in turn be oxidized to ferric iron. The ferric iron can be hydrolyzed to form ferric hydroxide and more hydrogen ions (and a lower pH) as shown below:

$$Fe^{+3} + 3\ H_2O = Fe(OH)_3 + 3\ H^+ \text{ or,}$$

the ferric iron can directly attack the pyrite and marcasite and act as a catalyst in generating greater amounts of ferrous iron, sulfate and considerable hydrogen ions (acidity) as shown in the following equation:

$$FeS_2(s) + 14\ Fe^{+3} + 14\ H_2O = 15\ Fe^{+2} + 2\ SO_4^{-2} + 16\ H^+$$

In contrast, neutral or alkaline mine drainage has alkalinity that equals or exceeds acidity but can still have elevated concentrations of SO_4, Fe, Mn and other solutes. Neutral or alkaline mine drainage can originate as AMD that has been neutralized by reaction with carbonate minerals, such as calcite and dolomite, or can form from rock that contains little pyrite. Dissolution of carbonate minerals produces alkalinity, which promotes the removal of Fe, Al and other metal ions from solution, and neutralizes acidity. However, neutralization of AMD does not usually affect concentrations of $SO_{4.}$

AMD is not a major consideration in the reclamation of the surface-mined lands in the semi-arid and arid parts of western states, although acid-forming materials have been encountered at a few sites. Most economic western coal deposits are non-marine in origin and therefore, low-sulfur. Also, the geochemistry and climate of the region tend to mitigate acidity because the arid conditions lead to accumulations of alkaline materials. The acidic solution produced by pyrite weathering is readily neutralized by reacting with calcite and dolomite, releasing calcium (Ca^{2+}), magnesium (Mg^{2+}), and bicarbonate (HCO_3^-) ions. The divalent cations released by these reactions may be carried upwards through capillary action and deposited near the surface as sulfate or carbonate minerals or they may displace sodium from the exchange sites of sodium-saturated shrink/swell clays as the solutions move downward through the spoil material. The sodium released through the exchange reactions may be leached into the ground-water system during periods of excess moisture. Sodium sulfate ground water with high pH is a serious problem in the semiarid environments of the Northern Great Plains (Senkayi and Dixon, 1988). Weathering of materials in arid environments can also lead to the formation of sodium bicarbonates and calcium sulfates that can affect ground water throughout the western region.

During the process of chemical weathering, which involves hydrolysis, hydration, solution, oxidation, and carbonation, salts are gradually released. Soluble salts that occur in soils and spoils consist primarily of the cations calcium, magnesium, and sodium and the anions chloride and sulfate. Potassium, carbonate, bicarbonates, nitrate and borate are found in smaller quantities (Willliams and Schuman, 1987). In humid environments, weathering of the newly exposed overburden material is accelerated, but salts are readily leached and carried away in solution, and thus do not accumulate. In arid climates, where annual evapotranspiration greatly exceeds annual rainfall, very little water percolates through the spoil under normal conditions. The result is that, although the lack of water reduces the intensity of spoil mineral weathering, the products of weathering (i.e., salts) tend to accumulate in the spoil. A major influx of water will, however, flush many of these salts out of the spoils and they may enter the ground or surface water systems.

The portions of the preceding discussion pertaining to acid mine drainage were taken from Chapter 1, Geochemistry of Coal Mine Drainage. (Link to: http://www.dep.state.pa.us/dep/deputate/minres/districts/cmdp/chap01.html) and

Chapter 8, Influence of Geology on Postmining Water Quality: Northern Appalachian Basin (Link to: http://www.dep.state.pa.us/dep/deputate/minres/districts/cmdp/Chap08-1.html)
of the Handbook on Coal Mine Drainage Prediction and Pollution Prevention in Pennsylvania (October, 1998).

[NOTE– ***Links to the technical reference: Coal Mine Drainage Prediction and Pollution Prevention in Pennsylvania are provided throughout this section. We found it to be a relevant and comprehensive synthesis of ideas, concepts, and research on the topics of overburden analysis, coal-mine drainage prediction, and related topics. At the same time, the user should be aware that the Pennsylvania document may have limitations when applied to other areas. In this context, we encourage use of this technical reference, where applicable.*****]**

e. Acid Drainage Technology Initiative

We also note the work products of the Acid Drainage Technology Initiative (ADTI), (Link to: http://www.nrcce.wvu.edu/nmlrc) ADTI is a partnership-based joint venture in which OSM has joined with industry, the states, academia, other government agencies and groups to identify science-based solutions to AMD problems. The ADTI operations committee initially set up two Workgroups on AMD Avoidance/Remediation and on AMD Prediction to address these issues for coal mining in the Eastern U.S. (A new metal mining section was added in 1999 to address the same two issues for hard rock mining in the Western U.S.)

The initial work product of the Avoidance/Remediation Workgroup is a user manual/handbook on AMD remediation methods, including historical case studies of previously conducted AMD remediation technology experiments, data and information. This handbook was published in June, 1998. (Acid Drainage Technology Initiative, 1998)
(Link to: http://www.nrcce.wvu.edu/nmlrc)

The handbook covers four main areas of AMD remediation technology - Alkaline Addition and Overburden/Refuse Reclamation; Engineered Structural Techniques; Active Treatment Technologies; and Passive Systems Technologies. The Handbook is a technical resource designed to aid the user in obtaining information on the best technology that is suited to a particular situation that is economically feasible. The handbook aids in determining research needs and cost effectiveness for various options. The Workgroup plans to update the handbook periodically to add new information obtained from additional case studies and research.

The AMD Prediction Workgroup effort focused on technical guidelines on the best science and technology to predict AMD potential in the Appalachian coal fields of the Eastern U.S. The Workgroup has completed a technical manual, "Prediction of Water Quality At Surface Coal Mines" which is available in print (Acid Drainage Technology Initiative, 2000) and on the website below.
(Link to: http://www.nrcce.wvu.edu/nmlrc)

f. Structural Geology

Structural geology may have a major influence on the occurrence and movement of surface and ground water. A description of the structural geology should include both local and regional features that might affect the local and regional hydrologic balance. The description of structural geology includes the structural features of rocks as well as their distribution and includes the general disposition, attitude, arrangement, or relative positions of the rock masses. It also includes deformational processes, such as faulting and folding. Structural features should be discussed with particular reference to the control of, or effect on, surface and ground water resources.

While not strictly structural geology, it may also be appropriate to discuss fluvial features in this section, such as the occurrence of significant colluvial or alluvial deposits. Such discussion may be needed to understand the occurrence and significance of alluvial valley floors (AVFs) in the western U.S. or the occurrence of alluvial aquifers along streams. AVFs are a special concern in the arid and semiarid regions located west of the one hundredth meridian west longitude. AVFs are unconsolidated stream-laid deposits containing streams with water availability sufficient for subirrigation or flood irrigation agricultural activities such as farming or pasturing or grazing of livestock. Whether AVFs can be mined depends on their significance to farming and impacts to the quality and quantity of the surface- and ground-water systems. Federal regulations at 30 CFR Part 822 describe additional requirements for surface coal mining operations on or affecting AVFs.

(1) Structural Descriptions Such As Strike and Dip

The structural description should include both the strike and dip of major geologic units such as sandstones or other aquifers as well as the coal seam or underclay. The description should include an area large enough to evaluate the effects of the structure on both the local and regional surface and ground-water movement. A regional dip in one direction does not preclude local ground-water flow in another direction. It is easy to overlook structural features that affect the movement of ground water locally.

While the dip of strata can affect ground-water movement, particularly in unconfined conditions, it does not always dictate the direction of ground-water flow. For example, a surface operation may mine downdip; then upon reclamation the spoils will saturate and ground water will flow in a downdip direction. However, water may eventually move along the strike of the strata at the buried highwall face. This is due to the relative permeabilities of the spoils and the undisturbed strata. The presence of semi-confining units or discontinuous permeable zones may also result in ground-water movement contrary to geologic structure of the area. For confined and unconfined water-bearing units, water moves from areas of high hydraulic head (recharge zones) to areas of lower hydraulic head (discharge zones) regardless of the strike and dip of the strata.

For these reasons, the ground-water divide does not necessarily coincide with the surface-water divide. For unconfined aquifers, the ground-water divide often coincides with the local topographic divide. For unconfined alluvial and confined aquifers the ground-water divide is independent of the local topographic divide.

(2) Structural Features From Deformational Processes

Structural features resulting from deformation can have major effects on ground-water flow by increasing bedrock permeability and controlling direction of flow. This is known as secondary permeability. The geology section should include a discussion and/or maps of features such as joints, fractures, lineaments, and faults. The geologic description should discuss the degree, spacing, and orientation of joint (fracture) patterns and faults.

Fractures can have a direct influence on ground-water flow rate due to the generally lower frictional resistance to ground-water flow within fractures versus intergranular pores and through the fractures' role in lessening flow system tortuosity. Fracture features and their degree of interconnection are important in controlling ground-water flow in bedrock aquifers. The following is a list of secondary permeability features which can impart significant local and/or regional controls on flow systems:

- <u>Joints</u> - A joint is a rock fracture along which displacement has not occurred. The joint pattern is cumulative and represents a record of all stress events sufficient to induce fractures. Systematic joints are planar joints in shales and sandstones and the face cleats in coal. Nonsystematic joints are curved joints in shales and sandstones and butt cleats in coal. Spacing suggests the number of joints available for ground-water pathways. The width indicates the ability of the joints to transmit water. Systematic joints tend to be more important to ground-water flow since they are often continuous and can transmit water longer distances, more rapidly, than non-continuous, non-systematic joints.

- Stress-relief fractures - Stress-relief fractures are a fracture network unrelated in age and orientation to tectonic stresses, and are often associated with stream downcutting and deglaciation. They include vertical fractures parallel to valley walls and horizontal bedding plane separation in valley bottoms. Studies of stress-relief fractures typically describe a highly permeable, valley-related, shallow flow system which consists of interconnected valley-wall and valley-floor fracture sets, and which are often the most transmissive part of an aquifer. Sections of the valley-floor portion of the subsystem can become artesian due to the presence of alluvial clay which generally occurs mid-valley and can serve as a confining layer. See Wyrick and Borchers (1981) for discussion of stress relief fractures.

- Zones of fracture concentration **-** Fracture zones are relatively restricted areas where numerous fractures dissect the rock mass. They are commonly identified through fracture traces and lineaments shown on a geologic map. The degree of interconnectedness varies. The hydrologic impacts of a fracture zone can be profound. Fracture zones are often valley-related phenomena where they can become integrated with valley stress-relief fracture systems. These features can, and do, serve as major conduits for ground-water occurrence and flow. In zones of relatively intense fracturing, hydraulic conductivities are often several orders of magnitude higher than in unfractured rocks, resulting in fracture-dominated flow.

- Bedding-plane partings **-** Inherent weaknesses in rock arising from thin bedding (laminations), fissility and/or lithologic contacts often are zones which will provide avenues for ground-water migration. Sometimes the contact between geologic strata can provide more ground-water flow than the unit itself. It is not uncommon to see water seeping from the top of a sandstone at a bedding-plane.

- Faults **-** A fault is a fracture or fracture set along which there has been displacement. Faults can be important conveyers of ground water relative to the surrounding unbroken rock mass.

The preceding discussion on secondary permeability features is taken from Chapter 2, Groundwater Flow on the Appalachian Plateau of Pennsylvania, of the Handbook on Coal Mine Drainage Prediction and Pollution Prevention in Pennsylvania (October 1998) (Link to: http://www.dep.state.pa.us/dep/deputate/minres/Districts/CMDP/chap02.html).

g. Lithology and Stratigraphy

Lithology pertains to the physical and chemical description of a series of rocks. All changes in lithologic character in a local section reflect changes in the conditions of deposition of the rocks in the section. These lithologic differences are the result of shifts in paleoclimate, paleodepositional environment, and recent surface weathering. These changes in environmental conditions have a direct influence on the rock chemistry in the section.

Stratigraphy pertains to the formation, composition, sequence, and correlation of stratified rocks. The stratigraphic description is a generalized, composite description of the stratigraphy of a mine area as determined by measuring and describing the sequence of strata at several locations. Stratigraphy data can be graphically reported as a stratigraphic column. The description should represent the entire area to be affected and identify significant facies changes laterally across the site. This information is important for identifying discrete zones of acid- or toxic-producing overburden for special handling considerations. Site-specific lithology and stratigraphy information is primarily derived from drill hole data. This information is reported or displayed on drill logs, cross-sections, and structural maps.

Lithologic and stratigraphic data are obtained from visual observations, microscopic examination, and physical and chemical analyses of the strata. Descriptions may include data such as:

- Color.
- Grain size.
- Fossils.
- Mineral composition.
- Bedding character.
- Relative hardness/induration.
- Field fizz test.
- Stratum thickness.

Using this information and physical testing of core samples, characteristics like porosity, permeability, resistance to physical weathering, rippability, and others may be estimated. The location and thickness of water bearing zones in the geologic section should be identified.

Rock characteristics help to define hydrologic conditions. For example, a sandstone overburden may result in greater infiltration rates than an overburden that is primarily shale and siltstone. A more permeable strata such as some sandstones can also lead to greater leakage through the pit floor than a clay strata. Additionally, the higher weathering rates of shales, as opposed to sandstones, can cause problems in backfill stabilization. Finally, typically the smaller the overall grain size, the faster the chemical reactions, such as AMD generation, within the backfill. However, the potential for AMD generation in a sandstone and shale with equal sulfur contents may be greater in the sandstone due to greater permeability.

h. Maps and Cross Sections

Geologic information must include cross sections and maps.

Information that should be placed on maps includes:

- Elevations and locations of test borings and core samplings.
- All crop lines and the strike and dip of the coal to be mined and other important strata within the proposed permit and adjacent areas.
- Bedrock geology, major surficial deposits, and structural features such as faulting and folding.
- Location and extent of known workings of active, inactive, or abandoned underground mines, including mine openings to the surface within the proposed permit and adjacent areas.
- Location and extent of subsurface water, if encountered, within the proposed permit or adjacent areas.
- Location and extent of existing or previously surface-mined areas within the proposed permit and adjacent areas.
- Location, and depth if available, of gas and oil wells within the proposed permit area and water wells in the permit area and adjacent area.

A geologic cross section is a diagram or drawing portraying a vertical section of the earth with a certain depth and height. Each geologic cross section should depict the overburden or other material from the upper limit of disturbance down to, and including, the deeper of either the stratum immediately below the lowest coal seam to be mined or any aquifer below the lowest coal seam to be mined that may be adversely impacted by mining. A cross section should be drawn from a minimum of two data points, such as core hole/drill hole sites and/or highwall/face up observation points. However, the more real data that can be projected onto the cross section, the more accurate the spatial representation. Single-point data presentation does not meet the requirements for, or definition of, a geologic cross section. Usually, at least one cross section should be drawn as nearly parallel to the strata dip as possible, but primary consideration should always be given to an accurate portrayal of the permit and adjacent areas. The number of cross sections needed to depict an area may vary, depending upon the geology of the area and the size and type of mining operation. At least one cross section should be drawn for each area of surface disturbance associated with surface or with underground mining operations. For underground mines, it is recommended that at least one cross section be drawn to represent the areas of the projected underground workings. For area type surface mines, cross sections should depict both the length and width of the proposed site, and at least one cross section should intercept any pronounced structural feature such as a fault. A legend and both horizontal and vertical scales should be indicated on the drawing, with any scale exaggerations noted.

Each geologic cross section should portray the nature, depth, and thickness of all strata including coal or rider seams, using standard geologic terminology and symbols matching those used on the stratigraphic column. The "nature" of each stratum identifies the type of material and its lithologic characteristics. An elevation scale should be included on the drawing to allow calculations of the depth and thickness of each stratum.

A common graphical technique to display geologic information from more than two stratigraphic sections (e.g., drill holes) is a fence diagram. This aids in the presentation and interpretation of geologic data in a horizontal as well as vertical direction.

2. Overburden Analysis

a. Purpose of Overburden Analysis

The purpose of any overburden analysis program is to:

- Provide data to prepare a PHC and demonstrate that the proposed mining can be accomplished without causing AMD or toxic discharges.

- Assess the probable cumulative impacts of mining on the hydrologic balance.

- Aid in the design of the mining and reclamation plan to minimize damage to the hydrologic balance within the permit and adjacent areas and prevent material damage outside the proposed permit area.

Through the overburden analysis it is possible to:

- Identify the vertical and horizontal distribution of acid and toxic forming materials.

- Identify alkaline zones which can be incorporated into a mining plan to prevent acidic drainage.

- Determine the distribution of pyritic zones which may require special handling or avoidance.

- Calculate alkaline addition rates.

- Determine reclamation feasibility by identifying volumes of suitable and unsuitable material.

- Determine mining feasibility, including potential environmental impacts, before investing a large amount of money in leasing (advance royalties) and permit application preparation.

  - Identify topsoil substitutes and supplements.

b. Considerations for A Successful Sampling Program

The obvious and most frequently asked questions that operators and permit consultants have when preparing an overburden analysis proposal are:

- Should holes be drilled for overburden analysis?

- How many overburden analysis holes are needed?

- Where should they be drilled?

Answers to these types of questions depend on many factors such as available data and site-specific conditions. A perspective based on regional issues is provided by summaries of actual permitting scenarios described later in this document. Many states have developed their own procedures and guidelines for overburden sampling.

The site-specific mining information needed to properly plan an overburden analysis include:

  - Mining limits.

  - Boundaries of the proposed area to be affected by coal removal.

  - Proposed maximum highwall heights.

  - Type of mining - for example, contour/block cut or hill top removal.

  - Accessibility to the site.

  - Geologic considerations, such as coal seam identification, depth of weathering, and stratigraphic variation.

  - Information that is available in the permit files of the regulatory authority, such as water-quality data from previous permits or applications covering the same or adjacent areas.

- Overburden analysis from the same or adjacent areas.

- Other considerations in developing an overburden analysis drilling plan include:

    - Exploration equipment. It is important to understand the limitations that are likely with different types of drilling equipment. These differences will have an impact on the ability to obtain unbiased representative samples. The choice of exploration equipment is also important in establishing costs.

    - Type of overburden analysis to be performed. This is important in knowing how much sample is required for the specific type of testing to be employed, and the time needed to analyze the samples.

c. Representative Samples

Any overburden drilling program must be designed to collect samples that accurately represent the affected strata of the area. Most overburden holes will be located within the limits of the proposed mining area. Ideally, some holes must be located at maximum highwall conditions, and the holes must represent all of the strata to be encountered by mining. Other holes should be located under low and average cover conditions to provide representative sampling of the overburden where zones may be missing or which may have been altered due to surface weathering. It is important to provide enough drill holes to adequately represent the geology of the site, including any spatial lithologic variation.

Adequate exploratory drilling is essential to the development of a sampling plan that will accurately reflect the range of overburden characteristics. Sulfur is not uniformly distributed in a homogeneous fashion. Because of this, accurately determining the mean percent total sulfur of a particular stratum may be difficult, which could in turn lead to faulty predictions of the potential to produce AMD. The concentration of total sulfur at a mine site may not be the critical factor of whether or not AMD will be produced.

d. Sample Collection

Overburden sampling is accomplished by drilling or direct collection of the sample from an open source such as a highwall. Primary drilling methods that are generally used to obtain overburden samples include:

- Diamond coring

- Air rotary rig: normal circulation

- Reverse circulation rotary rig

Other types of sampling approaches for overburden include augering and highwall sampling.

- Augering - Auger drilling is not recommended for general overburden sampling. It is typically used for unconsolidated or highly weathered materials. The auger lifts the materials on the auger screw. They are in constant contact with the overlying stratum, thus providing for intermixing. However, augering can be successfully used in homogeneous materials such as glacial till and/or old mine spoil.
- Highwall Sampling - Direct collection of samples from an open source, such as a highwall within or near a proposed permit area, can be used for overburden analysis, provided several caveats are understood. First, samples may be weathered to such a degree that they do not represent the strata to be mined. Second, highwall sampling is limited by the availability and accessibility of highwalls. Therefore, care should be taken to collect only unweathered samples from the highwalls in close proximity to and representative of the proposed mining. It is recommended that open source (outcrop, highwall, etc.) samples be used primarily as a supplement to drilled samples.

The above discussion pertaining to overburden was taken from Chapter 5 (Link at: http://www.dep.state.pa.us/dep/deputate/minres/Districts/CMDP/chap05.htm) of the Handbook on Coal Mine Drainage Prediction and Pollution Prevention in Pennsylvania (October, 1998).

For one example of acceptable techniques for sample collection, compositing, and laboratory preparation see OSM Document "Overburden Sampling and Analytical Quality Assurance and Quality Control (QA/QC) Requirements for Soils, Overburden and Regraded Spoil Characterization and Monitoring Programs for Federal Lands in the southwestern U.S. at (Link at: http://www.osmre.gov/pdf/osmswguide.pdf)."

e. Analytical Parameters

Geochemical parameters to be analyzed, methods of analysis, and suitability criteria vary by region based on environmental conditions and concerns. The potential impacts of surface mining operations on the surface and subsurface water quality depend on several factors, including the physical and mineralogical characteristics of the overburden, the degree of infiltration, the extent of spoils weathering and oxygen availability. All these factors must be considered in predicting impacts and in evaluating the parameters which may control these impacts.

The regulatory authority should be consulted for specific analytical requirements. The parameters that may be a concern in overburden quality, and that could subsequently affect water quality, are outlined below.

(1) Acid Base Accounting (ABA)

ABA is based on the premise that the propensity for a site to produce acid mine drainage can be predicted by quantitatively determining the total amount of acidity and alkalinity the strata on a site can potentially produce. The values of maximum potential acidity (MPA) (expressed as a negative) and total potential alkalinity, termed neutralization potential (NP), are summed. When ABA was first used, if the result was positive, the site should have produced alkaline water; if it was negative, the site should have produced acidic water. Early landmark studies originally defined any strata with a net potential deficiency of 5 tons per 1,000 tons or greater as being a potential acid-producer for the use of mine soil prediction. (See Sobek and Others, 1978). This threshold limit is no longer universally accepted for predicting AMD. The MPA is stoichiometrically calculated from the percent sulfur in the overburden. However, the appropriate calculation factor is somewhat controversial. Early researchers noted that 3.125 g of $CaCO_3$ is theoretically capable of neutralizing the acid produced from 1 g of S (in the form of FeS_2), suggesting that the amount of potential acidity (PA) in 1,000 tons of overburden could be calculated by multiplying the percent S times 31.25. This factor is derived from the stoichiometric relationships and carries the assumption that the CO_2 dissipates as a gas:

$$FeS_2 + 2\ CaCO_3 + 3.75\ O_2 + 1.5\ H_2O \dashrightarrow Fe(OH)_3 + 2\ SO_4^{-2} + 2\ Ca^{+2} + 2CO_2\ (g).$$

Recent research has suggested that in backfills where CO_2 cannot readily dissipate into the atmosphere, some dissolves and reacts with water to form carbonic acid. If all the CO_2 dissolves in the water, then the MPA, in 1,000 tons of overburden, should be derived by multiplying the percent S times 62.50. (See discussion by Cravotta and others, 1990). In most cases, the 31.25 value is used because of a lack of specific information on the amount of CO_2 gas that ends up as carbonic acid.

The neutralization potential (NP) is determined by digesting a portion of the prepared sample in hot acid, and then by titrating with a base to determine how much of the acid the sample consumed. NP represents carbonates and other acid neutralizers and is commonly expressed in terms of tons $CaCO_3$ per 1,000 tons of overburden. Negative NP values are possible, and are sometimes derived from samples of weathered rock that contain residual weathering products which produce acidity upon dissolution.

Interpretation of ABA data involves the application of numerous assumptions; some of the more significant assumptions often used are:

- All sulfur in a sample will react to form acid.
- All material in the sample which consumes acid during digestion in the lab will generate alkalinity in the field.
- The reaction rate for the sulfur will be the same as the dissolution rate for the neutralizing material.
- NP and percent sulfur values below certain threshold levels do not influence water quality.

As these assumptions imply, interpretation of ABA data is far more complicated than simply summing the MPA and NP values. The assumptions are discussed un more detail in Chapter 11 entitled "Interpretation of Acid-Base Accounting Data" (Link to: http://www.dep.state.pa.us/dep/deputate/minres/Districts/CMDP/chap11.html) of the Handbook on Coal Mine Drainage Prediction and Pollution Prevention in Pennsylvania (October, 1998).

In addition to the percent sulfur and NP determinations, two other measured parameters in an ABA overburden analysis are paste pH and fizz. Other derived values typically include calculations of MPA, tons of neutralization potential, tons of PA, and tons net neutralization potential for each sample, as well as for the entire bore hole. Since acid mine drainage results from accelerated weathering of sulfide minerals, the amount of sulfur in a sample, or in an overburden column, is obviously an important component of ABA. As noted above, ABA uses the percent sulfur to predict the MPA that a particular overburden sample or column could produce if all the sulfur reacts.

Sulfur determinations for ABA are often performed for total sulfur only; however, determinations for forms of sulfur are sometimes included. Sulfur generally occurs in one of three forms in the rock strata associated with coals: sulfide sulfur, organic sulfur, and sulfate sulfur. Sulfide sulfur is the form which reacts with oxygen and water to form acid mine drainage. The sulfide minerals most commonly associated with coals are pyrite and marcasite, both of which are FeS_2, chemically. Other sulfide minerals such as chalcopyrite ($CuFeS_2$) and arsenopyrite (FeAsS) may also be present in small amounts. Organic sulfur is that sulfur which occurs in carbon-based molecules in coal and other rocks with significant carbon content; since organic sulfur is tied up in compounds that are stable under surface conditions, it is not considered a contributor to acid mine drainage. Organic sulfur can represent a significant fraction of the total sulfur found in coal seams.

Sulfate sulfur often occurs in partially weathered materials as reaction by-products of sulfide mineral oxidation. Common hydrous iron sulfates such as melanterite, rozenite, copiapite and coquimbite represent “stored acidity.” The stored acidity can be released when these secondary minerals dissolve and Fe^{+3} undergoes hydrolysis. This process can significantly affect water quality and generate AMD well after pyrite oxidation has been curtailed. However, sulfate sulfur may or may not produce acid. Alkaline earth sulfate minerals such as gypsum ($CaCO_3 \cdot 2H_2O$) contribute to the sulfate sulfur fraction, but unlike some iron sulfate phases, the alkaline earth sulfate minerals do not produce acid. Nevertheless, when dissolved, these weathering by-products are a source of sulfate ion that is a contaminant found in AMD. Secondary sulfate minerals tend to be highly soluble and may be leached from the upper portion of spoil during the wetter times of the year. For a more complete discussion of secondary mineral formation, see Chapter 1, Geochemistry of Coal Mine Drainage. (Link to: http://www.dep.state.pa.us/dep/deputate/minres/Districts/CMDP/chap01.html) of the Handbook on Coal Mine Drainage Prediction and Pollution Prevention in Pennsylvania (October, 1998).

Commonly used methods of the American Society for Testing and Materials (ASTM) for performing total sulfur determinations include: high temperature combustion methods (ASTM D4239), the Eschka Method (ASTM D3177) and the Bomb Washing Method (ASTM D3177). Of these methods, the high temperature combustion methods are the simplest and most frequently used and provide accurate, reproducible results. A common method used for determining forms of sulfur is ASTM D2492. Research has shown that modifications of these methods are required for accurate and reproducible results. When properly analyzed, total sulfur determinations are typically simple to do, are reproducible, and can be calibrated and verified using available standards. Complete discussion of the modified methods can be found in Chapter 6, Laboratory Methods for Acid-Base Accounting: an Update, (Link to: http://www.dep.state.pa.us/dep/deputate/minres/Districts/CMDP/chap06.html) of the Handbook on Coal Mine Drainage Prediction and Pollution Prevention in Pennsylvania (October, 1998) and Hossner (Texas Mine Land Reclamation Monitoring Program Issues, A report of the Soils Working Group October 1998). (Link to: http://www.osmre.gov/pdf/TXMONITORING.pdf).

Pyritic sulfur determinations are done using a variety of methods (sometimes not standardized, and at least one of which is considered inappropriate for rock samples), produce results which are often not reproducible between laboratories, and cannot be calibrated and verified using available standards. Given these considerations, and that pyritic sulfur is the most abundant form in coal overburden (but not necessarily in the coal), total sulfur determinations currently provide the best basis for calculating MPA.

- <u>Fizz Test</u>

  The fizz test is frequently presented as a minor part of the NP test; however, the fizz test can have a large impact on the reliability and reproducibility of NP data, so it is discussed separately here. The fizz test is a measure of the reactivity of alkaline materials in a sample after adding a small amount of dilute hydrochloric acid. The fizz test results are a matter of human judgement and, therefore, somewhat subjective. The greater the reactivity, the higher the fizz test.

  The fizz test can be used as a check on the NP determination, since there should be a qualitative correlation between the two. More importantly, however, the fizz test determines the volume and the strength of the acid which is used to digest the prepared sample, which in turn can affect the NP determination results. The NP result is then somewhat dependent on the fizz test results.

  Given the difficulties which the current fizz test system introduces into NP determinations, a reproducible, objective carbonate-rating test could significantly improve the reproducibility of NP data. Until such a test is refined, individuals who generate and interpret ABA data need to be much more aware of the influence of the fizz test values on the NP determinations. Where fizz test results and NP values seem to be at odds, further testing would be prudent. When a carbonate rating system other than the familiar fourtiered fizz test is used, data interpretation will have to be adjusted and interpretive rationales will have to be "recalibrated."

- Neutralization Potential (NP)

Carbonate minerals, such as calcite and dolomite, are known to be the major contributors to ground-water alkalinity in the coal regions. The acid-digestion step of the NP test is suspected of dissolving various silicate minerals when excess acid is used as a result of the fizz test. This results in an NP determination that overstates the amount of carbonate minerals in a sample.

Siderite ($FeCO_3$) is common in coal overburden and has long been suspected of interfering with the accuracy of NP determinations and of complicating the interpretation of the data. If iron in solution from the siderite is not completely oxidized when the titration is terminated, then the calculated NP value will be high, since complete oxidation of the iron would produce additional acidity. An unstable titration end point can obviously affect the reproducibility of the NP results.

Several researchers have proposed adding a hydrogen peroxide step to the NP determination procedures to eliminate the problems with the method caused by siderite. (See Skousen and others, 1997). If the hydrogen peroxide step performs according to its intent, it should generally decrease the NPs of strata with a significant siderite content, but should not appreciably affect the NP values of strata that do not include significant amounts of siderite. It should also lead to better reproducibility of NP data between laboratories, especially for samples with significant siderite content.

- Other Methods of Determining Carbonate Content

The NP test has been adapted and widely used to approximate the carbonate content of mine overburdens largely because it is relatively quick, inexpensive, and easy to perform. However, as noted, it may not always provide results which are accurate and reproducible. Ongoing research may result in a test that is more reliable and reproducible.

In summary:

1. The MPA (i.e., total sulfur) component of the ABA analytical technique should be used to avoid problems in:

- Determining forms of sulfur
- Underestimating acid contributions from all forms of sulfur

2. The NP test should include the hydrogen peroxide step to account for the presence of siderite.

The above discussion pertaining to acid base accounting was taken from Chapter 6, Laboratory Methods for Acid-Base Accounting: an Update, (Link to: http://www.dep.state.pa.us/dep/deputate/minres/Districts/CMDP/chap06.html) of the Handbook on Coal Mine Drainage Prediction and Pollution Prevention in Pennsylvania (October, 1998).

(2) Kinetic Tests

Kinetic tests can supplement ABA analyses or simulate the products of weathering in the backfill material. Kinetic tests include both field and laboratory tests to simulate the physical, chemical, and biological processes that affect the chemistry of water as it migrates through rock. These tests try to address the unique mechanisms and chemical reaction rates that occur when rock is mined and subjected to the environment. Factors such as weathering, adsorption/desorption, biological decay, and rainfall/recharge are often simulated or measured directly in kinetic tests. Column leach tests, soxhlet reactors, lysimeter test plots, and humidity cells are just some of the common test methods that have been used on coal spoil.

While much attention has been given to kinetic tests for acid mine drainage prediction, other non-AMD impacts such as prediction of salt loading or nutrient leaching better lend themselves to kinetic tests. The rates of reactions can also be simulated, such as a leach test to determine how quickly the alkalinity component of spoil leaches out in comparison to the acidity component. For example, in one case, a major sandstone tested out as alkaline in an acid-base accounting test. However, a leach test later determined that the sandstone did not weather quickly enough for the alkalinity to be released and contribute to neutralizing the acidity of adjacent strata. After mining, field evidence confirmed that the sandstone did not release alkalinity.

There have been many reports in the literature on the success and failures of kinetic tests. Some of the major problems of kinetic tests include: simulating grain size, simulating freeze/thaw action, finding a representative sample, simulating rainfall/recharge, controlling ground-water contact with the rock, controlling biological conditions, and simulating pore gas composition. For this reason, it is recommended that kinetic tests be used as a supplement to static testing such as ABA or other methods, such as sampling spoil water from adjacent mined areas. Like any predictive technique, kinetic tests are just one tool available for making overall predictions. For more information on kinetic tests see Chapter 7, Kinetic (Leaching) Tests for the Prediction of Mine Drainage Quality (Link to: http://www.dep.state.pa.us/dep/deputate/minres/Districts/CMDP/chap07.html) of the Handbook on Coal Mine Drainage Prediction and Pollution Prevention in Pennsylvania (October, 1998).

(3) pH

The pH is a measure of the acidity or alkalinity of the overburden. A low pH is an indicator of acid toxicity and a high pH generally indicates extremely sodic conditions. The pH affects the availability of chemical elements, thereby controlling the level of nutrients and toxic elements in overburden and water. The activity of microorganisms also responds to pH levels. Generally, a moderate pH - not extremely acid or alkaline - provides the most adequate biological conditions.

(4) Electrical conductivity (EC)

The EC is a measure of the soluble salts present in the overburden. It includes chlorides and sulfates of potassium, sodium, calcium and magnesium. These salts are easily leached from exposed soil or overburden material. Excess salinity can increase osmotic pressure in the root zone, resulting in less water uptake by the plants. Salinity can also impact the suitability of water for irrigation and livestock. Landscape position and precipitation will have an effect on salinity levels. Salts are transported with water over the landscape and will therefore move down slope and collect at the bottom of slopes and in depressions. Salts may also be brought toward the surface by upward movement of water. Presence of salts is influenced by season and rainfall patterns. Salinity hazard is assessed by measuring the EC of an aqueous extract of the overburden. Many states have suitability criteria for electrical conductivity. High levels of soluble salts in overburden are generally associated with arid climates where evapotranspiration exceeds rainfall. The products of weathering are not leached downward, but eventually accumulate at or near the surface. However, salts released from spoil can pose problems in humid regions as well, where they may deter seedling establishment before being flushed from the rooting zone.

(5) Sodium Adsorption Ratio (SAR)

Sodium (Na) is a common constituent in unleached overburden. It can be present in the form of salts in solution, or adsorbed onto clays. Sodium is highly mobile and is readily released from exposed spoil. Once mobilized it can migrate upward from the spoil into the root zone in arid regions such as the western U.S.. The primary concern with sodium is physical degradation of soil structure due to dispersion and swelling of clay. Dispersion causes blocked pores and swelling causes smaller pores. Water infiltration and hydraulic conductivity are reduced, which limits the amount of available water for plants and decreases the leaching of salts, which can accumulate to hazardous levels. Dispersion and swelling may also cause surface crusting, which reduces aeration, inhibits germinating seedling emergence, and increases runoff and erosion. The suitability of water supplies for irrigation and livestock can also be affected by high levels of sodium.

SAR is the standard measure of sodicity. SAR is a comparison of the concentrations of extractable Na, Ca, and Mg and takes into account the moderating effects of calcium and magnesium ions on sodium hazards.

$$SAR = Na^{+} / [(Ca^{+2} + Mg^{+2})/2]^{1/2}$$

In laboratory analysis, it may not be appropriate to base dilutions for all analytes on the highest concentration analytes such as Na, which can cause inaccurate readings for Ca and Mg and will have a large effect on overall results.

Other factors influence the effects of sodium, and SAR criteria may be modified based on local environmental conditions. Parameters considered in determining the degree to which sodium may be detrimental include salinity, soil texture, and clay mineralogy.

- Salinity- The tendency of clay particles to disperse in sodic soils decreases with increasing electrolyte concentration up to certain levels.

- Soil texture- Textural analysis determines the amount of clay available for dispersion/swelling. Fine-textured soils are affected to a greater degree than coarse textured soils. Most western states modify SAR suitability criteria based on texture.

- Clay mineralogy - Material with a high fraction of smectitic minerals (2:1 clays, such as montmorillonite) are susceptible to swelling, and therefore generally more affected by high levels of sodium that lead to reductions in hydraulic conductivity than are clays with other mineralogy. Saturation percent provides an indirect measure of shrink/swell clays.

(6) Saturation percent

Saturation percent is a measure of soil water-holding capacity. It is correlated with soil texture and swelling tendency. High saturation percent tends to be associated with high clay content soils that are dominated by smectitic clay mineralogies. Materials with high proportions of swelling clays have reduced infiltration and available water.

Most regulatory authorities, particularly in the arid West, have minimum saturation percent criteria of 25, as an indicator of low water-holding capacities (e.g., sands), and maximum saturation percent criteria of 80-85, as an indicator of the presence of swelling clays that may restrict water movement and exacerbate sodium problems at locations with high SARs.

(7) Texture

Textural analysis to determine the proportion of sand, silt, and clay in the overburden material is important in determining the infiltration, hydraulic conductivity and water holding capacity of the material as well as assessing erosivity. Fine-textured materials limit water movement. Small pores allow less air and water to move into and through the overburden which increases runoff and erosion. Also, due to the high surface area in clay, water adheres tightly to clay particles and becomes less available to plants. Clays are also more susceptible to compaction from heavy equipment. Raindrop splash can lead to crust formation in finer materials, as particles are washed into surface pores. This inhibits seedling emergence and again contributes to runoff and erosion. Coarse-textured materials, on the other hand, have high permeabilities and low water-holding capacity which can also limit the availability of water for plants.

(8) Selenium

Selenium (Se) is a common trace element that is commonly associated with pyrite and has similar geochemistry to sulfur. Soluble forms tend to concentrate in sedimentary materials, especially dark shales, coal stringers and carbonaceous shales. High concentrations are commonly restricted to the arid West and some areas of the Midwest. Solubility of Se is controlled by its oxidation state, which is governed by redox potential and pH. The most soluble forms of selenium occur in alkaline and oxidizing environments. Soluble selenates and organic selenium are forms most readily available to plants.

Although selenium is an essential nutrient, it can also be extremely toxic to animals. Selenosis (selenium toxicity) is a hazard to livestock when excess selenium accumulates in either water or plants. Care must be taken not to place selenium overburden material in the recharge zone where it could contaminate underlying aquifers.

The RA may require analysis of both total and soluble selenium in overburden. Analysis for total selenium provides the long-term potential of available Se. Soluble selenium tests measure the readily available Se in the overburden. Se fractionation can be used to determine forms and stability of Se in soil medium, a technique that is generally not required but gives the best indication of a selenium hazard in the area.

(9) Boron

Boron (B) is a widely distributed trace element in many rock types, especially in coal and carbonaceous shales, and has a tendency to concentrate in arid soils. Boron is more mobile in alkaline environments than acidic environments. Increased mobility enhances the potential for increased bioavailability. The range for boron toxicity and deficiency to plants in soils is narrow. Boron concentrations of irrigation waters in the arid west, are particularly important because many crops are susceptible to even extremely low concentrations of this element. Coal combustion by-products can contain elevated levels of boron.

(10) Trace metals

Trace metals, such as arsenic and molybdenum, may require analysis.

See Appendix D, Baseline Information, for a sample outline for collecting and organizing PHC baseline data.

3. Ground Water

Conducting a thorough baseline ground-water investigation requires following several key steps in order to collect the data needed to adequately describe the local ground-water hydrology. Available ground-water information must be reviewed, existing ground-water resources must be inventoried, baseline sampling sites must be appropriately located, wells must be properly constructed and sufficient data collected to define the ground-water system and to determine baseline quantity and quality under seasonal conditions.

a. Regulatory Requirements

Minimum ground-water information requirements for surface and underground mining permit applications are stated in the regulations at 780.21(b) and 784.14(b). This information includes:

- Location and ownership of existing wells, springs and other ground-water resources such as seeps for both the proposed permit area and adjacent areas
- Seasonal quality of ground water
- Seasonal quantity of ground water
- Ground-water use

These are only minimum requirements. Additional information may be required depending upon the complexity of the hydrologic system and the concerns of the RA.

b. Resource Inventories and Available Information

Before any baseline ground-water sampling and analysis can be done, the location of all ground-water sources should be identified. Both a field inventory and a literature review to collect the ground-water inventory information should be conducted. There are many different types of hydrologic information sources and data bases available (See Appendix A and B). Although use of existing information is important, a field examination is also necessary for verification.

Minimum baseline ground-water information requires an inventory of wells and springs near the permit area, including location, ownership (including any information regarding ground-water rights), quantity, seasonal usage rates, spring discharge rates, depth to water and specified measurements of quality. Water use inventory information will be used to determine whether mining has adversely impacted individual water supplies. In addition, any adjudicated or otherwise vested water rights should be identified.

Providing information about existing wells may be necessary. This information could include:

- Well driller's log
- Location of well (e.g., latitude-longitude, UTM)
- Elevation and description of measuring point (e.g., surface and top of casing)
- Depth and diameter of wells
- Position of screens or uncased (open) hole
- Position of pump, indicated in the well driller's logs
- Geophysical logs
- Aquifer characteristics (e.g., transmissivity, storativity and specific capacity)
- Sampling protocol for consistent water quality and level measurements
- Periodic measurements of static water level
- Pumping water level
- Well yield
- Water quality

c. Site Selection

Properly planned selection of ground-water evaluation sites is important in order to collect the data necessary to accurately determine baseline conditions. The number of ground-water sites selected for documenting baseline quality and quantity conditions should be sufficient to generally reflect the geographic variability of quality and quantity values. Baseline sites should be distributed on and around the proposed operation and located both up gradient and down gradient from the area to be disturbed. Baseline information collected should be adequate to characterize conditions throughout the portions of the aquifer that may be impacted later by the proposed operation.

The use of observation wells is preferred in most cases to characterize the aquifer. However, it may be acceptable to use information from existing wells that were identified in the water-use inventory. An existing well in use generally describes the ambient condition of the developed portion of the aquifer unaffected by the proposed mine. An existing well in use should not be used to describe the undeveloped portion of the aquifer. Older wells may be in poor condition or lack completion and other information to describe baseline conditions. Therefore, observation wells may have to be drilled in order to get sufficient site-specific information.

Two observation sites (e.g., springs, wells) from each aquifer identified, one located up gradient and the other down gradient from the permit area, will usually provide adequate coverage to characterize water quality. Three observation sites are needed to describe the ground-water potentiometric surface and flow direction. As the system complexity increases, more sites may be necessary.

All information related to well construction and well development should be included as part of the baseline data collection plan. Any existing well used for baseline data collection and analysis must be:

- Completed properly in the aquifer to be characterized
- Located to reflect conditions in the permit and adjacent areas
- Constructed with non-reactive casing material which will not alter the chemical quality of the water
- Accessible for water-level measurements and sampling

d. Defining Quantity

Baseline water-quantity descriptions should include approximate rates of discharge or usage and depth to water in the coal seam and each aquifer above and potentially impacted stratum below the coal seam. In addition, an understanding of the regional hydrologeologic setting and ground-water system, including rate, direction and overall pattern of ground-water movement is essential for predicting impacts to ground-water quantity. Both surface and underground mining have the potential to disrupt and permanently alter the physical characteristics of the ground-water system through the following:

- Reduction of ground-water availability through the removal of aquifers in the overburden or removal of the coal seam itself
- Changes in ground-water storage as measured by water-level declines
- Alterations of stream baseflow conditions
- Increases in ground-water recharge, storage and transmissivity by spoil aquifers

The characterization of the ground-water system should include:

- A description of hydrologic characteristics of geologic units within the aquifer and overburden systems

- The rate and direction of water movement as defined by the water table or potentiometric surface

- The rate and direction of water movement between aquifer units or between the aquifer and associated streams

- The location and rate of recharge or discharge

Characterization commonly requires the measurement and testing at selected sites for specific aquifer properties such as:

- Porosity (percentage of void space)

- Permeability (measure of interconnected void space)

- Hydraulic conductivity (measure of the ability of rock to transmit water)

- Transmissivity (measure of the ability of an aquifer to transmit water)

- Storage coefficient (measure of the amount of water an aquifer releases from or takes into storage)

- Specific yield (measure of storage coefficient for an unconfined aquifer)

The aquifer properties listed above represent various ways of defining hydraulic characteristics of geologic strata. Heath (1983) presents a clear and concise discussion of these basic aquifer properties. Information on aquifer properties is determined mainly through aquifer tests (pump or slug tests) conducted in the field. Richards (1985) provides a detailed discussion on the collection and evaluation of ground-water quantitative information for coal mine permit applications. Subjects covered include well drilling completion and development information, aquifer characterization and aquifer testing, relationship between ground and surface water, and fractured rock hydrology. Richards (1987) provides eleven case histories of ground-water studies in the different coal-producing areas of the U.S. It is important to select appropriate analytical tools to determine well yield and, as needed, hydraulic properties of fractured bedrock aquifers because many of the common techniques for quantifying aquifer properties have limitations when applied to fractured bedrock aquifers.

e. Defining Quality

At a minimum, the regulations require a description of total dissolved solids or specific conductance corrected to 25° C, pH, total iron and total manganese must be included in the baseline data collection. However, it is important to stress that these are the minimum regulatory data requirements and will not adequately characterize the overall baseline water quality. In order to determine impacts or potential for acid/toxic drainage, a thorough understanding of the premine water quality is necessary. Therefore, baseline water-quality data collection should include the parameters (see below) necessary to determine premining quality and water type and to evaluate analytical accuracy (e.g., cation/anion balance or TDS ratio).

Suggested Parameters for a Standard Chemical Analysis:

pH	Chloride
Acidity (hot)	Bicarbonate/Carbonate
Alkalinity	Nitrate/Nitrite
Specific Conductance	Sulfate
Total Dissolved Solids (TDS)	Sodium
Aluminum (total and dissolved)	Calcium
Iron (total and dissolved)	Magnesium
Manganese (total and dissolved)	Potassium

Ground-water quality is locally variable, resulting from chemical reactions with the minerals in the soil and the unsaturated and saturated zones. A comprehensive overview on the study and interpretation of the chemical characteristics of natural water can be found in Hem (1985). Ground-water quality impacts resulting from mining activities usually involve changes in the concentration of dissolved constituents rather than addition of new contaminants. Therefore, a well planned and comprehensive overburden/geology study plan is necessary in order to determine which chemical constituents could create problems either during mining or after mining is completed. This may require the analysis for additional parameters. For example, in the semiarid coal-producing regions of the western U.S. baseline water-quality parameter sets also include boron and selenium. In areas where AMD is a problem copper, nickel, zinc, cadmium, forms of dissolved iron and other trace metals may need to be analyzed. If CCBs are to be placed on the mine site, additional parameters related to the CCB chemistry may be needed.

f. Seasonal Characterization

The regulations require documentation of ground-water quality and quantity under seasonal flow conditions. The quality and quantity, or yield from wells and springs vary directly with the precipitation, infiltration and recharge to the water-bearing strata. Because seasonal phenomena are cyclic, one sample from a given site is not adequate for accurately describing complete seasonal flow conditions. The seasonal requirement may be satisfied by quality and quantity values from samples collected during actual calendar seasons (spring, summer, fall and winter). Another acceptable approach would be to collect data during times of seasonal recharge/discharge conditions – high, low and moderate water-table conditions associated with seasonal flow trends rather than arbitrary events. The intent of the regulation is to document a hydrologically-sound seasonal database to be used to establish the baseline and to be used for future comparisons for the PHC and for CHIA development.

Under certain conditions, historical hydrologic information to document seasonal variation may also be used. However, the representativeness of historical information should be judged on the basis of environmental changes that have occurred after the collection of the original data. For example, significant changes such as other mining activities, logging or highway construction might preclude the use of this data. If historical data are used extensively, a statement should be provided in the application that demonstrates why the information is still valid.

See Appendix D, Baseline Information, for a sample outline for collecting and organizing PHC baseline data.

4. Surface Water

Conducting a thorough baseline surface-water investigation requires following several key steps in order to collect the data needed to adequately describe the local surface-water hydrology. Available surface-water information must be reviewed, existing surface-water resources must be inventoried, baseline sampling sites must be appropriately located, and sufficient data collected to define the surface-water system and to determine baseline quantity and quality under seasonal conditions.

a. Regulatory Requirements

Minimum surface-water information requirements for surface and underground mining permit applications are stated in the regulations at 30 CFR 780.21(b) and 784.14(b). This information includes:

- Name, location, ownership, and description of all surface water bodies
- Location of any discharge into any surface water body in the proposed permit and adjacent areas
- Seasonal quality of surface water
- Seasonal quantity of surface water
- Surface-water usage

These are only minimum requirements. Additional information may be required depending upon the complexity of the hydrologic system and the concerns of the RA.

b. Resource Inventories and Available Information

Before any baseline surface-water sampling and analysis can be done, the location of all surface-water resources should be identified. Both a field inventory and a literature review to collect the surface-water information should be conducted. There are many different types of hydrologic information sources and data bases available. Although use of existing information is important, a field examination is also necessary for verification.

Minimum baseline surface-water information requires an inventory all water bodies, discharges, and withdrawals near the permit and adjacent areas, including location, ownership, quantity, seasonal usage rates, discharge rates, and specified measurements of quality (Curtis, undated). In addition, all registered water rights should be listed.

c. Site Selection

Properly planned selection of surface-water evaluation sites is important in order to collect the data necessary to accurately determine baseline conditions. Baseline sites should be distributed on and around the proposed operation and located both upstream and downstream from the proposed disturbed area. The upstream site should be located above the area of influence of the operation.

The number of surface-water sites selected for documenting baseline information should be related to the number of streams or impoundments which will receive point-source discharges from the proposed operation. Generally, all intermittent and perennial streams that are proposed to receive a discharge from the proposed operation should be included in the baseline sampling program. In the case of more than one proposed point-source discharge to a receiving stream, baseline sampling points should be established upstream and downstream from the uppermost and lowermost discharge points, respectively. The downstream site should be far enough downstream to yield a well-mixed sample of the different discharges but should not reflect the influence of any other mining operation. Consideration should be given to how the data will be used. For example, if one needs to know the quality of underground mine water, then a sample should be taken at the portal. However, if one needs to know how the underground mine affects the nearby stream, then a sample may be needed upstream and downstream of where the mine discharge enters the stream.

The applicant may select a baseline intermittent or ephemeral stream location. In these cases, baseline data collection may not be possible at all times because of no-flow conditions. Information for ephemeral streams, though possibly difficult to interpret, may still provide a source of data useful for estimating impacts on the streams.

d. Defining Quantity

At a minimum, baseline water-quantity descriptions should include seasonal flow rates. There are a number of techniques to measure stream flow. These techniques are described in a publication by the USGS (1982). There are regional differences in flow conditions. It is important to understand the factors contributing to these regional differences in order to describe surface-water quantity. Both surface and underground mining have the potential to disrupt and permanently alter the flow characteristics of the surface-water system by:

- Pumping and discharging to adjacent watersheds
- Increasing or decreasing storm hydrograph peaks
- Changing runoff characteristics due to groundcover changes
- Altering drainage patterns and drainage area size
- Changing stream baseflow conditions
- Collecting and storing water in temporary ponds or permanent impoundments

The description of the surface-water system should include:

- The drainage patterns and stream channel slopes
- Location and storage for impoundments and lakes
- The location and amount of water discharged to or withdrawn from any stream

Information on peak flows is a necessary component of baseflow information. The duration and frequency of sampling for all the baseline sites must be sufficient to demonstrate the seasonal variability of measured parameters. Additional information may be required, depending on the complexity of the hydrologic system related to other mining or impacts from other land uses and RA concerns.

Streamflow characterizations require several years of record to develop. Detailed USGS gauging station data are available from many locations. If a gauging station is not located in the proposed permit and adjacent areas, a set of instantaneous flow data may be correlated with coincident data from the nearest USGS station to interpolate and extrapolate on the limited baseline record. Regionalization techniques are discussed in Riggs (1973) and Searcy and Hardison (1960). Thus adequate baseline, peak and other discharges may be estimated from records at gauging stations or intermittent surface-water record stations located close to mining areas. Parameters like peak flow and baseflow are used to characterize seasonal baseline watershed and flow conditions. Seasonal water quality conditions also need to be determined.

f. Defining Quality

At a minimum, a description of total suspended solids, total dissolved solids or specific conductance corrected to 25^{o} C, pH, total iron and total manganese must be included in the baseline data collection. However, it is important to stress that these are the minimum data requirements. In order to determine impacts or acid/toxic drainage, a thorough understanding of the premine water quality is necessary. Therefore, baseline water-quality data collection should include the parameters (See below) necessary to determine premine quality and water type and to evaluate analytical accuracy (i.e., cation/anion balance or TDS ratio).

Suggested Parameters for a Standard Chemical Analysis:

pH	Chloride
Acidity (hot)	Bicarbonate/Carbonate
Alkalinity	Nitrate/Nitrite
Specific Conductance	Sulfate
Total Dissolved Solids (TDS)	Calcium
Total Suspended Solids (TSS)	Sodium
Aluminum (total and dissolved)	Magnesium
Iron (total and dissolved)	Potassium
Manganese (total and dissolved)	

A comprehensive overview on the study and interpretation of the chemical characteristics of natural water can be found in Hem (1985). Surface-water quality impacts resulting from mining activities usually involve increases in the concentration of dissolved constituents rather than addition of new contaminants. This occurs primarily because of greater reactive surface areas in spoil material derived from the broken up overburden. When this ground water discharges to the surface through springs or seeps, it impacts the surface-water system. Therefore, the interconnection between the ground-water system and the surface-water system needs to be evaluated.

The need for additional parameters to adequately describe the surface water system should always be considered based on the types of users and resources present. For example, baseline data for areas where water is used for irrigation in the semiarid coal-producing regions of the Western U.S. would commonly include boron and selenium. Information on aquatic resources such as macroinvertebrates, benthics and fish may also need to be collected as part of the baseline.

g. Seasonal Characterization

The regulations require documentation of surface-water quality and quantity under seasonal flow conditions. Because seasonal phenomena are cyclic, one sample from a given site is not adequate for accurately describing complete seasonal flow conditions. The seasonal requirement may be satisfied by quality and quantity values from samples collected during actual calendar seasons (spring, summer, fall and winter). Another acceptable practice would be to collect during times of seasonal high and low flow conditions – high, low and moderate runoff and baseflow conditions associated with seasonal flow trends rather than arbitrary events. The intent of the regulation is to document a hydrologically sound seasonal database to be used to establish the baseline and to be used for future comparisons for the PHC and for CHIA development.

Under certain conditions, historical hydrologic information to document seasonal variation may also be used. However, the representativeness of baseline information should be judged on the basis of environmental changes that have occurred after the collection of the original data. For example, significant changes such as other mining activities, logging or highway construction might preclude the use of these data. If historical data are used extensively, a statement should be provided in the application that demonstrates why the information is still valid.

See Appendix D, Baseline Information, for a sample outline for collecting and organizing PHC baseline data.

C. Baseline Information For CHIA

Before a permit can be approved the RA must conduct an assessment of the cumulative hydrologic impacts (CHIA) of all anticipated mining on the hydrologic balance in the cumulative impact area (CIA) and must find that the proposed operation has been designed to prevent material damage to the hydrologic balance outside the permit area. CHIA preparation is an integrated process which embodies a specific application of hydrologic information management at each step of the process. A sample outline for the CHIA report is available in Appendix E. With proper enforcement of surface mining regulations, the hydrologic impacts of individual mining operations should be minimized. The hydrologic impacts that cannot be mitigated through implementation of the hydrologic reclamation plan may not be major when considered individually. However, when the impacts from existing mines, as well as from all anticipated mining within a specific area are considered, their additive effects may become major and create the potential for material damage to the hydrologic balance. The CHIA is intended to assure that such additive impacts will not be overlooked in the approval of individual permit applications.

Both the PHC and CHIA are predictive tools that evaluate the potential for adverse hydrologic impacts. The baseline data acquisition, as well as the subsequent operational monitoring, is largely aimed at providing information to accomplish these predictions.

Any major change in mining operations, such as the addition of a new area, a change in mining or reclamation methods, or the discovery of an unforeseen geologic or hydrologic condition necessitates a significant permit revision. This generally entails a reconfirmation of the accuracy of the PHC and CHIA findings, or a revision and updating of the findings.

At 30 CFR 780.21 (c) (1) the operator is required to identify and provide to the RA data for the CIA available from appropriate federal and state agencies. See Appendices A and B. Submission of these data are mandatory and will be used by the RA in preparing the CHIA.

In order to help expedite the permitting process, the operator may gather and submit the data not readily available from the federal and state agencies. Generally, it would be to the permit applicant's advantage, particularly with respect to time, to assist the RA by providing the necessary hydrologic and geologic information. However, it is the responsibility of the RA to verify the validity of these data.

To determine the type of hydrologic and geologic information needed for the CIA, the operator will have to work closely with the RA. The CIA, the anticipated mining, the information being submitted through other permits, and the type and amount of additional hydrologic and geologic information need to be determined. By working with the RA, the coal mine operator can facilitate and ensure the necessary hydrologic and geologic information is available.

The CHIA predicts the type and magnitude of impacts to the hydrologic system attributable to the proposed operation in conjunction with existing and anticipated mining. Thus, during the CHIA process the RA should:

- Define the area to be studied, the CIA
- Describe the baseline hydrologic system
- Identify hydrologic concerns
- Select material damage criteria
- Estimate the cumulative impacts of mining on the hydrologic balance
- Prepare a written material damage finding

This document on baseline data is concerned only with the first three items above. A sample outline for collecting and organizing CHIA baseline data is contained in Appendix E.

1. Delineating the CIA

The CIA is an area where impacts from the proposed operation, in combination with other anticipated operations may cause material damage. Anticipated mining includes, at a minimum, existing operations, proposed operations for which permit applications have been submitted to the RA, and operations required to meet diligent development requirements for leased Federal coal for which there is actual mine development information available.

When establishing a CIA, the RA should be aware that boundaries should be flexible and can be changed if analyses or new data reveal conditions or concerns not previously identified. In the interim, a "working" CIA may be delineated based on estimates or calculations of the down-gradient extent of measurable impacts to surface water or ground water. As the analysis progresses for the various parameters being evaluated, the need may arise for adjustment of the "working" CIA boundary. A sample procedure for delineating the CIA is provided in Appendix F.

The size and location of the CIA will depend on the surface- and ground-water system characteristics, the hydrologic resources of concern to the RA, and projected impacts from the operations included in the assessment. A ground-water CIA should extend from the up-gradient extent of impacts down-gradient to aquifer discharge points unless it can be demonstrated that measurable impacts do not extend that far. In some cases measurable ground-water impacts may extend down-gradient to surface-water bodies which receive ground water discharge.

Among other factors, two items generally of importance for ground-water CIAs are water-level drawdown areas and areas through which plumes of degraded water may migrate. Similarly, a surface-water CIA should extend from a downstream point at which all mining impacts can be cumulated, and upstream to either a watershed boundary or to a point at which upstream effects can be isolated from mining impacts, such as at a stream gauging station. This suggests that the CIA may require separate delineations for ground- and surface-water issues.

2. Define Baseline Hydrologic Conditions

The surface-water and ground-water systems should be described in sufficient detail to identify their significant characteristics and interactions. The description should focus on the hydrologic resources that may be affected by anticipated mining. This will enable the RA to focus the cumulative impact description and analysis on these same resources. Much of the data describing the hydrologic resources will be available in permit applications. However, areas outside permit boundaries may require additional data from other sources.

3. Identify Hydrologic Concerns

The RAs task in the CHIA is to estimate the magnitude and importance of changes to hydrologic resources as a result of mining. Lumb (1982) provides guidance and examples for determining the magnitude and significance of mining impacts. The hydrologic considerations differ greatly in the different coal regions of the U.S. primarily due to regional variations in rainfall, temperature, water use, topography, and geology. For example, typical hydrologic concerns in areas associated with the coal fields of the western U.S. may include:

- Reductions in the quantities of relatively scarce surface-water and ground-water resources which may be completely appropriated under state water rights laws. Available supplies may be reduced as a result of changes in surface runoff conditions or the lowering of ground-water levels. Beneficial changes can also occur, such as reduction of runoff peaks through increased infiltration, and increased stream baseflow through increased ground-water discharge.

- Increases in TDS or SAR in surface- or ground-water irrigation supplies which may cause critical crop production losses.

- Increases in the concentration of total suspended solids (TSS) which may cause destruction of aquatic habitat or the loss of reservoir storage capacity due to siltation.

- Changes in flow rates or suspended solids loads which can change the erosional balance of streams resulting in downcutting. In addition to increased sedimentation, erosional downcutting may lower adjacent water tables below plant-rooting depths.

- Changes in water quality which may critically affect some sites through increased concentrations of constituents such as boron, selenium, iron, or manganese.

Typical examples of hydrologic concerns in areas associated with coal mining in the eastern U.S. may include:

- Changes in the chemical composition of streamflow due to the addition of mine drainage (e.g., total iron, total manganese, sulfate, total dissolved solids and pH) that may cause adverse impacts to public supplies and aquatic organism populations

- Increases in the sediment load from the disturbed areas which may cause destruction of aquatic habitat in streams and ponds

- Changes affecting surface-water runoff which may add to the flood hazard of a watershed

- Disturbances of overburden due to mine excavation that may increase the availability of some chemical constituents that cause deleterious effects in water (e.g., total iron, manganese, aluminum, total dissolved solids, trace elements)

These are only typical hydrologic concerns and represent only a small number of possible impacts. At each site and within individual CIAs, the hydrologic considerations should be determined on the basis of water usage in the area, existing water-quality standards, and local hydrologic conditions.

Baseline information for the CIA may be required for identifying and describing all anticipated mining, ground-water and surface-water systems and for characterizing hydrologic concerns.

Geologic information of the following types could, in certain situations, be required for the CIA to help define potential impacts to ground-water systems off the permit area.

- Lineament maps prepared by an examination of aerial photographs– because of the significant effect of large-scale faults and fracture zones (reflected by lineaments) on local and regional ground water movement

- Mapping of alluvial stream deposits – because such deposits commonly contain significant quantities of ground water available for use and important also in maintaining the hydrologic balance of the area

- Structural geology – because the regional movement of ground water can be controlled by geologic structure including folding and fractures

Hydrologic baseline information of the following types could be required for the CIA.

- Streamflow information

- Water-quality information for ground and surface water

These types of information are commonly collected at USGS gauging and water-quality monitoring networks and are published in basic data and study area reports. In addition, basic data for individual stations is available at USGS web sites hot linked in Appendix A.

The examples cited above represent only a few of the possible types of geologic information that may be necessary for the CIA and how that information is useful.

D. Summary and Examples

The number of locations at which site-specific baseline data for geology, overburden, surface water and ground water needs to be collected depends on many variables. Rather than presenting and attempting to rationalize minimum or maximum numbers and locations for surface-water stations, boreholes for overburden data, ground-water observation wells and frequency and duration of water sampling, we have included summaries of baseline information for geology and hydrology as it exists in planned or actual permits. We refer to these summaries as regional examples of baseline data requirements. In this context, regional can refer to hydrologic issues as may exist in one region but not all regions of the country and for which precise kinds and amounts of data are needed to establish, for example, the potential for acid-mine drainage formation. Regional may also refer to differences in philosophy and technical approach to sampling and standards deemed acceptable for baseline geology and hydrology information from one state or region to another.

The three examples of baseline information collection from different regions of the country are presented in Appendices H, I, and J.

CHAPTER III
QUALITY ASSURANCE/QUALITY CONTROL FOR BASELINE INFORMATION

The purpose of quality assurance and quality control (QA/QC) procedures is to ensure that data collected for the permit represents actual conditions at the site for the time of sampling. These data need to be accurate and reproducible. Effective QA/QC procedures are essential to ensure the validity of geologic and hydrologic data and ultimately the decisions utilizing geologic and hydrologic data in the coal mine permit process. QA/QC procedures commonly apply to sample collection, sample preservation, control and analysis, as well as the effectiveness of geologic and hydrologic data in monitoring a permitted operation.

Quality control refers to specific procedures used to achieve prescribed standards of performance. Quality assurance is an integrated planning process for assuring the reliability of geologic and hydrologic data so that it can be used independently or with other comparable kinds of data with some definable degree of confidence. Quality assurance components commonly include:

- Outlining the intended use of the data, such as to support permit issuance or revisions, to verify compliance with performance standards, or to verify self-monitoring data.

- Identifying factors that influence the design of the monitoring system such as the homogeneity or lack thereof of the geologic and hydrologic systems being measured or monitored.

- Selecting the parameters to be monitored and the frequency of monitoring.

- Specifying sampling protocols and analytical methods to be used.

- Specifying detection limits where applicable and required precision and accuracy for all types of geologic and hydrologic measurements.

- Identifying quality control procedures to document whether these requirements are being met.

A. Precision, Accuracy and Bias

In scientific measurement, there are three main attributes that describe the quality of the resulting information: precision, bias, and accuracy. The 19th edition of *Standard Methods for the Examination of Water and Waste-Water* (1995) defines them as follows:

- Precision is a measure of the degree of agreement among replicate analysis of a sample, usually expressed as the standard deviation.
- Bias is the consistent deviation of measured values from the true value, caused by systematic errors in procedure.
- Accuracy is a combination of bias and precision of an analytical procedure, which reflects the closeness of a measured value to a true value.

B. Data Quality Objectives

The majority of geologic and hydrologic data will be collected through sampling of the mine permit area. Other data may come from data bases or other sources such as nearby operations. Regardless of the type of information assembled and collected, it is important to determine the objectives of data collection. Surprisingly, sampling objectives are often not clearly defined. As a result, data may be collected that do not need to be collected or data may be collected that do not provide the information necessary to support a particular decision.

Formulation of the appropriate sampling objectives can be achieved in a variety of ways. One model used in environmental applications is the USEPA's *Data Quality Objectives (DQO)* approach (U.S. EPA, 1994). The purpose of DQOs is to (1) clarify the study objective; (2) define the most appropriate data to collect; and (3) specify tolerable limits on decision errors, which will be used as the basis for establishing the quantity and quality of data needed to support the decision. It has been used effectively to establish sampling priorities, manage sampling budgets, and reduce conflict between regulatory and industry groups. The seven basic DQO steps are set forth below:

Step 1: State the problem.
Step 2: Identify the decision.
Step 3: Identify the inputs to the decision.
Step 4: Define the study boundaries.
Step 5: Develop a decision rule.
Step 6: Specify tolerance limits on decision errors.
Step 7: Optimize the design.

Complete discussion of the detailed DQO process is beyond the scope of this document. The above discussion is extracted from a report edited by Hossner (Texas Mine Land Reclamation Monitoring Program Issues, A report of the Soils Working Group October 1998). (Link to: http://www.osmre.gov/pdf/TXMONITORING.pdf)

C. Water Quality Sampling Procedures

Much information has been developed for QA/QC over the years for collection and analysis of water samples. Recently, the USGS released a report dealing with standard methods for sampling ground and surface waters. The purpose is to provide sampling methods that result in accurate data that are reproducible within defined limits of accuracy. Some of the topics covered include: preparations for water sampling, selection of equipment, collecting and processing of water samples and field measurements. The report can be accessed at the following web site. Link to: http://water.usgs.gov/owq/FieldManual

TIPS has software programs to perform cation and anion balance for standard complete water samples. Through programs like HydroChem and AquaChem, one can determine the validity of water quality analyses.

QA/QC discussions and procedures for analysis of water samples are contained in Part 1000 of the Standards Methods for Examination of Water and Wastewater (1995) publication. Topics covered include precision, bias, calibration with standards and analysis of duplicates.

D. Geology and Overburden Sampling Procedures

The following discussion on sampling collection, sample preparation and storage, quality assurance program elements, and related topics was taken from OSM's Overburden Sampling and Analytical QA/QC Requirements. (See Reference in Chapter V.) Other adequate sources of QA/QC procedures exist and may be used.

1. Sampling Methods

The following sampling procedures can be used:

- Core drilling produces a continuous record of the geologic column encountered; it is therefore a preferred method. Drilling may be used to produce continuous cores using air, air-water mist, or water (non-contaminating, low in salts) as the drilling medium. Care must be taken to ensure that mud, water, and lubricants do not contaminate the core.

- Air rotary chip sampling is often used because it is quicker and less costly than core drilling. However, because the chips tend to get mixed as they are blown from the borehole, sampling of discrete intervals becomes more difficult. Chip sampling is often used as a supplement to continuous core drilling.

- Thin-wall tubes, split-barrel samplers, or other drive or press devices can be used to sample unconsolidated materials.

- Each sample should represent a single lithologic unit except where intervening strata are less than 1 foot in thickness. However, single samples should not represent more than 5 feet of the core.
- Coal stringers or lithochromic strata (10YR 3/2 or darker) greater than 6 inches should be sampled separately.
- When core sampling, sampling intervals should be broken if an obvious change in chroma, texture, mineralogy, or weathering intensity is noted, or where an anomalous strata, such as a coal/lithochromic zone, appear
- To avoid contamination of the top 5 feet of each core, one sample from each soil horizon to 5 feet should be obtained separately from each of the core locations. These soil samples should be retrieved from excavated pits by a soil scientist. All analytical parameter analyses, listed in these guidelines, must be completed on each sample. The data from these samples will complement the soil survey and may identify suitable top dressing materials to the 5-foot depth. These procedures are required to assure the acquisition of reliable overburden data to identify materials for root zone reclamation and topsoil substitution are available.

- All analytical methods, parameter limits, and suitability criteria required by the RA must be followed by the industry when characterizing potentially acid- and toxic-forming materials, topsoil substitutes/supplements, and materials proposed for root zone reclamation.

2. Drill Logs

Geologic logs of each drill hole must be recorded and submitted as part of the drilling report in the Permit Application Package (PAP) or required annual reports. Both the cores and any other lithic samples should be kept in case they are needed in the future. Drill logs must be a complete and accurate record of drilling activities and should include the following information:

- Name and qualifications of individual making interval separations and sampling of cores

- Core number, location (northing and easting), collar elevations, depth intervals, lithology and lithological constituents, and Munsell color

- Dates of drilling
- Dates samples sent to laboratory for analyses or storage
- Personnel conducting drilling
- Drilling method used
- Interpretation of water bearing zones
- Identification of lost or non-retrievable cores
- Zones of lost circulation of drill fluids
- Any unusual conditions encountered during drilling activities

3. Sample Collection, Handling and Transport

To meet the requirements of 30 CFR 780.22 (b) (2) and (c) and 30 CFR 777.13(a), the company and laboratory must list, with references, the methods of sample preparation and analyses used to analyze soil, overburden and regraded spoil. The following procedures are suggested for preparation and storage of samples:

- When sampling for monitoring programs, the RA must be notified at least 2 weeks in advance so that it may have the opportunity to observe, and/or participate in, sampling practices and procedures.
- It is important that samples not be exposed to high temperatures. During the warmer months, an insulated container should be provided for storage during sampling and transport. If temperatures exceeding 35^{o} C are possible, the overburden/spoil samples should be kept cold using clean ice or a similar product that will not contaminate the samples.
- Samples will be identified and labeled using a system that will correspond with submitted sample location maps and laboratory analytical results. Samples will be labeled in a numerical sequence, not by site and strata/horizon, when submitted to the laboratory.
- Sufficient sample quantities must be collected to meet the needs for sample splits outlined in the following sections of this document.

- Time between sample collection and preparation should not exceed 30 days.

4. Sample Preparation and Storage

The following are suggested procedures to be followed for preparation and storage of samples:

a. Laboratory Preparation

All analyses must be performed on air-dried samples with data being reported on an oven-dry weight basis (110^{o} C).

b. Drying

Drying must be initiated as soon as possible after the samples arrive at the laboratory. Air dry at a temperature not exceeding 35^{o} C by spreading samples on non-metallic trays to a depth of 1-2 cm. Drying can be excluded for sample analyses that require an "as received basis" for analyses completion. Break up large soil masses so that there are none larger than 1 cm in diameter. Mix the sample daily and re-spread to allow for faster drying. Drying may be accelerated by passing air from a fan over the samples.

c. Core Crushing

Core crushing must be accomplished utilizing equipment that minimizes particle size reduction. Equipment used must also have a minimal chance of chemical contamination of the samples used and be easily cleaned between samples. The entire core sample must be crushed to < 2 mm with constant sample removal.

d. Soil Flailing

Soil samples are to be flailed to <2 mm with constant removal of reduced material. Determination of the coarse fraction (weight basis) is to be made on the basis of the field sample. Soil samples are to be sieved, prior to flailing, with separation of >1 cm coarse fragments.

e. Grinding

Samples for Leco Furnace analysis (total sulfur and organic carbon) must be ground to <0.25 mm.

f. Splitting

The sample should be passed through a mechanical sample splitter and recombined four to five times to insure complete sample mixing. Depending upon how many subsamples are needed, the mixed sample is to be split using a mechanical splitter into several small samples and then recombined to achieve the desired number of sub-samples.

The laboratory must prepare and maintain three splits of the original sample with one sample being retained by the laboratory for analyses, one returned to the company, and one to be provided to the RA when requested.

g. Sample Storage

Samples are to be stored in the laboratory, or elsewhere, at temperatures between 10^o and 30^o C. After preparation, samples are to be stored in sealed glass containers under controlled storage conditions. Storage conditions used must be outlined in the final reports to the RA.

5. Quality Assurance Program Elements

The following information should be provided to the company and RA for each sample/set of samples:

- Names and qualifications of personnel handling sample at each stage of collection, preparation and analyses

- Name and qualifications of individual making interval separations and sampling of cores

- Dates and conditions of each stage of sample collection, transport, preparation and analyses

- Detailed description of core collection, storage, and preparation procedures

- Laboratory procedures as specified. If procedure modifications are made, the laboratory must describe the modifications in detail and should submit statistical data correlating data with original methodology.

Additional internal laboratory QA/QC procedures on all analytical parameters are to be supplied to the Company and to the RA in final reports.

6. Quality Control Program Elements

The following elements should be considered in the quality control program:

a. Sample Control

A sample is physical evidence collected from a facility or from the environment. An essential part of soil, overburden or spoil sampling programs is to control the evidence gathered. To accomplish this, companies will require that their drillers and contracted laboratory initiate and complete chain-of-custody and document control programs. Copies of program procedures must be submitted to the RA with all soil, overburden, and spoil analytical results.

Time from sample collection to completion of analyses should be as short as possible because minerals begin to break down upon exposure to air.

b. Instrumentation

Detection limits must have been established for each instrument immediately prior to analyses of any field samples. A log of each instrument's detection limits should be kept.

Establish working limits prior to beginning each test. Determine the concentration that is three times the detection limits of the instrument for each analyses in the extraction solution. Prepare calibration standards in graduated amounts.

c. Analytical Controls

Calibration standards must be prepared:

- At an appropriate range approximating that of field samples
- Using the same acids or salts used in the digestion or extraction of the field samples
- As a blank, and at least three calibration standards in graduated amounts for each analytical parameter

Duplicate samples must be prepared and analyzed:

- For samples of a similar matrix type and concentration as the major samples analyzed
- With ten percent duplication for analyses which are routinely accomplished with minimum difficulty in accuracy and precision; i.e., pH, electrical conductivity (EC), etc. These samples should be randomly selected.
- With twenty percent duplication for analyses which are known to be difficult to accomplish with high levels of accuracy and precision; i.e., cation exchange

capacity (CEC), exchangeable sodium percentage (ESP), extractable selenium and boron. These samples should be randomly selected.

d. Reports

Control charts must be developed, including:

- Chronological data tables for calibration standards, control samples, duplicate samples, and detection limit results

- Chronological statistical computation of data

Data must be presented using systematic report formats including:

- 0Uniform analytical units

- Uniform significant figures

- Uniform tables for computer reader use (See Data Submittal Format Section)

- Submittal of data in hard copy and in electronic format

CHAPTER IV
TECHNICAL SOFTWARE AND DATA MANAGEMENT

Many tools exist for collecting, storing and analyzing environmental data. Automated computer techniques can efficiently manage environmental data and predict potential impacts . This is accomplished using electronic data, database management systems and geographic information systems that are linked to other automated analytical tools such as statistical and geochemical analysis packages, surface- and ground-water models, and other spatial analysis software.

With the growth in the use of micro-computers and high speed graphical scientific work stations, there is a large selection of software available that aids in the management of hydrologic data, in the analysis of baseline hydrologic, geologic and other information, and in the quantification of PHC and CHIA . A careful and systematic approach is required in the selection of a suite of software and hardware to assure that the system can be effectively and efficiently used to store, manage and analyze hydrologic data . One such system available to OSM offices, states and Tribes with responsibilities under SMCRA is the OSM Technical Information Processing System (TIPS) . This chapter contains a brief summary of the suite of software available through TIPS that may be useful in evaluating baseline information . For more information on the TIPS program and on the current TIPS software, see the main TIPS website found at:
www.tips.osmre.gov
and the TIPS software and hardware support website found at:
www.tips.osmre.gov/SoftwareHardware.htm.

The following software summary is an excerpt from the TIPS core software description website found at: http://www.tips.osmre.gov/coresoftware_2001.htm.

The TIPS websites will provide the most current information on the core software and hardware configuration; however, the following is provided for convenience and to illustrate the currently available software.

A. TIPS Core Software

1. AQTESOLV Professional

Description: A suite of tools to analyze movement and quantity of ground water, estimate aquifer parameters and to evaluate pump/slag well test results.

Used by: Hydrologists and geologists.

Additional Information: http://www.aqtesolv.com/

2. AquaChem

Description: Water quality, typing and equilibrium water chemistry analyses.

Used by: Hydrologists, geochemists, and geologists.

Additional Information: http://www.flowpath.com/software/aquachem/aquachem.html

3. ARC/INFO

Description: ArcInfo is a high-end GIS with capabilities for automation, modification, management, analysis, and display of geographic information. Because of its Open Development Environment, ArcInfo allows users to easily build custom applications and interfaces. Various extensions are available to extend core functionality. ArcInfo adheres to modern software engineering and computing standards and runs on a variety of hardware platforms, including UNIX workstations as well as Windows NT computers.

Used for: Spatial data analysis.

Used by: Technical or computer specialists.

Additional Information: http://www.esri.com/software/arcgis/arcinfo/index.html

4. ArcView

Description: User-friendly interface with ArcInfo to allow the users to visualize, tabulate, chart and layout GIS data. Does not require ArcInfo to run.

Used for: Visualizing, querying and analyzing spatial data.

Used by: Regulatory or AML specialists, or managers working with maps and database applications in the ARC/INFO environment.

Additional Information: http://www.esri.com/software/arcview/

5. AutoCAD Map 2000

Description: Map drafting. A professional automated mapping tool for creating, maintaining, and communicating mapping and GIS information

Used by: Regulatory or AML scientists specializing in geology, soil science, hydrology, civil or mining engineering, or related natural sciences.

Additional information: http://www.autodesk.com/products/acadmap/index.htm

6. EarthVision

Description: 3D modeling of both surface and sub-surface features and information to produce layered topographic and base maps, as well as detailed volumetric calculations.

Used for: Spatial analysis.

Used by: Geo-scientists, hydrologists, and engineers who model/ analyze spatial information such as overburden toxicity, water quality and quantity, geology, and topography, and those engaged in reclamation design and Approximate Original Contour (AOC) evaluation.

Additional Information: http://www.dgi.com/earthvision/index.shtml

7. Galena

Description: GALENA is a simple, user-friendly yet very powerful slope stability software system, which allows for the simulation of complex geological, ground water and external force conditions. GALENA incorporates three methods of slope stability analysis in order to assess a wide range of ground stability problems in both soils and rocks -

- The BISHOP Simplified method determines the stability of circular failure surfaces.
- The SPENCER-WRIGHT method for either circular or non-circular failure surfaces.
- The SARMA method for problems where non-vertical slices are required or for more complex stability problems.

Used for: Slope stability analysis

Used by: Engineers, geotechnical specialists.

Additional Information: http://galena.clovertechnology.com.au

8. Geochemist Workbench

Description: A collection of sophisticated modules for solving aqueous geochemistry problems.

Used by: Hydrologists, geochemists, and geologists.

Additional Information: http://www.rockware.com/

9. Groundwater Modeling System (GMS)

Description: Ground-water model design system that converts map data into MODFLOW, MODPATH and MT3D grid data.

Used by: Hydrologists, geochemists and geologists

Additional Information: http://www.ems-I.com/gms.htm

10. Ground Water Vistas

Description: Ground Water Vistas is a model-independent graphical design system for MODFLOW, MODPATH and MT3D.

Used by: Hydrologists and geologists

Additional Information under **Software** at **Groundwater Vistas** at:
http://www.groundwatermodels.com

11. HEC-RAS

Description: A water surface profile model for analyzing rivers of both natural and man-made channels, as well as flow hydraulics, and bridge and culvert hydraulic analysis.

Used by: Hydrologists and engineers.

Additional Information:
http://www.hec.usace.army.mil/software/software_distrib/hec-ras/hecrasprogram.html

12. KeyServer

KeyServer is not a general use, technical software application - It is software license management software that will work over a wide area network (WAN) which is available from Sassafras Software. In order to make the technical software more widely available, while limiting software procurement costs, TIPS uses KeyServer as a network software license manager. KeyServer monitors the use of technical software packages through the TIPS WAN and limits availability to no more than the number of legitimately purchased licenses. The software application runs locally on the users computer for higher speed, but will only load when authorized by the KeyServer manager over the network. For more information on KeyServer, see the website found at: http://www.sassafras.com/

13. Pathfinder Office

Description: Software to assist in interpreting, correlating and plotting GPS unit data.

Used for: Verification of stream buffer zones, locating roads, outcrops, ponds, or other features relative to permit boundaries; inventory ground-water discharge locations, outcrops, etc.; mapping of AML site locations and acreage; measuring the size of minesite disturbance areas, etc.

Used by: Geo-scientists, inspectors hydrologists, and engineers who collect spatial information such as overburden toxicity, water quality and quantity, geology, topography, etc., and those engaged in reclamation design and approximate original contour (AOC) evaluation.

Additional Information: http://www.trimble.com/products/pd_gi.htm

14. Revised Universal Soil Loss Equation (RUSLE)

Description: Soil loss prediction software which includes a suite of modules for determining soil loss factors.

Used by: Engineers, geologists, hydrologists, soils scientists

Additional Information: http://www.sedlab.olemiss.edu/rusle/

15. Surface Deformation Prediction System (SDPS)

Description: SDPS is an integrated approach to the problem of calculating and predicting ground deformations above undermined areas. Based on empirical or site-specific regional parameters, the model quantifies a variety of ground deformation indices for both longwall and high extraction room-and-pillar mines such as subsidence profile, angle of draw, strain, slope, and curvature. The application includes a graphing program as well as a pillar stability program that can help evaluate the stability of pillars in room-and-pillar mines.

16. SEDCAD for Windows

Description: A suite of curve-number based watershed rainfall-runoff models, RUSLE-based sediment yield analysis, and channel and hydraulic structure design utilities.

Used by: Engineers, geologists, hydrologists, soils scientists.

Additional Information: Website - None.

17. Statgraphics

Description: Statgraphics is a statistical analysis software package that allows complex statistical evaluations and graphing of data.

Used for: Uses include comparison, summary statistics, time series analysis, prediction, hypothesis testing, sample-size determination, regression and other correlation of environmental data.

Used by: Geologists, hydrologists, soils and vegetation specialists to interpret data.

Additional Information: http://www.statgraphics.com

18. StratiFact

Description: StratiFact is designed to store and display borehole or well data. It also provides an effective tool for stratigraphy correlation. The program consists of two integrated components: a database manager paired with interactive graphics.

Used for: Storing, displaying and correlating borehole or well data.

Used by: Geologists and hydrologists.

Additional Information: http://stratifact.com/

19. SurvCADD 2000 for AutoCAD

Description: SurvCADD is application software for civil engineering, surveying, and mine engineering which runs with AutoCAD. It produces topography maps, base maps, and simulated 3D pictures of surface terrain. It also includes functions to model channel designs used in analyzing small watersheds and storm runoff.

Used for: Customizes AutoCAD for earthmoving and engineering additional commands and enhancements. SurvCADD consists of the following Modules: Cogo-Design, DTM-Contour, Section-Profile, Mining, Hydrology, SurvCOGO and Roadway & Sewer.

Used by: Regulatory or AML scientists in civil or mining engineering, geology, or related disciplines.

Additional Information: http://www.carlsonsw.com/survcadd.htm

20. Trimble Global Positioning System (GPS)

Description: GPS Hardware.

Used for: Satellite mapping. Uses include verification of stream buffer zones, locating roads, outcrops, ponds, or other features relative to permit boundaries; inventory ground-water discharge locations, outcrops, etc.; mapping of AML site locations and acreage; measuring the size of minesite disturbance areas, etc.

Used by: Geo-scientists, inspectors, hydrologists, and engineers who collect spatial information such as overburden toxicity, water quality and quantity, geology, topography, etc., and those engaged in reclamation design and AOC evaluation.

Additional Information: http://www.trimble.com/index.htm

B. Data Bases

The most significant national and state/tribal data bases are described in Appendices A and B, respectively. The applicability of national data bases to a proposed coal mine operation is generally limited. As a result, it may be desirable for RAs to consider establishing and using hydrologic data bases on a statewide, coal field, watershed, or aquifer basis from information commonly available in permit application files, inspection reports and monitoring reports.

REFERENCES

Acid Drainage Technology Initiative, 1998, A Handbook of Technologies for Avoidance and Remediation of Acid Mine Drainage: National Mine Land Reclamation Center, West Virginia University, Morgantown, West Virginia, 131 p.

—— 2000, Prediction of Water Quality at Surface Coal Mines: National Mine Land Reclamation Center, West Virginia University, Morgantown, West Virginia, 241 p.

American Public Health Association, American Water Works Association and the Water Environment Federation, 1995, Standard Methods for the Examination of Water and Wastewater, 19th Edition. 1220 p.

Cravotta, C.A., III, Brady, K.B.C., Smith, M. K. and Beam, R. L., 1990, Effectiveness of alkaline addition at surface mines in preventing or abating acid mine drainage: Part 1, Geochemical considerations: In: Proceedings of the 1990 Mining and Reclamation Conference and Exhibition, West Virginia University, Charleston, West Virginia, p. 221-226.

Curtis, W.R., undated, A Manual for Training Reclamation Inspectors in the Fundamentals of Hydrology: U.S. Department of Agriculture, Forest Service, 56 p.

Heath, R.C., 1983, Basic Ground-Water Hydrology: U.S. Geological Survey Water-Supply Paper 2220, 85 p.

Hem, J.D.,1985, Study and Interpretation of the Chemical Characteristics of Natural Water: U.S. Geological Survey Water-Supply Paper 2254, 263 p.

Hossner, Lloyd (ed), 1998, Texas Mineland Reclamation Monitoring Program Issues: Texas Mining and Reclamation Association, Austin, Texas, 73 p.

Lumb, A.M., 1982, Procedures for Assessment of Cumulative Impacts of Surface Mining on the Hydrologic Balance: U.S. Geological Survey Open File Report, 82-334, 50 p.

Office of Surface Mining, 1985, *Draft* Guidelines for the Preparation of a Probable Hydrologic Consequences (PHC) Determination: U.S. Department of the Interior, Office of Surface Mining Reclamation and Enforcement, 34 p.

—— 1985, *Draft* Guidelines for the Preparation of a Cumulative Hydrologic Impact Assessment (CHIA): U.S. Department of the Interior, Office of Surface Mining Reclamation and Enforcement, 76 p.

—— 1985, *Draft* Appendices to PHC and CHIA Guideline Documents: U.S. Department of the Interior, Office of Surface Mining Reclamation and Enforcement, 169 p.

—— 1990, Hydrology Handbook for the Federal Program for Tennessee: U.S. Department of the Interior, Knoxville, Tennessee, 67 p.

—— 1997, Managing Hydrologic Information, A Resource for Development of Probable Hydrologic Consequences (PHC) and Cumulative Hydrologic Impact Assessments (CHIA): U.S. Department of the Interior, Office of Surface Mining Reclamation and Enforcement, 109 p.

—— 1999, Overburden Sampling and Analytical Quality Assurance and Quality Control (QA/QC) Requirements for Soils, Overburden and Regraded Spoil Characterization and Monitoring Programs for Federal Lands in the Southwestern U.S.: U.S. Department of the Interior, Office of Surface Mining Reclamation and Enforcement, Western Regional Coordinating Center, 21 p.

Pennsylvania Department of Environmental Protection, 1998, Coal Mine Drainage Prediction and Pollution Prevention in Pennsylvania: Pennsylvania Bureau of Mining and Reclamation, 371 p.

Rantz, S.E. and others, 1982, Measurement and Computation of Streamflow: Volume 1. Measurement of Stage and Discharge: U.S. Geological Survey Water-Supply Paper 2175, QE 75.W376, No. 2009A, 38 p.

Richards, D.B., 1985, Ground-Water Information Manual: Coal Mine Permit Applications, Volume I: U.S. Department of the Interior, Office of Surface Mining Reclamation and Enforcement, Prepared in Cooperation with U.S. Geological Survey, 275 p.

Richards, D.B. (Ed.), 1987, Ground-Water Information Manual: Coal Mine Permit Applications, Volume II: U.S. Department of the Interior, Office of Surface Mining Reclamation and Enforcement, Prepared in Cooperation with the U.S. Geological Survey, 396 p.

Riggs, H.C., 1973, Regional analyses of streamflow characteristics: U.S. Geological Survey Techniques of Water Resource Investigations, Book 4, Chapter B3, 15 p.

Searcy, J.K., and Hardison, C.H., 1960, Double-mass curves: U.S. Geological Survey Water-Supply Paper 1541-B, p. 31-66.

Senkayi, Abu L., and Dixon, J. B., 1988, Mineralogical Considerations in Reclamation of Surface-Mined Lands: In: L.R. Hossner (ed.) *Reclamation of Surface-Mined Lands, Volume 1*. CRC Press, Inc., Boca Raton, Florida, p. 105-124.

Skousen, J., Renton, J., Brown, H., Evans, P., Leavitt, B., Brady, K.B.C., Cohen, L., and Ziemkiewicz, P., 1997, Neutralization potential of overburden samples containing siderite: Journal of Environmental Quality, Vol. 26, no. 3, p. 673 - 681.

Sobek, A.A., Schuler,W.A., Freeman, J. R., and Smith, R. N., 1978, Field and Laboratory Methods Applicable to Overburden and Minesoils: U.S. Environmental Protection Agency Report EPA-600/2-78-054, 203 p.

U.S. Environmental Protection Agency, 1994, Guidance for the Data Quality Objectives Process: EPA AQ/G4, Office of Research and Development, Report # EPA/600/R-96/055, 74 p.

U.S. Geological Survey, undated, National Field Manual for the Collection of Water Quality Data: Techniques of Water-Resources Investigations, Book 9., TD 223.1, various pages.

Williams, R.D. and Schuman, G. E., (eds.), 1987, Reclaiming mine soils and overburden in the Western U.S.: Soil Conservation Society of America, Ankeny, Iowa, 336 p.

Wyrick, G., and Borchers, J.W., 1981, Hydrologic Effects of Stress-Relief Fracturing in an Appalachian Valley: U.S. Geological Survey Water-Supply Paper 2177, 51 p.

APPENDIX A
NATIONAL DATA BASES

National data bases are a source of ground water, surface water and geologic information that may be used to supplement or satisfy some of the data requirements.

A. U.S. Geological Survey National Water Information System

Information discussed below for the U.S. Geological Survey (USGS) National Water Information System (NWIS) was taken from a description of the NWIS found at the following web site:

http://water.usgs.gov/public/pubs/FS/FS-027-98

The USGS investigates the occurrence, quantity, quality, distribution, and movement of the surface and underground waters that constitute the Nation's water resources. The USGS is the principal Federal water-data agency that collects and disseminates the data being used by State and local governments, public and private utilities, and other Federal agencies to develop and manage our water resources. Data are collected by USGS personnel in all 50 States, plus Puerto Rico and Guam. These hydrologic data are used not only for determining the adequacy of water supplies, but also for implementing flood-warning systems; designing dams, bridges, and flood control projects; allocating irrigation water; locating sources of pollution; planning for energy development; and predicting the potential effects of radioactive waste disposal on water supplies.

1. Description Of The NWIS

As part of the Survey's program of disseminating water data to the public, the Water Resources Division (WRD) maintains a distributed network of computers and fileservers for the storage and retrieval of water data collected through its activities at approximately 1.4 million sites. This system is called the NWIS.

The NWIS is a distributed water database in which data can be processed over a network of computer workstations and fileservers at Survey offices throughout the U.S. The system is composed of four subsystems: the Ground-Water Site-Inventory System, the Water-Quality System, the Automated Data-Processing System, and the Water-Use Data System.

Many types of data are stored in the NWIS distributed, local data bases, including:

- Site information
- Time-series (flow, stage, precipitation, chemical)
- Peak flow
- Ground water
- Water quality
- Water use

2. Ground-Water Site Inventory System

The Ground-Water Site Inventory (GWSI) System contains and provides access to inventory information about sites at stream reaches, wells, test holes, springs, tunnels, drains, lakes, reservoirs, ponds, excavations, and water-use facilities. The system also provides for entering new sites within the local database.

Approximately 300 components make up the descriptive elements of the GWSI. These components are stored in one general data file called the Site File, which contains site information common to all subsystems of the NWIS, and eight GWSI data files that contain ground-water-related information. The eight GWSI data files contain well-construction, ground-water level, ground-water well or spring discharge, geohydrologic characteristics, observation-well report header, aquifer hydraulics, ground-water use by state, and miscellaneous data.

The GWSI retrieval program can be used for retrieving information from the Site File and the associated GWSI files to generate two types of general data tables, four types of water-level tables, or a file suitable for input to other programs.

Through the system menu, the GWSI System maintains the local databases and performs other administrative tasks, including data dictionary modifications and site identification changes, and provides programs for entering field data into files used to update the local database.

3. Water Quality System

The Water Quality System contains results of more than 3.5 million analyses of water samples that describe the chemical, physical, biological, and radiochemical characteristics of both surface and ground waters. Types of chemical data include filtered and/or unfiltered concentrations of major ions, trace elements, nutrients, pesticides, base-neutral organics, acid organics, and volatile organic compounds. Physical characteristics data include pH, specific conductance, water and air temperature, dissolved oxygen, barometric pressure, and percent dissolved oxygen saturation.

Water samples data are analyzed at laboratories equipped to perform chemical analyses ranging from determinations of simple inorganic compounds, such as chlorides, to complex organic compounds, such as pesticides. As each analysis is completed, the results are verified by laboratory personnel and transmitted to the originator of the data by use of a computer, and then stored in their water-quality database.

Sediment data in the Water Quality System include suspended-sediment concentrations in water, sediment-size distributions, and chemical concentrations of suspended sediments and bottom sediments. Biological data in the system include population densities and diversity indexes of periphyton, phytoplankton, and benthic invertebrates.

The system can produce three types of tables of water-quality data and one table of biological population data. Types of summary tables include frequency percentiles; analytical detection limits; sample summary; and alert limits. Several standard output formats, such as flat-file and the 1- and *- format, are available for input to applications. The system's graphic outputs include: X-Y plots, regression plots, box plots, time-series plots, Stiff diagrams, and Piper diagrams.

4. Automated Data-Processing System

The Automated Data Processing System (ADPS) contains more than 850,000 station years of time-series data that describe stream-water levels, streamflow (discharge), reservoir water levels, surface-water quality, ground-water levels, and rainfall. ADPS consists of a collection of computer programs and databases.

The water data stored in ADPS results from the processing of data collected by automated recorders and by observations and manual measurements at field installations around the nation. The data from these sites are transported by field personnel or are relayed through telephones or satellites to offices where USGS personnel, using ADPS procedures, process the data.

The data relayed through the Geostationary Operational Environmental Satellite (GOES) system are processed automatically in near-real time, and in many cases are available within minutes at the local USGS web pages.

5. Water-Use Data System

The Water-Use Data System (WUDS) stores summary data on water use throughout the nation and includes two database systems: the Site-Specific Water-Use Data System (SWUDS), and the Aggregate Water-Use Data System (AWUDS). SWUDS stores measurements and estimates of water use by individual users. AWUDS stores aggregated estimates of water use by county, hydrologic unit, and aquifer. The WUDS is used to enter and update existing water-use data. and to provide retrievals and displays of data that are stored in a local database.

6. NWIS Assistance

General assistance in the operation and application of NWIS is available from the NWIS office in Reston, Virginia. Write to or call:

National Water Information System
U.S. Geological Survey
MS 437, National Center
Reston, VA 20192
Telephone: 703 648-5306.

Water data are available at local Web sites that can be accessed at http://water.usgs.gov/index.html.

Contact information for the USGS State Representatives is available at http://water.usgs.gov/public/staterep.html.

B. USGS National Coal Resources Data System

During the energy crisis of the mid-1970's, the U.S. Geological Survey (USGS), in cooperation with state geological organizations, initiated an ambitious project to create a comprehensive national coal information database. This database, known as the National Coal Resources Data System (NCRDS), was to locate, measure, and characterize all of the Nation's coal resources, regardless of bed thickness, depth, location, or quality. An initial goal of the project was to obtain and characterize at least one sample per coal bed from every geographic quadrangle (approximately 50 to 60 square miles) underlain by coal.

During the 20 years since its inception, the NCRDS Coal Quality database has developed into the largest publicly available database of its kind. As part of this effort the USGS has maintained a coal quality database of national scope, which contains data on more than 13,000 samples). The data in the coal quality database represent analyses of the coal as it exists in the ground. For each sample, 136 parameters are recorded, including location and descriptive data, ASTM analyses (on an as-received moisture basis), and major-, minor-, and trace-element analyses (on a remnant moisture basis). The analyses are presented on a whole-coal basis, except for the oxides, which are presented on an ash basis. Many of these data have been published in various USGS Open-File Reports or other publications.

Public data analyses for 7,430 coal samples representing complete-bed thicknesses at various localities, are available on the USGS Open-File Report (OF97-134) CDROM or by searching the COALQUAL database and NCRDS database found at the following USGS web site: http://energy.er.usgs.gov/products/databases/coalqual/docs/pdflist.pdf

Data for individual analyses, not representing the complete-bed thickness, may be requested from the USGS Eastern Energy Resources Team. Requests for the CDROM, which is available to the public at no charge, or requests for data searches should be made to:

Linda Jean Bragg
USGS
956 National Center
Reston, VA 20192
Email: lbragg@usgs.gov
Phone: 703-648-6451
Fax: 703-648-6419

Requests for information should reference the Freedom of Information Act. When more than one hour is required to complete a data search, costs to cover materials and the hourly wages of the employee performing the search will be charged. Vertical and Lateral Distribution of Coal Quality Components

Further information regarding the availability of USGS data sources can be obtained by accessing the USGS.world wide web on the Internet. See links below.

Home page: http://www.usgs.gov

Water Resources Division: http://h2o.usgs.gov/

C. U.S. Bureau of Land Management (BLM)

While the U.S. Geological Survey is probably the premier data collection agency, the U.S. Bureau of Land Management has a great source of information and data at their “Meta Data and WWW Mapping Home Page.” There is much geospatial data and this site has a large, useful array of literally hundreds of links with directions. Link to:

http://www.blm.gov/gis/narsc/metadata/nsdi.html

D. U.S. Department of Agriculture

The Natural Resources Conservation Service has technical resources on maps, soils data, water, climate and other related subjects. Link to: http://www.nrcs.usda.gov/TechRes.html

E. U.S. Environmental Protection Agency

1. STORET

STORET is a computerized data base utility maintained by the U.S. Environmental Protection Agency (EPA) for the STOrage and RETrieval of parametric data pertaining to the quality of the waterways within and contiguous to the U.S. Since its inception in the early 1960s, the original data base has evolved into a comprehensive system, capable of performing a broad range of reporting, statistical analysis and graphics functions, while continuing to serve in its original role as a repository of parametric water quality data. STORET is accessed by hundreds of users, utilizing computer terminals located throughout the country.

The system is comprised of several individual but related files, which contain various types of information, including:

- Geographic and other descriptive data about the sites where water quality data have been collected, referred to in STORET as "station" data.
- Data related to the physical characteristics and chemical constituents of the water, fish tissue, or sediment sampled, referred to in STORET as "parametric" data.
- Information on pollution-caused fish kills.
- Daily stream flow data.

The data contained in STORET are collected, stored, and used by a variety of Federal, State, and local government agencies and their contractors.

EPA Headquarters provides extensive operational support for the STORET user community, through the STORET User Assistance Section, Assessment and Watershed Protection Division in the Office of Water. User Assistance personnel are available by telephone from 8:00 a.m. to 5:00 p.m. eastern time, Monday through Friday, to answer questions. During those hours, users may call toll free (800) 424-9067. The STORET User Handbook contains complete documentation on how to use the system. Copies of the Handbook are distributed to all new users. A current list of Handbook owners is used as a mailing list for updates, periodicals, memoranda, and other items that may be made available to STORET users.

User assistance personnel also periodically conduct basic and advanced STORET training seminars. (Prerequisites for the advanced seminar are completion of the basic seminar and at least 6 months experience as an active STORET user.) In addition, an annual 3-day users' meeting provides a forum for users from across the country to exchange ideas and share experiences with the use of the system.

Representatives of Federal, State, interstate, and local government agencies and private individuals all are eligible to become STORET users. Depending on the affiliation of the user, there are several methods of monetary compensation of EPA for the use of the system. Charges assessed will not exceed the direct costs in responding to a data request.

For further information on funding or on how STORET can help you fulfill your water quality data analysis needs, contact your Regional STORET representative.

STORET User Assistance ((800) 424-9067) can furnish you with the name and telephone number of your representative. See also the EPA web site at: http://www.epa.gov/storet

F. Pennsylvania State University Coal Data Base

The Pennsylvania State Coal Database contains information on nearly 1,500 coal samples collected from all seven U.S. coal provinces over the past 30 years for inclusion in the Pennsylvania State Coal Sample Bank. These are the PSOC series samples used worldwide and frequently cited in research papers, as well as the recent DECS series. For general purposes, the most useful samples are those representing the entire thickness of the seam at the sample site, of which there are about 675. The others are subsamples which illustrate the heterogeneity of coal properties through the vertical extent of a seam. The database is now operated with Microsoft Access 97.

The data can be divided into several broad categories:

- Sample location, type, description, and geology
- Standard chemical data (proximate, ultimate, sulfur forms, calorific value)
- Petrographic data (maceral analysis and vitrinite reflectance)
- Inorganic constituents (major and trace inorganic elements)
- Technological & utilization testing (Gieseler plastometry, ash fusion data, Hardgrove grindability index, etc.)

Many of the individual analyses are recalculated to several different bases of expression, increasing the number of data fields required. In total over 400 fields are used, although not all are completed for every sample. For the majority of recent samples, the standard printed report format requires four pages to fully describe each sample.

Users may obtain data through Pennsylvania State personnel in several ways, and many transactions can be completed with a telephone call. A standard printed report on an individual sample usually fills four pages. Database searches can be performed and the results used to select individual reports, create a composite table of data, or transmit an electronic data set in one of several file formats. Current fees for these services can be obtained through the contact listed below.

A searchable subset is available on the web site so that users may obtain data directly at no cost. Thirty-one of the most commonly requested data fields and 587 whole-seam, working-section or run-of-mine samples are included. Simple searches based on location, seam name or analytical data are possible. These result in a table listing samples meeting the search criteria, and a one-screen-per-sample data summary is accessible. The web site is expected to provide additional capabilities in the future.

Contact:

Gareth D. Mitchell, Research Associate	Phone	(814) 865-6543
Coal and Organic Petrology Laboratories	Fax	(814) 865-3573
The Pennsylvania State University	email	n8h@psu.edu
105 Academic Projects Bldg.		
University Park, PA 16802-2300		
http://www.ems.psu.edu/COPL		

APPENDIX B

STATE/TRIBAL INFORMATION AND DATA SOURCES

ALABAMA

Alabama Surface Mining Commission **(mining)**
1811 Second Avenue, 2nd Floor
P.O. Box 2390
Jasper, AL 35502-2390
(205) 221-4130
(205) 221-5077 FAX
http://www.surface-mining.state.al.us/

Alabama State Programs Division **(mining)**
Department of Industrial Relations
649 Monroe Street
Montgomery, AL 36131-5200
(334) 242-8265
(334) 242-8403 FAX
http://www.dir.state.al.us/sp.htm

Geological Survey of Alabama and State Oil and Gas Board of Alabama **(geology)**
P.O. Box 869999
Tuscaloosa, AL 35486-6999
(205) 349-2852
http://www.gsa.state.al.us/
http://www.ogb.state.al.us/

Alabama Department of Environmental Management **(Clean Water Act agency)**
1400 Coliseum Blvd.
Montgomery, AL 36110-2059
(334) 271-7823
http://www.adem.state.al.us

ALASKA

Alaska Division of Mining, Land and Water
Surface Coal Mining Section **(mining)**
Water Resources Section **(water)**
Atwood Building
550 West 7th Avenue
Anchorage, AK 99501-3577
(907) 569-8625
Fax: (907) 563-1853
http://www.dnr.state.ak.us/mlw/index.htm

Alaska Department of Natural Resources **(water) (maps)**
Maps Plats and Data
http://www.dnr.state.ak.us/pic/maps.htm

Alaska Division of Geological and Geophysical Surveys **(geology)**
794 University Ave., Suite 200
Fairbanks, AK 99709
(907) 451-5000
Fax: (907) 451-5050
http://wwwdggs.dnr.state.ak.us/

Alaska Div. Of Facility Construction and Operation **(Clean Water Act agency)**
P.O. Box 0
3220 Hospital Drive
Juneau, AK 99811-1800
(907) 465-2610
http://www.state.ak.us/local/akpages/ENV.CONSERV/

Alaska Geospatial Data Clearinghouse **(GIS)**
http://agdc.usgs.gov/

ARIZONA

Arizona State Mine Inspector (mines)
1700 West Washington, Suite 400
Phoenix, AZ 85007
(602) 542-5971
http://www.asmi.state.az.us/

Arizona Dept. of Environmental Quality **(Clean Water Act agency)**
2005 N. Central
Phoenix, AZ 85004
(602) 257-2305
http://www.adeq.state.az.us/

Arizona Department of Water Resources **(water)**
http://www.adwr.state.az.us/relatedlinks.htm

Arizona Geographic Information Council **(GIS)**
http://www.agic.az.gov/agic/agichome.html

ARKANSAS

Arkansas Department of Environmental Quality, Mining Division **(mining)**
P.O. Box 8913
8001 National Drive
Little Rock, AR 72219-8913
(501) 682-0807
Fax: (501) 682-0880
http://www.adeq.state.ar.us/mining/

Arkansas Department of Environmental Quality, Water Division **(Clean Water Act agency)**
P.O. Box 8913
#1 State Police Plaza Drive
Little Rock, AR 72219-8913
(501) 682-0656
Fax: (501) 682-0910
http://www.adeq.state.ar.us/water/

University of Arkansas **(GIS)**
http://www.cast.uark.edu/

COLORADO

Colorado Division of Minerals and Geology **(mining)**
1313 Sherman Streeet, Room 215
Denver, CO 80203
(303) 866-3567
Fax: (303) 832-8106
http://mining.state.co.us/

Colorado Division of Water Resources **(water)**
Denver, CO
(303) 866-3581
http://water.state.co.us/

Colorado Geological Survey **(geology)**
1313 Sherman Street., Room 715
Denver, CO 80203
(303) 866-2611
Fax: (303) 866-2461
http://geosurvey.state.co.us/

Colorado Water Quality Control Division. (Clean Water Act agency)
Dept. of Health
4210 East 11th Avenue, Room 320
Denver, CO 80220
(303) 331-4534
http://www.cdphe.state.co.us/wq/wqhom.asp

CROW TRIBE

Crow Regulatory Program **(mining)**
P.O. Box 159
Crow Agency, MT 59022
(406) 638-2601
Fax: (406) 638-7283

GEORGIA

Georgia Dept. of Natural Resources **(Clean Water Act agency)**
Floyd Towers East, Suite 1152
205 Butler Street, SE
Atlanta, GA 30334
(404) 656-4713
http://www.dnr.state.ga.us/

THE HOPI TRIBE

Abandoned Mine Land Program **(mining)**
Department of Natural Resources
P.O. Box 123 Kykotsmovi, AZ 86039
(502) 724-1879 (Flagstaff)
Fax: (502) 714-1877

ILLINOIS

Illinois Office of Mines and Minerals **(mining)**
300 W. Jefferson, Suite 300
Springfield, IL 62701-1787
(217) 782-6791
http://dnr.state.il.us/mines/mtoc.html

Illinois Environmental Protection Agency **(Clean Water Act agency)**
2200 Churchill Road (alternate ZIP code 62706)
P.O. Box 19726
Springfield, IL 62794-9276
(217) 785-5735
http://www.epa.state.il.us/

Illinois State Geological Survey **(geology)(water)**
615 E. Peabody
Champaign, IL 61820
(217) 333-4747
http://www.isgs.uiuc.edu/isgshome.html

Illinois Geospatial Data Clearinghouse **(geology)(water)(GIS)**
http://www.isgs.uiuc.edu/isgshome/dig-data.htm

INDIANA

Indiana Division of Reclamation **(mining)**
R.R. 2, Box 129
Jasonville, IN 47438-9517
(812) 665-2207
Fax: (812) 665-5041
http://www.state.in.us/dnr/reclamation/

Indiana Dept. of Environmental Management **(Clean Water Act agency)**
P.O. Box 6015
Indianapolis, IN 46206-6015
(317) 232-8476
http://www.state.in.us/idem/

Indiana Geological Survey **(geology)**
611 Walnut Grove
Bloomington, IN 47405
(812) 855-7637
http://igs.indiana.edu/

Indiana Division of Water **(Water)**
http://www.state.in.us/dnr/water/

Indiana GIS Initiative **(GIS)**
http://www.state.in.us/ingisi/

IOWA

Iowa Department of Agriculture & Land Stewardship
Division of Soil Conservation **(Mining) (Water)**
Wallace State Office Building
East 9th and Grand Streets
Des Moines, IA 50319
(515) 281-5347
Fax: (515) 281-6170
http://www.agriculture.state.ia.us/soilconservation.html

Iowa Environmental Protection Div. **(Clean Water Act agency)**
Wallace State Office Building
900 E. Grand Ave.
Des Moines, IA 50319
(515) 281-6284
http://www.state.ia.us/dnr/organiza/epd/

Iowa Geological Survey Bureau **(water) (geology)**
109 Towbridge Hall
Iowa City, IA 52242-1319
(319) 335-1575
Fax: (319) 335-2754
http://www.igsb.uiowa.edu/browse/browse.htm

Iowa Department of Natural Resources **(GIS)**
http://www.igsb.uiowa.edu/nrgis/gishome.htm

KANSAS

Kansas Surface Mining Section **(mining)**
Department of Health & Environment
4033 Parkview Drive
Frontenac, KS 66763
(316) 231-8540
Fax: (316) 231-0753
http://www.kdhe.state.ks.us/mining/

Kansas Dept. of Health and Environment **(Clean Water Act agency)**
Building 740
Forbes Field
Topeka, KS 66620
(913) 296-5502
http://www.kdhe.state.ks.us/environment

Kansas Data Access and Support Center **(GIS)**
http://gisdasc.kgs.ukans.edu/

KENTUCKY

Kentucky Dept. of Surface Mining Reclamation and Enforcement **(mining)**
#2 Hudson Hollow Complex
Frankfort, KY 40601
(502) 564- 6940
http://www.nr.state.ky.us/nrepc/dsmre/NRDSMRE/dsmrehome.htm

Kentucky Natural Resources and Environmental Protection Cabinet **(Clean Water Act agency)**
Fort Boone Plaza
18 Reilly Road
Frankfort, KY 40601
(502) 564-3410
http://water.nr.state.ky.us/dow/dwhome.htm

Kentucky Office Of GIS **(GIS)**
http://ogis.state.ky.us/

LOUISIANA

Department of Natural Resources **(mining)**
Office of Conservation
Injection and Mining Division
P.O. Box 94725
Baton Rouge, LA 70804-9275
(504) 342-5528
Fax: (504) 342-3094
http://www.dnr.state.la.us/CONS/CONSERIN/Surfmine.ssi

Louisiana Dept. of Environmental Quality **(Clean Water Act agency)**
P.O. Box 44091
625 N. Forth St. (alternate ZIP: 70802)
Baton Rouge, LA 70804-4091
(504) 342-6363
http://www.deq.state.la.us/welcome.htm

Louisiana Geographic Information Center **(GIS)**
http://lagic.lsu.edu/

MARYLAND

Maryland Department of the Environment
Bureau of Mines **(mining)**
2500 Broeing Highway
Baltimore, MD 21224
(410) 631-3000
(800) 633-6101
http://www.mde.state.md.us/

Maryland Deptartment of the Environment **(Clean Water Act agency)**
2500 Broening Highway, 2nd Floor
Baltimore, MD 21224
(301) 631-3086
http://www.dnr.state.md.us/

Maryland State Government Information Coordinating Committee (GIS)
http://www.msgic.state.md.us/

MISSISSIPPI

Mississippi Department of Environmental Quality **(mining)(water)(geology)**
2380 Highway 80 West
P.O. Box 20307
Jackson, MS 39289-1307
(601) 961-5500
http://www.deq.state.ms.us/

Mississippi Automated Resource Information System **(GIS)**
http://www.maris.state.ms.us/

MISSOURI

Land Reclamation Program **(mining)(geology)**
Department of Natural Resources
P.O. Box 176
Jefferson City, MO 65102
(573) 751-4041
Fax: (573) 751-0534
http://www.dnr.state.mo.us/geology.htm

Missouri Clean Water Commission **(Clean Water Act agency)**
P.O. Box 176
205 Jefferson St. (alternate ZIP: 65101)
Jefferson City, MO 65102
(314) 751-1142

Missouri Spatial Data Information System **(GIS)**
http://msdis.missouri.edu/

MONTANA

Department of Environmental Quality
P.O. Box 200901
Helena, MT 59620-0901
(406) 444-5270
Fax: (406) 444-1923
http://www.deq.state.mt.us/

Montana Dept. of Health and Environmental Sciences **(Clean Water Act agency)**
Cogswell Building
Capitol Station, Room A206
Helena, MT 59620
(406) 444-2406

Montana NRIS and GIS Coalition **(GIS)**
http://sun1.giac.montana.edu/mlggc.html
http://nris.state.mt.us/gis/gis.html

NAVAJO NATION

Navajo Nation Abandoned Mine Land Reclamation Department **(mining)**
P.O. Box 1910
Window Rock, AZ 86515
(928) 871-6982
Fax: (928) 871-7190
http://www.navajoaml.osmre.gov

Navajo Nation Minerals Department **(mining)**
Division of Natural Resources
P.O. Box 1910
Window Rock, AZ 86515
(928) 871-6587

NEW MEXICO

Mining and Minerals Division **(mining)**
Minerals and Natural Resources Department
2040 South Pacheco Street
Santa Fe, NM 87505
(505) 827-5902
Fax: (505) 827-5988
http://www.emnrd.state.nm.us/mining/

New Mexico Environmental Improvement Division **(Clean Water Act agency)**
Harold Runnels Building, N. 2100
1190 St. Francis Drive
Santa Fe, NM 87503
(505) 827-2793

New Mexico GIS Advisory Council **(GIS)**
http://www.state.nm.us/gisac/gisac_home.html

NORTH DAKOTA

Reclamation Division **(mining)**
North Dakota Public Service Commission
Capitol Building
Bismark, ND 58505
(701) 328-2251
Fax: (701) 328-2410
http://www.psc.state.nd.us/reclaim_frame.htm

North Dakota Dept. Of Health and Consolidated Laboratories **(Clean Water Act agency)**
P.O. Box 5520
1200 Missouri Ave., Room 102
Bismarck, ND 58502-5520
(701) 224-2374

North Dakota State Data Center **(GIS)**
http://www.ndsu.nodak.edu/sdc/

OHIO

Department of Natural Resources
Division of Mines and Reclamation**(mining)**
1855 Fountain Square, Bldg. H-3
Columbus, OH 43224
(614) 265-7079
Fax: (614) 262-7999
http://www.dnr.state.oh.us/

Ohio Environmental Protection Agency **(Clean Water Act agency**)
P.O. Box 1049
1800 Watermark Drive (alternate ZIP: 43215)
Columbus, OH 43266-0149
(614) 644-2001

Ohio Geographically Referenced Information System
http://www.state.oh.us/ogrip/

OKLAHOMA

Oklahoma Department of Mines **(mining)**
4040 North Lincoln Blvd., Suite 107
Oklahoma City, OK 73105
(405) 521-3859
Fax: (405) 427-9646
http://www2.mmind.net/odmmcfo/

Oklahoma State Dept. of Health **(Clean Water Act agency)**
P.O. Box 53551
1000 NE 10th Street
Oklahoma City, OK 73152
(405) 271-8058

Oklahoma Spatial and Environmental Clearinghouse **(GIS)**
http://www.seic.okstate.edu/

PENNSYLVANIA

Pennsylvania Bureau of Mining and Reclamation **(mining)**
mail: P.O. Box 8461
Harrisburg, PA 17105
street: Rachel Carson State Office Building
Harrisburg, PA 17105
(717) 787-5103
Fax: (717) 783-4675
http://www.dep.state.pa.us/dep/deputate/minres/bmr/bmrhome.htm

Pennsylvania Bureau of Water Supply and Wastewater Management **(Clean Water Act agency)**
mail: P.O. Box 8774
Harrisburg, PA 17105
street: Rachel Carson State Office Building. 11th Floor
Harrisburg, PA 17105
(717) 787-5017
http://www.dep.state.pa.us/dep/deputate/watermgt/watermgt.htm

Pennsylvania Mapping and Geographic Information Consortium **(GIS)**
http://www.pamagic.org/

SOUTH DAKOTA

Minerals and Mining Program **(mining)**
South Dakota Department of the Environment and Natural Resources **(mining)**
523 E. Capitol
Joe Foss Building
Pierre, SD 57501
(605) 773-4201
http://www.state.sd.us/denr/DES/mining/mineprg.htm

TENNESSEE

Tennessee Water Pollution Control **(Clean Water Act agency)**
6th Floor, L&C Annex
401 Church Street
Nashville, TN 37243-1534
(615) 532-0625
http://www.state.tn.us/environment/wpc/

TEXAS

Railroad Commission of Texas **(mining)**
Surface Mining and Reclamation Division
P.O. Drawer 12967, Capitol Station
Austin, TX 78711-2967
(512) 463-6900
Fax: (512) 463-6709
http://www.rrc.state.tx.us/divisions/sm/sm.html

Texas Natural Resource Conservation Commission **(Clean Water Act agency)**
P.O. Box 13087
12100 Park 35 Circle
Austin, TX 78753
(512) 239-1000
http://www.tnrcc.state.tx.us

Texas Water Development Board **(water)**
1700 N. Congress Ave.
P.O. Box 13231
Austin, TX 78711-3231
(512) 463-7847
Fax: (512) 475-2053
http://rio.twdb.state.tx.us

Texas Geographic Information Council **(GIS)**
http://www.tgic.state.tx.us/

UTAH

Utah Division of Oil, Gas and Mining
1594 West North Temple
Box 145801
Salt Lake City, UT 84114-5801
(801) 538-5370
Fax: (801) 359-3940

Utah Division of Oil, Gas and Mining **(mining)**
http://www.ogm.utah.gov/

Water Quality Database **(water)**
http://linux1.ogm.utah.gov/cgi-bin/appx-ogm.cgi

Utah Coal Mining Hydrology Information Center **(water)**
http://ogm.utah.gov/coal/water/default.htm

Utah Division of Environmental Health **(Clean Water Act agency)**
P.O. Box 16690
288 N. 1460 W.
Salt Lake City, UT 84116-0690
(801) 538-6148

Utah Department of Natural Resources **(water)**
http://www.nr.utah.gov/

Utah Automated Geographic Reference Center **(geology)**
http://agrc.its.state.ut.us/

University of Utah GPS Networks **(geology)**
http://www.mines.utah.edu/~rbsmith/RESEARCH/UUGPS.html

VIRGINIA

Virginia Department of Mines, Minerals and Energy **(mining)**
Ninth Street Office Bldg., 8th Floor
282 North Ninth Street
Richmond, VA 23219
(804) 692-3202
Fax: (804) 692-3237
http://www.mme.state.va.us/

Virginia Department of Environmental Quality **(water)**
629 East Main Street
Richmond, VA. 23219
P.O. Box 10009
Richmond, VA 23240
(804) 698-4000
(800) 592-5482
http://www.deq.state.va.us/

Virginia State Water Control Board **(Clean Water Act agency)**
P.O. Box 11143
211 North Hamilton Street
Richmond, VA 23230-1143
(804) 367-6384

WASHINGTON

Washington Deptartment of Ecology **(Clean Water Act agency)**
Mail Stop PV-11
Olympia, WA 98504-8711
(206) 459-6101
http://www.ecy.wa.gov/

Washington State Geographic Information Council **(GIS)**
http://www.wa.gov/gic

WEST VIRGINIA

Division of Environmental Protection **(mining)**
10 McJunkin Road
Nitro, WV 25143-2506
(304) 759-0515
Fax: (304) 759-0526
http://www.dep.state.wv.us/item.cfm?ssid=9

WVDEP Mapping and Databases **(mining, water, maps)**
http://www.dep.state.wv.us/

West Virginia Division of Water Resources **(water) (Clean Water Act agency)**
1201 Greenbrier Street
Charleston, WV 25311-1088
Phone: (304) 558-2107
Fax: (304) 558-5905
http://www.dep.state.wv.us/item.cfm?ssid=11

West Virginia Geological and Economic Survey
Mont Chateau Research Center
P.O. Box 879
Morgantown, WV 26507-0879
(800) 984-3656
(304) 594-2331
Fax: (304) 594-2575
http://www.wvgs.wvnet.edu/www/allabout/allabout.htm

WYOMING

Department of Environmental Quality **(mining)**
Herschler Bldg., 4th Floor West
122 West 25th Street
Cheyenne, WY 82002
(307) 777-7682
(307) 777-5973
http://deq.state.wy.us/lqd/index.asp?pageid=9

Wyoming Water Quality Division **(Clean Water Agency)**
Herschler Bldg., 4th Floor
122 West 25th
Cheyenne, WY 82002
(307) 777-7072
http://deq.state.wy.us/wqd/index.asp?pageid=5

Wyoming GIS Home Page **(geology)**
http://www.sdvc.uwyo.edu/index.html
http://wgiac.state.wy.us/

SAMPLE DATABASE

**(Other states may have similar databases.
Contact your State Regulatory Authority)**

Utah Division of Oil, Gas and Mining
Water Quality Database

In the early 1990s, The Utah Division of Oil, Gas and Mining (DOGM) decided to pursue development of a statewide coal hydrology database. This included placing all available historic mining related water quality data into the database. The DOGM had 17 years of hard copy data which needed to be entered. Various database prototype were examined.

In 1995, funding was obtained through grants from the USDA Forest Service and the Office of Surface Mining. These funds were used to hire several data entry personnel to manually enter available hard copy data. The database is located on a Unix server using the Applications Excellence Software, (APPX). Users can access the database directly through the Unix server after being set up with a user ID and password. Data transfer is done via Telnet. The public and non-users may access the system through the Internet at:
http://linux1.ogm.utah.gov/cgi-bin/appx-ogm.cgi

Water quality data for surface-water sites including National Pollutant Discharge Elimination System sites and ground water (springs and wells) associated with coal mine sites are available through the database.

In 1997 the DOGM developed a general information web page to provide the public with information related to mining and water. The Utah Coal Mining Hydrology Information Center can be found at:
http://ogm.utah.gov/coal/water/default.htm

Currently the DOGM is working towards the electronic submittal and automatic entry of data directly from the various mining companies. This is in conjunction with the Division's Electronic Permitting initiative.

For more information contact:

Dana Dean, P.E.
Reclamation Specialist
(801) 538-5320
danadean@utah.gov

APPENDIX C

NATIONAL COAL AREA HYDROLOGY REPORTS

A. The Coal Hydrology Program Of The U.S. Geological Survey As It Pertains To Public Law 95-87[1]

In 1974, a cooperative hydrologic studies program was established between the U.S. Geological Survey (USGS) and the Bureau of Land Management (Bureau or BLM) to aid the latter in the acquisition of data and preparation of Environmental Impact Statements (EIS) and Environmental Assessments (EA) required for Federal coal leases.

In fiscal year 1975, the USGS was funded by Congress to investigate the relationship between coal development and water resources, primarily on Federal lands. This complemented and supplemented the work being done for the Bureau but also addressed more basic research needs. In particular, studies of the geochemistry of coal and coal spoils were initiated to assess water-quality impacts.

In 1977, Public Law 95-87, Surface Mining Control and Reclamation Act (SMCRA), was enacted and served to place environmental constraints on all coal through the permitting process. SMCRA stipulated that a state or federal agency would supply the hydrologic information necessary to describe the hydrology of the general area of mining; furthermore, that each mining permit applicant would make an analysis of the potential hydrologic consequences of the proposed mine operation and that the regulatory agency, federal or state, would perform a probable cumulative impact analysis of all anticipated mining in the area. Thus, as a result of the Act, the USGS received significant increases in funding in 1979 and 1980 for hydrologic data acquisition and dissemination, particularly for work in the heavily mined areas of the East.

The passage of the Act set national policy regarding the control of the surface impacts on water resources, and the need to assess and mitigate these potential impacts is spelled out in the Act. One section, 507(b)(11), requires the "appropriate Federal or State agency" to provide "hydrologic information on the general area" to the mining permit applicant. The Congress recognized that this requirement could not be met by existing hydrologic data systems and, therefore, authorized over seven years beginning in Fiscal Year l979, a total of approximately $40 million to the Water Resources Division (WRD) to be used in acquiring and disseminating the necessary hydrology

[1] Adapted from : Kilpatrick, F. A., 1984, Coal Hydrology Program of the U.S. Geological Survey: 1984 Symposium on the Geology of Rocky Mountain Coal, Proceedings: North Dakota Geological Society, Bismarck, North Dakota 58502, 80 - 88 pp.

information in support of the Act. Particularly significant is that the program now addresses coal mining related hydrology nationwide on both Federal and private lands.

Deficiencies in hydrologic data were most widespread in the eastern coal areas because of the emphasis in previous years on Federal coal. Furthermore, the intensity of mining and number of mines in the East posed a much greater permitting load on regulatory authorities as well as on the USGS to supply supporting hydrologic data. Initial efforts in the eastern states have been concentrated on surface-water data networks due to the complexity of ground water in the Appalachian coal areas. It is expected that site-specific ground-water data eventually will be available from monitoring requirements imposed on mining permittees. The program which was implemented in the East took two approaches: (1) additional water-quality and sediment data were collected at continuous recording surface-water stations and a limited number of new stations were installed on small drainage area streams, and (2) several thousand synoptic sites were established on small streams draining the coal areas. Synoptic measurements are those taken intensely over a broad area at a set time to give a "snap shot" of hydrologic conditions. For example, many measurements are made quickly over a large area during a period of low flow to reveal the severity of underground mine drainage to compare with a similar set of measurements made during a period of runoff to measure the effects of surface mining which would be more pronounced during periods of rainfall.

B. Products

The principal products of the USGS's Coal Hydrology Program are reports which convey to the mining industry and to regulatory and management agencies, data and knowledge of the hydrology of coal mining. As mentioned earlier, a primary responsibility of the USGS in support of the Act was to acquire and disseminate hydrologic information on the general areas of mining. To accomplish this objective, a series of 62 "coal area" reports was planned to provide an overview of the hydrology of the major coal areas of the Nation.

The reporting units are major regional hydrologic sub-basins and correspond to areas of actual and potential coal mining. Fifty seven of the reports are currently completed. Five of the reports are unscheduled due to low priority and lack of funds. The reports are based on existing data and include much of the water-quality data collected as part of the monitoring program. These reports rely heavily on map presentation of data. They typically contain the following types of information on the area being described:

1. General discussions on:

   (a) Geology
   (b) Land forms
   (c) Surface drainage
   (d) Land use
   (e) Soils
   (f) Precipitation

2. Water-use and stream classifications.

3. A description of the hydrologic networks, including surface and ground water where such exist

4. Hydrologic data and information on surface-water quantity such as:

   (a) low flow
   (b) flood flow
   (c) flow duration

5. Information on surface-water quality includes:

   (a) specific conductance
   (b) pH
   (c) sediment
   (d) iron
   (e) manganese
   (f) sulfate
   (g) trace elements
   (h) other as available

6. Information on ground water includes:

   (a) source, recharge, and movement
   (b) water-level fluctuations
   (c) availability
   (d) quality

7. Water-data sources and references to other information that may be useful in appraising the hydrology of the data

C. Examples of Coal Area Reports

Destroy, M. G., Skelton, J., and others, 1983, Hydrology of Area 38, Western Region, Interior Coal Province, Iowa and Missouri: U.S. Geological Survey Water-Resources Investigations 82-1014.

Herb, W. J., and others, 1983, Hydrology of Area I, Eastern Coal Province, Pennsylvania: U.S. Geological Survey Water-Resources Investigations 82-223.

Slagle, S. E., and others, 1983, Hydrology of Area 49, Northern Great Plains and Rocky Mountain Coal Provinces, Montana and Wyoming: U.S. Geological Survey Water-Resources Investigation 82-682.

Wangsness, D. J., and others, 1983, Hydrology of Area 30, Eastern Region, Interior Province, Illinois and Indiana: U.S. Geological Survey Water-Resources Investigation 82-1005.

D. Additional Information

For details about obtaining copies of specific coal area reports and related hydrologic data contact:

Office of Assistant Chief Hydrologist for Information
U.S. Geological Survey, Water Resource Division
439 National Center
Reston, Virginia 20192
Telephone: Carol Marlow (703) 648-6803 or
Celso Puente (703) 648-5601)

APPENDIX D

SAMPLE REPORT OUTLINE FOR PROBABLE HYDROLOGIC CONSEQUENCES (PHC) DETERMINATION

Baseline Information

I. Description of the permit and adjacent area

A. Description of the mining operations including:

- Identify any problems with overburden based on data developed from analyses of test borings or core sampling
- Describe the geology of the permit and adjacent areas
- Describe overburden chemistry
- Review acid-base accounting data for adjacent operations

B. Description of the surface-water system:

- Identify all ephemeral, intermittent, and perennial streams; locate on appropriate maps
- Identify all lakes, ponds, and springs; locate on appropriate maps
- Collect all available surface-water quality and surface-water quantity baseline data for the general area containing the permit plan area
- Identify all water users and locate points of diversion and water quantity and quality needs of users
- Obtain data for similar mining operations in the area

C. Description of the ground-water system:

- Identify all ground-water wells, seeps, and other ground-water discharge areas and locate on appropriate maps
- Collect all available ground-water quality and ground-water quantity baseline data for the general area containing the permit plan area
- List known aquifers and locate on appropriate maps and cross sections
- Describe local and regional components of ground-water flow and their interaction with the surface-water system in the general area containing the permit plan area

- Identify all ground-water users and quantity and quality needs of users
- Obtain data for similar mining operations in the area

D. Description of climatic conditions:

- Collect existing precipitation data for the permit and adjacent areas including monthly and mean annual values
- Collect existing monthly temperature and snowfall data for the permit and adjacent areas
- Collect existing rainfall frequency data for storms for the permit and adjacent area
- Calculate premining estimates of the monthly runoff, evapotranspiration and storage for the permit and adjacent areas

II. Description of baseline data collection program

A. Overburden:

- Existing data
- Sampling program
- Evaluation of data and potential impacts on hydrology

B. Surface water:

- Evaluation of existing data to determine additional data needs
- Describe sampling frequency and identify chemical and physical parameters for analysis
- Present baseline data

C. Ground water:

- Describe the evaluation of existing data to determine additional data needs
- Identify existing domestic wells that may be used to measure ground-water surface, and that can be sampled for water quality
- Describe any additional wells drilled and developed to obtain water levels, water quality data, and for performing aquifer tests
- Present baseline data

D. Soil loss and sediment yield:

- Describe how on-site erosion concerns were identified and predicted
- Determine unstable stream and riparian zones by field and map inspection
- Collect the following data to quantify soil loss and sediment yield:

    - Soils information from published sources

- Water samples during medium and high flow for laboratory analyses of suspended solids
- Field measurements of channel gradients, bank materials, and channel cross sections

E. Alluvial Valley Floors

- Identify Alluvial Valley Floors if mine is located semiarid or arid areas west of the 100th Meridian

Analysis and Prediction Information[2]

III. Prediction of probable hydrologic consequences of the mining operation

A. Prediction of mining impacts (surface water):

- Provide rationale for selection of the hydrologic technique that allows for prediction of the potential impact based on overburden, mining methods, hydrologic concerns, and reclamation plans. The following are some examples:
- Erosion changes (MUSLE, RUSLE)
- Runoff changes (S.S., HEC-1, Rational Equation)
- Chemical quality impacts (empirical relationships to overburden, mixing equations that will handle alkaline-acid buffering, etc.)
- Disruption or elimination of aquifers by removal of the coal resource.
- Assess impacts to receiving streams and water users.

B. Prediction of mining impacts (ground water):

- Identify and select hydrologic techniques that allow for prediction of potential impacts based on chemical analysis of overburden, mining methods, hydrology and reclamation plans. The following are some possible examples of hydrologic analyses:
- Loss or gain of ground water by prediction and analysis of water level changes in unconfined aquifers.
- Changes in aquifer characteristics.
- Chemical change of ground water by solute transport analysis, correlation with overburden chemistry, etc.
- Disruption or elimination of aquifers by removal of the coal resource.
- Assess ground-water impacts on receiving streams, regional aquifers, and local water users.

---

2 To be used with subsequent analysis and prediction technical reference document

C. Make predictions of mining impacts on stream morphology:

- Changes in stream stability.
- Upland stability problems.
- Impact on land use, water uses, etc.
- Effect of permanent structures (ponds, diversions, etc.) on stream morphology.

IV. Summary And Conclusions

APPENDIX E

SAMPLE REPORT OUTLINE FOR A CUMULATIVE HYDROLOGIC IMPACT ASSESSMENT (CHIA)

Baseline Information

I. Discussion of CHIA process elements

A. Cumulative impact area (CIA)

- Maximum upstream and downstream extent of CIA.

  a. Discuss criteria used to evaluate significance of spatially remote operations.
  b. Discuss application of criteria and resulting CIA extremes.

- Delineate watershed area between these points on suitable map.

  a. Discuss existing and other anticipated mining operations and locate on map.
  b. Discuss process of delineating surface-water CIA.
  c. Discuss process of delineating ground-water CIA.
  d. Show working CIA on suitable map.

B. Hydrologic baseline conditions in the CIA

1. Determine adequacy of available hydrologic data.

   a. Surface-water data.
   b. Ground-water data.

2. Characterization of the hydrologic system.

   a. surface-water system.

      i. Physical description of surface-water system.
      ii. Flows.
      iii. Surface-water quality.
      iv. Inventory surface-water usage.

   b. ground-water system

      i. Physical description of ground-water system.
      ii. Ground-water flow.
      iii. Ground-water quality.
   iv. Inventory ground-water usage.

C. Hydrologic concerns and associated indicator parameters

1. Surface-water concerns

   a. Identify concerns (Discuss rationale for inclusion of each concern.)
   b. Indicator parameters used to evaluate surface-water concerns (Discuss reasons for selection of specific parameters.)
   c. Impact assessment sites.

      i. Discuss selection of sites where impacts are to be assessed.
      ii. Locate sites on map of CIA (Use map prepared in step I.A.).

2. Ground-water concerns

   a. Identify concerns (Discuss rationale for inclusion of each concern.)
   b. Indicator parameters used to evaluate ground-water concerns (Discuss reasons for selection of specific parameters.)
   c. Impact assessment sites.

      i. Discuss selection of sites where impacts are to be assessed.
      ii. Locate sites on map of CIA.

Analysis and Prediction Information[3]

D. Material damage criteria considerations

1. Existing water-quality standards.
2. Existing water-quantity standards.
3. Development of limiting parameter values for concerns inadequately covered by existing standards.
4. Site-specific material damage criteria.

    a. Prepare list of criteria for each parameter at each site.

E. Assessment of cumulative impacts of mining on indicator parameters

1. Mining methods used within the CIA.

    a. Describe the mining methods used.
    b. Discuss the effects of various mining methods on hydrology of the CIA.

2. Surface water

    a. Predictive methods used.

        i. Discuss reasons for using these methods.
        ii. Discuss assumptions of the methods.
        iii. Discuss data requirements of the methods.
        iv. Discuss procedure used to calibrate method.

    b. Projected values of indicator parameters at identified surface-water impact sites--long- and short-term impacts.

        i. Discuss difference in procedure to obtain short-and long-term parameter values.
        ii. Discuss quantity parameters for each site.
        iii. Discuss quality parameters for each site.

---

[3] To be used with subsequent analysis and prediction technical reference document

3. Ground water

    a. Predictive methods used.

        i. Discuss reasons for using these methods.
        ii. Discuss assumptions of the methods.
        iii. Discuss data requirements of the methods.
        iv. Discuss procedure used to calibrate method.

    b. Projected values of indicator parameters at identified ground-water impact sites.

II. Determination and statement of findings

A. Determination of material damage potential

1. Surface water

    a. Comparison of projected values with material damage criteria.
    b. Potential for material damage to the surface-water system.

2. Ground water

    a. Comparison of projected values with material damage criteria.
    b. Potential for material damage to the ground-water system.

B. Statement of findings

1. Summary of findings
2. Discussion

III. <u>References</u>

IV. <u>Appendices</u>

- Baseline hydrologic data

APPENDIX F

SAMPLE PROCEDURE FOR DELINEATING THE CUMULATIVE IMPACT AREA (CIA)

Step I. Define the maximum upstream and downstream extent of CIA

- Develop criteria for excluding operations from the CIA that are spatially remote from the proposed operation but that are within the same major surface drainage system.

- Apply criteria to locate maximum extent of working CIA, both upstream and downstream from the proposed operation. (Note: In the case of a first order watershed, there will be no upstream point. The CIA will be, in part, defined by the watershed boundary.) This may include extending the CIA to a nearby public water-supply intake.

- Delineate the watershed area enveloping these two points. This is the first approximation of the CIA.

Step II. Delineate the working CIA within area defined in Step 1

- Identify all anticipated mining operations. This includes life-of-mine area of proposed operation, existing operations, operations with submitted applications, and Federal leases with diligence requirements within the area defined in step 1.

- Identify the downstream limit of the surface-water CIA. Identify on a receiving stream common to two or more anticipated mining operations a point downstream from all tributary stream channels whose flows are likely to be affected by mining. Consider this point as the downstream limit of the surface-water CIA on that stream. Repeat on other receiving streams, as necessary.

Step III. Identify the downgradient limit of the ground-water CIA

- Identify all geologic strata likely to be affected by the anticipated mining operations. Also, identify recharge and discharge areas for the aquifers.

- Delineate area over which ground-water quantity and quality may be affected by the identified mines. (Requires determining, or making reasonable estimates, of the direction(s) and rate(s) of ground-water movement.)

  a. Delineate area of ground-water drawdown (cone of depression) caused by each operation in each aquifer.

  b. For each aquifer, delineate the potential area that ground-water pollution from each operation would pass through in moving from the mine to probable discharge points.

3. Identify probable stream reaches that discharge into, or receive discharge from, aquifers affected by the identified mining operations.

Step IV. Delineate working CIA

a. Surface-water CIA. Delineate surface-water CIA boundary along natural drainage boundaries which completely encompass all the impact areas of the operations in Step 2.

b. Ground-water CIA. Delineate ground-water CIA boundary to encompass the maximum potential extent of pollution and areas of drawdown. Include all cones of depression and areas of potential pollution that may affect or discharge to common surface streams or alluvial aquifers, or are contiguous with cone or plume of proposed operation.

c. The composite of the ground- and surface-water CIAs is the working CIA for the proposed operation.

APPENDIX G

STATUTORY REQUIREMENTS FOR DETERMINATION OF PROBABLE HYDROLOGIC CONSEQUENCES AND CUMULATIVE HYDROLOGIC IMPACT ASSESSMENT

A primary purpose of the Surface Mining Control and Reclamation Act of 1977, 30 U.S.C. 1201 *et seq.* (SMCRA or the Act), is "to protect society and the environment from the adverse effects of surface coal mining." In particular, the Act stresses protection of the hydrologic balance. Sections 507, 508, 510, 515, 516, and 717 of the Act set forth the main hydrologic and geologic requirements for permitting, mining, and reclaiming a surface coal mining operation.

Two of the main elements in the permitting process are the determination of PHC and the CHIA. Hydrologic protection, in general, constitutes a major focus of the Title V program and applicable statutory references are excerpted below.

Section 507 - Application Requirements

507(b) The permit application shall be submitted in a manner satisfactory to the regulatory authority and shall contain, among other things –

* * * * * * *

507(b)(11) a determination of the probable hydrologic consequences of the mining and reclamation operations, both on and off the mine site, with respect to the hydrologic regime, quantity and quality of water in surface and ground water systems including the dissolved and suspended solids under seasonal flow conditions and the collection of sufficient data for the mine site and surrounding areas so that an assessment can be made by the regulatory authority of the probable cumulative impacts of all anticipated mining in the area upon the hydrology of the area and particularly upon the water availability: <u>Provided, however</u>, that this determination shall not be required until such time as hydrologic information on the general area prior to mining is made available from an appropriate Federal or State agency: <u>Provided further</u>, that the permit shall not be approved until such information is available and is incorporated into the application.

507(b)(14) cross sections, maps or plans of land to be affected by an application for a surface mining and reclamation permit shall be prepared by or under the direction of a qualified registered professional engineer or geologist, or qualified registered professional land surveyor in any State which authorizes land surveyors to prepare and certify such maps or plans, with assistance from experts in related fields such as land surveying and landscape architecture, showing pertinent elevation and location of test borings or core samplings and depicting the following information: the nature and depth of the various strata of overburden; the location of subsurface water, if encountered, and its quality; the nature and thickness of any coal or rider seam above the coal seam to be seam mined; the nature of the stratum immediately beneath the coal seam to be mined; all mineral crop lines and the strike and dip of the coal to be mined, within the area of land to be affected; existing or previous surface mining limits; the location and extent of known workings of any underground mines, including mine openings to the surface; the location of aquifers; the estimated elevation of the water table; the location of spoil, waste, or refuse areas and topsoil preservation areas; the location of all impoundments for waste or erosion control; any settling or water treatment facility; constructed or natural drain ways and the location of any discharges to any surface body of water on the area of land to be affected or adjacent thereto; and profiles at appropriate cross sections of the anticipated final surface configuration that will be achieved pursuant to the operator's proposed reclamation plan (as amended November 4, 1983).

507(b)(15) a statement of the result of test borings or core samplings from the permit area, including logs of the drill holes; the thickness of the coal seam found, an analysis of the chemical properties of such coal; the sulfur content of any coal seam; chemical analysis of potentially acid or toxic forming sections of the overburden; and chemical analysis of the stratum lying immediately underneath the coal to be mined except that the provisions of this paragraph (15) may be waived by the regulatory authority with respect to the specific application by a written determination that such requirements are unnecessary.

Section 508 - Reclamation Plan Requirements

508(a) Each reclamation plan submitted as part of a permit application * * * shall include, in the degree of detail necessary to demonstrate that reclamation required by the State or Federal program can be accomplished, a statement of:

* * * * * * *

508(a)(5) the engineering techniques proposed to be used in mining and reclamation and a description of the major equipment; a plan for the control of surface-water drainage and of water accumulation; a plan, where appropriate, for backfilling, soil stabilization, and compacting, grading, and appropriate re-vegetation; a plan for soil reconstruction, replacement, and stabilization, pursuant to the performance standards in section 515(b)(7)(A), (B), (C), and (D), for those food, forage, and forest lands identified in sections 515(b)(7); an estimate of the cost per acre of the reclamation, including a statement as to how the permittee plans to comply with each of the requirements set out in section 515.

508(a)(9) the steps to be taken to comply with applicable air and water quality laws and regulations and any applicable health and safety standards.

508(a)(12) the results of test boring which the applicant has made at the area to be covered by the permit, or other equivalent information and data in a form satisfactory to the regulatory authority, including the location of subsurface water, and an analysis of the chemical properties including acid-forming properties of the mineral and overburden: Provided, that information which pertains only to the analysis of the chemical and physical properties of the coal (excepting information regarding such mineral or elemental contents which is potentially toxic in the environment) shall be kept confidential and not made a matter of public record.

508(a)(13) a detailed description of the measures to be taken during the mining and reclamation process to assure the protection of:

(A) The quality of surface and ground water systems, both on- and off-site, from adverse effects of the mining and reclamation process.

(B) The rights of present users to such water.

(C) The quantity of surface- and ground-water systems, both on- and off-site, from adverse effects of the mining and reclamation process or to provide alternative sources of water where such protection of quantity cannot be assured.

Section 509 - Performance Bonds

509(a) After a surface coal mining and reclamation permit application has been approved but before such a permit is issued, the applicant shall file with the regulatory authority, on a form prescribed and furnished by the regulatory authority, a bond for performance payable, as appropriate, to the U.S. or to the State, and conditional upon faithful performance of all the requirements of this Act and permit. The bond shall cover that area of land within the permit area upon which the operator will initiate and conduct surface coal mining and reclamation operations within the initial term of the permit. As succeeding increments of surface coal mining and reclamation operations are to be initiated and conducted within the permit area, the permittee shall file with the regulatory authority an additional bond or bonds to cover such increments in accordance with this section. The amount of the bond required for each bonded area shall depend upon the reclamation requirements of the approved permit; shall reflect the probable difficulty of reclamation giving consideration to such factors as topography, geology of the site, hydrology, and re-vegetation potential, and shall be determined by the regulatory authority. The amount of the bond shall be sufficient to assure the completion of the reclamation plan if the work had to be performed by the regulatory authority in the event of forfeiture and in no case shall the bond for the entire area under one permit be less than $10,000.

Section 510 - Permit Approval or Denial

510(b) No permit or revision application shall be approved unless the application affirmatively demonstrates and the regulatory authority finds in writing on the basis of the information set forth in the application or from information otherwise available which will be documented in the approval, and made available to the applicant, that –

* * * * * * *

510(b)(3) the assessment of the probable cumulative impact of all anticipated mining in the area on the hydrologic balance specified in section 507(b) has been made by the regulatory authority and the proposed operation thereof has been designed to prevent material damage to hydrologic balance outside permit area.

510(b)(5) the proposed surface coal mining operation, if located west of the one hundredth meridian west longitude, would -
(A) not interrupt, discontinue, or preclude farming on alluvial valley floors that are irrigated or naturally subirrigated, but, excluding undeveloped range lands which are not significant to farming on said alluvial valley floors and those lands as to which the regulatory authority finds that if the farming that will be interrupted, discontinued, or precluded is of such small acreage as to be of negligible impact on the farm's agricultural production, or
(B) not materially damage the quantity or quality of water in surface or underground water systems that supply these valley floors in (A) of subsection (b)(5).

Section 515 - Environmental Protection Performance Standards

515(b) General performance standards shall be applicable to all surface coal mining and reclamation operations and shall require the operation as a minimum to –

* * * * * * *

515(b)(4) stabilize and protect all surface areas including spoil piles affected by the surface coal mining and reclamation operation to effectively control erosion and attendant air and water pollution.

515(b)(8) create, if authorized in the approved mining and reclamation plan and permit, permanent impoundments of water on mining sites as part of reclamation activities only when it is adequately demonstrated that--

(A) The size of the impoundment is adequate for its intended purposes.

(B) The impoundment dam construction will be so designed as to achieve necessary stability with an adequate margin of safety compatible with that of structures constructed under Public Law 83-566 (16 U.S.C. 1006).

(C) The quality of impounded water will be suitable on a permanent basis for its intended use and that discharges from the impoundment will not degrade the water quality below water quality standards established pursuant to applicable Federal and State law in the receiving stream.

(D) The level of water will be reasonably stable.

(E) Final grading will provide adequate safety and access for proposed water users.

(F) Such water impoundments will not result in the diminution of the quality or quantity of water utilized by adjacent or surrounding landowners for agricultural, industrial, recreational, or domestic uses.

515(b)(9) conduct any augering operation associated with surface mining in a manner to maximize recoverability of mineral reserves remaining after the operation and reclamation are complete; and seal all auger holes with an impervious and noncombustible material in order to prevent drainage except where the regulatory authority determines that the resulting impoundment of water in such auger holes may create a hazard to the environment or the public health or safety: Provided, that the permitting authority may prohibit augering if necessary to maximize the utilization, recoverability or conservation of the solid fuel resources or to protect against adverse water quality impacts;

515(b)(10) minimize the disturbances to the prevailing hydrologic balance at the mine site and in associated off-site areas and to the quality and quantity of water in surface and ground water systems both during and after surface coal mining operations and during reclamation by- -

(A) Avoiding acid or other toxic mine drainage by such measures as, but not limited to- -

(i) Preventing or removing water from contact with toxic producing deposits.

(ii) Treating drainage to reduce toxic content which adversely affects downstream water upon being released to water courses.

(iii) Casing, sealing, or otherwise managing boreholes, shafts, and wells and keeping acid or other toxic drainage from entering ground and surface waters.

(B)(I) Conducting surface coal mining operations so as to prevent, to the extent possible using the best technology currently available, additional contributions of suspended solids to streamflow, or runoff outside the permit area, but in no event shall contributions be in excess of requirements set by applicable State or Federal law;

(ii) Constructing any siltation structures pursuant to subparagraph (B) (I) of this subsection prior to commencement of surface coal mining operations, such structures to be certified by a qualified registered engineer to be constructed as designed and as approved in the reclamation plan.

(C) Cleaning out and removing temporary or large settling ponds or other siltation structures from drain ways after disturbed areas are re-vegetated and stabilized; and depositing the silt and debris at a site and in a manner approved by the regulatory authority.

(D) Restoring recharge capacity of the mined area to approximate premining conditions.

(E) Avoiding channel deepening or enlargement in operations requiring the discharge of water from mines.

(F) Preserving throughout the mining and reclamation process the essential hydrologic functions of alluvial valley floors in the arid and semiarid areas of the country.

(G) Such other actions as the regulatory authority may prescribe.

515(b)(17) insure that the construction, maintenance, and postmining conditions of access roads into and across the site of operators will control or prevent erosion and siltation, pollution of water, damage of fish or wildlife or their habitat, or public or private property.

515(b)(18) refrain from the construction of roads or other access ways up a stream bed or drainage channel or in such proximity to such channel so as to seriously alter the normal flow of water.

515(b)(24) to the extent possible using the best technology currently available, minimize disturbances and adverse impacts of the operation of fish, wildlife, and related environmental values, and achieve enhancement of such resources where practicable.

Section 516 - Surface Effects of Underground Coal Mining Operations

516(b) Each permit issued under any approved State or Federal program pursuant to this Act and relating to underground coal mining shall require the operator to –

* * * * * * *

516(b)(4) with respect to surface disposal of mine wastes, tailings, coal processing wastes, and other wastes in areas other than the mine workings or excavations, stabilize all waste piles created by the permittee from current operations through construction in compacted layers including the use of incombustible and impervious materials if necessary and assure that the leachate will not degrade below water quality standards established pursuant to applicable Federal and State law surface or ground-waters and that the final contour of the waste accumulation will be compatible with natural surroundings and that the site is stabilized and re-vegetated according to the provisions of this section.

516(b)(9) minimize the disturbances of the prevailing hydrologic balance at the minesite and in associated off-site areas and to the quantity of water in surface ground-water systems both during and after coal mining operations and during reclamation by –

(A) Avoiding acid or other toxic mine drainage by such measures as, but not limited to–

(i) Preventing or removing water from contact with toxic producing deposits.

(ii) Treating drainage to reduce toxic content which adversely affects downstream water upon being released to water courses.

(iii) Casing, sealing, or otherwise managing boreholes, shafts, and wells to keep acid or other toxic drainage from entering ground and surface waters.

(B) Conducting surface coal mining operations so as to prevent, to the extent possible using the best technology currently available, additional contributions of suspended solids to streamflow or runoff outside the permit area (but in no event shall such contributions be in excess of requirements set by applicable State or Federal law), and avoiding channel deepening or enlargement in operations requiring the discharge of water from mines.

516(b)(12) locate openings for all new drift mines working acid producing or iron producing coal seams in such a manner as to prevent a gravity discharge of water from the mine.

Section 517 - Inspections and Monitoring

517(b) For the purpose of developing or assisting in the development, administration, and enforcement of any approved State or Federal program under this Act or in the administration and enforcement of any permit under this Act, or of determining whether any person is in violation of any requirement of any such State or Federal program or any other requirement of this Act –

* * * * * * *

517(b)(2) for those surface coal mining and reclamation operations which remove or disturb strata that serve as aquifers which significantly insure the hydrologic balance of water use either on or off the mining site, the regulatory authority shall specify those –

(A) monitoring sites to record the quantity and quality of surface drainage above and below the minesite as well as in the potential zone of influence.

(B) monitoring sites to record level, amount, and samples of ground water and aquifers potentially affected by the mining and also directly below the lowermost (deepest) coal seam to be mined.

(C) records of well logs and borehole data to be maintained.

(D) monitoring sites to record precipitation.

The monitoring data collection and analysis required by this section shall be conducted according to standards and procedures set forth by the regulatory authority in order to assure their reliability and validity.

Section 519 - Release of Performance Bonds

519(c) The regulatory authority may release in whole or in part said bond or deposit if the authority is satisfied the reclamation covered by the bond or deposit or portion thereof has been accomplished as required by this Act according to the following schedule:

* * * * * * *

519(c)(2) after re-vegetation has been established on the regraded mined lands in accordance with the approved reclamation plan. When determining the amount of bond to be released after successful re-vegetation has been established, the regulatory authority shall retain that amount of bond for the re-vegetated area which would be sufficient for a third party to cover the cost of reestablishing re-vegetation and for the period specified for operator responsibility in section 515 of reestablishing re-vegetation. No part of the bond or deposit shall be released under this paragraph so long as the lands to which the release would be applicable are contributing suspended solids to streamflow or runoff outside the permit area in excess of the requirements set by section 515(b)(10) or until soil productivity for prime farm lands has returned to equivalent levels of yield as un-mined land of the same soil type in the surrounding area under equivalent management practices as determined from the soil survey performed pursuant to section 507(b)(16). Where a silt dam is to be retained as a permanent impoundment pursuant to section 515(b)(8), the portion of bond may be released under this paragraph so long as provisions for sound future maintenance by the operator or the landowner have been made with the regulatory authority.

Section 717 - Water Rights and Replacement

717(b) The operator of a surface coal mine shall replace the water supply of an owner of interest in real property who obtains all or part of his supply of water for domestic, agricultural, industrial, or other legitimate use from an underground or surface source where such supply has been affected by contamination, diminution, or interruption proximately resulting from such surface coal mine operation.

Section 720 - Subsidence

720(a) Underground coal mining operations conducted after the date of enactment of this section shall comply with each of the following requirements:

* * * * * * *

720(a)(2) promptly replace any drinking, domestic, or residential water supply from a well or spring in existence prior to the application for a surface coal mining and reclamation permit, which has been affected by contamination, diminution, or interruption resulting from underground coal mining operations.

APPENDIX H

REGIONAL EXAMPLE SHOWING BASELINE INFORMATION FOR GEOLOGY AND HYDROLOGY

EASTERN SITE

The number of locations at which site-specific baseline data for geology, overburden, surface water and ground water needs to be collected depends on many variables. Rather than presenting and attempting to rationalize minimum or maximum numbers and locations for surface-water stations, boreholes for overburden data, ground-water observation wells and frequency and duration of water sampling, we have included summaries of baseline information for geology and hydrology as it exists in planned or actual permits. We refer to these summaries as regional examples of baseline data requirements. In this context, regional can refer to hydrologic issues as may exist in one region but not all regions of the country and for which precise kinds and amounts of data are needed to establish, for example, the potential for acid-mine drainage formation. Regional may also refer to differences in philosophy and technical approach to sampling and standards deemed acceptable for baseline geology and hydrology information from one state or region to another.

The three examples of baseline information collection from different regions of the country are presented in Appendices H, I, and J.

- The following eastern permit example represents an area surface mine in a temperate humid region.

- The mid-continent permit example which is presented in Appendix I represents an area lignite mine in temperate continental region.

- The western example which is presented in Appendix J summarizes an actual work plan for baseline data collection for an area mine in a semiarid region. The plan was developed by the operator in close cooperation with the RA. The work plan illustrates how the need for new ground- and surface-water stations and data collection was based on an evaluation of existing information from nearby mines.

The Appalachian Region (AR) Mine is an area mine. The mine is situated in southeastern Tennessee in Sequatchie County about 35 miles northwest of Chattanooga. The area is within the Cumberland Mountains. The site is somewhat hilly with elevations ranging from 1800' to 1960'. The site receives about 54 inches of precipitation per year, and is primarily hardwood forested. The proposed acreage to be mined is 950 acres. Two draglines were proposed to be utilized along with “cast-blasting” techniques to move the overburden. In cast-blasting operations, the overlying 60 - 80 foot sandstone is drilled and blasted in such a manner to cast it into the previous pit. The coal seam has a history of producing acid or toxic mine drainage.

A. Geologic Setting

1. Physiography and Topography

The proposed mine site is located within the physiographic division of Tennessee known as the Cumberland Plateau. It is part of the Appalachian Plateau physiographic province of the eastern U.S. which extends from southern New York to central Alabama. The plateau consists of broad and relatively flat uplands which are capped with resistant Pennsylvanian age sandstones. These sandstones have protected the underlying, less resistant formations from erosion. The plateau is about 1000 feet higher than the surrounding lowlands. Surface elevations range from 1,700 to 2,000 feet in the region with some knobs considerably higher.

The eastern border of the plateau consists of an abrupt escarpment which is slightly dissected by eastern flowing streams. The western edge of the plateau is irregular and deeply dissected by western flowing streams.

The permit area for this operation is situated on the southern half of the Cumberland Plateau which is bisected by the Sequatchie Valley, a northeast-southwest trending valley approximately 180 miles long. The part of the Sequatchie valley which lies in Tennessee is 75 miles long and averages 5 miles wide.

2. Regional Structure

The Cumberland Plateau is bounded on the east by the Valley and Ridge Province which is characterized by imbricate faulting and folding and bounded on the west by the Nashville Dome, a broad arch with gentle southeast dip. The plateau region is divided into well drained sub-provinces of gentle dip which are separated by sharp structural features.

The mine site lies in the sub-province known as the Southern Cumberland Plateau, a broad symmetrical syncline, the axis of which is parallel to and near the western side of Sequatchie Valley. Along the western escarpment of the valley, the rocks dip steeply to the northwest, then gradually flatten out and begin to rise gently to the northwest in response to the syncline. Local variations of the regional dips are present as a result of local structure features but are often obscured due to the lack of detailed mapping.

3. Regional Stratigraphy

The subject area is entirely underlain by rocks of the Crab Orchard Mountain Group of the Pottsville series of lower Pennsylvanian age. This group contains, in descending order, the Rockcastle Conglomerate, Vandever Formation, Newton Sandstone, Whitwell Shale, and the Sewanee Conglomerate. The strata present in these formations are comprised mainly of well-cemented, often conglomeritic sandstones, olive-gray shales, and silty to sandy olive-gray shales. Coal seams of varying thicknesses are found in the shale zones throughout the group. The total thickness of the Crab Orchard Mountain Group in this area is 450 to 550 feet.

The Rockcastle Conglomerate is the youngest formation occurring in the group and it caps many of the higher ridges on the Plateau. This unit is a medium to coarse grained, conglomeritic, massive, cross-bedded sandstone and contains a persistent shale split generally less than 15 feet thick which contains the Nemo coal seam.

The next younger formation is the Vandever Sandstone. It usually consists of a lower shale member, a middle sandstone, and an upper shale member. This formation ranges up to 400 feet thick and usually contains at least 2 coal zones. The lower coal is less than 1 foot thick in the mine area.

The Newton Sandstone underlies the Vandever Formation and consists of a fine to medium grained, sometimes friable sandstone. Its thickness in the area is about 100 feet.

Below the Newton Sandstone lies the Whitwell Shale. This formation varies in thickness from 30 to 200 feet and sometimes contains a sandstone unit which is locally conglomeritic. The Whitwell Shale usually contains one important coal seam, the Sewanee, and often contains the Richland seam which occurs near the base of the formation. In areas where the Whitwell attains its maximum thickness, there can be four coal seams present.

The Whitwell Shale grades downward in the Sewanee Conglomerate. This formation ranges in thickness from 60 to 200 feet on the plateau. It generally occurs as a medium to coarse grained, crossbedded, massive, extremely conglomeritic sandstone, although sometimes the quartz pebbles may be completely absent. This sandstone is generally a very persistent, recognizable marker bed throughout the plateau except in the northwest region of the plateau where it rapidly pinches out.

4. Site Structure

The site structure consists of rocks with a northeast strike between 10 degrees and 25 degrees and a dip to the southeast between 1 and 2 degrees. Local rolls in the Sewanee coal zone are common and may result in slight variations in local dip. No major structural features are present within or immediately adjacent to the permit area.

5. Site Stratigraphy

A typical mining section within the permit area consists of 30 to 100 feet of Newton Sandstone overlying 10 to 50 feet of Whitwell Shale. The Newton Sandstone is a well indurated, micaceous orthoquartzite. Individual quartz grains comprising the sandstone are predominantly held together by silica cement. Occasionally, however, the silica cement will be replaced by sparry calcite.

The Whitwell Shale consists of olive gray thinly bedded shale. Lateral and vertical graduations to silty or sandy shale are present on the site and generally occur below the Newton Sandstone near the top of the Whitwell. Pronounced thickness variations in the two units have resulted from depositional factors and should be expected within the permit area.

The Sewanee coal seam lies near the middle of the Whitwell shale and is 15 to 60 inches thick. It is separated from the Sewanee Conglomerate by an average of 20 to 50 feet of Whitwell shale. The Richland coal seam lies approximately 20 feet below the Sewanee coal and consists of thin, discontinuous stringers.

The operation will mine the Sewanee coal seam, without disturbing the Richland seam. In some higher elevations in the permit area, the Lantana coal seam will be encountered, but the seam is too small and of poor quality to mine.

6. Structural Features from Deformational Processes

The site is relatively flat in comparison to many typical Appalachian mines. This means fracturing from stress relief is not significant. However, where first order streams have dissected the mine area there is some 10 to 40 feet of relief and some stress relief fracturing can be seen. On the eastern end of the property the mine nears Big Brush Creek, a second and third order drainage. Here the relief can approach 200 feet and stress relief fracturing can be significant. For this reason, the operation will remain 200 to 300 feet away from the major stream valley to minimize spoil leakage to the fracture zone.

7. Drilling Program

Much was known about the acid and toxic forming material at the site through experience with adjacent operations. There are three other large area mines adjacent to the site that provided important field data on the spoil water chemistry. The coal seam and overburden have pockets of acid-forming material that in other areas have caused acid mine drainage with pH just below 6 units and elevated iron and manganese concentrations.

Core drilling was conducted at the site. However, the drilling methods, equipment, and recovery techniques were not specified and sample and composite methods were not noted. The coal seams and overburden were analyzed for fizz, paste pH, total sulfur, pyritic sulfur, modified neutralization potential to account for siderite, and potential acidity. About 10% of the coal is not recovered in this type of operation so the acid base accounting model included a 10% coal waste factor. Analysis followed procedures contained in "EPA Field and Laboratory Methods Applicable to Overburdens and Mine Soils." (EPA 600 3.2 and ASTM C-25) The modified neutralization potential procedure consisted of addition of 5 ml of 30% H_2O_2 and then re-boiling before titrating the sample.

Drill hole samples were sent to the lab within 3 days to 18 days. Because samples can weather in a little as 3 days depending on humidity, OSM required future samples to be placed in plastic bags and delivered to the lab within 7 days.

The 60 foot sandstone unit above the Whitwell Shale was not analyzed except for the bottom 12 feet, because this strata normally tests out as net neutral, even when siderite is accounted for. The sandstone strata has been extensively tested at two adjacent mines adjoining this operation. The U.S. Bureau of Mines conducted x-ray diffraction tests on the overburden. The sandstone was subjected to leach tests by Dr. Frank Carrucio that showed that even though the rock has little potential acidity and much potential neutralization, it does not weather and release the stored alkalinity. For this reason, the sandstone was considered inert in the acid base accounting model, a conservative assumption.

In order to evaluate the AMD potential at the AR Mine, the applicant drilled 23 drill holes. This is equivalent to one drill hole per 40 acres. Almost every drill hole showed some acid/toxic forming material, primarily in the Whitwell Shale. There is also acid/toxic material associated with the Lantana coal seam which is present in the west portion of the proposed permit area. A thickness weighted Net Acid Base (NAB) value was calculated for each hole for the Whitwell Shale zone, using total sulfur. Volume weighted calculations were not necessary since the site is flat and the operation will not mine to the outcrop.

Drill hole data from the adjacent AR2 Mine was also evaluated since it was drilled on 500 foot centers (or one drill hole per 5.7 acres). This data showed the shale zone as having the major portion of pyritic material.

OSM used Universal (I) Kriging software to interpolate the data at the AR2 Mine and extrapolate into the adjacent proposed AR Mine. A 500' by 500' grid was created using ARC/INFO software. The Kriging program calculated a predicted NAB value for empty cells based on cells that contained drill hole data. Ninety nine drill holes were used in the simulation. The results showed most of the acid-forming materials is confined to the south 1/3 of the permit area.

OSM also used a statistical technique called Semivariographs, to evaluate the proper drill spacing. The model calculates the semivariance between each pair of drill holes located so many feet apart. The difference is squared and summed, then divided by the number of pairs squared. This produces a semivariance for a distance X. Then another set of drill holes located a slightly larger distance apart is analyzed. The result is a plot of semivariance versus drill hole distance. The line is fitted to one of several distributions for a proper fit. If the plot results in a plateau, the distance at which the semivariance flattens out is deemed to be the optimum drill hole spacing. Drilling closer than this distance results in more holes than needed; drilling farther than this distance results in missing variation in the geochemistry. The basis for Kriging and Semivariograms, including its limitations and assumptions, is the subject of much debate. However, using these two methods did provide an impartial evaluation of drill hole spacing and appeared to confirm an optimum drill hole spacing of about 650 feet.

As a result OSM required the operator to conduct additional drill hole sampling on 650 foot centers as the mining progressed to fine tune the amount of lime to apply on site.

8. Overburden Analysis

The acid-base accounting model was used to determine areas where net acid-forming materials were located that would need lime amendments. The operator assumed that any strata with a net neutralization potential less than zero would be acidic. The coal, floor clay and pit cleanings were found to be acidic throughout the mine area. For this reason, a separate acid base account model was run for these strata. Then a map was created showing zones of how much lime would need to be added to the pit floor to make it net neutral.

The acid base account model used for adjacent mining operations showed the Newton sandstone to be net alkaline throughout the adjacent areas. However, column leach tests also showed that this material does not weather easily and therefore does not release the alkalinity. For this reason, the Newton sandstone was excluded from the acid base accounting model for this mine. This makes the accounting model conservative, as it is expected some alkalinity will be released from the 80-foot sandstone over time.

The remaining shale strata were then evaluated using the acid base accounting model. Acid forming material was found to be non-heterogeneous and non-isotopic within the permit area. In some areas the net neutralization potential (NNP) was above 30, in other areas the NNP was below 20 tons/1000 tons. For this reason, the operator divided the mine areas into zones with similar NNP. A map was developed showing these zones so that proper lime amendments could be determined.

B. Baseline Information On The Hydrologic Balance

In order to make a finding of no “material damage to the hydrologic balance outside the permit area” OSM required the company to discuss and provide baseline information on the hydrologic balance. Part of the information supplied by the operator was a water budget (See Tables H-1 and H-2 below).

TABLE H-1: Annual premining water balance

Land Use = forest
No treatment or practice
Hydrologic condition = good
Soil type = sandy loam

Infiltration = average
SCS runoff curve number (AMC II)=55
Monthly runoff coefficient (AMC II) = 0.3

MONTH	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Soil depth, inches	24	24	24	24	24	24	24	24	24	24	24	24
Water holding capacity, inches/inches	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Max. soil storage, inches	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4
Hydrologic Soil Group	B	B	B	B	B	B	B	B	B	B	B	B
Precipitation, inches	4.5	6.8	7.6	4.4	4.7	6.0	4.5	4.8	4.7	3.7	4.4	7.8
Precipitation, number of days	8.0	6.3	8.0	7.7	7.4	9.3	8.4	6.9	6.3	5.4	5.4	7.4
Average number days between events	3.9	4.4	3.9	3.9	4.2	3.2	3.7	4.5	4.8	5.7	5.6	4.2
Precipitation/event	0.6	1.5	2.0	1.1	1.1	1.9	1.2	1.1	1.0	0.6	0.8	1.9
Average Precipitation over 5 days	0.7	1.7	2.5	1.5	1.3	2.9	1.6	1.2	1.0	0.6	0.7	2.2
Antecedent Moisture	2	3	3	2	1	3	2	1	1	1	2	3
Potential Evapotranspiration, inches	0.2	0.3	0.8	2.2	4.8	7.1	7.8	6.0	3.0	1.0	0.3	0.2
AMC-adjusted curve number	55	74	74	55	34	74	55	34	34	34	55	74
AMC-adjusted monthly curve number	0.3	0.4	0.4	0.3	0.2	0.4	0.3	0.2	0.2	0.2	0.3	0.4
Direct Runoff, inches	1.3	2.7	3.1	1.3	0.9	2.4	1.3	0.9	0.9	0.7	1.3	3.1
Previous month soil moisture	2.4	2.4	2.4	2.4	2.4	1.6	0.4	0.1	0.0	0.9	2.4	2.4
Net inflow to soil, inches	3.0	3.8	3.7	0.9	-1	-3.5	-4.7	-2.1	0.9	2.0	2.7	4.5
Accumulated potential loss	0.0	0.0	0.0	0.0	-1.0	4.0	-9.2	-11.	0.0	0.0	0.0	0.0
Current month soil moisture	2.4	2.4	2.4	2.4	1.6	0.4	0.1	0.0	0.9	2.4	2.4	2.4
Change in moisture, inches	0.0	0.0	0.0	0.0	-0.8	-1.2	-0.3	-0.0	0.9	1.5	0.0	0.0
Moisture surplus, inches	3.0	3.8	3.7	0.9	0.0	0.0	0.0	0.0	0.0	0.5	2.7	4.5
Available for recharge, inches	5.9	6.7	7.1	4.4	2.2	1.1	0.6	0.3	0.1	0.5	3.0	6.0
Recharge/baseflow, inches	3.0	3.4	3.6	2.2	1.1	0.6	0.3	0.1	0.1	0.3	1.5	3.0
Detention, inches	3.0	3.4	3.6	2.2	1.1	0.6	0.3	0.1	0.1	0.3	1.5	3.0
Recharge/Baseflow in $feet^3$ per square miles	2.58	3.23	3.08	1.98	0.96	0.50	0.24	0.12	0.06	0.23	1.34	2.58

Table H-2. Annual water budget summary

Precipitation, in.	**63.9 in.**
Evapotranspiration, in.	**24.9 in.**
Direct Runoff, in.	**19.9 in.**
Recharge, in.	**19.1 in.**
Baseflow in cfs per sq. mile	**1.42 cfs/sq. mi.**

From: AR Mine Permit, PHC, using Thomthwaite.

1. Surface-Water Baseline Flow and Quality Information

The OSM and permittee evaluated three basic data sources for surface water information: (1) regional water resource data supplied by the US Geological Survey (USGS), Tennessee Geological Survey, and EPA Storage and Retrieval Database (STORET); (2) local hydrologic data provided by the US Department of Agriculture (USDA), Forest Service (Dyer, 1982) and the Tennessee Department of Environment and Conservation; and (3) site data provided by the mining company.

The table at the right (Table H-3) shows the watershed area for the three regional streams. In addition, the tables below show comparative flow rates for various recurrence intervals. The USGS regression equations were used to estimate discharge rates for a 24 hour storm. As a check, one stream (Little Brush Creek) that had actual daily discharge records for more than 10 years was evaluated for peak flows. The data was taken from a USGS report (Weaver, 1993, p.10). The peak flow calculations in Table H-4 were made by taking the logarithms of annual peak flow and fitting them to a Log Pearson Type II distribution. The gauge had 28 years of record. The results from both methods showed similar results but the method by Weaver would be expected to be more accurate since it is based on actual data from the gauging station. Also included in Tables H-5. and H-6. are calculated low flows for various flow durations, flow volumes, and monthly flows at various recurrence intervals using USGS procedures (Wetzel, 1986).

Table H-3. Watershed areas for three regional streams

Watershed	Acres	Sq mile
Big Brush Creek at Little Brush	**30528**	**47.7**
Little Brush Cr.	**9856**	**15.4**
Big Brush Cr. at Sequatchie River	**42304**	**66.1**

Table H-4. Calculated and actual peak flows, in cfs, for three regional streams

Watershed	Qp-2	Qp-5	Qp-10	Qp-25	Qp-50	Qp-100
Big Brush Cr.	**3146**	**4959**	**6342**	**8320**	**9965**	**11796**
Little Brush	**1327**	**2146**	**2785**	**3712**	**4498**	**5381**
(Actual data)	**1870**	**2520**	**2940**	**3460**	**3840**	**4220**
Big Brush at Sequatchie R.	**4072**	**6387**	**8147**	**10663**	**12751**	**15075**
Sequatchie R.	**11328**	**16697**	**21470**	**25531**	**29420**	**33568**

Peak flows; (Wetzel,1986) Qp= a * $Area^{b1}$ * $(Precip-30)^{b2}$ * $Slope^{b3}$

Table H-5. Mean annual and monthly flow in cfs, for three regional streams

	Year	J	F	M	A	M	J	J	A	S	O	N	D
Big Brush	92	164	185	199	148	80	40	37	25	20	18	53	119
Little Brush	31	53	61	65	49	27	13	12	8	7	6	19	41
Brush at Sequatchie	124	226	255	272	202	108	53	51	34	27	23	71	159
Sequatchie R.	530	999	1108	1179	858	459	228	226	152	114	94	288	645

Flows; (Wetzel,1986) Qp= a * $Area^{b1}$ * $(Precip-30)^{b2}$ * $Elevation^{b3}$

The USGS methodology was also used to calculate the low flow for a 7-day 2-year, 7-day 5-year, 7-day 10-year, 7-day 20-year, 3-day 2-year, 3-day 10-year, and 3-day 20-year low flows (Wetzel, 1986). Table H-6 below shows the results. The standard error in these calculations is fairly high making interpretations difficult, especially for smaller watersheds.

Table H-6. Low flow (x-day, y-year), for three regional streams

FLOW IN GPM @	Q 7,2	Q7,5	Q 7,10	Q 7,20	Q 3,2	Q3,10	Q 3,20
Big Brush Creek at Little Brush	0.67	.006	.0018	.0018	0.327	.0008	.0007
Little Brush Cr.	0.18	.002	.0004	.0005	.087	.0002	.0002
Big Brush Cr. at Sequatchie River	0.818	.007	.0019	.002	.393	.0009	.0007
Sequatchie River	4.46	.04	.103	.0098	2.14	.0044	.0039

@ Gallons per minute = a Area Precp^{b3} Slope^{b4} Storage^{b5} Elev^{b6} Cratio^{b7}, as described in Wetzel, 1980.

Regional water quality data was scarce for the study area. USGS gauging and sampling stations were reviewed as well as EPA's STORET database. The USGS stations are located on Big Brush Creek, Little Brush Creek, and at the confluence with Sequatchie River. Stream water quality data from 1977-1979 was reviewed to evaluate water quality conditions prior to implementation of SMCRA. Table H-7 below compares Big Brush Creek with Little Brush Creek and Sequatchie River upstream at Mt. Airy as well as downstream at Whitwell. Most of the mining in Big Brush Creek watershed has occurred after 1978.

Table H-7. Water quality conditions in Big Brush Creek, Sequatchie River at Mt. Airy and at Whitwell prior to implementation of SMCRA

Big Brush Cr	Q	EC	pH	Tem	Alk	S04	tFe	dFe	Mn	TSS
11/6/79	88	39	7.1	11	10	6.3	.14	.02	.01	<10
3/18/80	700	32	7.4	8	9	5.6	.27	.02	.02	7
Little Brush										
11/6/79	18	38	7.6	9.5	10	7.3	.13	.01	.01	<10
3/18/80	192	40	7.9	7	8	6.6	.18	.01	.02	6
Sequatchie at Mt Airy										
11/6/79	292	200	7.8	12	95	7.9	.44	.06	.04	10
3/18/80	1300	160	7.5	11	84	8.4	2.3	.06	.24	126
Sequatchie at Whitwell										
11/6/79	493	155	7.8	11	66	8.6	.39	.03	.05	86
3/18/80	3420	95	7.4	10	36	7.8	1.2	.06	.11	46

Data in mg/L except discharge (Q) in cfs, electrical conductivity (EC) in mhos/cm and pH in standard units.

The results show a stream system relatively unimpacted by mining as evidenced by the low sulfate values, neutral pH, and low conductivity. Other data from the 1970's show similar results for other times of the year. In addition, data from EPA's STORET database included data collected by the Tennessee Valley Authority (TVA) on Big Brush Creek just above the confluence with Little Brush Creek. These data also show a stream system little impacted by mining or other land uses. Low alkalinity is typical of undisturbed watersheds in the Cumberland Plateau.

Data from the U.S. Forest Service was reviewed to characterize nearby mined and unmined drainages (Dyer, 1982). The review identified 6 sites within a couple of miles of the Big Brush Watershed. Data was collected June 1977 through August 1979 just after passage of SMCRA.

Table H-8 following lists the sites:

Table H-8. List of U.S. Forest Service Coal Hydrology Stations *

Site	Dates of Mining	Acres	Percent Disturbed	Description
7141	Unmined	217	0	Tributary to Savage Creek
7142	1950-1973	43	40	Tributary to Dry Creek At Cagle
7143	1948-1969	38	42	Tributary to Big He Creek
7152	1948-1974	15	35	Tributary to Big Branch
7153	1948-1972	340	10	Tributary to Big Branch
7156	1955-1970	357	6	Tributary to Spring Creek

* Dyer, 1982

The metal and trace element concentrations were low. Some acidity in the range of 5 to 12 mg/L as $CaC0_3$ was also present. This is not uncommon since stream flow in many undisturbed watersheds is similar to the chemistry of rain water.

The permittee also calculated the 7-day, 10-year low flow; the 3-day, 20-year low flow; and the 30-day, 2-year low flow for each of the major streams. This is because the water quality criteria apply down to certain low flow events, depending on whether the user is a domestic, aquatic, livestock, or irrigation user.

2. Surface Water Data

Table H-9 following shows the dates of sampling by the permittee at the site:

Table H-9. Dates of sampling by permittee at various monitoring sites

Site[1]	Sampling Dates						
SW-1	4/26/95	6/28/95	10/25/95	4/30/96	5/14/96	6/20/96	9/5/96
SW-2	4/26/95	6/28/95	10/25/95	- - -	5/14/96	6/20/96	9/5/96
SW-3	4/26/95	6/28/95 (dry)	10/25/95	- - -	5/14/96	6/20/96	9/5/96
SW-4	4/26/95	6/28/95	10/25/95	- - -	5/14/96	6/20/96	9/5/96
SW-5	1/14/95	4/13/95	10/15/95	- - -	5/14/96	6/20/96	9/5/96
SW-6	- - -	- - -	- - -	- - -	5/14/96	6/20/96 (dry)	9/5/96 (dry)
SW-7	- - -	- - -	- - -	- - -	5/14/96	6/20/96 (dry)	9/5/96 (dry)
BBC	- - -	- - -	- - -	4/30/96	5/14/96	6/20/96	9/5/96
GF	- - -	- - -	- - -	4/30/96	5/14/96	6/20/96	9/5/96
BBC (TS)	- - -	- - -	- - -	4/30/96	5/14/96	6/20/96	9/5/96
BBC (127)	- - -	- - -	- - -	4/30/96	5/14/96	6/20/96 (dry)	9/5/96 (dry)

[1]Site	Description
SW-1	Big Brush Creek (BBC) above the permit area - Perennial Stream
SW-2	Unnamed tributary to BBC - Intermittent
SW-3	Unnamed tributary to BBC - Intermittent
SW-4	Unnamed tributary to BBC - Intermittent
SW-5	Big Brush Creek below permit area - Perennial Stream
SW-6	Unnamed tributary to BBC- Intermittent
SW-7	Unnamed tributary to BBC- Intermittent
BBC	Big Brush Creek upstream of site SW-1 - Perennial
GF	Glady Fork at confluence with BBC - Perennial
BBC (TS)	Big Brush Creek at Trend Station - Perennial
BBC (127)	Big Brush Creek at Highway 127 - Perennial

a. Water Quality

Basic parameters were analyzed quarterly, including field measurements and laboratory analysis. An expanded list of metals and trace elements was analyzed each summer in addition to the standard parameters.

(1) Field Measurements (Monthly)

pH
Temp
Specific Conductivity
Dissolved Oxygen
Discharge

(2) Laboratory - Standard parameters.

Unfiltered samples were taken to allow comparison with Tennessee Water Quality criteria, which are based on total recoverable metals.

pH
Total Acidity
Total Alkalinity
Total Suspended Solids
Total Dissolved Solids
Total and Dissolved Iron
Total and Dissolved Manganese
Sulfate
Specific Conductivity

(3) Laboratory - Expanded Analysis

Total Aluminum
Total Calcium
Total Magnesium
Total Hardness
Total Arsenic
Total Chromium
Total Copper
Total Lead
Total Mercury
Total Nickel
Total Selenium
Total Zinc

(4) Flow Measurements

ASTM Method D3858 (Area Velocity Method) - Using engineer's tape and determining width of stream at sampling point. Stream depth measured at each foot interval across stream section with velocity recorded at $6/10^{th}$ at each interval using a Mead flowmeter. Total discharge determined by summing the discharges of each partial section.

Low or small discharges where velocity meter could not be used were measured using bucket/stopwatch if a pipe was available or by measuring width and estimating velocity via a partially floating object.

(5) Preservation

All samples were field cooled (wet ice) and delivered to the laboratory in an insulated cooler. Metal samples were field preserved with nitric acid (2 ml or pH 2). Other sample bottles were prepared as appropriate for the analytical parameter. Each sample shipment had a chain-of-custody for the laboratory to accept receipt of samples. The chain-of-custody record contained sufficient information to trace sample possession from collection to analysis.

Samples routinely include:

1) One liter plastic container for general analysis.

2) One liter plastic container, plus nitric acid for metals (total).

3) A 500 ml plastic container, field filtered (.45 micron), plus nitric acid for dissolved metals analysis.

4) One 500 ml plastic container, plus sulfuric acid for ammonia analysis.

(6) Analysis procedures (QA/QC)

All laboratory analysis followed EPA or ASTM methods in accordance with 30 CFR 780.21(a). Likewise, for each set of analysis, a sample duplication, field blank, spikes, and standards were analyzed. A quality control program which conforms to 40 CFR 146 was followed by each lab and was included in the application.

b. Precipitation records and chemistry

Much of the ambient streamflow is from surface runoff and ground-water discharge (soil / bedrock interflow, and fracture flow). In areas undisturbed by mining, the stream water quality can mirror rainfall chemistry. The data on rainfall chemistry included the statistical analysis of 95 weeks of sulfate data, 86 weeks of conductivity data and 87 weeks of pH data from the National Trends

Precipitation Network gauge at the Hatchie National Wildlife Refuge rain gauge at Hillville, Tennessee. Data is from October 1993 to September 1995. The pH is about 4.5, the sulfate median is 1.75 mg/L, and the median conductivity is about 19 umhos/cm. These values compare with stream quality in undisturbed drainages in the vicinity of the mine area.

In addition, the permittee included seven years of rainfall records from the adjacent mine site.

c. Biological Data

The permittee was required to conduct an aquatic survey of the first order drainages that flowed within the permit area. The study evaluated physical stream characteristics, such as stream substrate, pool and riffle characteristics, riparian vegetation, stream flow, and evidence of man-made impacts.

Fish populations were sampled at five locations on three separate creeks that were proposed to be mined through. Observations were also made of amphibians, reptiles and waterfowl that were encountered. The traveling kick method (TKM) was used to sample the macroinvertebrate populations. Two TKM's were taken on a transect about mid-riffle. A kicknet with a mesh of 1050 microns was placed on the substrate and moved in an upstream direction for 10 feet in two minutes. Samples were fixed in the field with 5% formalin and preserved in the laboratory with 70% alcohol. Identification was done by standard references by Pennak, 3rd edition; and by Merrit and Cummins, 2nd edition.

The fish community was summarized using the Index of Biological Integrity (IBI) specified by EPA. The macroinvertebrate population used similarity indexes, modified Family Biotic Index, Total taxa and particular taxa diversity (EPT), and Trophic Relationship Comparisons.

d. Sediment Data

The permittee conducted a sediment sampling program at OSM's suggestion to document the physical and chemical nature of stream sediment adjacent to the operation, prior to any mining. Both the physical characteristics, such as color and texture, were evaluated, as well as chemistry. The chemistry was determined using sequential acid-extraction methods on the fine sediments.

e. Ground-Water Baseline

Twelve Ground-Water Monitoring Stations were installed:

- 3 wells were drilled into the Newton Aquifer.

- 3 wells were drilled into the Sewanee Conglomerate Aquifer.

- 3 wells were drilled into the Sewanee Coal seam.

- 3 wells were drilled into the Richland Coal seam.

Regional potentiometric data is also available for the upper reaches of Big Brush Creek. The application included a potentiometric map submitted as part of a prior coal exploration permit that included the AR Mine area. The map was constructed with water level data from more than 16 wells. The exact dates of the water levels used in the map are unknown. The permittee also included four potentiometric contour maps of the mine area using data from on-site wells. These four maps were generated using water elevation data collected during four different quarters to show the seasonal variations in potentiometric head.

Aquifer tests have been conducted in the Newton Sandstone as well as the backfilled spoils at the company's other mines in the area. Data for 7 wells, available from the coal exploration permit previously cited, are summarized in Table H-10 below.

Table H-10. Summary of information derived from aquifer tests at seven well in the Newton Sandstone

Well	Pump Rate (gpm)	Draw-down (ft)	Time (min)	Specific Capacity (gpm/ft)	Transmissivity (gpd/ft)	Storage Coeff.	Est.[1] Hydr. Cond.
801	12	<60	247	>0.20	>400	NA	1.34
802	12	6	242	NA	417	.00066	1.39
802	12	22	8	<0.68	NA	NA	-
803	12	0.12	50	NA	NA	NA	-
804	12	108	10	0.14	<140	NA	.46
805	12	98	15	0.15	<150	NA	.50
806	12	<65	20	<0.23	<230	NA	.77

[1] Hydraulic conductivity, in ft/day, assuming 40 feet saturated thickness

The transmissivity and hydraulic conductivity can only be considered rough estimates. No data were available on saturated thickness which are needed to calculate hydraulic conductivity. The permittee also conducted a pump test in a spoil aquifer at an adjoining mine that had been mined and reclaimed using the same operations plan. The result showed a transmissivity many times greater than the undisturbed sandstones in the area.

(1) Ground-Water Quality

Baseline ground-water quality data are available for the Newton Sandstone in the vicinity of the proposed mine. Well data from April and June of 1995, and from May, June, and September, 1996 were evaluated. There was little variation in water levels. The pH ranged from 6.2 to 6.5 units.

Specific conductance (EC) ranged from 56 to 107 with a median value of 71 umhos/cm. Sulfate was always less than 5 mg/L. Dissolved iron ranged from 0.04 to 1.64 mg/L with a median value of 0.54 mg/L. Manganese was less than 0.6 mg/L. A full suite analysis was conducted on one sample dated 9/5/96. Results showed alkalinity of 40 mg/L, TDS 70 mg/L, calcium 10 mg/L, and 2 mg/L of magnesium. None of the metals and trace elements were high except for iron. These data indicate that ground water from the Newton sandstone is similar to the baseline (unmined) surface water quality.

(2) Ground-Water Parameters

The analysis dates and parameters for the twelve monitoring wells were similar to the surface-water baseline data program.

(3) Well Bailing Procedures

The well's static water level and total depth were measured prior to any bailing. Wells were purged using a low capacity variable rate pump mounted on a four wheel mini-ATV. The rate of pumping was maintained slow enough to prevent total dewatering of the well or rapid drawdown that may stir up the well. At least three well volumes were purged prior to sampling. The sample was taken 24 hours later after the sediment in the well was allowed to settle out. A PVC bailer was used.

(4) Sample Preservation

All well samples were field filtered with a 0.45 micron filter to remove any man-induced sediment that may have been stirred up during bailing. Water moving through these ground water systems is so slow that sediment is not transported. All samples were field cooled (wet ice) and delivered to the laboratory in an insulated cooler. Metal samples were field preserved with nitric acid (2 ml or pH 2). Other sample bottles were prepared as appropriate for the analytical parameter. Each sample shipment had a chain-of-custody for the laboratory to accept receipt of samples. The chain-of-custody record contained sufficient information to trace sample possession from collection to analysis.

(5) Data Presentation

Both the surface- and ground-water data were presented using a variety of methods including graphs, trilinear diagrams, stiff diagrams, boxed notch and whisker diagrams, bar charts, and histograms. Over 60 charts were included in the application to allow a visualization of the data.

C. Baseline Data For The CHIA

The Cumulative Impact Area (CIA) for this operation consists of the Big Brush Creek Watershed down to the confluence with Little Brush Creek. All of the operation is contained within and discharged to Big Brush Creek. In addition, the ground water in the shallow fracture system and deeper bedrock aquifers moves to the southeast and discharges into Big Brush Creek about 2 miles downstream of the operation.

For preparation of the CHIA, OSM collected data in cooperation with the State Division of Water Pollution control. Eight surface water sites were sampled for chemistry and seven ground water monitoring wells were sampled. The chemical parameters included:

Field pH	Calcium
Field Temperature	Chromium
Field conductivity	Copper
Flow or water elevation	Iron
Alkalinity	Manganese
Acidity	Lead
Total Suspended Solids	Magnesium
Total Dissolved Solids	Mercury
Chloride	Nickel
Sulfate	Potassium
Fluoride	Selenium
Phosphorus	Silica
Aluminum	Silver
Arsenic	Sodium
Barium	Thallium
Boron	Zinc
Cadmium	

OSM evaluated the water quality from other mines in adjacent CIAs that mined the Sewanee coal seam. This was done to determine which metals, trace elements and major ions would be important to look for. Tables H-11 and H-12 show that a number of chemical parameters were found in significant concentrations.

Table H-11. Metals and trace elements of concern (concentrations in mg/L)

PARAMETER	AVERAGE	MAXIMUM	ACUTE WQ[1]	CHRONIC WQ[2]
Al, Total	1.735	11.2	0.750	0.087
Al, dissolved	0.354	2.87		
Cd, Total	0.0035	0.011	0.0018	0.00066
Cd, dissolved	0.0033	0.011		
Cu, Total	0.0141	0.08	0.0093	0.0065
Cu, dissolved	0.0016	0.004		
Fe, Total	19.3	125	1.0	1.0
Fe, dissolved	4.39	51.4		
Pb, Total	0.0078	0.047	0.0344	0.00134
Pb, dissolved	0.0014	0.004		
Ni, Total	0.130	0.63	0.789	0.0877
Ni, dissolved	0.111	0.63		
Zn, Total	0.1726	1.13	0.065	0.0589
Zn, dissolved	0.075	0.411		

Note: A value of 50 mg/L hardness is assumed in deriving criteria.

[1] The acute water quality criteria is usually the 24 hour average.

[2] The chronic water quality criteria is usually the 4-day average concentration.

Table H-12. Major ions found

CATIONS	AVERAGE, in mg/L	AVERAGE, in meq/L
Calcium	65	3.23
Magnesium	31	2.57
Sodium	8	0.35
Potassium	4.3	0.11
Manganese	7.2	0.26
Iron	4.39	0.24
Aluminum	0.35	0.04
ANIONS		
Sulfate	296	6.17
Bicarbonate	87	1.42
Chloride	1.7	0.005
Ammonia	0.27	0.02
Fluoride	0.28	0.015
Nitrate	0.11	0.013

OSM also obtained unpublished pump test data on 7 wells in the CIA along with regional potentiometric maps from the operator.

The State also conducted a biological assessment of the aquatic life in the streams. Four biological survey sites were established to collect ambient aquatic life conditions in the streams adjacent to and downstream of the site. Sampling of benthic organisms was conducted along with fish sampling.

D. References

ASTM Method D3858-95, Standard Test Method for Open-Channel Flow Measurement of Water by Velocity-Area Method; American Society for Testing and Materials, West Conshohocken, PA.

Dyer, K.L.,1982 Stream Water Quality in the Coal Region of Tennessee, USDA, Forest Service, Northeast Forest Experimental Station, General Technical Report NE-77; Berea, Kentucky.

Merritt, Richard W. and Cummins, Kenneth W., 1984, An Introduction to the Aquatic Insects of North America, Second Edition; Kendall/Hunt Publishing Company, Dubuque, Iowa.

Pennak, Robert William, 1989, Fresh-Water Invertebrates of the U.S.: Protozoa to Mollusca, 3rd Edition; John Wiley & Sons.

Sobek, A.A., W.A. Schuller, J.R. Freeman, and R.M. Smith, 1978, Field and Laboratory Methods Applicable to Overburdens and Mine Soils. EPA 600/2-78-054, U.S. EPA, Cincinnati, Ohio.

Wetzel, K.L.and Bettandorff, J.M., 1986, Techniques for Estimating Streamflow Characteristics in Eastern and Interior Coal Provinces of the United States; USGS Water-Supply Paper 2276, 80 p.

Weaver, Jess D. and Gamble, Charles R., 1993, Flood Frequency of Streams in Rural Basins of Tennessee; USGS Water Resources Investigations Report 92-4165.

APPENDIX I

REGIONAL EXAMPLE SHOWING BASELINE INFORMATION FOR GEOLOGY AND HYDROLOGY

MID-CONTINENT SITE

The number of locations at which site-specific baseline data for geology, overburden, surface water and ground water needs to be collected depends on many variables. Rather than presenting and attempting to rationalize minimum or maximum numbers and locations for surface-water stations, boreholes for overburden data, ground-water observation wells and frequency and duration of water sampling, we have included summaries of baseline information for geology and hydrology as it exists in planned or actual permits. We refer to these summaries as regional examples of baseline data requirements. In this context, regional can refer to hydrologic issues as may exist in one region but not all regions of the country and for which precise kinds and amounts of data are needed to establish, for example, the potential for acid mine drainage formation. Regional may also refer to differences in philosophy and technical approach to sampling and standards deemed acceptable for baseline geology and hydrology information from one state or region to another.

The three examples of baseline information collection from different regions of the country are presented in Appendices H, I, and J.

- The eastern permit example which is presented in Appendix H represents an area surface mine in a temperate humid region.

- The following mid-continent permit example represents an area lignite mine in temperate continental region.

- The western example which is presented in Appendix J summarizes an actual work plan for baseline data collection for an area mine in a semiarid region. The plan was developed by the operator in close cooperation with the RA. The work plan illustrates how the need for new ground- and surface-water stations and data collection was based on an evaluation of existing information from nearby mines.

The Mid-Continent Region (MCR) Mine example is an area lignite mine that is expected to encompass more than 20,000 acres over the projected life of the mine. The MCR Mine is located along the border of Leon, Limestone and Freestone Counties in Texas. Surface mining began in 1985 and is scheduled to continue until approximately the year 2018. The most recent permit action was a 1994 permit renewal including approximately 2580 new acres. The renewal involves a continuation of the mining operation from area A into area B utilizing a single dragline operation. In area C, a single dragline operation will continue, alternating between the north and south end of the pit. In area D, a bucket wheel excavator with an around-the-pit conveyor will be utilized in conjunction with a single dragline operation. Dewatering activities will continue as in previously permitted operations for areas A/B and C and in advance of the excavation in area D. In all areas, topsoil substitution is being requested.

The permit area is characterized by gently rolling hills dissected by dendritic drainage patterns. Surface elevations prior to mining ranged from about 550 feet on the divide between the Brazos and Trinity River Basins to about 350 feet along the east permit area at Alligator Creek. The surface water drainage divide separating the Brazos River Basin on the west and the Trinity River Basin on the east generally coincides with a massive sand channel which divides the permit area into west and east portions. See Figure I-1 for location of MCR and two other active mines, MCR 2 and MCR 3, in relation to major drainage features in the area.

The highest areas in the western portion are in the central area and result from the presence of erosion resistant remnants of iron-cemented sand and mud units capping relatively loose sand deposits. The lowest portion in the western area is in the vicinity of the Lambs Creek and Mine Creek tributaries of Lake Limestone. Surface drainage from the western portion of the Permit area is in a westerly direction toward Lake Limestone and the Navasota River. Principal tributaries are Lambs Creek and Mine Creek which drain to Lake Limestone. A small portion is drained by tributaries of Birch Creek which flows into the Navasota River downstream of Lake Limestone. The Navasota River flows into the Brazos River about 80 miles downstream of Lake Limestone.

The highest areas in the eastern portion are in the north area, also resulting from the presence of erosion resistant remnants of iron-cemented sand and mud units capping relatively loose sand deposits. The lowest portion in the east area is in the southeast where the tributaries draining the eastern Permit area flow into Alligator Creek. Surface drainage from the eastern portion of the permit area is in a southeasterly direction. Principal tributaries are Silver Creek, Rena Branch, the upper reaches of Buffalo Creek and several unnamed tributaries. All of this area drains to Alligator Creek which drains to the Trinity River about 25 miles downstream.

A. Geology

The permit area is in the Gulf Coast Basin, an extensive gulfward-dipping homocline. Locally, the region is broken by Tertiary fault systems, which reflect gulfward subsidence and moderate uplift to the west. The East Embayment, a structurally low area roughly parallel to the Sabine Uplift, extends to the northwestern corner of Leon County where surface and subsurface units dip and thicken toward the center of the Embayment. Domal structures, generally related to

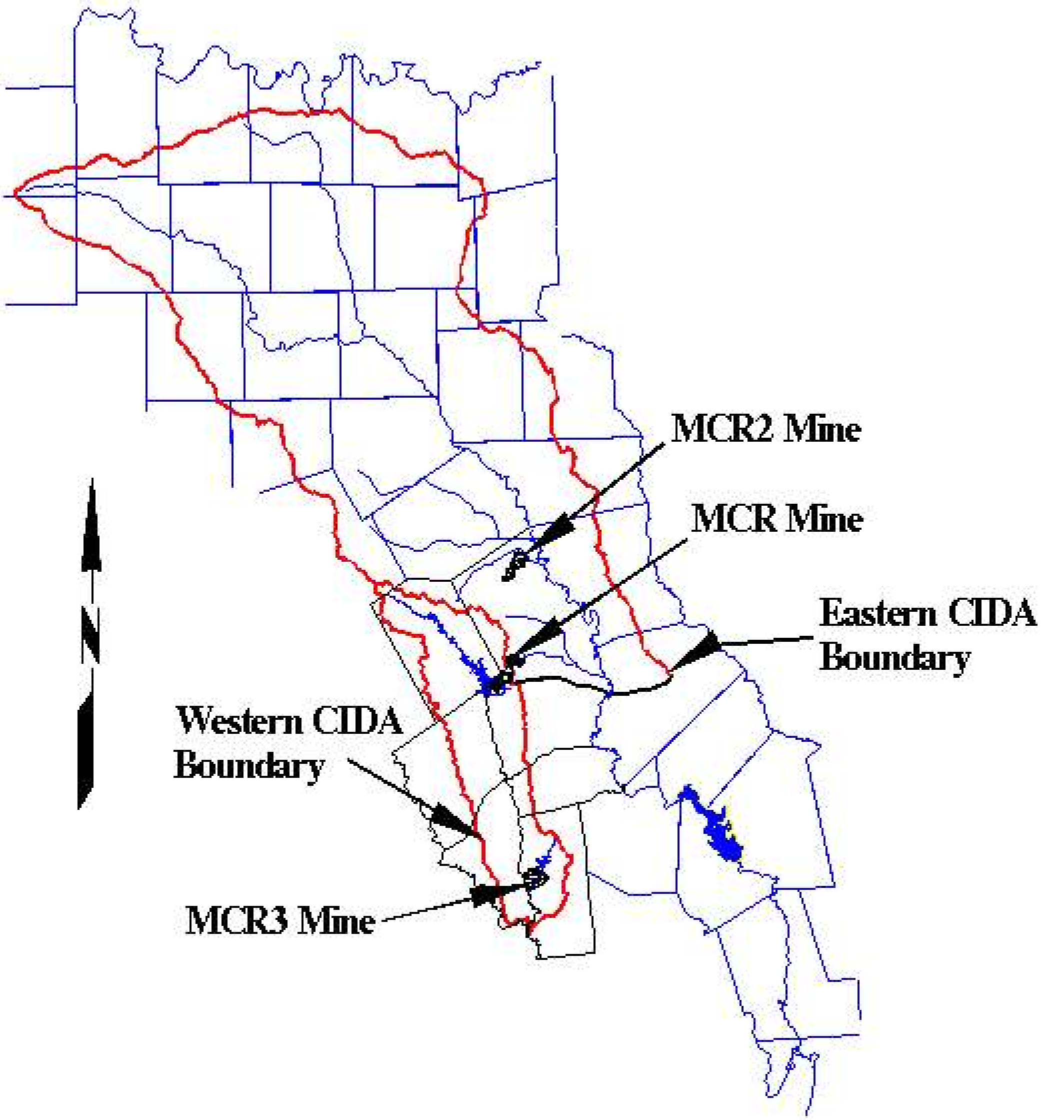

Figure I-1. Location of MCR and two other active mines, MCR 2 and MCR 3, in relation to major drainage features of the Navasota and Trinity River basins.

salt intrusions, are located along the axis of the Embayment. Over most of the permit area, the structural characteristics are generally consistent with the regional framework. Formations strike northeast to southwest and dip about 1^0 to the southeast (Gulfward). Structure mapping of the lignite seams reveals local undulations that depart from the regional dip and are thought to be the result of differential compaction of the sediments.

The permit area lies in the proximity of two systems of faults. The Mexia-Talco Fault system is located to the northwest and trends north-northeast. (Baker and others, 1963; Fogg and Kreitler, 1982; and Jackson, 1982). The Mexia-Talco Fault Zone is a series of echelon faults that coincide with the updip limits of the underlying Jurassic Louann Salt (Kreitler and others, 1980). Jackson (1982) agrees that the location of the Mexia-Talco Fault Zone was controlled by the updip limit of the Louann Salt and also suggests that it was partly controlled by Triassic rift faults. Thinning of the Louann Salt over the Sabine Uplift indicates that it was probably a positive feature before Louann Salt deposition and has remained so throughout geologic time (Kreitler and other, 1980). The Mexia-Talco Fault, which commonly dips from 45^0 to 65^0 with displacement up to 1000 feet at the top of Cretaceous, forms a graben complex.

The Elkhart-Jarvis-Mount Enterprise Fault System lies to the east and trends east. Keritler and others, (1980) also suggest that the Elkhart-Mount Enterprise Fault System was a structurally elevated relict shelf edge on the Gulf Coast Basin. The formations in the Wilcox Group generally strike northeast. The regional dip ranges from about 50 to 100 feet per mile, increasing to the southeast (Behout and others, 1976).

Geologic units of particular hydrogeologic importance at the permit area are the Upper Calvert Bluff Formation of the Wilcox Group and the overlaying Carrizo Sand of the Claiborne Group. The primary surface sediments mapped at the permit area are the Carrizo Formation and the Wilcox Group of Eocene Age. Alluvial deposits associated with recent drainage systems are also present. Geologic units relevant to the current investigation include: Quaternary alluvium and terrace deposits and the formations of the Wilcox Group.

The Calvert Bluff Formation of the Wilcox Group and the Carrizo and Reklaw Formations of the Claiborne Group are the principal geologic units which crop out within and immediately adjacent to the MCR Mine area. Minor exposures of Quaternary alluvium deposits occur along stream valleys in the area, but these deposits are very thin and discontinuous. These alluvial deposits occur to a greater extent along the major river valleys and tributaries of the Navasota River to the south and west and the Trinity River to the east and north.

The upper part of the Calvert Bluff Formation crops out in about half of the surface area of the MCR Mine. The Calvert Bluff occupies mainly the lower elevations of the northwestern portion of the mine area, giving way to the generally greater relief, higher elevation sand hills of the Carrizo Formation in the southeastern area of the mine. As much as 300 feet of upper Calvert Bluff section is observed in the deeper grid holes drilled in the MCR Mine area. Kaiser and Black (1978) interpreted the depositional setting of the Calvert Bluff Formation as the transition zone between the lower alluvial plain and the upper delta plain.

The Calvert Bluff Formation consists of the following sediment types as observed in continuous cores CC-1 through CC-20: gray to dark gray to olive gray silty clays, occasionally containing thin laminae of silt or silty sand; dark gray to dark grayish brown carbonaceous and lignitic clays, with varying amounts of silt, carbonaceous material (carbonaceous plant fragments and remains, and lignite laminae) and pyrite; gray to dark gray silts with varying amounts of clay, sand and carbonaceous material; very fine-to fine-grained silty sands with varying amounts of clay, sand and carbonaceous material; very fine- to fine-grained silty sands with varying amounts of clay; fine- to medium-grained clean sands with varying amounts of silt. Accessory minerals present include limonite, pyrite, various opaque (dark) minerals, muscovite mica, glauconite, and gypsum. Lignite and carbonaceous fragments are also commonly found. Moderately to highly indurated, iron-cemented silts and sands with ferruginous concretions occur in the oxidized zone in many parts of the area. Pyrite occurs as irregularly shaped modules and disseminated grains in sediments and as nodules, fracture-fill, veins, and disseminated grains within lignite seams. The pyrite is typically found within the reduced zone. Occasionally beds of sand or silt with siliceous or calcareous cement are present.

The Carrizo Sand crops out over about a third of the surface area of the MCR Mine. Carrizo outcrops occupy slightly higher elevations than outcrops of the Calvert Bluff, as evidenced by the increase in average elevation from the northwestern to the southwestern parts of the permit area (downdip). The Carrizo exists as moderately steep sand hills in its outcrop area, either in the form of continuous ridges or isolated hilltops. The Carrizo reaches a maximum thickness of about 120 feet in the permit area and is generally about 80 to 100 feet thick.

1. Data Collection Activities For Geology and Overburden

The geology description is based on data collected through grid drilling, continuous coring, and laboratory analysis of overburden, interburden, and underburden stratigraphic intervals. Grid drilling and logging began in the late 1970's and continued as necessary, through the present. An approximate chronology of continuous core collection is summarized in Table I-1 below.

Table I-1. Chronology of Core Collection

Mine Area	1986	1987	1989	1991	Total
A	3	5	5	6	19
C	3	6	4	2	15
D	3	8	8	3	22
Total	9	19	17	11	56

The cores were described in the field by a geologist and analyzed for a variety of physical and chemical parameters of interest in mining reclamation. The core descriptions along with geophysical logs of core holes were used to map the subsurface geology. Geologic descriptions of selected physical and chemical characteristics were included in the permit application.

Grid drilling and geophysical logging at the MCR Mine began in the late 1970's and has continued through the present. For this permit renewal application about 1,437 grid hole logs plus the information from 56 continuous cores were the basis for the characterization of the geology and oxidized zone within the MCR Mine.

Grid holes are normally drilled and logged about 10 to 20 feet below the deepest minable lignite seam. The grid holes were drilled under the supervision of an qualified geologist who logged the samples. A combination of natural gamma, gamma-gamma density, caliper and single point resistivity logs were run in each hole.

a. Core Drilling

Continuous cores were collected at 56 sites within the MCR Mine for the purpose of (1) characterizing the physical and chemical properties of strata down to and including the strata directly below the deepest minable coal seam, and (2) identifying the oxidized zone.

Coring was conducted with Failing 1250 and Failing 1500 hydraulic rotary rigs (using a Failing CFD-1B, mud rotary, drilling rig). Due to poor access and wet conditions some cores were completed with an Ardco buggy rig. Core locations were stalked and surveyed before the coring program.

Typically, after moving to a core location, a pilot hole was drilled 10 feet below the expected depth of the core and geophysically logged. A suite of logs including natural gamma, gamma-gamma density, resistivity and caliper were run in the pilot hole. Geophysical logging was performed by a private Geophysical Company.

After completion, the pilot hole was plugged according to the procedure specified by the RA, and the rig was moved about ten feet to begin the continuous core. The initial 10 to 15 feet of continuous core were collected with Shelby tubes and mechanically extruded. The remainder of the core, to a depth of 10 to 20 feet below the base of the deepest minable coal seam was obtained with a 4 3/4 inch diameter, ten-foot long, Christiansen core barrel with a 3-inch diameter, split-inner barrel or continuous barrel.

After a single core run, the inner barrel was removed and opened. The core was shaved (cleaned of drilling mud), measured, and percent recovery was calculated. Major lithological contacts were identified and measured before the core was transferred from the inner barrel to a PVC core trough. The core was then described by a geologist. Field analysis of the core included description of texture (grain size), color (Munsell color chart), dominant and subordinate lithology, roundness and sorting of grains, matrix quality and composition, major and accessory minerals, cementation, and sedimentary structures.

b. Overburden Sample Compositing

Core sample intervals for laboratory chemical and physical analysis were chosen in the field using lithologic character and geophysical log signature. Individual sample intervals varied from less than one foot to about ten feet, averaging about four feet. After intervals were chosen and described, representative samples were placed in plastic bags, sealed and delivered for laboratory analysis. Laboratory analytical methods for each parameter and the laboratory reports are discussed below.

After completion of the core, the drilling rig was moved. The hole was geophysically logged (using the same suite of logs as for the pilot holes) and plugged according to the procedure specified by the RA. The overall core recovery for the 56 cores was 90 percent or greater for each core including the re-cored intervals.

c. Laboratory Analysis

A number of tests were performed in the laboratory on samples of the overburden material collected during the coring program. The procedures used for the individual tests identified below were listed in the permit application. The tests were for overburden materials in general and for native soils or units proposed for soil substitution. The parameters included:

pH
electrical conductivity (EC)
Calcium (Ca)
Magnesium (Mg)
Potassium (K)
Sodium (Na)
Sodium adsorption ratio calculated (SAR),
Bicarbonate (HCO_3)
Carbonate (CO_3)
Chloride (Cl)
Sulfate (SO_4),
Cation Exchange Capacity (CEC)
Exchangeable bases calculation
Extractable bases
Texture/classification
Exchangeable Aluminum (Exch Al)
Base saturation percent (BS %)
Available nitrate (NO_3-N)
Available phorphorus (P)
Available potassium (K)
Available trace elements (copper, iron, manganese and zinc)
Exchangeable acidity (EA)
Pyritic sulfur
Potential acidity calculation (PA),
Neutralization potential (NP)
Inorganic carbonates (IC)
Acid base accounting calculation
Arsenic (As)
Boron (B)
Cadmium (Cd)
Chromium (Cr)
Copper (Cu)
Lead (Pb)
Manganese (Mn)
Molybdenum (Mo)
Nickel (Ni)
Selenium (Se)
Zinc (Zn).

d. Data Presentation

The data were presented in a series of tables for each core hole that listed parameter values, sample interval, and laboratory number. For example, a core from location 640/270 CC1 showed the total depth was 212 feet and 43 samples were collected, an average of one sample for every five feet. The actual sample interval ranged from as little as one foot to as much as 11 feet. In this example, each of the 43 samples included analyses of sand, silt and clay fraction and texture, pH, NP, Total S, CEC, Inorganic CO_3, Pyritic sulfur, Pot acidity, Exch acidity, A/B, CEC, EC, Ca, Mg, K, Na, SAR, Avail P, Avail K, Cd, Se, and values for total As, B, Tot Cd, Cr, Cu, Mn, Ni, Pb, Se, Zn, U and V.

Summary diagrams of selected physical and chemical characteristics were prepared for the 56 continuous cores within the MCR Mine. In addition to the geophysical logs, the diagrams include: a lithologic column based on the geologist's field description, sample number and interval, textural data, Soil Conservation Service (Natural Resources Conservation Service) soil textural classification, pH, EC, percent pyritic sulfur, NP, and an identified stratigraphic unit.

The geophysical logs are used to correlate physical and chemical characteristics of the different sedimentary units as the tool is slowly brought up from the bottom of the core hole to ground surface. The logs consisted of natural gamma ray, gamma-gamma density and single point resistivity.

B. Surface-Water Baseline Data

1. Lakes and Impoundments

USGS 7.5 minute topographic maps depicting pre-mine conditions of the area were examined to identify the locations of surface water bodies. In addition, Leon, Limestone, and Freestone County maps from the Department of Highways and Public Transportation provided information on surface impoundments constructed since 1964.

Lake Limestone, a 225,400 acre foot capacity reservoir, is located adjacent to the western boundary of the area. The lake is impounded by a dam on the Navasto River in Robertson, Limestone, and Leon Counties. The purpose of Lake Limestone is to "conserve and develop the water resources of the upper Navasto River in order to provide dependable water supplies to meet municipal, domestic, industrial and agricultural needs in the area of the upper Navasto watershed and in the lower Brazos Basin and adjoining coastal areas downstream of the project. The most urgent immediate need is for water for cooling of steam-electric generating facilities to be built in the upper Navasto watershed, where extensive deposits of lignite will be utilized to replace dwindling gas and oil supplies as a source of fuel for production of electric energy" (U.S. Corps of Engineers, 1976).

The total drainage area of Lake Limestone is about 674 square miles. The only major impoundments within the drainage area are Lake Mexia on the Navasto River about 100 river miles upstream of the Sterling C. Robertson Dam, and Lake Springfield downstream of Lake Mexia. The total drainage area above Lake Mexia and Lake Springfield are about 198 and 238 square miles, respectively. Lake Mexia impounds 10,000 acre-feet and is used as a source of water supply for the City of Mexia and the Mexia State Park.

There are over 400 naturally occurring or man-made ponds found throughout the area. Surface areas of these ponds range from about 0.1 acre to 30 acres, with water depths ranging from a few inches in some naturally swampy areas to more than ten feet in some of the larger man-made impoundments.

The majority of man-made ponds are located in headwater areas, gullies at lower topographic elevations, or excavations at the base of hillsides. Many of the man-made ponds are constructed utilizing earthen embankments. Many of the ponds on tributaries of named streams are constructed in series. Natural ponds are found in low swampy areas along streams and creeks and in isolated depressions scattered throughout the area. The normal substrate in these natural ponds is usually a sandy mud.

With the exception of those impoundments constructed for the oil and gas activities and sedimentation ponds associated with the current active mining, most ponds are used for hunting, fishing and livestock watering.

2. Seeps and Springs

The available literature identifies several springs located near the area (Brune, 1981). Ground-water discharge furnishes water to both the Navasto River and Trinity River Basins. In the outcrop of the aquifer, the water generally moves from higher elevations toward the lower elevations of the creeks and rivers.

3. Area C Streamflow Investigations

Baseline surface-water data was obtained from USGS records and a monitoring program to collect hydrologic data for the MCR Mine established in October 1986. Data collection activities for this hydrologic investigation included the installation of 14 crest gauge stream monitor stations and installation of one continuous recording stream monitoring station with companion rain gauge. Nine of the 14 stations were in watersheds unaffected by mining. The remaining five stations were located in watersheds in which some portion was disturbed by active mining during the monitoring period or had some portion in a reclaimed condition. Photographs of these stations were included in the permit application.

Monthly sampling of the surface water and instantaneous stream stage measurements were made at the 14 stream monitor stations in addition to three locations on Lake Limestone. One-time surface-water sampling was conducted at 20 pond locations located in or adjacent to the area. Photographs of the one-time monitoring stations were included in the permit application.

4. Continuous Streamflow Monitoring

A continuously recording stream gauging station was installed on Lambs Creek where it crosses the Renewal Area boundary. This station monitors a drainage area of about 3050 acres which is about 19 percent of the entire Lambs Creek drainage area. About 2540 acres of the monitored area is within the Renewal Area which is about 12 percent of the entire area.

a. Sampling Procedures

The discharge at the continuously recording station was measured on a monthly basis using the same methods as the crest gauge stations. These discharge measurements, in which the stage height at the time of measurement is recorded, were used to develop a rating curve for the station. The rating curve is based on limited low-flow data to define the preliminary relationship between stage height and flow. Hydraulic principles were used to further extrapolate the rating curves for gauge heights greater than those measured in the field. For the continuous stage station, the stage data was reduced to flows and the rating curve was then used with the electronically recorded time versus stage data to develop the preliminary continuous hydrograph (time versus discharge) for the station.

b. Recording Rain Gauge

A continuously recording rain gauge was installed upstream of the continuously recording stream monitoring station (SW-12) in the Lambs Creek watershed. The rain gauge consists of a tipping bucket gauge and an Omnidata DP101 Datapod Recorder. The gauge is mounted on a steel platform supported by a concrete anchored six-foot piece of five-inch O.D. steel pipe. Adjacent to the pipe's anchor is a wooden cellar in which a water-tight housing for the recorder is stored. The subterranean location of the data recorder was necessary to maintain a suitable operating temperature. Rainfall data was recorded at one-minute intervals.

5. Periodic Streamflow Monitoring

a. Description of Monitoring Stations

Fourteen crest gauge stream monitor stations were installed at various locations throughout the C Area. The locations of these stations were selected based on delineation of drainage basins within the area, site accessibility, channel shape and reach, and channel stability. The cross sections of the stream channels were surveyed at each of the crest gauge monitor stations by mine personnel. The watersheds monitored ranged in size from 27,700 acres to 523 acres. Plots of the stream cross sections for the 14 crest gauge monitor stations are provided in the permit, and the stage reference point for each station refers to the elevation of the bolt on the typical crest gauge installation.

Installation of the crest-gauge structure entailed the digging of a 6- to 10-inch diameter hole about three feet deep near the channel edge. A 5-foot section of 2-inch O.D. galvanized pipe with a 3-foot length of 2-inch O.D. threaded, galvanized anchor was placed in the hole followed by enough concrete around the anchor to reach ground level. A removable redwood measuring staff was placed inside the gauge pipe. A bolt through the pipe about 5 inches above ground level was used as a support for the measuring staff. Powered cork was placed inside the gauge pipe and a galvanized threaded cap was screwed on the top of the pipe to keep the staff in a fixed position. As flow occurs in the stream, the powdered cork rises to the stream stage and is deposited on the redwood staff. The crest gauge is read by noting the highest occurrence of cork on the staff, indicating the highest stream stage that has occurred since the last monitoring visit. The instantaneous stream stage occurring during a sampling visit could also be measured by one-tenth of a foot increments painted on the exterior of the gauge pipe.

b. Sampling Procedures

On a monthly basis, field personnel visited each station and measured the instantaneous discharges. At stations where the flow was low and somewhat controlled such as a pipe culvert, a stopwatch and bucket of known volume were used to measure the flow. Where flow or stream channel conditions made this method impractical, a velocity meter was used to measure stream velocity. Velocity and flow depth measurements were made with the velocity meter on one-foot wide increments along the stream channel cross section.

Velocity readings were taken at sixty percent of the flow depth to represent the average velocity. Based on the incremental width, velocity, and flow depth, the flow rate for each increment was accumulated to get the total flow rate for the stream. When wading into the stream was considered unsafe due to higher stages and velocities, the discharge was computed from a velocity measurement at the bank times the cross-sectional area of the stream. The depth which was measured at the point of velocity measurement was used to estimate the corresponding cross-sectional area from the stream cross-sections developed from surveying when the stream was dry. The instantaneous stage height of the stream was also measured, and the maximum crest stage since the last inspection was noted.

Streamflow information for the area is composed of monthly streamflow measurements. Monthly streamflow data at the area were collected. The streamflow data are composed of a measured flow rate and stage at the time of monitoring and a stage crest since the previous monitoring visit.

5. Regional USGS Stream Gauging Stations

There are no long-term historical gauging stations on the streams potentially impacted by mining. Therefore, a regional approach was also used to estimate runoff characteristics for a receiving stream. This approach involved the extrapolation of data from gauged watersheds influenced by similar hydrometerology and sharing similar physiographic, soil and vegetational characteristics as the receiving stream watersheds. The records of the USGS were reviewed for streamflow gauging stations in the vicinity of the area. The criteria used in the selection of stream gauge data for the regional streamflow characterization of the receiving streams are: first, the period of record of the historical data should be sufficiently long to include both wet and dry periods; secondly, the drainage area upstream of the gauge should be on the same order of magnitude in size as the receiving streams; and finally, the gauged data should not be influenced by large upstream regulations or diversions.

6. Surface-Water Quality

Water quality data were collected on a monthly basis from October 1987 through July 1988. Five stream monitoring stations received untreated and/or treated runoff from disturbed or active mine areas during the monitoring period. The water quality analyses of samples taken at these sites will not be discussed in terms of characterizing the baseline surface water quality conditions for the renewal area.

Monthly water samples were also taken at three Lake Limestone monitor stations. Water quality samples were collected at the monitoring stations to determine representative water quality. The water quality parameters of the samples include and exceed those specified in the Regulations. Temperature, pH, specific conductance and dissolved oxygen were also measured in the field.

The samples collected by the mine were prepared as follows. Each sample was divided into four subsamples which were prepared for laboratory analysis according to the parameters to be analyzed. One subsample was filtered through a 0.45 micron cellulose acetate filter using a positive pressure (peristaltic) pump and acidified with nitric acid. The other three subsamples were left unfiltered. Reagent grade nitric acid to one subsample and sulfuric acid was added to another subsample. The fourth subsample was not acidified. The sample bottles were labeled with the following information: date, sample identification, type of aliquot (e.g. filtered preserved with type acid) and the initials of the sample collector. The sample containers were then packed in ice and shipped to the laboratory within 24 hours of sample collection.

7. One-Time Water Quality Sampling

To more completely characterize the quality of surface water in the area, the sampling program included a one-time sampling of surface-water bodies. The sampling sites were selected based on the size of water body, land access, and location of the site in relation to the permit application. Sampling procedures were similar to those used to collect the monthly surface-water samples, as previously discussed.

C. Ground-Water Baseline Data

1. Water-Level Measurements

Ground-water levels have been monitored at the C Area since 1985 for the long term monitoring wells, unless the well was mined through or otherwise destroyed. Water levels were generally measured in those wells on a quarterly basis.

2. Water Sampling and Chemical Analyses

Ground water has been sampled from various wells at the C Area since 1986. Samples were usually obtained after pumping the well until at least three casing volumes of ground water had been removed and the water temperature, conductivity and pH had stabilized. Field filtration and preservation were done, if necessary, at the time of sampling. Sample bottles were labeled, put on ice, and delivered to the laboratory.

The ground-water chemistry parameters analyzed most frequently during the various field programs within area C were carbonate, bicarbonate, chloride, sulfate, calcium, magnesium, sodium, potassium, pH, conductivity, and total dissolved solids. Methods used to analyze these parameters, as well as methods used to analyze other ground-water chemistry parameters investigated at the mine were documented in the permit application. Results of the field and laboratory analyses for wells at the C Area are presented in the permit.

3. Hydrogeologic Testing

Aquifer tests have been conducted at 22 locations within area C. Test programs have included pump tests and slug tests. All pump tests were constant-discharge and recovery tests. The slug tests were performed by dropping a sand-filled section of PVC pipe into the water column of each well. Results of the aquifer and slug tests conducted and analyzed by the mine, as well as descriptions of the geologic units being tested, are summarized in the permit application. Results of other aquifer tests not analyzed by the mine are presented also in the permit application. Details concerning specific hydrologic testing at the mine are provided in the following section.

Twenty two aquifer tests have been included in the C area. Aquifer test summary sheets and selected graphical plots from tests analyzed by the mine are provided in the permit application. The mine has conducted and analyzed twelve aquifer tests in the C Area.

4. Water Well And Oil And Gas Well Inventories

In 1987 the MCR mine conducted a combined field investigation, literature review and records search in order to update the 1979 water well inventory that was submitted with the 1983-1989 mining permit application. In June and July of 1992 they conducted another literature review and records search to update the 1987 well inventory. In addition to field verification by Northwestern, the following sources were used to obtain information about water wells in and within one mile of the proposed permit area: State Water Commission, Mine Company, State Department of Health and the State Water Development Board.

The 1979 State Department of Health inventory identified 118 wells within one mile of the permit boundary; the 1987 update identified 146 additional wells; and the updates in 1992 identified another 44 wells. Well locations and the well inventory are included in the permit application.

5. Hydrogeology

Principal sources of shallow ground water in the region of the MCR Mine area C include the Newby Sand of the Reklaw Formation, the Carrizo Sand, and sand units in the upper portion of the Calvert Bluff Formation. Ground-water velocities and flow directions in these hydrogeologic units are highly variable across the area and are dependent in part on the geometry and hydraulic properties of water-bearing zones. The areal extent and thickness of sand units vary considerably over the area, and different degrees of interconnection exist between the sands. On a local scale, ground-water flow is likely to follow a more variable path than suggested by the general direction of flow indicated by water table and potentiometric contour maps.

Ground-water flow directions within the permit renewal area were evaluated on the basis of water level measurements taken in monitoring wells located throughout the mine area. The historical water level data are presented in the permit application. Three water level maps were constructed using data from the second quarter of 1992. Water level measurements from shallow monitoring wells were used together with a topographic map to construct a map of the approximate water table elevation for the unconfined overburden. Measurements from monitor wells completed in the overburden interval between the L4 and L6 lignite seams were used to construct a confined overburden (interburden) potentiometric map. Measurements from monitoring wells completed beneath the L6 seam were used to construct an underburden potentiometric map. A list of wells that were monitored and their zone of monitoring is provided in the permit application.

6. Hydraulic Properties

The hydraulic properties of the geologic units within the C area were estimated from monitor well data and the results of a series of aquifer tests of selected sand intervals. Aquifer tests were not performed in one geologic formation because it covers only a small part of the mine area. Construction Specifications and water level data for monitoring and test wells are presented in the permit application. Summaries of selected aquifer tests outlined below and selected data plots are presented in the permit application. A summary of the results of aquifer tests conducted and analyzed by the mine are presented in the permit application. Results of other aquifer tests not analyzed by the mine are summarized in the permit application.

7. Recharge Capacity

Recharge capacity is defined as the "ability of the soils and underlying materials to allow precipitation and runoff to infiltrate and reach the zone of saturation" (SRA Coal Mining Regulations, 1988).

The premining recharge capacity of the C area was estimated using the method of Thornthwaite and Mather (1957) as modified by the EPA (Fenn and others, 1975). This procedure uses empirically-derived equations and tables to estimate the amount of incident precipitation (on a monthly and annual basis) which may become direct surface runoff, evapotranspiration, and percolating soil water. The water that percolates below the root zone will either be discharged at seeps and springs or will become recharge water to the ground-water system.

The average annual precipitation in the C area is 38.4 inches per year (Section 779.131), with average monthly precipitation ranging from a high of 4.5 inches in April to a low of 2.0 inches in July (Larkin and Bomar, 1983).

The percent of incident precipitation which immediately becomes surface runoff was estimated using runoff coefficients presented by Chow (1964). Runoff coefficients are equal to the fraction of precipitation which becomes direct surface runoff. The coefficients are empirically derived and are based upon vegetation cover, soil type and slope conditions.

Runoff coefficients range from 0.08 for level sandy pastures in the summer, to 0.25 for loamy rolling woodland in the winter and spring.

Also required for the water balance equation was an estimate of the soil moisture retention capacity of the soil. The retention capacity is the product of the available water at field capacity and thickness in the root zone. The retention capacity of the soils at the C area was estimated from a table presented by Thornthwaite and Mather (1957) which is based on soil type and vegetation cover.

8. Ground-Water Quality

Chemical characteristics of ground water within the Permit Area C were evaluated on the basis of water samples collected from 59 monitor wells. Of these 59 wells, twenty-four of the wells are screened in the unconfined overburden (water table) aquifer, seventeen of the wells are screened in the confined overburden (interburden) aquifer, and eighteen of the wells are screened in the underburden aquifer. Copies of the laboratory data reports are included in the permit application.

The use of cation-anion electrical balances (charge-balance error) provides a check against errors in water analyses. The difference between the sum of the major cations and the sum of the major anions divided by the sum of the two values (in milliequivalents per liter) and multiplied by 100 is the cation-anion electrical balance, expressed as percent. Charge-balance errors in the range of 5 to 10 percent are generally considered the maximum limits for reliable data in scientific work.

9. Water Chemistry in the Overburden

Twenty-four wells completed in the overburden were sampled. The wells range in depth from 15 to 188 feet. The analytical results for the 24 samples were plotted on a trilinear, or Piper, diagram, a method for graphically illustrating chemical water types. The concentration of the dominant cations (calcium, magnesium, sodium and potassium) and anions (bicarbonate, carbonate, chloride, and sulfate) were converted to milliequivalents per liter, and the percentage of contribution of each chemical species for each group was plotted on the diagram. The trilinear plot of the 24 analyses illustrates that the ground water in the overburden is variable in character. The cation distribution indicates that the samples range in composition from sodium/potassium to predominantly mixed cation. There is a small percentage of the ground water that has a calcium cation classification. In the anion triangle, there is a tendency toward a chloride/bicarbonate type water to a mixed anion-type water. Sulfate type water dominates only one sample.

The concentrations of TDS in samples from the overburden ranges from 51 to 6722 mg/L, with a mean of 485 mg/L. Values of pH range from 4.0 to 7.1 units, with a mean of *5.6* units. The maximum concentrations of dissolved iron and manganese were 51 and 4 mg/L, respectively. Two wells have concentrations of TDS in excess of 1000 mg/L. The high TDS concentration is most likely due to the proximity of these wells to mined out areas, where TDS concentrations are commonly higher than ambient concentrations.

10. Water Chemistry in the Interburden

Seventeen wells completed in the interburden were sampled. The wells range in depth from 90 to 286 feet. A trilinear plot illustrates that the water of the interburden is primarily of a mixed cation type, with lesser amounts of calcium and sodium. In the anion triangle, waters are generally of a mixed anion to a bicarbonate type. A few wells plot in the sulfate and chloride portions of the diagram. In the diamond plot, the water falls in several different chemical domains, illustrating the variable nature of the interburden waters.

The concentration of TDS ranges from 72 to 976 mg/L, with a mean of 250 mg/L. Values of pH range from 5.1 to 7.0 units, with a mean of 6.0 units. The mean concentration for dissolved iron and manganese is 2.81 mg/L and 0.85 mg/L, respectively.

11. Water Chemistry in the Underburden

Nineteen wells completed in the underburden were sampled. The wells range in depth from 88 to 299 feet. Trilinear plots of the analyses illustrate that the underburden ground water ranges from a mixed cation to calcium type water. The dominant anion is bicarbonate/carbonate, with mixed anion type water comprising the majority of the rest of the water. A single sample plotted in each of the sulfate and chloride type corners.

The concentration of TDS ranges from 135 to 1807 mg/L, with a mean of 380 mg/L. The range of pH is from *5.7* to 7.4 units, with a mean of 6.6 units. The mean concentration of dissolved iron is 1.33 mg/L and of dissolved manganese is 0.88 mg/L. With the exception of one sample having a TDS concentration of 1807 mg/L, the water quality within the underburden is of relatively good quality.

12. Ground-Water Use Inside And Within One Mile Of The Permit Area C Boundary

Inventories of existing water wells were performed in 1979, 1987, and 1992 to document locations, uses, and other information for wells inside or within one mile of the Permit Renewal Boundary. The 1987 and 1992 surveys primarily included a file search of the State Water Commission records and a field verification (conducted by the mines). Available information for each well is presented in the permit application.

The breakdown of water use from the 308 wells reported in this inventory is as follows: domestic - 139 wells, industrial - 13 wells, irrigation/stock - 10 wells, abandoned - 12 wells, public supply - 11 wells, destroyed - 1 well, mixed use (domestic and irrigation/stock) - 46, and none or unknown use - 76 wells. A majority of all wells within one mile of the permit renewal boundary are completed to a depth greater than 200 feet, in the underburden.

D. Baseline Information For CHIA

Under the coal mining regulations, the RA is required to provide an assessment of the probable CHIA on surface- and ground-water systems by proposed and anticipated mining operations within a defined cumulative impact area (CIA). For purposes of permit approval, the development of a CHIA must be sufficient to determine whether or not these operations have been designed to prevent material damage to the hydrologic balance outside the permit area. This involves the assessment of the aggregate effects of existing and proposed surface-mining activities on the hydrologic environment within the affected watershed systems.

The effects of mining in the western part of the MCR Mine were included in the CHIA prepared for the mining revision application submitted for the MCR3 Mine IV; both mines are located within the Navasota River drainage basin. The CHIA presented herewith contains the assessments of the effects due to the proposed mining expansion in the western part of the MCR Mine. Also included in this new CHIA are the cumulative effects of projected mining in the eastern MCR Mine and the MCR2 Mine on surface-water uses within the Trinity River Basin. The effects on the ground-water resources adjacent to each mine also are assessed. Figure I-1 shows the extent of the drainage areas, part or all of which are referred to as the Cumulative Impact Drainage Areas (CIDA's) of the Navasota and Trinity River Basins. Included in Figure I-1 are the Water Commission stream segments for which water-quality standards have been determined.

1. Delineation of Cumulative Impact Area

a. Surface Water

The surface-water CIA may be described as that area over which existing and proposed mining activities may cause measurable changes in specified hydrological parameters. The mining activities of the CIA within the Navasota River drainage include all the MCR3 Mine areas and the western portion of the MCR Mine area (Figure I-2). The mining activities of the CIA within the Trinity River drainage include the eastern part of the MCR Mine plus the MCR2 Mine areas (Figure I-2).The geographical boundaries used to describe the surface-water CIA follow the drainage basins which encompass all the proposed operations and any existing mines. For this CHIA, the mining activities are located in the Navasota River and Trinity River drainage basins (Figure I-1). In order to accurately describe the potential effects of the mining activities on the surface-water system of each CIA, a separate CIDA has been delineated. This CIDA takes into account all the surface-water drainage areas that influence the CIA. The CIDA's (Figure I-1) follow the watershed boundaries of each drainage basin.The CIA within the Navasota CIDA includes the headwaters of the tributaries that drain the MCR Mine Area and flow into Lake Limestone (Figure I-2). The CIA is delineated along the natural stream channel of the Navasota River to just upstream of the tributaries draining the MCR3 Mine areas. At this point, the CIA encompasses the watershed associated with these tributaries of the Navasota River. This CIA includes all of the MCR3 Mine areas and about half of the MCR Mine area. The downstream boundary of the CIA is located at the confluence of the Navasota and Brazos rivers. The total area of the CIA area is approximately 350 square miles.

The CIA for the eastern MCR and the MCR2 mine areas within the Trinity CIDA encompasses the areas draining both mines (Figure I-2). It includes part of the Tehuacana Creek downstream from the MCR2 Mine and along the Trinity River to the USGS gaging station near Crockett (No. 08065350). It also includes the area along Buffalo Creek downstream from the eastern MCR Mine area and along the Trinity River to the same USGS gauging station, the downstream boundary of the CIA, which consists of about 200 square miles. Both Tehuacana and Buffalo Creeks are tributaries to the Trinity River.

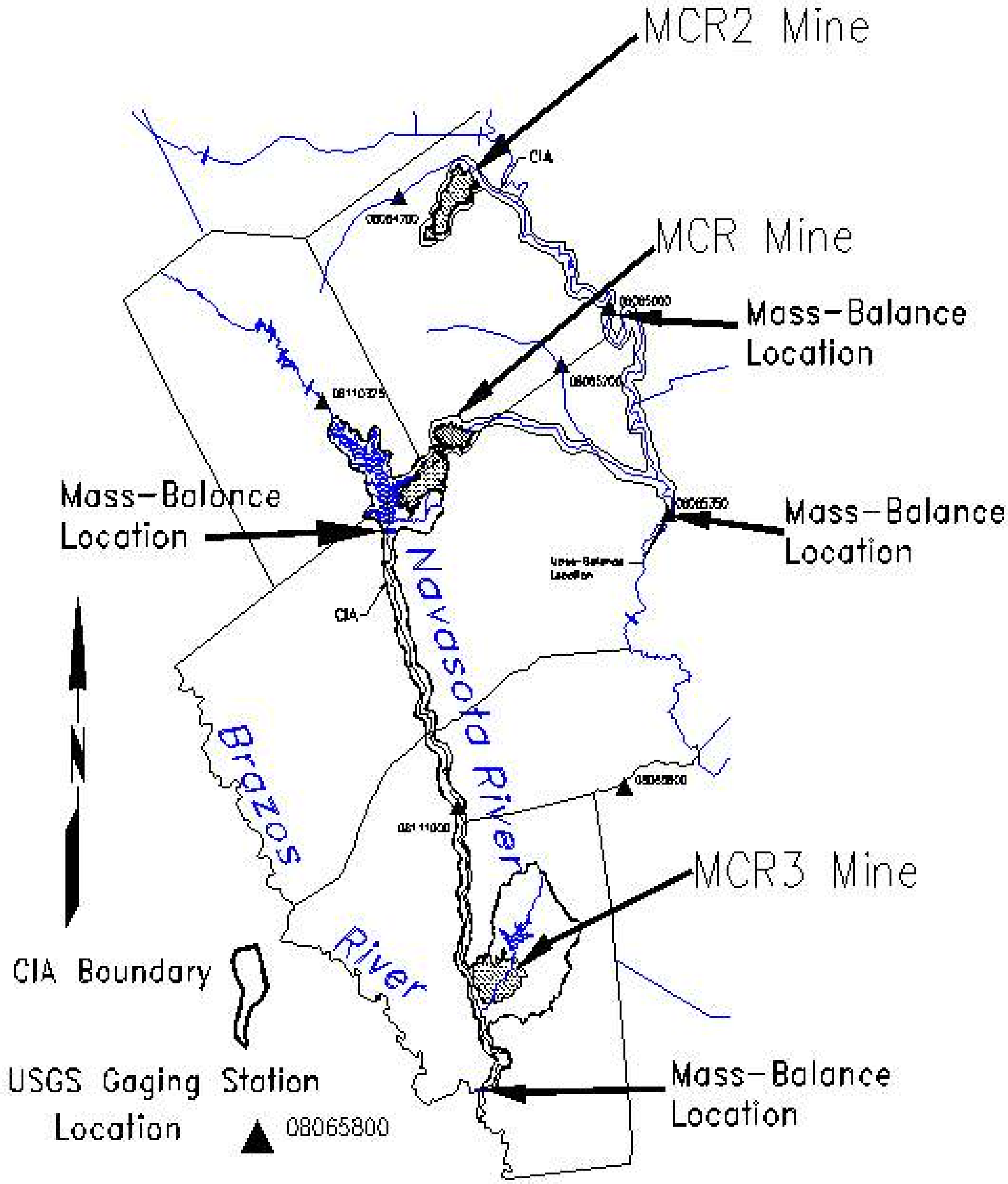

Figure I-2. The surface-water CIA and proposed mining activities within the Navasota River drainage

b. Ground Water

In the lignite-mine areas within the Wilcox and Jackson-Yegua geologic systems, two different sets of physical limits must be identified to describe the appropriate ground-water CIA. One set involves the boundaries of the impacted aquifer systems in each mine area; this is normally derived from the applicants' Probable Hydrologic Consequences (PHC) analyses. (The areal aquifer impacts caused in all mines within a hydrologic system are accumulated in the preparation of the CHIA.) The other set consists of the limits to which the long-term ground-water contributions to stream baseflow in the reclaimed mined areas affect the downstream surface-water uses. The latter usually encompasses a much larger area than the former and thus becomes the principal basis for the ground-water CIA.

In all three mines (MCR3, MCR, and MCR2), the effects of the surface-mining activities on each area's aquifer systems are expected to be confined to areas within or in proximity to the permit boundaries. Long-term impacts associated with the spoils-area ground-water contributions to streamflow probably will be insignificant. However, analyses related to these items are completed in this CHIA to estimate the effects on ground-water users adjacent to the mines and on downstream surface-water users.

The only significant use of surface water downstream from the western MCR Mine area is at Lake Limestone (industrial cooling, public supply). Surface-water users downstream from the MCR3 Mine include industrial uses and an irrigation permit (645 acres) to divert Navasota River water about 24 miles downstream from the mine. In addition, some riparian-rights users for domestic, stock, and irrigation are located in the small Navasota River reach between the mine and its confluence with the Brazos River. The drainage area of the Navasota River above this confluence is 2211 square miles.

The uses of surface water downstream from the MCR2 Mine area are those located along the Trinity River reach between the mine and the USGS streamflow gauging station near Oakwood (No. 08065000, Figure I-2). Trinity River water is diverted for industrial uses near the mine and for minor irrigation and municipal uses along the entire reach. Uses of surface water downstream from the western MCR Mine area include minor irrigation, municipal, industrial, and domestic and stock riparian-rights uses along the Trinity River below the USGS streamflow station near Crockett (No. 08065350, Figure I-2). There are no known uses for Buffalo Creek effluent nor for the flow at Tehuacana Creek between the MCR2 Mine and the Trinity River.

For purposes of delineating the ground-water CIA's for this CHIA, the surface-water CIA's will suffice. However, the CIDA's for the Navasota and Trinity Rivers (Figure I-1) will be used in mass-balance calculations.

2. Baseline Hydrologic Conditions and Summary of Data Used

a. Surface Water

The CIDA for the western portion of the MCR Mine drains approximately 2,211 square miles of the Navasota River Basin. The CIDA for the eastern portion of the MCR Mine drains approximately 13,911 square miles of the Trinity River Basin. Surface-water records available for this area include USGS gauging stations and applicant baseline monitoring stations.

Within the MCR Mine area, several USGS gauging stations characterize the regional runoff attributes. Station 08110325 on the Navasota River above Lake Limestone has a drainage area of 239 square miles. Based on records collected from 1978 through 1991, the average discharge is 76,070 acre-feet per year for an annual unit runoff of 0.50 acre-feet per acre. The Tehuacana Creek gauge (USGS Station 08064700) is situated in the Trinity River basin near Streetman. It has a drainage area of 142 square miles and a unit area discharge of 0.67 acre-feet per acre averaged over 23 years of discharge data. The series of USGS stations along the two drainage basins indicate a wide range of runoff. The Upper Keechi Creek gauge has a long period of record with flow being measured from a basin which has no regulated flow. Average flow from the Upper Keechi Creek station was used in the mass-balance analysis to characterize the flow for the area. The Upper Keechi Creek station, USGS Station 08065200, located east of the MCR Mine and South of the MCR2 Mine, has a drainage area of 150 square miles, and an average flow of 52,890 acre-feet per year for a 29-year period of record, and a unit area discharge of 0.55 acre-feet per acre.

Baseline water-quality records from the MCR Mine area indicate average concentrations for total iron of 2.49 mg/L, total manganese of 0.51 mg/L, total suspended solids of 37 mg/L, total dissolved solids of 376 mg/L, and a pH of 6.9 standard units.

Water uses of concern downstream of the MCR Mine area include industrial (cooling purposes), public supply and recreation. All of these uses are in the immediate Lake Limestone area.

Within the MCR3 Mine area, USGS station 08111000 on the Navasota River near Bryan drains 1,454 square miles. During the water years 1961 through 1991, the average flow was 418,800 acre-feet per year for a unit discharge of 0.45 acre-feet per acre. The Bedias Creek near Madisonville (USGS Station 08065800) is located northeast of the MCR3 Mine areas. It has a drainage area of 321 square miles and an average unit area discharge of 0.705 acre-feet per acre during the period of 1967 through 1991.

Surface-water quality for the MCR3 Mine area indicates elevated constituent levels compared to the MCR Mine area. Baseline TDS values for the MCR3 stations averaged 421 mg/L (based on a flow-weighted average of TDS concentrations provided in MCR3 V baseline information; see Tables .129-10 and .129-11) and ranged from 183 mg/L to 837 mg/L. Total suspended solids average concentrations ranged from a trace to 140 mg/L. Average total iron concentrations ranged from 0.10 mg/L to 1.77 mg/L. Average total manganese concentrations ranged from 0.27 mg/L to 0.85 mg/L.

Downstream from the MCR3 Mine, water users include a water-use permit issued to a Municipal Power Agency. The intended use is for industrial purposes. Other uses in this area include some riparian rights for domestic, stock and irrigation uses.

Surface-water quality for the MCR2 Lignite Mine area indicates elevated constituent levels similar to those of the MCR Mine area. Baseline TDS values for the MCR2 stations averaged 324 mg/L and ranged from 76 mg/L to 814 mg/L. Total suspended solids average concentrations ranged from <5 mg/L to 131 mg/L for all stations. Average total iron concentrations ranged from 0.77 mg/L to 3.66 mg/L. The average for total manganese concentrations was 0.54 mg/L.

Downstream of the MCR2 Lignite Mine, a utilities electric company holds a water contract which authorizes the use of 20,000 acre-feet of water per year from the Trinity River. The intended use is for industrial purposes.

b. Ground Water

The main aquifers in the MCR Mine area are the sands within the Claiborne and Wilcox Groups of Eocene age. The fairly permeable Carrizo Sand of the Claiborne Group is part of the shallow overburden and varies from 0 to more than 100 feet in thickness. The Calvert Bluff of the Wilcox Group consists of the lignite-bearing formation that overall forms most of the less permeable overburden system (0-300 feet thick); however, this formation also contains some very permeable sand channels. The underburden consists of deeper Wilcox sediments that are several hundred feet thick, including the Simsboro Sand, a major aquifer in the regional area.

Baseline ground-water information for the MCR Mine area is derived from 75 monitoring wells, 56 continuous cores, more than 1400 boreholes for geophysical logs, 22 aquifer tests and an inventory of more than 300 private wells. Fluctuations of aquifer head away from mining areas are small, whereas aquifer heads near mined areas have declined as much as 20 feet. The shallow water-table aquifer (Carrizo-Wilcox) contains water that varies from about 50 to more than 6000 mg/L in TDS, but the average is only about 485 mg/L. The confined Wilcox overburden contains water with a TDS content varying from 70-1000 mg/L, with an average of only 250 mg/L. The water in the confined Wilcox underburden has a TDS range of 135 to more than 1800 mg/L and an average of about 380. An average annual recharge of 2.7 inches was estimated to reach the water table, from where movement may be traced along the topographic relief. Movement in the confined Wilcox sands of the western mine area generally is eastward and southeastward along a regional gradient towards stream-valley lows within the Navasota River watershed. In the eastern area, movement is toward Buffalo Creek, a tributary of the Trinity River. About 60 percent of the inventoried private wells are used for domestic and stock purposes, and nearly 30 percent are in the category of wells that are unused, abandoned, destroyed, or the use is unknown; the rest are used for public supply, industrial, and irrigation needs.

Eight fine-grained sand units (aquifers) are identified within the Manning and Wellborn Formations of the Jackson Group, which is about 1600 feet thick in Grimes County and contains the lignite seams being mined in the MCR3 mine. Throughout each of the mine-block areas of the mine, the overburden strata consists of a pair of the sand units, interbedded with clay-silt lenses. Some of these sands may be as much as 100 feet thick, but most vary between 0 and 50 feet. The underburden system is similar, with one or two of the sand units making up the first permeable strata below the major lignite zones. Hydraulic conductivities of the sand-unit aquifers generally are less than 3 feet per day under predominantly confined conditions.

Baseline ground-water information for the existing MCR3 mine areas has been derived from more than 800 boreholes for geophysical logging, 22 aquifer tests, 24 continuous overburden cores, about 200 monitoring wells, and an inventory of more than 250 private wells. Ground-water movement in the identified sand units is generally southward (locally southeastward or southwestward) toward the MCR3 and Navasota River drainage areas. Recharge has been estimated to range from 1 to 6 inches per year over the outcrop area from an average annual rainfall of 39 inches. Average flow velocities within the overburden sand units range from 10 to 180 feet per year, but these can be much greater locally where hydraulic gradients are large. The chemical quality of the water in the sand units is quite variable, with pH values ranging from about 3 to 6, and TDS ranging from less than 500 to more than 8,000 mg/L with varying amounts of hydrogen sulfide gas. Most of the water is only marginally suitable for agricultural and industrial uses; some fresh water is used for domestic supplies.

The principal aquifers in the MCR2 Mine area are the sands within the lignite-bearing Calvert Bluff Formation of the Eocene Wilcox Group. Only the channel sands within this system have a significant transmissivity; most of these sands are found in the overburden material, which is 20 to 150 feet thick above the first of two lignite seams. Total saturated-sand thickness in the overburden varies from 0 to about 80 feet. The interburden between the two seams, plus the immediate underburden below the second seam, generally contain minor, thinly interbedded sand systems.

Baseline ground-water information for the MCR2 Mine is derived from more than 600 boreholes for geophysical logging, about 65 principal monitoring wells, 23 aquifer tests, 26 continuous overburden cores, and a private-well inventory of almost 140 wells. The total dissolved solids concentration of ground water in the unconfined overburden varies from slightly more than 100 to nearly 1800 mg/L, but the average is only slightly above 600 mg/L. The confined interburden and underburden ground water is generally lower in TDS content, varying from about 250 to slightly more than 1000 mg/L. Recharge to the water table is estimated to vary between 3 and 10 percent of the average annual rainfall of about 38 inches. Movement of the unconfined water in the overburden generally follows the topographic relief in the general direction westward and northward toward Tehuacana Creek, at velocities varying from 20 to about 300 feet per year. Movement in the confined interburden and underburden systems is more gradual and much slower, with velocities averaging about 12 feet per year. The direction of ground-water movement in the interburden is similar to that of the overburden; however, the underburden ground water moves eastward and northward toward the Trinity River and its alluvial system. Only about one-fourth of the inventoried private wells are active, and most of these are used for supplying domestic and stock needs.

3. Hydrologic Concerns

a. Surface Water

The principal hydrologic concerns, in relation to the probable impacts to surface water by the proposed surface-mining operations on the delineated CIA are as follows:

(1) Chemical changes in receiving streamflow

The chemical constituents found in the surface water flowing within and through the permit area may be affected by (1) exposure to new mineral surfaces due to spoil removal and replacement, (2) a change in the quantity of constituent loading on receiving streams in the CIA due to the change in amount of surface-water runoff from permit area, and (3) the chemically inferior contributions of the spoils ground water to the baseflow in the area.

(2) Physical changes in receiving streamflow.

The premine to postmine contour changes within the permit area drainage basins, and the introduction of impoundments and other surface-water control structures to the surface-water regime, may change the availability and quantity of surface water. Low flow, peak flow and the variations in flow through time from a specific precipitation event may be altered because of (1) changes in shape, slope, land cover, and soil type of watersheds in the permit area, (2) retention and detention of surface water in impoundments, (3) rerouting of overland flow, and (4) construction of stream channel diversions. Changes in TSS of receiving streams in the permit area should also be evaluated.

(3) Geomorphic changes within the CIA's drainage basins

The physical changes in the permit area may result in geomorphic instability of the drainage basins within the CIA. Changes in the amount of sediment produced from the premine, active-mine, and postmine conditions may affect the receiving stream's erosional or accretion capacity. Geomorphic changes may, in turn, result in additional physical changes in receiving streams or their watersheds.

2. Ground Water

The principal hydrologic concerns, in relation to the probable impacts to ground water by the surface-mining operations in these lignite mines, are as follows:

a. Aquifer-head drawdowns and declines

The water levels in private wells located within or outside the permit area may be drawn down by (1) pit inflow resulting from the removal of the shallow overburden material, (2) pumping wells drilled for dewatering the overburden in advance of mining, and (3) deep pumping wells drilled into the underburden to depressurize the aquifer in order to avoid mine-floor heave. All of these surface-mining activities will have the potential effect of reducing the availability of ground water to the private wells tapping the various aquifers in the area.

b. Physical changes in the reclaimed spoils areas

The removal of stratified overburden sediments and the replacement with mixed overburden material (spoils) will result in physical changes that affect resaturation and the ground-water flow regimen. Initially, porosity and the vertical permeability very likely will be greater than those during premine conditions, and the resaturation rates will be larger than the premine recharge rates. These parameters should decrease with compaction, and the resaturation also will decrease. The bulk transmissivity in the reclaimed spoils may be less than during premine conditions, which will bring about a different equilibrium of ground-water flow as resaturation takes place. This may result in different water-table gradients as well as local changes in the quantity and location of the natural discharge (springs, seeps) to surface drainage ways.

c. Chemical changes in the spoils ground water

Resaturation of the spoils area will create a system containing a more mineralized ground water than that which existed during premine conditions. This is due to the leaching of the fluffed overburden mix. The nature of the increases in the total dissolved solids, acidity, and toxic elements is critical to the eventual contributions of spoils ground water to adjacent aquifers and to springs and seeps. The quality of the well water that is withdrawn from these adjacent, as well as deeper, aquifers could be impaired. Surface water being used downstream from the reclaimed areas could be affected by the chemically inferior contributions of the spoils ground water to the base flow in the area.

E. References

Baker, E.T., Jr., A.T. Long, R.D. Reeves, and L.A. Wood, 1963, Reconnaissance Investigation of the Ground-Water Resources of the Red River, Sulfur River, and Cypress Creek Basins, Texas: Texas Water Commission Bulletin 6306, 126 pp.

Bedout, D.G. P.E. Luttrell, and J.H. Seo, 1976, Regional Tertiary Cross Sections - Texas Gulf Coast: The University of Texas, Bureau of Economic Geology, Geologic Circular 76-5, 10 pp.

Brune, Gunnar, 1981, Springs of Texas: Volume I, Branch-Smith, Inc., Fort Worth, Texas.

Chow, V.T., editor, 1964, Handbook of Applied Hydrology – A Compendium of Water Resources Technology, New York, McGraw Hill.

Fenn, D.G., K.M. Hanley, and T.V. De Geare, 1975, Use of the Water Balance Method for Predicting Leachate Generation from Solid Waste Disposal Sites: U.S. EPA, 530/SW-168, 40 pp.

Fogg, G.E., and C.W. Krietler,1982, Ground-Water Hydraulics and Hydrochemical Facies in Eocene Aquifers of the East Texas Basin: The University of Texas at Austin, Bureau of Economic Geology Report of Investigations No. 127, 75 pp.

Jackson, M.P.A., 1982, Fault Tectonics of the East Texas Basin, The University of Texas at Austin, Bureau of Economic Geology Geologic Circular 82-4, 31 pp.

Kaiser, W.R., 1978, Depositional Systems in the Wilcox Group Lignite Belt, East Texas and the Occurrence of Lignite; in Proceedings of Gulf Coast Lignite Conference: Geology, Utilization, and Environmental Aspects: The University at Austin, Bureau of Economic Geology, RI 90.

Larkin, T.J. and G.W. Bomar, 1983, Climatic Atlas of Texas, Texas Department of Water Resources, LP-192, Austin, 151 pp.

Railroad Commission of Texas (RCT), 1988, Revised Coal Mining Regulations.

Thornthwaite, C.W. and J.R. Mather, 1957, Instruction and Tables for Computing Potential Evapotranspiration and the Water Balance: Drexel Institute of Technology, Laboratory of Climatology, Publications in Climatology, Vol. X, No. 3.

U.S. Corp of Engineers, 1976, Final Environmental Statement, Sterling C. Robertson Dam and Limestone Lake on the Navasota River, Texas, Fort Worth, Texas.

APPENDIX J.

REGIONAL EXAMPLE SHOWING BASELINE INFORMATION FOR GEOLOGY AND HYDROLOGY

WESTERN SEMIARID SITE

The number of locations at which site-specific baseline data for geology, overburden, surface water and ground water needs to be collected depends on many variables. Rather than presenting and attempting to rationalize minimum or maximum numbers and locations for surface-water stations, boreholes for overburden data, ground-water observation wells and frequency and duration of water sampling, we have included summaries of baseline information for geology and hydrology as it exists in planned or actual permits. We refer to these summaries as regional examples of baseline data requirements. In this context, regional can refer to hydrologic issues as may exist in one region but not all regions of the country and for which precise kinds and amounts of data are needed to establish, for example, the potential for acid mine drainage formation. Regional may also refer to differences in philosophy and technical approach to sampling and standards deemed acceptable for baseline geology and hydrology information from one state or region to another.

The three examples of baseline information collection from different regions of the country are presented in Appendices H, I, and J.

- The eastern permit example which is presented in Appendix J represents an area surface mine in a temperate humid region.

- The mid-continent permit example which is presented in Appendix I represents an area lignite mine in temperate continental region.

- The following western example summarizes an actual work plan for baseline data collection for an area mine in a semiarid region. The plan was developed by the operator in close cooperation with the RA. The work plan illustrates how the need for new ground- and surface-water stations and data collection was based on an evaluation of existing information from nearby mines.

The proposed WR Mine site covers approximately 3,500 acres and is located approximately 35 miles south of Chindeton on lands of the Chinde Reservation. (See Figure J-1.) It is in the arid and semiarid climatic region of the Colorado Plateau physiographic province of the Western U. S., geographically west of the 100th meridian west longitude. Elevation ranges from 5,000 to 5,700 feet above sea level. The average annual precipitation is 8.00 inches with an average net evaporation rate of 55 inches. Native vegetation is characteristic of the Colorado Plateau salt-desert shrub ecosystem. This ecosystem contains a large number of salt tolerant species, such as saltbrush, and a significant shrub component. Land use is characterized by very low intensity livestock grazing, with a few scattered dwellings and few primitive roads crossing the area.

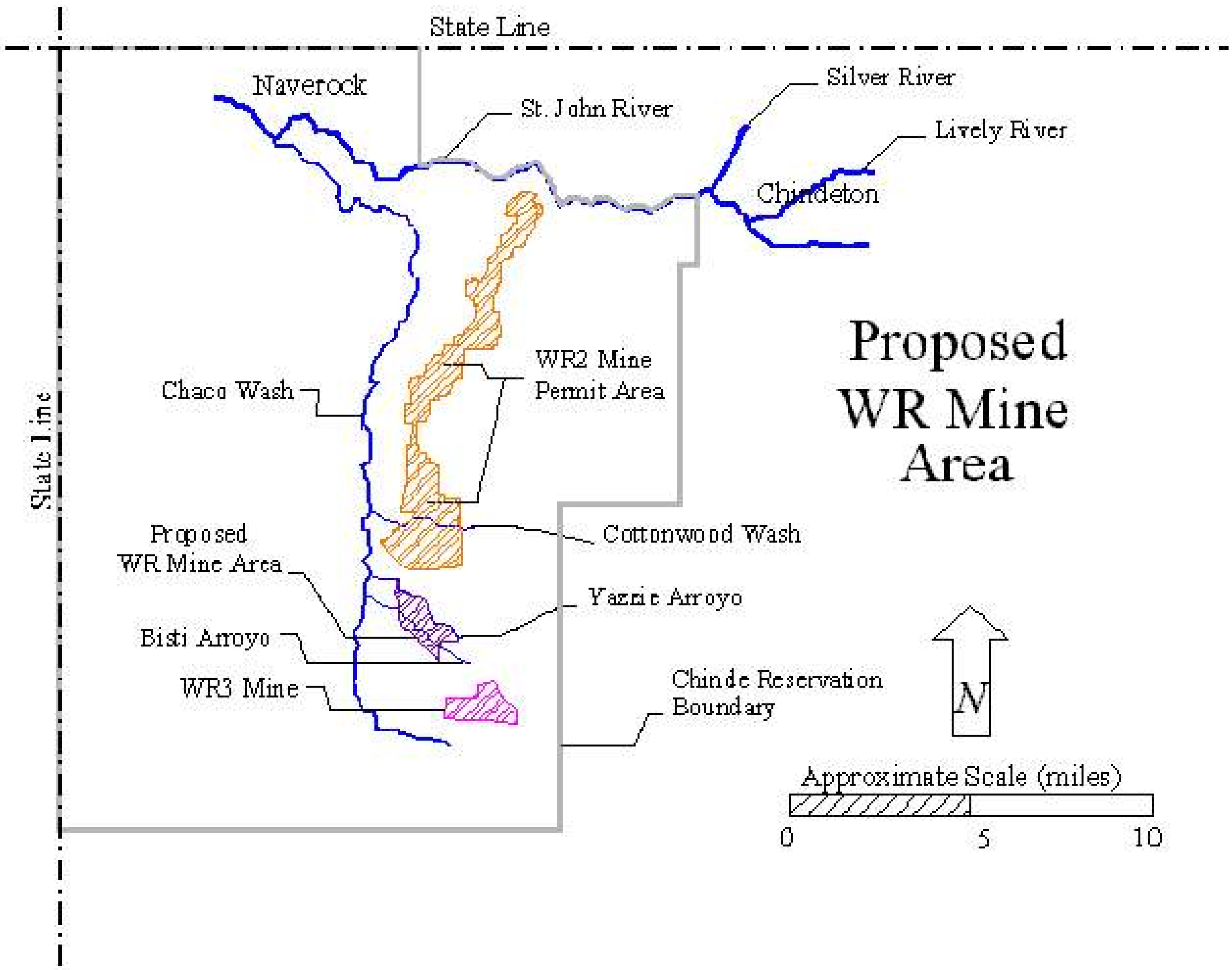

Figure J-1. Location of the Chinde Mine and other mines in vicinity.

A. Geologic Setting

The proposed mine site is along the western flank of the San Juan Basin, a northwest trending structural basin. The basin is bounded on the northwest by the Hogback mononcline and on the north by the San Juan Uplift. The eastern rim is formed by the Brazos Uplift and the Nacimiento Uplift. The Zuni Uplift and the Chaco Slope form the southern margin of the basin and the Defiance Uplift and Four Corners Platform complete the northwestern rim of the basin (Fasset and Hinds, 1971).

Rock strata strike north-south and dip an average of 2 degrees to the east. No major faults cut the area, although minor low-angle compaction faults and slumps up to seven feet in displacement are common. The area is seismically stable. There have been no historically recorded earthquakes of sufficient magnitude to damage structures (U.S.D.I., Bureau of Reclamation, 1975).

The stratigraphic section reflects the Late Cretaceous transition of shallow marine depositional environment to terrestrial fluvial depositional environment. Major stratigraphic units, in ascending order, are the Lewis Shale, the Pictured Cliffs Sandstone, the Fruitland Formation and the Kirtland Shale. Also, deposits of Quaternary alluvial and eolian sands occur within the proposed permit area.

The Lewis Shale consists of gray to black shale with some interbedded sandy limestone, brown sandstone and bentonite. The Pictured Cliffs Sandstone conformably overlies and intertongues with the Lewis Shale. The upper two-thirds of the Pictured Cliffs consists of a generally coarsening upward sequence of light gray, fine to medium grained sandstone. The lower one-third consists of interbedded shale and sandstone. The Fruitland Formation conformably overlies the Pictured Cliffs and consists of thinly bedded fine to medium grained sandstones, siltstones, sandy and silty claystones, carbonaceous claystones, bentonitic claystones and coal. The Kirtland Shale conformably overlies the Fruitland Formation and is divided into two units, the upper and lower shale members. The lower shale member is composed of gray claystone shales that are interbedded with a few thin sandstones and siltstones. The upper shale member consists of purple, green, white and gray claystone shales interbedded with sandstone lenses.

The economically important stratigraphic interval is the lower 250 feet of the Fruitland Formation where 11 different minable coal seams occur. These coal seams are very lenticular in nature and are minable in very localized areas only. The coal seam to be mined at the proposed WR Mine is the B Seam.

The following work plan for baseline data collection describes the individual tasks involved in collecting geology/overburden, ground-water and surface-water data needed for the permit application.

B. Work Plan For Baseline Data Collection

1. Geology/Overburden

The following 3 tasks will be undertaken to develop the baseline information for geology/overburden:

- Assemble existing geology and overburden information
- Collect additional geology and overburden information
- Describe the baseline geology

a. Task 1

Available geologic and mineral resource data that pertain to the proposed WR Mine area will be obtained. The data will be reviewed and verified. Information from the nearby WR2 Mine will also be reviewed, because of its close proximity to the proposed project and the similarities in geology and minerals. Additional information will be gathered from Federal, Tribal, and State agencies.

Available geologic and seismic maps of the proposed project and nearby areas will be researched and coal geology, surficial geology, active faults, seismic areas, overburden characteristics, and geochemical characteristics will be described. Geochemical characterization of overburden material test data will be reviewed for adequacy. Available aerial photographs will be reviewed in an effort to evaluate present and past mine disturbance. All other existing or available geologic data or appropriate data from WR2 Mine will be reviewed.

b. Task 2

(1) Drilling Program Description

Rotary drilling will be used to retrieve continuous overburden cores. The holes will be drilled with a 5-1/8" to 5-5/8" diameter bit. Core diameter will be 3 inches. All holes will be drilled with a rubber-tired exploration drill. The drilling medium used will be air or air-water mist. The use of drilling mud is not anticipated during the project. However, if it becomes necessary, a self-contained trough will be used as a repository for the mud. Any such mud will be disposed of at an approved facility. Cutting logs, core logs, and geophysical logs will be kept for all drill holes.

The drilling plan consists of up to 22 drill locations in a two-phase program. Phase I consists of 14 holes, of which 10 are continuous core holes for overburden characterization and 4 are rotary core pairs to define coal structure. The continuous core holes will average 150 feet in depth. The rotary core pairs will average 170 feet in depth and will consist of a plug-drilled hole to locate the seams and a combination plug and core drilled hole for recovery of the coal samples. Holes are generally expected to intersect 15-35 feet of coal spread over three to eight seams with a maximum single seam thickness of about ten feet. Phase II will be drilled only if additional overburden drill data are required and coal information will be collected.

(2) Analysis of Phase I Drilling

The following outline specifies steps that will be taken for the statistical analysis of data collected during Phase I drilling. If clear decisions can be made regarding overburden suitability from the first phase analysis, then further data analysis will not be conducted.

(3) Outline of Proposed Statistical and Geostatistical Characterization of Overburden at the Proposed WR Mine

I. Preliminary analysis of existing data from 4 cores drilled near theWR Mine site

   a. Investigation of vertical spatial correlation

   b. Investigation of horizontal spatial correlation assuming similarity within lithologic layers and similar formative processes across lithologic layers

II. Analysis of 10 cores from the WR Mine site for estimating means and totals

   1. Investigation of spatial correlations in vertical direction.

   2. Parameter statistical means

      - Estimates for entire mine site

      - Estimates stratified by lithologic layer

      - Optionally, estimates stratified by lithologic layer and spatial subregions

      - Investigation of sample adequacy based on precision of estimates

3. Proportion of overburden material which is suitable for reclamation

    - Methods are based on estimating binomial proportions for each parameter of interest

    - Sample adequacy is judged based on precision of estimates

4. Probability of hot-spots, if none were detected in samples collected

III. Spatial mapping

- Kriging can be employed to develop point estimates in two or three dimensions

IV. Discussion of adequacy and further drilling needs. If mine planning and economic decisions cannot be made with adequately low probability of error, then additional drilling would be required in order to refine spatial resolution of the overburden characteristics.

(4) Data Analysis

Analysis of overburden material will follow the methods shown below to determine whether acid-or-toxic-forming materials exist and if special handling procedures will be required. Geochemical analysis will be conducted for the parameters listed in Table 1. Verbal communications with the OSM indicated that metals are not an issue in this area. Therefore, analysis of metals for theWR Mine area will not be conducted.

The overburden strata, including coal strata that would not be mined, and the strata up to 5 feet below the lowest coal seam to be mined will be analyzed. Sampled intervals shall be a minimum of 1-foot length of 3-inch diameter core, and a maximum of 5 feet length based on OSM guidelines. Each sample will represent a single lithologic unit except where intervening strata are less than one foot in thickness. Strata thicker than 5 feet may be represented by one or more samples.

Table J-1. Overburden Parameters

Parameters	Sample Method Reference
Sodium Absorption Ratio (SAR) - saturated paste Electrical conductivity Extractable calcium, magnesium, and sodium	Page, 1982
Boron - hot water soluble	Page, 1982
Selenium - hot water soluble	Page, 1982
Selenium - Total	Bajo, 1978. (The Bajo Method of total digestion is followed by the hydride method of detection)
Acid-Base Potential (ABP)	Skousen, et al, 1997 Sobek, 1978 (Sulfur fractionation will be performed if the ABP $\leq$ -5)
Calcium carbonate percentage	U.S. Salinity Laboratory Staff, 1954
Saturation percentage	Page, 1982
Exchangeable Sodium Percentage (ESP) (ESP will be determined for 25% of samples with SAR values >18)	Page, 1982
Texture	Page, 1982
pH	Page, 1982

c. Task 3

Description of the baseline geology will involve compiling a detailed geologic map and description of general geology, surficial geology, seismic areas (if available), and geochemical characteristics of overburden material, in the proposed project and cumulative effects areas. Known geologic features such as faults and fractures in the project and cumulative effects areas will be described. One or more cross-sections will be provided showing stratigraphy (i.e., coal seams, shale, and sandstone units).

Known active or potentially active faults will be described on maps and discussed in the environmental impact statement. The seismic environment of the area will be described.

Abandoned and past mining activity in the general area will be summarized. This will be presented in tabular form, along with known existing plans, proximity to the proposed project, BLM or Tribal number (if available), operator, type of operation and acres of disturbed land. Where possible, aerial maps will be used to determine existing disturbance.

2. Ground-Water Baseline

The following 3 tasks that will be undertaken to develop the ground-water baseline:

- Assemble existing ground-water information
- Collect additional ground-water information
- Identify all water rights and determine present water use

a. Task 1

The baseline ground water assessment will consist of an evaluation of the prevailing ground-water hydrology. Considerable hydrologic information currently exists in the vicinity of the proposed project, including information on ground water from the nearby surface mining operation at theWR2 Mine, ground-water information associated with a proposed underground coal gasification project located immediately west of the proposed WR Mine (U.S.D.I., FES 76-2), regional hydrologic information from the U.S. Geological Survey and the New Mexico Bureau of Mines and Mineral Resources, and information associated with mining and reclamation at the nearby WR3 Mine.

In the vicinity of the proposed mine permit area, the hydrogeologic units which may yield water include the:

- The coal units of the Fruitland Formation
- Picture Cliffs Sandstone, located below the B Coal Seam
- Alluvium of the Yazzie and Bisti Arroyos

(1) Coal Units of the Fruitland Formation

Based on data contained in the WR2 Mine permit application, the flow directions within the Fruitland coal seams are primarily down dip toward the east. Aquifer testing of wells completed in the coal units at the WR2 Mine have shown very low values for transmissivity and hydraulic conductivity. The highest hydraulic conductivities, 1.80 ft/day and 0.25 ft/day, were observed in the H and I Coal Seams, respectively. The lowest hydraulic conductivities, 0.005 ft/day, were observed in the E, F and G seams.

Water-quality monitoring data from the WR2 permit application, show the coal seams to be of a sodium-bicarbonate-chloride type with very high concentrations of total dissolved solids (TDS). TDS concentrations have been found to range from about 4,400 mg/L to over 49,000 mg/L, with the lower concentrations within the mine area and closer to the outcrop. Sampling of coal baseline wells will be combined with information from the coal wells at the WR2 Mine to define the baseline water quality of the Fruitland Formation coal seams in the permit area.

Based on the mining experience at the WR2 Mine, the overburden and interburden in the Fruitland Formation is not expected to yield much water during mining. The saturated sands that occur are of limited extent and only yield significant water when supplied by water from the nearby Chinde Agricultural Products, Inc. (CAPI) irrigation project. CAPI irrigation project influences are not expected to extend into the stream drainages at the proposed WR2 Mine. Also, direct recharge of overburden and coal seams is expected to be low because of the low average annual precipitation and the high evaporation rates. What little recharge that does occur is expected to occur primarily along the arroyos and at surface depressions and impoundments. No springs or seeps are known to occur within the permit area.

(2) Picture Cliffs Sandstone

The Picture Cliffs Sandstone is the first water bearing unit below the lowest coal seam to be mined (the B coal). Based on data contained in the WR2 mine permit application, the Picture Cliffs Sandstone is nearly 120 feet thick and dips toward the east. The sandstone is a well-cemented marine sand with relatively low permeability. Aquifer testing of wells completed in the Picture Cliffs Sandstone at the WR2 Mine showed very low values for transmissivity (1.2 and 0.8 gal/day/ft) and an average hydraulic conductivity of 0.0014 ft/day. Aquifer testing of Well O-1 completed in the Picture Cliffs Sandstone at the WR3 Mine showed slightly higher values for transmissivity of 6.3 gal/day/ft and for hydraulic conductivity of 0.0094 ft/day.

Based on water elevations from seven wells completed in the Picture Cliffs Sandstone within the vicinity of the proposed WR Mine permit area, the ground water flow direction is primarily toward the northwest. Most of these Picture Cliffs Sandstone wells were completed to monitor a proposed underground coal gasification project located immediately west of the WR Mine permit area.

The water quality of the Picture Cliffs Sandstone is a sodium sulfate type with high TDS concentrations. The TDS concentrations measured in Picture Cliffs Sandstone wells at the WR2 Mine have varied from 5,100 mg/L to 16,500 mg/L.

(3) Alluvium of Yazzie Arroyo and Bisti Arroyo

Alluvial fill deposits occur in the valley bottoms of Yazzie Arroyo and Bisti Arroyo. Portions of the alluvium of Yazzie Arroyo are saturated and will yield water to wells, as evidenced by the two dug wells located within the permit area. The alluvium of Bisti Arroyo was found to be dry based on an alluvial monitoring well installed for the proposed underground coal gasification project downstream of the proposed WR Mine permit area.

b. Task 2

(1) Wells

A program for collection of additional ground-water baseline data is proposed to supplement ground-water information available from other sources. The program will include construction of two wells (Wells1 and 2) screened in the B Coal Seam. Water elevations in these wells and the oxidized coal boundary will be used to determine the potentiometric surface in the B seam. Sampling and analysis of these wells will also be used to verify and supplement the water-quality results obtained for the coal units at the nearby WR2 Mine. If the results from the two B Coal Seam wells exhibit a water quality and yield adequate to support domestic or agricultural use, then an additional B seam well would be completed. One well will also be constructed and screened in the Picture Cliffs Sandstone (Well 3), the first water yielding unit below the coal seams.

One well screened in the first saturated bedrock unit will be constructed at a site adjacent to the Yazzie Arroyo alluvium (Well 4). This well will be constructed at the edge of the buffer zone along Yazzie Arroyo and near the alluvial monitoring well. The purpose of this well is to help quantify any drawdown influence in the alluvium of Yazzie Arroyo that may result from proposed mining. The well will determine the depth to saturated bedrock adjacent to the alluvium. Also, a pumping test of the well will be performed to determine the hydrogeologic properties of the saturated bedrock and to identify any response in the alluvial aquifer due to pumping the saturated bedrock. Sampling and analysis of the well will also be performed to enable a geochemical evaluation of the water quality of the saturated bedrock relative to the alluvium.

The anticipated well depths and screened intervals for the bedrock wells are as follows:

Location	Unit	Total Depth	Screened Interval
1	C Coal	100 feet	10 feet
2	C Coal	200 feet	10 feet
3	Picture Cliffs SS	165 feet	85 feet
4	Yazzie Arroyo	35-50 feet	10 feet

In addition, two wells will also be constructed and screened in the alluvium of Yazzie Arroyo (Wells Y1 and Y2) and two wells will be constructed and screened in the alluvium of Bisti Arroyo (Wells B1 and B2).

Given the projected depth of the proposed wells, Schedule 80 PVC casing will be used. Well screens will be installed using 4-inch diameter (ID) slotted Schedule 80 PVC screen with a slot size of 0.010 inches and fitted with a threaded end-cap. The remainder of the riser pipe of the well will be made up of 4-inch diameter (ID), flush-threaded Schedule 80 PVC. The annular space between the borehole wall and the well will be back-filled with 10-20 silica sand to a depth of one to two feet above screen. A minimum two-foot thick bentonite slurry plug will be placed above the sand pack and the remainder of the annulus will then be filled with cement grout mixed with 2% to 5% bentonite.

The well will be developed using a combination of bailing, surging, and air-lift pumping until cuttings in the produced water are minimal. The water produced by air lifting will be contained nearby to prevent channeling or erosion and allowed to infiltrate and evaporate

The wells to be completed in the alluvium of Yazzie Arroyo and in the alluvium of Bisti Arroyo will be drilled using hollow stem augers. Given the projected depth of the proposed wells of 30 feet or less, Schedule 40 PVC casing will be used. Wells will be constructed with 2-inch diameter mill-slotted, Schedule 40 PVC screen with a slot size of 0.010 inches and fitted with a threaded endcap. The remainder of the riser pipe of the well will be made up of 2-inch diameter, flush-threaded Schedule 40 PVC. A sand pack comprised of 10-20 silica sand will be placed around the screened interval of the monitoring wells through the annular space of the hollow-stem auger to a depth of approximately one to two feet above the screened internal. A two-foot bentonite seal will then be placed above the sand pack, and the remainder of the annulus will be filled with a Portland cement/bentonite grout slurry to ground surface.

The alluvial wells will be developed by bailing and surging until cuttings in the produced water are minimal. The water produced by air lifting will be contained nearby to prevent channeling or erosion and allowed to infiltrate and evaporate.

(4) Pumping Tests

A single-well pump test or slug test will be conducted at each installed well. If the water produced during well development indicates relatively low transmissivity for the well screened interval, slug tests will be conducted with interpretations based on recovery measurements. Otherwise, a constant rate pumping test will be conducted with interpretations obtained using both drawdown and recovery data.

Single-well tests will be run a sufficient length of time so that wellbore storage effects will not significantly influence the test results. Discharged water will be piped beyond the area of influence of the pumping well and released on the ground. Discharged water will be directed onto a sheet of plastic with rock baffles to spread the flow and avoid erosion of soil, at sufficient distance from the wells to avoid any measurable recharge during the course of the test. Discharge flow will be measured by a totalizing meter at the wellhead, and by a weir or flume at the discharge end of the line. Water levels will be monitored in the pumped well with a probe. Water levels will also be monitored after pumping ceases until the water level has recovered to at least 90 percent of pre-pumping levels.

(5) Data Collection

Data collection will be for a period of one year. The ground-water baseline data collection will include quarterly measurement of ground-water levels and water-quality sampling in all baseline wells. Field readings of pH, temperature and conductivity will be taken at the time of sampling. All water samples will be analyzed for the parameters listed below including cation/anion balance to check laboratory accuracy. All ground-water sampling and analysis will include sample collection and chain-of-custody documentation.

Table J-2. Ground-water quality parameters

pH	Sulfate	Mercury
Calcium	Barium	Bicarbonate-meq/L
Potassium	Magnesium	Chloride
TDS	Selenium	Nitrate
Fluoride	Zinc	Carbonate-meq/L
Conductivity	Copper	Silver
Iron (dissolved)	Radium 228	Arsenic
Iron (total)	Cadmium	Boron
Manganese (disssolved)	Radium 226	Lead
Manganese (total)	Chromium	Cation/Anion Balance
	Sodium	

Sampling will be performed using dedicated pumps or bailers. Prior to collecting a sample, the water in the wells will be purged until field parameters stabilize. Alternately, a mini-purge procedure using a low pumping rate may be adopted for collecting a sample of formation water from the screen interval without having to purge several casing volumes.

c. Task 3

An inventory of all water-supply wells located within three miles of the permit area will be conducted by reviewing records from the Department of Water Resources Management of the WR Nation. The tabulation will include descriptive information from the records, if provided, including: the user, total depth, producing interval and unit, date of completion, well elevation, specified use, water quality information, and production or yield. Identified wells will be located on a map. An attempt will be made to verify whether the well exists and is in use.

3. Surface-Water Baseline

The following 3 tasks will be undertaken to develop the surface-water baseline:

- Assemble existing surface-water information.
- Collect additional surface-water information.
- Identify all surface water rights and determine present surface water use.

a. Task 1

The baseline hydrology assessment will consist of an evaluation of the prevailing surface water hydrology. Considerable hydrologic information currently exists in the vicinity of the proposed project, including information from the nearby WR2 and WR3 Mines and regional hydrologic information from the U.S. Geological Survey and the New Mexico Bureau of Mines and Mineral Resources.

The surface-water baseline will provide a description of surface-water flow and water-quality conditions which currently exist within the permit and adjacent areas. Ephemeral streams within the proposed permit area and adjacent area include Bisti Arroyo and Yazzie Arroyo. Watershed descriptions and general basin characteristics for Yazzie Arroyo and Bisti Arroyo will be based primarily on existing data supplemented with additional information from activities described in Task 2.

The drainage basin areas for Yazzie Arroyo and Bisti Arroyo where they exit the lease area are 56.2 square miles and 8.4 square miles, respectively. The drainage basin area for Bisti Arroyo upstream of the lease is 1.9 square miles. Although the flow in both Yazzie Arroyo and Bisti Arroyo is ephemeral, the streams are defined by OSM regulations as perennial or intermittent because the drainage basin area is greater than 1 square mile. Yazzie Arroyo and Bisti Arroyo have not yet been monitored.

Flow and water-quality characteristics from neighboring streams will be used to characterize the flow regime and water-quality characteristics for surface water in the vicinity of the proposed mine. Cottonwood Arroyo, located immediately north of Yazzie Arroyo, is monitored for flow and water quality by the WR2 Mine. Brimhall Wash, located immediately south of Bisti Arroyo, is monitored for flow and water quality by theWR3 Mine. In addition, surface-water monitoring of Yazzie Arroyo and Bisti Arroyo will be implemented under Task 2 to obtain site-specific information from the mine permit area to supplement the regional hydrologic information.

Watershed evaluations of pre-mine flow and erosion will also be performed using the SEDCAD surface water hydrology program to determine expected storm runoff volumes, channel velocities and sediment yields.

b. Task 2

Although considerable baseline hydrology information is currently available for the surface mine operation, additional field data will be needed to support the proposed permit application.

The methods that will be used to collect this data are:

(1) Installation of Crest Stage Gauges and Sediment Samplers

As indicated in Task 1, watershed descriptions and general basin characteristics for the Yazzie Arroyo and Bisti Arroyo drainages will be based primarily on existing data. However, crest stage gauges and single stage sediment samplers will be installed at a suitable location near where these channels enter and exit the permit area, as shown in Figure 3 Surveyed channel profiles and cross sections will be established at the crest-stage gauge locations. Stage-discharge relationships will be developed for both crest gauge locations using Manning's equation and estimates of site-specific roughness coefficients.

The surface impoundment located on Bisti Arroyo just above the point where the Burnham Road crosses the channel will also be monitored with a staff gauge. The impoundment will be surveyed to establish a stage-capacity relationship.

(2) Channel Stability Evaluation

A channel stability evaluation will be prepared to describe pre-mining conditions for the main channels of Yazzie Arroyo and Bisti Arroyo. Key channel features that will be identified include road crossings, culverts, dams, tributary junctions, bedrock outcrops, and head cuts, knickpoints, and other erosional features. Locations of convex segments in the channel profile will also be identified and related to surficial geology features. The condition of the channel along its course will be described, including the vegetation conditions on the channel bottom and banks, the occurrence of steep bank slopes and evidence of bank failure, extent of scouring and deposition along the stream, and the classification of stream bed sediments. Photo documentation of the channel conditions will be included in the channel stability survey.

(3) Data Collection

The following items comprise the proposed surface-water data collection program:

- Data collection will be for a period of one year. The monitoring stations on Yazzie Arroyo and on Bisti Arroyo will be visited monthly and within one week following major storm runoff events to record and reset the crest gauges and to collect water samples from the single stage sediment samplers. Samples will be taken of any water found within the impoundment or stream channels during the baseline monitoring visits.

- Flows will be estimated with crest stage recordings in the channels and Manning's equation.

- Channel profiles and cross sections at the crest gauge locations will be surveyed at the beginning and end of the one year baseline monitoring program.

- All water samples obtained will be measured for pH, temperature and electrical conductivity in the field.

- All water samples will be analyzed for the list of analyses currently approved by OSM for sampling of surface water at the nearby WR2 Mine, including cation/anion balance to check lab accuracy. These analyses are listed below.

- All surface water sampling and analysis will include sample collection and chain of custody documentation.

Table J-3. Surface-water quality monitoring parameters

pH	Magnesium	Bicarbonate
TDS (180°C)	Manganese (dissolved)	Chloride
Conductivity	Manganese (total)	Calcium
Boron	Potassium	Fluoride
Iron (dissolved)	Selenium	Carbonate
Iron (total)	Sodium	Total Suspended Solids
Sulfate	SAR	Settleable Solids
		Cation/Anion Balance

c. Task 3

Surface-water rights in the permit area and within 3 miles of the permit area will be inventoried and tabulated using records from the Department of Water Resources Management of the Chinde Nation.

C. References

Bajo, Sixto, 1978, Volatilization of Arsenic (III,V), Antimony (III,V), and Selenium (IV,VI) Form mixtures for Hydrogen Fluoride and Perchloric Acid Solution: Application to Silicate Analysis. Anal. Chem. 50(4):649-651.

Fasset, J.E. and J.S. Hinds, 1971, Geology and fuel resources of the Fruitland Formation and Kirtland Shale of the San Juan Basin, New Mexico and Colorado: U.S. Geological Survey Professional Paper 676.

Page, A.L. (Editor), 1982, Methods of Soil Analysis. Part 2 - Chemical and Microbiological Properties, 2nd Edition. Agronomy Monograph No. 9. American Society of Agronomy, Inc., Soil Society of America, Inc., Madison, Wisconsin.

Skousen, J., Renton, J., Brown, H., Evans, P., Leavitt, B., Brady, K.B.C., Cohen, L., and Ziemkiewicz, P., 1997, Neutralization potential of overburden samples containing siderite: Journal of Environmental Quality, Vol. 26, no. 3, p. 673 - 681.

Sobek, A.A., W.A. Schuller, J.R. Freeman, and R.M. Smith, 1978, Field and Laboratory Methods Applicable to Overburdens and Mine Soils. EPA 600/2-78-054. U.S. EPA, Cincinnati, Ohio.

U.S. Department of Interior, Bureau of Reclamation, 1976, Western Gasification Company (WESCO) Coal Gasification Project and Expansion of the Navajo Mine by Utah International , Inc., New Mexico: Final Environmental Impact Statement (FES 76-2).

U.S. Salinity Laboratory Staff, 1954, Diagnosis and Improvement of Saline and Alkali Soils. Handbook 60. U.S. Department of Agriculture, Washington, D.C.