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Groundwater Quality Monitoring of Western Coal Strip Mining:

Preliminary Designs for Active Mine Sources of Pollution

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GROUNDWATER QUALITY MONITORING OF WESTERN COAL STRIP MINING:

Preliminary Designs for Active Mine Sources of Pollution

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DISCLAIMER

FOREWORD

Protection of the environment requires effective regulatory actions based on sound technical and scientific data. The data must include the quantitative description and linking of pollutant sources, transport mechanisms, interactions, and resulting effects on man and his environment. Because of the complexities involved, assessment of exposure to specific pollutants in the environment requires a total systems approach that transcends the media of air, water, and land. The Environmental Monitoring Systems Laboratory at Las Vegas contributes to the formation and enhancement of a sound monitoring-data base for exposure assessment through programs designed to:

- develop and optimize systems and strategies for monitoring pollutants and their impact on the environment

- demonstrate new monitoring systems and technologies by applying them to fulfill special monitoring needs of the Agency's operating programs

This report presents the second phase of a study to design and verify groundwater quality monitoring programs for Western coal strip mining. The development of a groundwater quality monitoring design for potential pollution sources and the pollutants associated with active mine sources is presented. A second report covering groundwater quality monitoring designs for reclaimed mine sources is under preparation. The results of this report will lead to a field data verification effort. It is anticipated that the verification program will result in modification to this initial monitoring design. The research program, of which this report is part, is intended to provide basic technical information and a planning format for the design of groundwater quality monitoring programs for Western coal strip mine operations. As such, the study results may be used by coal developers and their consultants, as well as the various local, State, and Federal agencies with responsibilities in environmental monitoring and planning.

Further information on this study and the subject of groundwater quality monitoring in general can be obtained by contacting the Advanced Monitoring Systems Division, Environmental Monitoring Systems Laboratory, U.S. Environmental Protection Agency, Las Vegas, Nevada.

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PREFACE

General Electric--TEMPO, Center for Advanced Studies, is conducting a 5-year program dealing with the design and verification of an exemplary groundwater quality monitoring program for Western coal strip mining. The coal strip mining activity discussed in this report is located in Campbell County, Wyoming. In addition to active mine sources and reclaimed mine sources, the investigation covers secondary water resource impacts of municipal and industrial support programs which accompany the mining effort. The report follows a stepwise monitoring methodology developed by TEMPO.

The report represents the second phase of this research program. Described herein is the initial design of a groundwater quality monitoring program for potential pollution sources and pollutants associated with active mine operations.

In the next phases of this research program, the preliminary monitoring designs are to be verified with available data. Initial verification study results may produce a reevaluation of the monitoring design presented in this report. The final product of the 5-year program will be a planning document which will provide a technical basis and a methodology for the design of groundwater quality monitoring programs for coal development companies and the various governmental agencies concerned with environmental planning and protection.

SUMMARY

Preliminary groundwater quality monitoring designs for coal strip mine stockpiles, mine water sources, and miscellaneous mine sources are developed in this report and summarized in Appendix B, Tables B-1, B-2, and B-3, respectively. Preliminary monitoring steps identifying potential pollutants are presented for each source. Subsequent monitoring steps based upon the TEMPO groundwater quality monitoring methodology are given for a representative source material in the stockpile and mine water source categories but are not given for miscellaneous sources. This is done to reduce unnecessary repetition. For example, potential pollutants for mine stockpiles, i.e., topsoil, overburden, and coal, coal refuse and coaly waste, are given. Further monitoring steps refer to topsoil source material, but are representative of the methodology utilized for overburden, coal, coal refuse, and coaly waste sources. A similar format is used for the active mine water sources. Miscellaneous sources include both solid and liquid materials and appropriate methods for groundwater quality monitor design can be found under stockpile or mine water sources.

Unit cost estimates for the monitoring designs, based on preliminary recommendations, are given in Appendix B, Tables B-1, B-2, and B-3. In developing these estimates, each monitoring step was considered separately and, therefore, some overlap in the capital costs occurs in these figures. For example, only one hand-driven soil sampler would be required to monitor topsoil, overburden, and coaly waste stockpiles. This overlap would not occur when capital costs were developed for a specific monitoring design. In addition, each major cost item (i.e., monitor well) would be installed in response to a perceived pollution threat and would not be developed simply to measure background levels. The assignment of major cost items to a particular monitoring step may, in the generic case, be somewhat arbitrary. Take, for example, a monitor well installed near a sedimentation pond as part of the hydrogeologic framework monitoring step. Before this well would be drilled, previous iterations through the monitoring design would have indicated that a significant amount of potential pollutants was infiltrating into and migrating through the vadose zone near the source area. With this information, monitor well(s) would be installed near the source area using data on the local flow patterns developed as part of the hydrogeologic framework. Alternatively, the costs of the well might have been attributed to mobility in the saturated zone, a subsequent monitoring step; however, the total cost to the monitoring program would remain unchanged.

CONTENTS

FIGURES

TABLES

LIST OF ABBREVIATIONS, CHEMICAL ELEMENTS AND COMPOUNDS

ABBREVIATIONS

ANFO	ammonium-nitrate--fuel oil
BOD	biochemical oxygen demand
Btu	British thermal units
cm	centimeters
COD	chemical oxygen demand
DEQ	Department of Environmental Quality
DMA	designated monitoring agency
DO	dissolved oxygen
DOC	dissolved organic carbon
DPTA	diethylenetriamine pentaacetic acid
EC	electrical conductivity
Eh	oxidation reduction
EPA	U.S. Environmental Protection Agency
epm	equivalents per million
g	grams
gpd	gallons per day
gpm	gallons per minute
JTU (turbidity)	Jackson turbidity units
m	meters
m^3	cubic meters
MBAS	methylene blue active substances
mg	milligrams
MLSS	mixed liquor suspended solids
NPDES	National Pollution Discharge Elimination System
ppm	parts per million
PVC	polyvinyl chloride
SAR	sodium adsorption ratio
SCS	Soil Conservation Service
SV solids	suspended volatile solids
TDS	total dissolved solids
TK	total Kjeldahl
TOC	total organic carbon
TSS	total suspended solids
µg	micrograms
µmhos	micromhos

CHEMICAL ELEMENTS AND COMPOUNDS

Ag	silver
As	arsenic
B	boron
Be	beryllium
C	carbon
Ca	calcium
$CaSO_4$	calcium sulfate
Cd	cadmium
CdS	cadmium sulfide
Cl	chlorine
Co	cobalt
CO_2	carbon dioxide
CO_3	carbon trioxide
Cr	chromium
Cu	copper
CuS	cuprous sulfide
F	fluorine
Fe	iron
FeS	ferrous sulfide
Ge	germanium
H	hydrogen
$HClO_4$	perchloric acid
HCO_3	bicarbonate
H_3PO_4	orthophosphoric acid
H_2SO_4	sulfuric acid
Hg	mercury
Hg_2S	mercurous sulfide
HgS	mercuric sulfide
HNO_3	nitric acid
K	potassium
$K_2Cr_2O_7$	potassium dichromate
Mg	magnesium
Mn	manganese
Mo	molybdenum
N	nitrogen
Na	sodium
NaCl	sodium chloride
NH_3-N	ammonium-nitrogen
NH_4^+	ammonium
Ni	nickel
NO_3	nitrate
NO_2	nitrogen dioxide
NO_2-N	nitrite-nitrogen
NO_3-N	nitrate-nitrogen
NO_x	mixed nitrogen oxides
O	oxygen
P	phosphorus
Pb	lead
PbS	lead sulfide
PO_4	phosphate
Ru	ruthenium
S	sulfur
Se	selenium
SiO_2	silica dioxide
SO_2	sulfur dioxide
SO_4	sulfate
Th	thorium
U	uranium
V	vanadium
Zn	zinc
ZnS	zinc sulfide

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SECTION 1

MONITORING PROGRAM DEVELOPMENT

INTRODUCTION

This report is the third in a series dealing with development of guidelines for the design of groundwater quality monitoring programs for Western coal strip mining. The initial report (Everett, 1979) dealt with the identification of potential sources of groundwater quality impact; characteristics of potential pollutants; source area hydrogeology and groundwater quality; and infiltration and mobility of pollutants in the subsurface. These assessments, which focused on a case study region around Gillette, Wyoming, resulted in a preliminary priority ranking of pollution sources in three categories: municipal, active mining, and reclaimed mine areas. Separate preliminary monitoring design reports have been developed for each of these categories.

Preliminary monitoring designs for active mine sources are presented in the following sections of this report. The term "design" is used in a broad sense here to mean a structured sequence of data gathering, evaluation, and decision steps which result in a determination of what monitoring activities are needed and what are the appropriate methods for addressing these needs.

Potential sources of groundwater quality impact associated with active mining have been grouped as follows for consideration in this report:

- Stockpiles (topsoil, overburden, coal, coal refuse, and coaly waste)
- Mine water (sedimentation ponds and pit water)
- Miscellaneous sources (explosives, mine solid wastes, liquid shop wastes, sanitary wastes, spills and leaks, and solid waste for road construction).

Ranking of pollution sources for coal strip mines is given in the first report in this series (Everett, 1979). This ranking is based on a sequence of data compilation and evaluation steps. These steps include identification of potential pollution sources given above, methods of waste disposal and potential pollutants associated with the various waste sources, and an assessment of the potential for infiltration and subsequent mobility of these pollutants in the subsurface. The three basic criteria used to develop the source-pollutant ranking are:

- Mass of waste, persistence, toxicity, and concentration

- Potential mobility

- Known or anticipated harm to water use.

A great deal of effort has been expended on the study of the hydrogeology of mine areas and a large amount of research has been conducted on coal strip mine development and environmental effects. However, significant information deficiencies exist with regard to potential pollutant characterization and the mobility of these materials in the hydrosphere. Hence, professional judgment plays a large role in proposing this preliminary source-pollutant ranking which is as follows (from Everett, 1979):

1. Spoils (below water table)

2. Spoils (above water table below ponds or streams)

3. Pit discharge (to streams).

Of these ranked pollution sources, pit discharge is covered in Section 3 of this report. Backfilled spoils, above and below the water table, will be covered in a subsequent report. Other sources discussed herein may have less impact on groundwater quality than those given in Appendix B, Table B-1.

The format for presenting these preliminary designs follows the generic monitoring methodology developed by General Electric Company--TEMPO (Todd et al., 1976):

- Identify potential pollutants

- Define groundwater usage

- Define hydrogeologic situation

- Study existing groundwater quality

- Evaluate infiltration potential

- Evaluate mobility in the vadose zone

- Evaluate attenuation of pollutants in the saturated zone.

For each of these information assessment steps, one must consider monitoring (information) needs and alternative approaches for addressing these needs. These basically technical assessments, along with cost data, result in selection of a monitoring approach. It is important to note that each step in this design sequence is a decision point: if for a given source the data and evaluations, at some point, indicate the absence of appreciable potential for impact to groundwater quality then this conclusion is the end product of the monitoring design. Additionally, conclusions at one step will refocus efforts for subsequent steps. Multiple passes through the methodology steps, with successive passes dealing with more detailed data sets and generally higher costs for developing required information, are employed to "scale-up" to an appropriate and cost-effective level of monitoring effort.

Thus, at specific sites, different monitoring designs may result for any of the potential pollution sources considered in this report. In order to address the general guideline goals of this study, the preliminary designs presented herein follow the above-outlined sequence of steps entirely through, and a monitoring approach is "selected." Given the decision-tree approach outlined above and only regional specificity, the designs thus developed must be considered in some respects generic. To balance this factor, certain example cases taken from coal strip mines near Gillette, Wyoming, are presented as part of this report.

SUMMARY OF PRELIMINARY MONITORING DESIGNS

Although the Permanent Regulatory Program for the U.S. Department of the Interior Surface Mining Control and Reclamation Act of 1977 was published in the Federal Register on 3-13-79, the U.S. Environmental Protection Agency (EPA) did not change the scope of the project to specifically cover this new legislation from the U.S. Department of the Interior. Technical reviews of the monitoring design, however, have been made by the Office of Surface Mining.

Specific sections of the Surface Mining Act deal with protection of the hydrologic system. In general, the provisions state that operations will be conducted so as to minimize water pollution. For example, practices to control and minimize pollution include diverting runoff. Overland flow may be diverted and conveyed away from disturbed areas. All surface drainage from the disturbed areas shall be passed through one or more sedimentation ponds before leaving the permit area.

Discharge, on the other hand, from areas disturbed by surface coal mining and reclamation operations must meet all applicable Federal and State laws and regulations. Specific numerical limitations have been established for iron, manganese, total suspended solids (TSS), and pH. In general, regulations require that a surface water monitoring program shall be conducted that provides adequate monitoring of all discharges from the disturbed area.

This report deals with detailed preliminary guidelines that may elaborate upon existing Federal and State regulations for groundwater quality monitoring of active coal mine sources.

SECTION 2

MONITORING DESIGN FOR MINE STOCKPILES

GENERAL CASE CONSIDERATIONS

Three categories of materials may be stockpiled at a coal strip mine: (1) topsoil, (2) overburden and interburden, and (3) coal, coal refuse, and coaly waste, discussed in more detail in Everett (1979).

The three types of stockpiles may yield different potential pollutants to the groundwater beneath them; therefore, the identification of potential pollutants is discussed separately for each material. The remaining steps are discussed for stockpiles in general.

Identify Potential Pollutants--Topsoil

The purpose of potential pollutant identification at the beginning of the monitoring program is to specify pollutants which should be monitored during subsequent steps of the methodology.

Potential groundwater pollutants in stockpiled topsoil may be due to (1) the natural poor quality of soils that are stockpiled, (2) fertilization and irrigation of the stockpiled soils, and (3) physical and chemical changes in the soils after they have been stockpiled for long periods of time. Poor quality soils may be treated as spoils or may be stockpiled with topsoil.

If vegetation is not immediately established on topsoil stockpiles, they will contribute excessive sediment to sedimentation ponds. However, if the stockpiles are fertilized and irrigated, it is possible that leaching could occur by waters percolating through the root zone. Compounds of nitrogen, phosphorus, and potassium could be potential pollutants, nitrates being of principal concern.

Gradual physical and chemical changes that may occur in stockpiles of long duration will primarily be due to leaching in the surface layer. It is expected that there may be leaching of nitrates and other readily soluble salts turned over from lower soil layers by the mixing that will occur during stockpiling operations. If the stockpiles are deep, microorganisms will be diminished at the lower levels, particularly in the soils underlying the stockpiles. Accordingly, an increase in ammonium-nitrate could be expected in the deeper layers.

Monitoring Needs--

Monitoring needs include identification and characterization of soils on the lease area, estimations of the locations, volumes and anticipated duration of topsoil stockpiles, and characterization of physical and chemical changes in soils which have been stockpiled for extended periods of time.

Alternative Monitoring Approaches--

In many cases, a nonsampling approach is preferable to sampling. Generally, nonsampling methods involve collecting and examining pollutant-related information for a potential pollution source, such as number of stockpiles, collection of available soil chemistry data, etc. The results of nonsampling methods may indicate that further monitoring activities are unwarranted. Possible alternative nonsampling and sampling approaches for identifying potential pollutants due to stockpiled topsoil are given below.

Soil inventory maps could be obtained and used to identify soils that may be stockpiled and their chemical characteristics. Plans for removal of topsoil could be compared with soil inventory maps for a closer estimate of future stockpile material. The plans could be used to estimate the volume of topsoil to be stockpiled and the expected life of individual stockpiles.

The volume of existing stockpiles could be estimated in three ways: (1) the stockpiles could be measured and the volumes computed, (2) aerial photography could be used to estimate the volume of stockpiles, and (3) the volume could be estimated from mine engineering and production records and mine plans. The documents could also yield information on the use of irrigation and fertilizers on stockpiles.

The volume of potential pollutants in the stockpiles could be estimated from the volume of the stockpiled material and information on potential pollutants in the topsoil.

Stockpiles which have been in place for a year or more could be sampled to assess physical and chemical changes occurring over time. Samples could be collected at 2-foot* intervals at no less than one point per acre of stockpiled material. They could be analyzed for pH (determination on paste), conductivity (mmhos/cm on saturated extract), saturation percentage, calcium, magnesium, sodium, sodium adsorption ratio (SAR), boron (hot water extract), nitrogen (sum of nitrate-nitrogen and ammonium-nitrogen in soil), phosphorus, potassium, trace metals, and total salts. Sampling could be performed annually.

Preliminary Recommendations--

The preferred monitoring approach would be to obtain soil inventory maps, topsoil removal and storage plans, mine engineering and production records, and mine plans. These would be used, together with existing soil

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* See Appendix A for conversion to metric units.

chemistry information, to identify the locations and quantities of potential pollutants in topsoil stockpiles. Stockpiles which have been in place for a year or more would be sampled as described above. The use of aerial photography would not be recommended for mines with small numbers of closely spaced stockpiles due to the expense of utilizing this method.

Costs for this monitoring approach would include labor for gathering existing information and sampling operation costs for sampling equipment and analyses. These costs are itemized in Appendix B, Table B-1.

Identify Potential Pollutants--Overburden and Interburden

The primary potential pollutants in the overburden are soluble salts. In addition, iron sulfide minerals and trace elements present in the overburden are of concern as possible sources of groundwater pollutants.

Monitoring Needs--

Data related to overburden materials in place may be useful in characterizing overburden stockpiles; however, it will also be necessary to monitor stockpiled overburden materials to determine if any appreciable changes in their overall composition have resulted from mining and stockpiling of the materials. Monitoring needs include: the chemical composition of in-place overburden; the volume, composition, and expected life of overburden stockpiles; and changes which take place in the overall chemical makeup of stockpiled overburden due to exposure to a new environment.

Alternative Monitoring Approaches--

A primary nonsampling approach could be to obtain, review, and interpret existing data on the chemical characteristics of the in-place overburden. The volume of overburden stockpiled for any appreciable time (1 year or more) could be estimated using any of the techniques discussed for topsoil stockpiles. The information gathered above could then be used to estimate the volume and chemical nature of potential pollutants in the stockpiled overburden.

Overburden samples expected to remain in place for a year or more could be sampled to determine if any changes are taking place in their chemical makeup. A rule of thumb would be to obtain samples at 10-foot intervals vertically through the stockpile (Wyoming Department of Environmental Quality, 1978). A minimum of two samples (a surface sample and one near the base) could be obtained from each stockpile sampling location regardless of total vertical depth of the stockpiled material. One sample hole per 10 acres of surface area should be sufficient. All samples could be analyzed for the quantities listed in Table 1.

Preliminary Recommendations--

The preferred approach for monitoring the potential pollutants in stockpiled overburden would be as follows:

TABLE 1. CHEMICAL ANALYSIS FOR OVERBURDEN STOCKPILES

Quantity	Method of analyses	Suspect level
pH	Paste	8.8-9.0
Conductivity	Saturation extract	4-6
SAR	Saturation extract	12
Texture	Hydrometer	40% clay, loamy sand and sand
Boron	Hot water extract	8 ppm
Cadmium	DTPA extract	0.1-1 ppm
Copper	DTPA extract	40 ppm
Iron	DTPA extract	not defined
Lead	DTPA extract	pH <6 (10-15) pH >6 (15-20)
Manganese	DTPA extract	60 ppm
Mercury	Conc. acid extract	400-600 ppb
Molybdenum	Acid ammonium oxalate	0.3 ppm
Nickel	DTPA extract	1.0 ppm
Selenium	Hot water extract	2.0 ppm
Zinc	DTPA extract	40 ppm
Ammonium-nitrogen	NaCl solute extraction	(a)
Nitrate-nitrogen	NaCl solute extraction or $CaSO_4$ NaCl solute extraction	(a)

[a] The significance of ammonium and nitrate stems from the water pollution potential of nitrate. The Federal drinking water standard is 10 ppm nitrate-nitrogen and a recommended maximum concentration for livestock is 100 ppm nitrite + nitrate-nitrogen. Ammonium can be biologically oxidized to nitrate if conditions are suitable.

Note: The quantities and their suspect levels listed above are those established by the Montana Coal and Uranium Bureau, Department of State Lands, 1978. A comparison with Wyoming standards can be found in Wyoming Department of Environmental Quality, 1978.

1. Review existing data on chemistry of in-place overburden

2. Determine the volume of overburden stockpiled by direct measurement

3. Sample the stockpile at 10-foot intervals; a minimum of two samples per location, with one hole every 10 acres

4. Analyze annually for parameters listed in Table 1; although leaching tests would be of value, they are too costly to be used routinely in a monitoring program.

Costs would include labor for gathering existing information and sampling and operational costs for sampling equipment and analyses. These costs are itemized in Appendix B, Table B-1.

Identify Potential Pollutants--Coal, Coal Refuse, and Coaly Waste

Coal, coal refuse, and coaly waste are considered together since they are geologically and chemically similar. Coal refuse is defined as the fine coal and waste material removed during the coal preparation process. Coaly waste includes the thin coal seams, impure coal, and carbonaceous shale that may occur in the overburden and within the partings between coal seams. These materials are handled separately because of their economic value and different water pollution potentials.

Coal is mined soon after exposure by stripping and is not allowed to weather or to have much water percolate through it to pick up pollutants created by the oxidation process. After mining, it will usually be processed in some manner. Common steps in coal processing include crushing, screening, and washing. Coal at Powder River Basin mines is usually only crushed. At the Wyodak Mine, it is crushed and part of it is sized and oiled for sale to the domestic market. So far as is known, no coal waste is produced during the preparation at mines within the project area. All of the coal, including the finest portion, is used. After crushing, coal is temporarily stored in silos, bunkers, or occasionally in open piles.

When coal refuse is produced during preparation, as is common with coal from other geographic areas, it is disposed of in refuse piles (large size material) and ponds (fine material carried as a slurry). Apparently, coal refuse will not exist at Powder River Basin mines.

Coaly waste material is considered separately from overburden because it usually has a different type and amount of water pollution potential. The geochemical properties of coaly waste materials affect its potential as a soil-forming material. Such materials commonly form toxic soils and are thus segregated from overburden during mining. A frequent method of handling is to attempt to place the coaly waste at or near the bottom of the spoil. In order to place the coaly waste selectively, it may be necessary to stockpile it temporarily.

Coal, coal refuse, and coaly waste probably contain some soluble salts, although no analysis of the soluble salt content of these materials has been found in the literature. The soluble salts are expected to be principally in the form of crystals of gypsum or similar minerals formed in open fractures.

One of the characteristics of the project area coals is the low sulfur content. However, some pyrite oxidation does occur, as is evidenced by spontaneous combustion of coal piles along the base of the high wall at the Wyodak Mine. Apparently, the acid that does form from oxidation of pyrite in Powder River Basin coal and associated carbonaceous strata is rapidly neutralized, probably by carbonate minerals in the soil and overburden, and does not cause measurable lowering of the pH of surface water and groundwater. It will, however, contribute dissolved solids in the form of sulfate, principally calcium and magnesium. The acid that is found might also dissolve some trace metals before it is neutralized.

Monitoring Needs--

All mining companies perform sample analyses of coal seams before mining. Usually, the proximate analyses include moisture content, volatile matter, fixed carbon, ash, Btu, softening, grindability, and specific gravity. The ultimate analyses may also include H, C, N, O, S, Cl, sulfate, pyrite, and organic content. Measurements have also been made of trace elements in Powder River Basin coals.

Sufficient information is available to characterize coals in the project area in terms of the potential pollutants they contain, with the exception of soluble salts. This does not appear to be the case for coaly waste. No records have been found to indicate that any attempts have been made to characterize coaly wastes. In order to characterize stockpiled coals in terms of their pollution potential, stockpiles should be sampled to determine if, in fact, soluble salts are present in sufficient amounts to present a problem.

Uncertainty exists about the location of coaly waste stockpiles and methods of disposal for this material on all mining sites. In most instances, it is mixed indiscriminately with overburden materials and backfilled. Any existing stockpiles of coaly waste need to be located in order to acquire grab samples for chemical analysis. This characterization of the coaly wastes will provide an identification of any potential groundwater pollutants.

Alternative Monitoring Approaches--

A primary nonsampling method for monitoring potential pollutants is to determine the volume of coal and coaly wastes stockpiled. The manner in which these materials are stockpiled will, to a large degree, determine if they present a threat to groundwater quality. For example, coal stored in open bunkers with concrete floors may not present a problem. The two alternatives for estimating the volume of these materials are: (1) directly measure the areal extent of the stockpiles and periodically update this information, or (2) work directly from mine engineering and production reports. Any available data on the chemical characteristics of the stockpiled materials could be obtained from the mine operators and used to estimate the total volume of potential pollutants in the stockpiles.

If the stockpiles are exposed to the elements, some weathering and possible leaching may take place. Most of the weathering will take place at or near the surface of the stockpiles. Grab samples could be taken at a few locations on the stockpiles. These samples could be analyzed for the following:

Ag	Pb	Se	Hg	As	Mo
Cu	Cd	Mn	B	Ge	U
Ni	Zn	Cr	Be	V	F

The analyses for these elements should be accomplished with an accuracy of ±20 percent of the actual population concentrations. Therefore, at least three replicates would be necessary for each stockpile. More may be required to achieve an acceptable error.

Spark-source mass spectrometry is recommended as the most accurate method. The analyses should include all identifiable trace elements, although only those listed would require an accuracy of ±20 percent.

Other methods, such as neutron activation analyses, may also be used. However, wet chemical methods are satisfactory and are used by most laboratories. Analyses by wet chemical methods should be performed as follows:

Ag - atomic absorption spectrometry

Cu - atomic absorption spectrometry

Ni - atomic absorption spectrometry

Pb - atomic absorption spectrometry

Cd - atomic absorption spectrometry

Zn - atomic absorption spectrometry

Se - atomic absorption spectrometry

Mn - atomic absorption spectrometry

Cr - atomic absorption spectrometry

Hg - double gold amalgam flameless atomic absorption

B - emission spectrometry

Be - emission spectrometry

As - colorimetric

Ge - colorimetric

V - colorimetric

Mo - colorimetric

U - fluorometric

F - specific ion electrode.

Additional analyses could include H, C, N, O, S, Cl, SO_4, and FeS_2.

Additional measurements should be adequate to follow any changes in the chemical characteristics of stockpiled coal, coal refuse, or coaly wastes. It will be unusual for coal to be stockpiled for such long periods of time. Frequently, the stockpiles will be added to or taken away from on a regular basis.

Preliminary Recommendations--

The preferred monitoring approach is to determine the volume of stockpiled materials by direct measurement and use this information, along with available data on the chemical characteristics of the stockpiled materials, to estimate the volume of potential pollutants in the stockpiles. Samples would be collected and analyzed as needed to fill data gaps.

Costs would include labor for volume measurements, sample collection, and review of existing data. The major operational cost would be for sample analysis. Specific costs are itemized in Appendix B, Table B-1.

Define Groundater Usage

Ultimately, source-related pollutants may deleteriously affect various groundwater uses (municipal, agricultural, and industrial) if recharge from the source occurs. An inventory of such uses, including the volume of usage and location of pumping centers, is an integral component of a monitoring design.

Pumpage of groundwater for domestic use from shallow wells in the vicinity of stockpiled materials is apparently nonexistent. Almost all water used for domestic purposes is pumped from the deeper Fort Union or Fox Hills aquifers.

Most of the groundwater used on the mine leases comes from pit discharge. Dust suppression is the primary use of pit discharge water during summer months. Deep wells supply water for drinking, bathing, and cleanup (equipment, shops, etc.). Potable water consumption varies depending on mine equipment, maintenance, shop house cleaning, and bath house capacity.

Although irrigation is not presently practiced at any of the mines in the Eastern Powder River Basin, the Federal strip mine regulations are specific in the requirement of establishing vegetation on topsoil stockpiles. It is quite likely that irrigation will be necessary later during the first and second growing seasons to obtain good plant establishment on topsoil stockpiles. Thus, there may be additional demands on existing wells or new wells may be required to supply water for irrigation.

Monitoring Needs--

The primary monitoring need is to determine if the stockpiled materials are to be irrigated and what their irrigation requirements would be, both in terms of water quantity and quality.

Alternative Monitoring Approaches--

If stockpiles are irrigated for revegetation, the groundwater applied should be monitored. Simple irrigation metering devices which cost less than $50 could be installed in the supply lines. The volume of water needed for irrigation could be estimated by computing the size of the stockpiled areas, vegetation consumptive water use, and soil characteristics. Consumptive use of 1 to 4 acre-feet of water per acre being revegetated is typical for the area.

Preliminary Recommendations--

The recommended preliminary approach is to determine whether stockpiles are to be irrigated. No further monitoring should be planned unless irrigation is decided upon. The only cost for this approach would be labor for discussions with mine personnel. However, labor, operation, and capital costs for monitoring stockpile irrigation have been summarized in Appendix B, Table B-1, should this plan be initiated.

Define Hydrogeologic Situation

Evaluation of the hydrogeologic framework of a pollutant source area includes description of the local and regional geology; identification of aquifer locations, interactions, and characteristics; determination of depths to groundwater and velocities of flow; and delineation of areas and magnitudes of natural groundwater recharge and discharge. The hydrogeology should be clearly understood in a source-specific sense; however, it is of equal importance that the regional hydrogeology be defined in order to predict the long-term impact of pollution from a source, including the effect of mixing of pollutants from several sources. Generally, this information is collected on a regional basis by the individual mining companies.

Monitoring Needs--

The most important monitoring requirement is collection and analysis of existing data. These data may then need to be supplemented by additional monitoring to characterize the site-specific hydrogeology.

Alternative Monitoring Approaches--

Available hydrogeological information could be collected from a number of sources, including the mine operator, private consultants, the U.S. Geological Survey, State agencies, etc. Types of information which could be solicited include: well locations, details on well construction (construction methods, depth, diameter, locations of perforations, completion techniques), drillers logs and geophysical data, and results of pumping tests for aquifer properties (including test methods). If necessary to complete the regional hydrogeologic picture, data could also be collected from adjoining mines.

Pumping tests and water level monitoring could be carried out in existing wells in the vicinity of stockpiled materials. If necessary, additional wells could be installed for these purposes.

Preliminary Recommendations--

The preliminary recommended approach is to collect and analyze all available hydrogeologic data. Plans for further drilling and testing can then be made on the basis of this information and data gathered from other monitoring steps. The only costs accrued for this work would be labor to compile and review existing data. If additional testing or monitoring wells were required, costs would include labor for well construction, drilling, and capital costs for well hardware and testing/sampling equipment. Costs for additional sampling of existing wells are given in Appendix B, Table B-1. Costs for installing new monitor wells are summarized in Appendix B, Table B-2.

<u>Study Existing Groundwater Quality</u>

The general purpose of determining groundwater quality in the vicinity of a potential source of pollution, such as stockpiles, is to characterize the impact of pollutant movement on the indigenous groundwater quality. Activities during this step will overlap related steps involving characterizing the hydrogeologic framework and determining the attenuation of pollutants in the zone of saturation.

Monitoring Needs--

Monitoring needs include the characterization of the chemical quality of groundwater both in the vicinity of stockpiled materials and on a regional basis.

Alternative Monitoring Approaches--

Available water quality data could be obtained and examined. Possible sources of data include: the mining company, the U.S. Geological Survey, consultants, etc.

A water sampling program could be initiated to characterize the current groundwater quality in the vicinity of stockpiled materials. Methods include sampling from existing monitor wells, if such wells are near the stockpiles; installation of supplemental wells; and a combination of these methods. Supplemental wells may have been constructed, as necessary, during the previous step (Define Hydrogeologic Situation).

Water samples could be obtained by a variety of alternative techniques, discussed in the municipal monitoring design report.

Three methods of water sample analysis are possible. All samples could be completely analyzed for the following constituents: calcium, magnesium, sodium, potassium, bicarbonate, chloride, sulfate, phosphate, silica, ammonium-nitrogen, nitrate-nitrogen, total nitrogen, iron, manganese, zinc, copper, chromium, arsenic, molybdenum, and selenium. Alternatively the first few samples could be examined completely. Once the principal constituents are identified (primarily those occurring in greater-than-permissible levels), subsequent analyses would be for these constituents only. Note that this approach should be used only for trace constituents. The major constituents should be determined for each sample. A third technique would be to field analyze pH, electrical conductivity (EC), dissolved oxygen, alkalinity, chloride, and nitrate. When pronounced changes (above instrument or experimental error) occur, a sample could be collected for laboratory analyses.

Possible sampling frequencies to characterize groundwater quality include daily, weekly, semimonthly, monthly, bimonthly, etc. Samples could be collected on a weekly basis until time trends in quality are established. Thereafter, samples could be obtained on a bimonthly basis. Note, however, that unusual events may necessitate a greater sampling frequency.

Preliminary Recommendations--

The recommended preliminary approach is to obtain and examine existing water quality data. A water sampling program would then be initiated, if necessary, using existing wells and any wells installed during alternate steps. The first five samples from each well would be analyzed completely, and parameters in excess of recommended limits would be delineated. Periodic field checks would then be conducted for such parameters as pH, EC, dissolved oxygen, nitrate, and chloride. Samples would be collected for laboratory analyses when marked changes occur between field checks. Samples would be analyzed for major constituents and those trace constituents previously found to be in excess of recommended limits. Sampling frequency would be as described above.

Costs for characterizing groundwater quality would include: labor costs for examining available water quality data and collecting samples; capital costs for pumps or bailers, pH, conductivity and dissolved oxygen meters, and a field kit for determining chloride and nitrate; and operational costs for sample analyses and miscellaneous items, such as sample bottles, thermometers, chemicals, storage chest, etc. These costs and those incurred during installation of a monitor well are given in Appendix B, Table B-1.

Infiltration Potential

The purpose of determining the infiltration potential of a source is to quantify the volume of water and associated pollutants moving into the underlying vadose zone. Premining soil surveys classify the hydrology of natural soils in general categories. However, this classification is of limited value in evaluating the infiltration characteristics of topsoil stockpiles. Information on these characteristics will have to be obtained for the stockpiles themselves.

Monitoring Needs--

There is a need to determine if water could move through the stockpiles in quantities sufficient to carry potential pollutants into the vadose zone. Although infiltration from rainfall or snowmelt will be high to moderately high on the loose materials of stockpiles, it is unlikely that infiltrating water will penetrate deep enough under the natural precipitation regime or artificial irrigation to contribute significantly to groundwater. However, this must be established, particularly for stockpile areas near natural stream channels or areas where the groundwater is shallow.

Alternative Monitoring Approaches--

Laboratory determinations of saturated conductivity on disturbed samples are of doubtful value for indicating infiltration characteristics. However, infiltrometer tests in the field are useful for establishing maximum limits of water penetration at the soil surface. A simple ring infiltrometer could be used to perform field tests on the stockpiles. Data could be analyzed to determine the probable penetration of water under natural rates of precipitation or under applied irrigation schedules. Several methods are available for determining infiltration under conditions of unsteady application of water at the surface. These methods could be used with climatic records to determine maximum expected depth of water penetration.

Preliminary Recommendations--

Simple ring infiltrometer tests would be run as discussed above. No fewer than three runs would be made on each stockpile, and more would be made if considerable variation is found to exist in the materials. Costs would include labor for conducting and analyzing the infiltration tests and capital costs for infiltrometers. These costs are itemized in Appendix B, Table B-1.

Evaluate Mobility in the Vadose Zone

The general purpose of this step is to measure or estimate the movement of pollutants in the vadose zone underlying a pollution source.

Monitoring Needs--

Information on the mobility of pollutants in the vadose zone within or beneath present or future topsoil and overburden stockpiles is not currently available. There is a need to first determine if water is moving in significant quantities through the stockpiles. If so, it will be necessary to monitor those pollutants which contribute contaminants in excess of background levels.

Alternative Monitoring Approaches--

The greatest amount of water movement in the vadose zone will occur as unsaturated flow. Although the soil surface may become saturated after heavy rainfall, snowmelt, or prolonged irrigation, subsequent movement will occur at pressures less than atmospheric along gravitational and soil matrix potential gradients. One way of monitoring unsaturated flow is through the installation of neutron probes in the stockpile. These could extend several feet into the underlying spoils or native soil. Measurements could be made with the neutron probe or on a monthly basis and more frequently after precipitation events or extended irrigation.

Tensiometers could be installed to measure pressure differentials with depth and thereby determine the rate and volume of flow. Tensiometers are only effective at moisture contents equivalent to negative pressure of less than 1 bar.

Porous cups installed within the stockpile at the same depths as the tensiometers could be used to extract the soil solution for analysis of pollutants if the moisture content is sufficiently high. The cups will fail at -0.8 atmosphere of soil water pressure. Samples could initially be analyzed for calcium, magnesium, sodium, potassium, bicarbonate, chloride, sulfate, phosphate, silica, ammonium-nitrogen, nitrate-nitrogen, total nitrogen, pH, and electrical conductivity. Subsequent monitoring could be limited to the quantities which appear to be in excess of 20 percent of the previously determined background levels.

Preliminary Recommendations--

It is unlikely that appreciable quantities of water will flow through stockpiled materials, even with irrigation. This idea would initially be tested by measurements of water movement in access tubes. The results should be corroborated by analyses of field infiltrometer tests conducted during the previous step. If little water movement is found, monitoring would subsequently be limited to monthly measurements with the neutron probe. If appreciable water movement is indicated, then the alternative methods discussed above would be limited at a later date.

Costs for this step would include: labor costs for conducting and analyzing neutron probe measurements, operational costs for installing access tubes, and capital costs for the neutron logger, steel pipe and miscellaneous materials for construction of access tubes. These costs are summarized in Appendix B, Table B-1.

Evaluate Attenuation of Pollutants in the Saturated Zone

The general purpose of this step is to measure or estimate the attenuation of source pollutants during migration in the zone of saturation. The pollutants of concern will be those which have not been completely attenuated during movement through the vadose zone.

Monitoring Needs--

Whether monitoring is justified to determine attenuation of pollutants in the saturated zone as may be affected by stockpiles will depend entirely upon whether water will penetrate through the piles and the underlying material to groundwater and, if it does, whether it would carry significant quantities of pollutants in excess of those existing in the natural groundwater system. Both possibilities are unlikely. The stockpiled material may be highly permeable, but the underlying soil will probably be less so due to scraping and compaction. If the stockpile is placed on compacted mine spoil with a characteristically large, shale-derived component, penetration of water to the saturated zone will be greatly restricted. Furthermore, the only pollutants other than those which occur naturally or through oxidation would come from fertilizer applications, principally nitrates. Since fertilizer would only be used to assist the development of a protective vegetative cover and not for agricultural production, application will be light.

Preliminary Recommendations--

No monitoring would be done during this step unless indicated by the results of previous steps. Labor, operation, and capital costs, as well as monitoring methodology, for sample collection and well installation are summarized in Appendix B, Table B-1 (define hydrogeologic situation and study existing groundwater quality), should monitoring in the saturated zone be required.

EXAMPLE CASE STUDY--AMAX BELLE AYR SOUTH

Identify Potential Pollutants

Stockpiled topsoil at the AMAX Belle Ayr South Mine was selected for study as being the most representative in the project area. The location of the topsoil stockpile is shown in Figure 1. The soils on the lease area were mapped on a reconnaissance level by the Soil Conservation Service (SCS) in 1939. Two soil series, the Arvada and Haverson, have high sodium adsorption ratios and calcium concentrations at depth. A review of the mine plan shows that these poor-quality soils are not specifically excluded from topsoil stockpiles at the Belle Ayr South mine. The U.S. Geological Survey (1976) states that 86 samples from four areas of the mine were analyzed. The sodium adsorption ratio was found to range between 0.2 and 7.5, with an average of 2.62; electrical conductivity varies from 0.13 to 1.53 mmhos, with an average of 0.81 mmho; and pH ranges between 7.2 and 8.1, with an average of 7.6. Trace element analyses are not available.

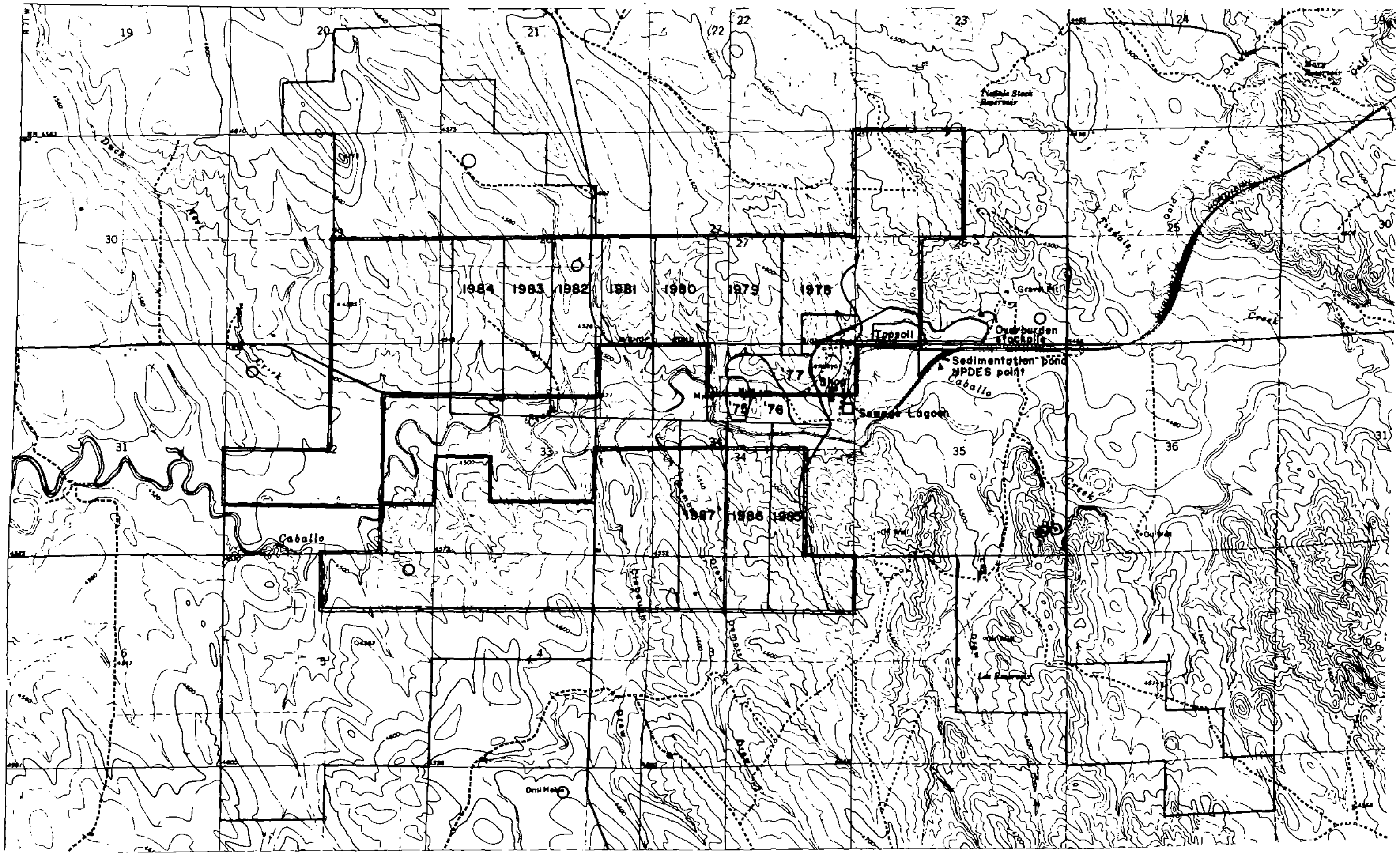


Figure 1. AMAX Belle Ayr South topsoil stockpile location.

AMAX Coal Co. prepares soil inventory maps of the lease area prior to mining as part of their Soil-Overburden Analysis Program. The program includes the development of maps of major soil series for review by the SCS. At least two sites in each soil series are sampled for analyses which include the following determinations: organic matter, electrical conductivity, pH, nitrogen, phosphorus, potassium, calcium, magnesium, sodium, selenium, boron, and molybdenum. There is no monitoring program for topsoil material after it is stockpiled.

Monitoring gaps include: an evaluation of the chemistry of the stockpiled soils, change in chemistry due to any fertilization or irrigation of the stockpiles, and physical and chemical changes in the stockpiled materials over long periods of time.

Define Groundwater Usage

The U.S. Geological Survey (1975) states that pit discharge will be used for dust control, with the excess being discharged to Caballo Creek. Pit discharge is about 100,000 gallons per day, and it was stated that as much as 80,000 gallons per day could be used for dust suppression during the summer. According to AMAX Coal Co. (1976), seepage to the pit is currently being totally consumed for dust control. Pit discharge decreased somewhat as the pit size increased; however, it still amounts to about 100,000 gallons per day.

A wash house has been constructed to serve 102 people. Water for this facility comes from wells drilled in the area; estimated usage is 2,500 to 4,000 gallons per day.

According to AMAX Coal Co. (1976), irrigation of reclaimed lands is not planned, but this does not preclude consideration at a later date should the situation warrant it. Topsoil stockpiles will require irrigation to establish and maintain vegetative cover. Approximately 3 acres of land will be required to store the topsoil from 50 mined acres and this would require from 1 to 2 million gallons of water per year to satisfy plant water requirements.

Define Hydrogeologic Situation

The regional hydrogeology of the AMAX Belle Ayr South lease has been summarized in Everett (1979).

Caballo Creek is the dominant surface feature on this lease site, flowing from west to east through the center of the area to be mined. The land near the stream is practically flat, rising to the north and south of Caballo Creek (U.S. Geological Survey, 1975).

The northwestern part of the lease is covered with rolling upland grasslands, with the terrain south of the river being more rugged with deeper washes and steeper slopes than those found north of the rivers. The east edge of the lease is characterized by topography typical of physiographic division number 2, forming a series of low, abrupt hills caused by the burning coal.

A considerable amount of data has been collected on aquifer performance through pumping tests. However, monitoring gaps exist regarding specific information on the hydrogeology in the vicinity of the stockpile areas, the hydraulic characteristics of the stockpiled materials, and the depth of the local water table.

Study Existing Groundwater Quality

Numerous groundwater quality samples have been collected by workers at the Belle Ayr South Mine. Although detailed sample collection procedures were not outlined in the Mining Plan Update (AMAX, 1977), the results of several analyses were reported. Tables 2 through 5 show the maxima and minima of these results, as well as the mean values. Significant deviations occur for some parameters, indicating a dynamic quality situation or sampling and analytical inconsistencies. Figures 2 and 3 are trilinear plots of the mean concentrations of major undissolved species.

In its mining plan update, AMAX states that the dominant water types within the Wasatch Formation are sodium sulfate and sodium bicarbonate. However, the data summarized in Figure 2 show that well N-5 would be classified as a calcium sulfate water. Analyses which reflect the reported sodic quality of the Wasatch waters should be compiled and reviewed. The plots on Figure 3 indicate that water types vary from location to location, and that the coal seam waters can be either sodic or calcic. AMAX's deep Fort Union water at well station WRRI-7 has seriously high sulfate contents for a potable water source. AMAX did not present data on other Fort Union wells which are reportedly used for office and shop requirements. The analysis presented for the scoria pit (Table 2) has a close epm balance (0.97), but the reported electrical conductivity is inconsistent with the rest of the results. If this inconsistency is ignored, the scoria pit water appears to be of fairly good quality. However, the relative amounts of groundwater inflow and surface runoff that make up this pit water are unknown, and it is assumed that groundwater within the scoria is not as good as this analysis might indicate.

Monitoring gaps include analysis of potable water from the deep Fort Union wells, characterization of the Wasatch waters, site-specific water quality in the coal seams, and reevaluation of the inconsistencies in the reported water quality information.

Evaluate Infiltration Potential

Monitoring to determine the infiltration potential of stockpiled materials is not done at the Belle Ayr South Mine.

Evaluate Mobility in the Vadose Zone

No monitoring of water or pollutant mobility exists for the stockpiles or in the underlying vadose zone.

TABLE 2. AMAX BELLE AYR WATER QUALITY--WASATCH FORMATION ABOVE THE COAL (AMAX, 1977)[a]

Parameter	Number of analyses	Maximum value	Minimum value	Mean	Standard deviation
Field pH	1	7.5	7.5	7.5	
Calcium	12	279.	180.	213.	30.6
Magnesium	12	208.	59.0	145.	37.2
Sodium	12	200.	113.	164.	27.6
Potassium	11	13.0	0.0	9.52	4.80
Carbonate	12	610.	0.0	101.	237
Bicarbonate	10	705.	500.	604.	51.0
Oil and grease	12	21.6	0.0	2.55	6.08
Sulfide	4	0.9	0.0	0.3	0.408
Arsenic	5	0.007	0.007	0.007	
Barium	5	0.5	0.5	0.5	
Boron	5	0.6	0.0	0.164	0.246
Cadmium	5	0.014	0.01	0.0108	0.0018
Copper	5	0.01	0.01	0.01	
Total chromium	4	0.1	0.1	0.1	
Chromium—HEX	1	0.01	0.01	0.01	
Total iron	8	5.7	0.1	2.59	1.70
Dissolved iron	8	5.0	1.8	3.20	1.19
Lead	5	0.1	0.01	0.082	0.0402
Manganese	5	0.27	0.1	0.186	0.0623
Mercury	4	0.001	0.001	0.001	
Nickel	5	0.1	0.1	0.1	
Selenium	4	0.002	0.001	0.013	0.0005
Silver	5	0.5	0.05	0.41	0.201
Zinc	5	0.12	0.01	0.052	0.0432
TK nitrogen	11	1.0	0.3	0.682	0.252
Conductivity MBAS	12	2,760.	1,580.	2,211.	310.
Ammonia	6	0.0	0.0	0.0	
Organic nitrogen	1	0.9	0.9	0.9	
Nitrate + nitrite	1	0.0	0.0	0.0	
Chloride	12	46.0	16.0	21.9	8.17
Fluoride	9	0.6	0.3	0.511	0.105
Cyanide	4	0.02	0.008	0.011	0.006
Sulfate	12	1,369.	650.	980.	205.
Phenol	5	0.034	0.0	0.0074	0.0149
MBSA	5	0.14	0.1	0.108	0.0179
BOD	1	31.0	31.0	31.0	
COD	12	28.4	0.4	8.71	9.19
Total dissolved solids	12	2,300.	1,480.	1,877.	250.
Suspended solids	7	178.	8.0	38.4	61.7
SV solids	6	100.	0.0	22.3	38.7
Lab pH	11	7.9	7.2	7.53	0.211
Turbidity (JTU)	7	29.0	1.3	10.9	9.76
Total CO_3	11	310.	250.	294.	16.7
Hardness	12	1,550.	742.	1,138.	211.
Alkalinity	3	516.	346.	454.	93.8

[a]Values in mg/l unless specified; Well station N-5; June 1972 to June 1976.

TABLE 3. AMAX BELLE AYR WATER QUALITY DATA--SCORIA PIT--WASATCH FORMATION ABOVE THE COAL (AMAX, 1977)

Parameter	Number of analyses	Maximum	Minimum	Mean
Field pH	1	7.6	7.6	7.6
Calcium	1	160.	160.	160.
Magnesium	1	25.0	25.0	25.0
Sodium	1	45.0	45.0	45.0
Potassium	1	18.0	18.0	18.0
Carbonate	1	0.0	0.0	0.0
Bicarbonate	1	156.	156.	156.
Cadmium	1	0.001	0.001	0.001
Copper	1	0.01	0.01	0.01
Total iron	1	0.07	0.07	0.07
Lead	1	0.01	0.01	0.01
Manganese	1	0.002	0.002	0.002
Mercury	1	0.002	0.002	0.002
Silver	1	0.05	0.05	0.05
Zinc	1	0.02	0.02	0.02
Conductivity (μmhos)	1	504.	504.	504.
Chloride	1	29.0	29.0	29.0
Sulfate	1	456.	456.	456.
Hardness	1	21.0	21.0	21.0

[a]Values in mg/l unless specified; well station scoria pit; June 1972 to June 1976.

TABLE 4. AMAX BELLE AYR WATER QUALITY DATA -- WYODAK COAL (AMAX, 1977)[a]

Parameter	Number of analyses	Maximum value	Minimum value	Mean	Standard deviation
Field pH	1	7.0	7.0	7.0	
Calcium	12	360.	180.	208.	49.1
Magnesium	12	320.	12.0	91.4	75.2
Sodium	12	640.	103.	210.	138.
Potassium	10	14.0	8.8	11.7	1.44
Carbonate	12	0.0	0.0	0.0	
Bicarbonate	12	560.	290.	510.	74.1
Oil and grease	12	12.1	0.0	2.34	3.55
Sulfide	4	1.1	0.1	0.525	0.505
Arsenic	5	0.007	0.007	0.007	
Barium	5	0.5	0.5	0.5	
Boron	5	1.1	0.0	0.27	0.465
Cadmium	5	0.01	0.001	0.0082	0.004
Copper	4	0.01	0.01	0.01	
Total chromium	4	0.1	0.1	0.1	
Chromium—HEX	1	0.01	0.01	0.01	
Total iron	9	5.1	0.2	2.19	1.65
Dissolved iron	7	2.5	1.49	2.07	0.379
Lead	5	0.1	0.02	0.084	0.0358
Manganese	5	2.0	0.1	0.774	0.839
Mercury	4	0.001	0.001	0.001	
Nickel	5	0.1	0.1	0.1	
Selenium	4	0.001	0.001	0.001	
Silver	5	0.5	0.05	0.41	0.201
Zinc	5	2.3	0.08	0.56	0.974
TK nitrogen	11	3.9	1.1	2.59	0.856
Conductivity (μmhos)	12	4,740.	1,720.	2,077.	841.
Ammonia	6	1.3	0.0	0.283	0.523
Organic nitrogen	1	3.1	3.1	3.1	
Nitrate + nitrite	1	0.0	0.0	0.0	
Chloride	12	31.0	3.6	9.16	7.46
Fluoride	10	1.3	0.4	0.75	0.222
Cyanide	4	0.02	0.008	0.011	0.006
Sulfate	12	3,400.	680.	940.	774.
Phenol	5	0.005	0.001	0.0026	0.0018
MBSA	5	0.16	0.1	0.112	0.0268
BOD	1	20.0	20.0	20.0	
COD	12	345.	28.0	71.6	88.4
Total dissolved solids	12	5,160	1,400.	1,785.	1,063.
Suspended solids	8	232.	8.0	68.2	74.7
SV solids	6	40.0	6.0	21.8	11.9
Lab pH	11	7.9	7.0	7.23	0.246
Turbidity (JTU)	8	125.	5.0	29.4	40.0
Total CO_3	11	270.	140.	251.	37.7
Hardness	12	2,200	530.	896.	422.
Alkalinity	3	450.	225.	373.	128.

[a]Values in mg/l unless specified; well station N-3; June 1972 to June 1973.

TABLE 5. AMAX BELLE AYR WATER QUALITY DATA--FORT UNION FORMATION BELOW COAL (AMAX, 1977)[a]

Parameter	Number of analyses	Maximum value	Minimum value	Mean	Standard deviation
Field pH	1	7.7	7.7	7.7	
Calcium	12	227.	121.	157.	26.1
Magnesium	12	85.0	36.0	46.4	12.6
Sodium	12	243.	154.	220.	23.3
Potassium	9	10.0	8.8	9.33	0.377
Carbonate	12	0.0	0.0	0.0	
Bicarbonate	12	440.	331.	398.	25.1
Oil and grease	12	6.0	0.0	1.72	2.01
Sulfide	4	3.0	0.0	1.07	1.39
Arsenic	5	0.02	0.007	0.0096	0.0058
Barium	5	0.5	0.5	0.5	
Boron	5	0.6	0.0	0.158	0.249
Cadmium	5	0.01	0.001	0.0082	0.004
Copper	5	0.01	0.01	0.01	
Total chromium	4	0.1	0.1	0.1	
Chromium—HEX	1	0.01	0.01	0.01	
Total iron	8	2.2	0.1	0.788	0.709
Dissolved iron	8	1.9	0.27	0.853	0.537
Lead	5	0.1	0.01	0.082	0.0402
Manganese	5	0.23	0.0	0.118	0.0823
Mercury	4	0.001	0.001	0.001	
Nickel	5	0.1	0.1	0.1	
Selenium	4	0.001	0.001	0.001	
Silver	4	0.5	0.05	0.387	0.225
Zinc	5	0.44	0.04	0.132	0.172
TK nitrogen	11	3.5	0.4	1.81	0.785
Conductivity (μmhos)	12	1,870.	1,600.	1,791.	80.1
Ammonia	6	0.3	0.0	0.05	0.122
Organic nitrogen	1	1.5	1.5	1.5	
Nitrate + nitrite	1	0.0	0.0	0.0	
Chloride	12	46.0	3.6	12.1	11.7
Fluoride	9	1.6	0.3	0.555	0.397
Cyanide	4	0.02	0.000	0.011	0.006
Sulfate	12	770.	600.	728.	47.5
Phenol	5	0.047	0.001	0.012	0.0197
MBSA	5	0.5	0.1	0.18	0.178
BOD	1	9.0	9.0	9.0	
COD	11	18.0	1.2	8.16	6.30
Total dissolved solids	12	1,500.	1,270.	1,400.	62.9
Suspended solids	7	206.	4.0	47.7	72.6
SV solids	6	108.	0.0	29.3	44.0
Lab pH	11	7.8	7.3	7.48	0.166
Turbidity (JTU)	7	44.0	0.7	10.0	15.3
Total CO_3	11	220.	190.	199.	8.39
Hardness	12	700.	450.	572.	58.4
Alkalinity	3	330.	162.	274.	96.9

[a]Values in mg/l unless specified; well station WRRI 7.

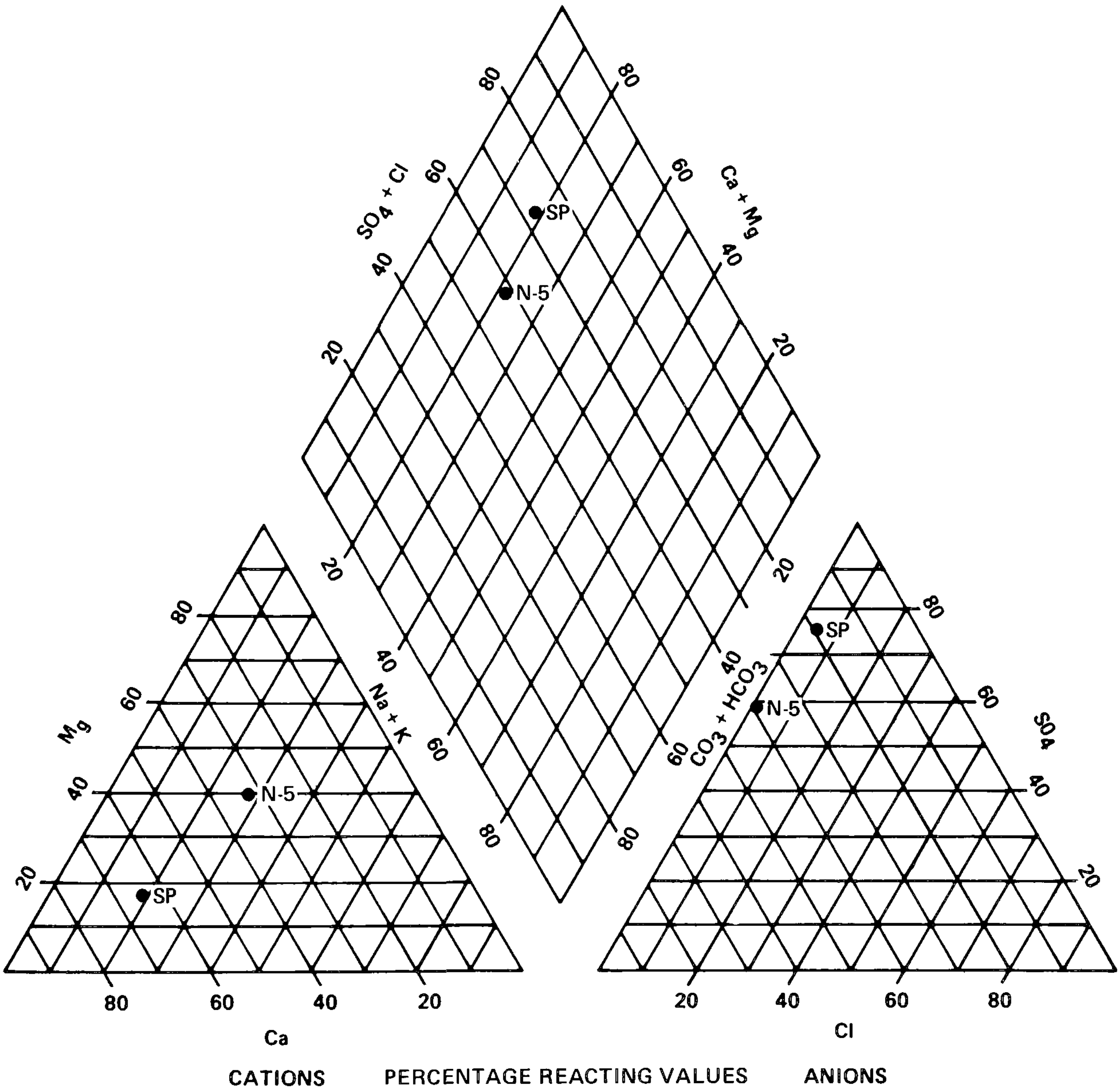


Figure 2. Water-analysis diagram, Belle Ayr South Wasatch Formation, N-5 and scoria pit (SP) wells.

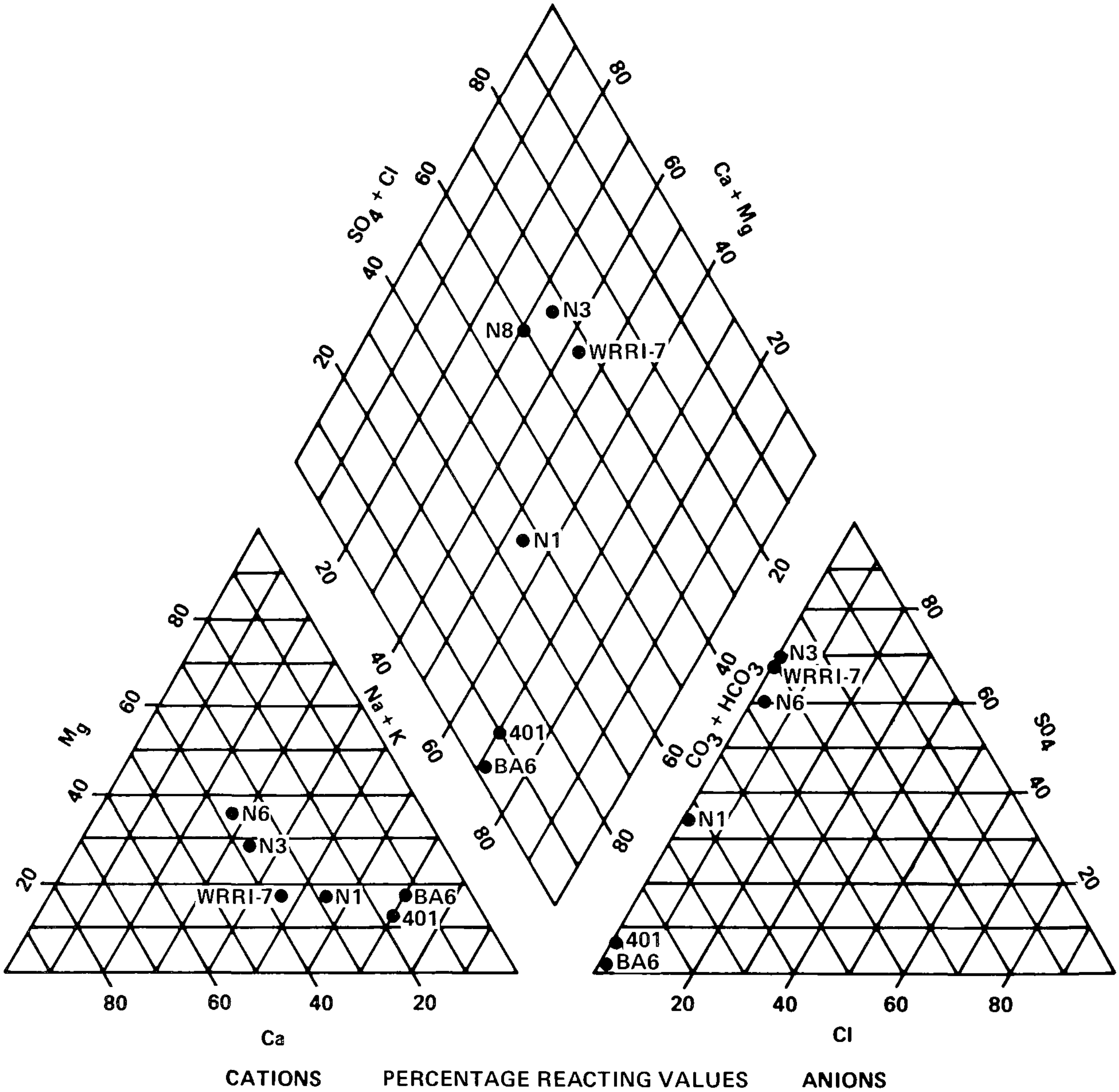


Figure 3. Water-analysis diagram, Belle Ayr South Wyodak coal mean values.

Evaluate Attenuation of Pollutants in the Saturated Zone

Source-specific monitoring in the saturated zone underlying present sites of stockpile materials is lacking. Data on the infiltration potential and mobility in the vadose and saturated zones could be developed through the monitoring methodology in the topsoil generic case study.

SECTION 3

MONITORING DESIGN FOR MINE WATER SOURCES

GENERAL CASE CONSIDERATIONS

Identify Potential Pollutants--Sedimentation Ponds

Potential sources of pollution which may affect the quality of water within sedimentation ponds include pit discharge, sewage effluent, and surface runoff. Pit discharge may contribute a large amount of suspended solids, some or all of the major inorganic chemical constituents (calcium, magnesium, potassium, sodium, bicarbonate, carbonate, chloride, sulfate, sulfide, phosphate, etc.), and trace contaminants (including iron, manganese, zinc, copper, cadmium, chromium, arsenic, lead, molybdenum, vanadium, uranium, thorium, radium, and selenium). Among the potential pollutants in ammonium-nitrate fuel oil (ANFO), used as an explosive for overburden removal, are nitric oxide, nitrogen dioxide, nitrous oxide, ammonia, hydrogen cyanide (1/10 of a pound of cyanide is produced for each 120-ton charge of ANFO), fuel oil, and trace organics. Gasoline, diesel fuel, and oil may be introduced by heavy equipment working in the pit.

Pollutants introduced into the sedimentation ponds from an on-site package plant include major inorganics and trace contaminants, organics (measured by BOD, COD), and microorganisms (see "Potential Pollutants," Everett, 1979). Surface runoff into the pit includes both sediment and wastes deposited on the ground surface, such as oils, chemical spills, salts, etc., as well as salts, organics, and microorganisms flushed from the soil surface.

Monitoring Needs--

Monitoring needs include: characterization of the sources of possible pollutants entering the sedimentation ponds, identification of potential pollutants entering the ponds, and determination of the chemical characteristics of the water in the ponds themselves.

Alternative Monitoring Approaches--

One method of characterizing potential pollutants would be to collect pollutant-specific information on monitoring activities relating to the sedimentation pond. For example, water quality data may be requested, together with information on the status of an NPDES permit for the basin. The NPDES usually also requires monitoring of flow, pH, TSS, Mg, and Fe.

Alternatively, the quantities of water discharging into the ponds from the main sources of potential pollution could be measured or otherwise determined in order to characterize pollutant loading. For example, flow meters could be installed within the pipeline or lines used to transport pit water to the ponds. Similarly, a Palmer-Bowlus flume or a weir could be placed in the line from the package plant. The watershed area above the pond could be characterized, and a rainfall-runoff relationship developed using techniques in the SCS National Engineering Handbook (Soil Conservation Service, 1972).

Another nonsampling method would comprise inventorying sources contributing possible pollutants to the sedimentation ponds. For example, the mass of ANFO used in overburden removal and coal fracturing could be determined. Sources contributing to the package plant could be inventoried during a parallel program. The surface runoff area above the ponds could be examined for surface stockpiles (e.g., topsoil, coal refuse, oil drums, etc.) containing potential pollutants. The sources could be located on a suitable base map.

Measurement of overflow from the ponds is required for an NPDES permit and these flow data may be used as part of the nonsampling program.

To obtain overflow measurements, appropriate weirs or flumes could be installed in a well-defined reach of the river into which the ponds discharge or as close as possible to the ponds. An automatic stage recorder could be installed for continuous measurement.

Water samples for characterizing pollutants within the sedimentation ponds and downstream runoff could be obtained from a number of alternative locations. For example, pit water discharging into the sedimentation ponds could be sampled directly at the pipeline discharge point. Similarly, samples of package plant effluent and surface runoff into the ponds could be obtained within the ponds and from the outfall to determine water quality transformations in transit. Finally, surface runoff comprising pond overflow could be sampled at a number of downstream locations.

Alternative water sampling methods include grab sampling, automatic composite sampling, and automatic discrete sampling. Grab samples are obtained to determine instantaneous water quality. Composite samplers are used to obtain blended water samples over a certain time interval (e.g., 24 hours). Discrete samplers extract water samples at timed intervals. The relative advantages and disadvantages of these techniques for wastewater sampling are reviewed by Harris and Keefer (1974).

Three alternative methods are possible for analyzing water samples. First, all samples may be submitted to a laboratory for complete analyses, including: suspended sediment; major inorganics (Ca, Mg, Na, K, HCO_3, Cl, SO_4, PO_4, SiO_2, NH_3-N, total-N, pH, and EC); trace constituents (Fe, Mg, Zn, Cu, Cl, Cr, As, Mo, V, U, Th, Ru, and Se); cyanide (possible byproduct of ANFO); organics (oils, grease,); and microorganisms (total and fecal coliform). Recommended quality control measures (e.g., submitting duplicate samples to other EPA-audited laboratories) could be an integral part of this approach.

A second technique is to analyze completely the first few water samples collected during the program. Subsequently, those trace constituents found to be present in low concentrations could be excluded from further analyses. Similarly, cyanide, low-level organics, and microorganisms could be deleted from routine analyses. It is recommended, however, that each sample be completely analyzed for the major organics. Similarly, package plant effluent would always be checked for BOD and coliforms. Quality control measures could be implemented.

A third method is to analyze samples in the field for constituents such as chloride and nitrate. This approach would require the purchase of a portable field kit (e.g., Hach Engineering Laboratory). When the results of such checks indicate a substantial change between testing, samples could be collected for laboratory analysis.

Selecting a sampling frequency to characterize the water-borne pollutants in a source, such as the sedimentation ponds, is generally a trial-and-error process. One alternative method is to sample frequently (e.g., every hour using a 24-hour discrete sampler) until time trends in the quality of the source are characterized. Subsequently, samples could be obtained by periodic grab sampling (e.g., weekly or monthly). An increase in sampling frequency may be warranted by unusual circumstances. For example, a spill of toxic substances on the watershed area draining into the ponds may justify an increase in sampling frequency.

Sampling frequency is also related to analytical costs. Thus, complete laboratory analyses of 24 samples collected during the 24-hour cycle of a discrete sampler could be prohibitively expensive. In this case, it could be more economical to obtain 6- or 12-hour discrete samples or a single 24-hour composite sample.

Preliminary Recommendations--

All of the above methods are deemed to be of importance in a program for identification of potential pollutants. However, source characterization, e.g., package plant discharge, will be included in parallel monitoring programs and will not be considered here. Similarly, inflow-outflow rate relationships will be considered as a sampling item under "Evaluate Infiltration Potential." Consequently, the following preferred monitoring approach is recommended:

- Available data on water quality would be obtained, including information on the NPDES permit.

- Samples of pit water, runoff from disturbed areas, and sewage effluent discharging into the detention basin would be collected via composite or discrete samplers. As discussed below, these samples would be used to characterize incoming quality trends and to assist in determining quality transformations in water during transit through the basin. In addition, time trends in certain quality parameters (e.g., BOD) may be warranted from results of parallel studies on the package plant. Subsequently, when trends are apparent, grab (discrete) samples would be collected.

- Surface runoff flowing into the ponds would be grab sampled at the inlet point.

- Discrete (grab) water samples would be taken at two or three areal locations within each pond and at two or three depths at each location, to characterize quality transformations during transit of water through the ponds.

- Pond discharge would be grab sampled at the outfall point and at two or three downstream locations.

All water samples would be collected, preserved, and transported in accordance with recommended procedures (see Brown, Skougstad and Fishman, 1970).

The following approach is recommended for analyses of water samples collected from the sedimentation ponds.

- Analyze completely the first five water samples from each sampling location for all constituents. Quality control measures would be implemented.

- Analyze field samples for representative constituents (e.g., nitrate, chloride). Collect samples for complete analysis if substantial changes in concentrations of these parameters occur during the nonsampling period.

- Analyze water samples collected on the basis of results under the second step, only for those constituents found during the first step to be present in above-permissible concentrations. Note, however, that the major inorganics would be completely analyzed and package plant effluent would be checked for BOD and microorganisms. Quality control measures would be implemented.

A preferred approach to sampling frequencies for sampling points related to the sedimentation ponds includes:

- Pit water and package plant effluent would be sampled at their respective discharge points on a 6-hour and 12-hour basis, using discrete samplers, three or four times a week for four weeks, or until time trends in quality are characterized. Thereafter, grab samples would be obtained on a semimonthly basis, unless more frequent sampling is warranted (e.g., discharge of toxic chemicals from the pit).

- Surface runoff would be grab sampled at the inlet point to the pit during one or two snowmelt runoff events and during one or two summer discharge events.

- Water samples would be collected at two locations in each of the two ponds at weekly intervals until quality trends are established. Thereafter, water samples would be obtained every month.

- Water samples would be collected at the outfall point from the detention basin at the same frequency and at the time that inflow discharges are sampled; that is, samples would be collected on a 6- or 12-hour basis, three or four times a week, until quality trends become apparent. Thereafter, a discrete sample would be collected twice a month. Water samples would be obtained when available from the outflow channel. If flows are sustained, samples would be taken twice a month.

The overall costs of this step would be high initially because of the need for complete analysis of source samples. These costs are summarized in Appendix B, Table B-2, and given below. Later, the sampling frequency and requisite analyses would be reduced. The process of using field checks to determine sampling frequency is another cost-reducing technique.

- Labor costs for inventorying and characterizing sources, installing and operating water sampling equipment, field checking quality, and collecting and transporting samples.

- Capital costs for purchasing composite or discrete samplers, and for equipment for field checking quality (Hach Kit). These items would generally be capital items available for the overall TEMPO monitoring program. Consequently, the proportionate charges against this source would be low.

- Operating costs for analyzing samples. These costs would be high initially but would lower as the list of constituents to examine is narrowed and when field checks are used to guide sampling.

Identify Potential Pollutants--Pit Water

Water entering the coal mine pits can originate from a number of sources, each of which may contribute pollutants. Common methods of disposal of pit water are discharge to sedimentation ponds and subsequent discharge to surface water, and use in dust control, such as for roads in the mine area. Monitoring of pit water disposal is discussed earlier in this section. Of concern in this discussion is the monitoring of water in the pit itself, and secondarily, determining the origin of the pollutants contained therein. Thus, the monitoring approach herein focuses on identification of potential pollutants. The subsequent steps of the monitoring methodology are applicable to the disposal processes and are not discussed further in this section.

Water in the pits may come from a number of sources: groundwater in the coal seam, groundwater percolating from nearby stream channels, through alluvium beneath the floodplain, groundwater in the overburden, groundwater in interburden and underburden, groundwater in spoils, direct precipitation, surface runoff into the pit, and waste disposal, such as sewage treatment plant effluent.

There are a number of potential sources of pollutants in the pit water, and most of these are discussed elsewhere in this report. Pollutants may come from: coal, overburden, interburden and underburden, explosives, spoils, solid waste disposal, polluted streamflow, liquid waste disposal, air pollutants and polluted precipitation, and spills and leaks. Some of these pollutants may be derived from natural sources. However, the modified hydrogeologic framework may allow them to enter the pit water.

Monitoring Needs--

There is a need to determine the quality of water in the pit and of discrete sources of water entering the pit. Secondarily, there is a need to determine the origin of pollutants present in pit water. This will likely entail additional monitoring beyond the pit. For example, effluent from a sewage treatment plant may percolate and move into the pit. Groundwater may also pick up substantial amounts of inorganic constituents from in-place and disturbed geologic formations or spoils during movement toward the pit.

Alternative Monitoring Approaches--

A water budget approach using existing data and field measurements could be used to determine the amount of water in the pit.

Pit water discharge could be measured by installing a continuously recording flow meter in the discharge lines and keeping an account of the number of truckloads of water hauled for dust suppression. Precipitation falling on the water surface could be measured by installing a continuously recording rain gage near the pit bottom. Evaporation could be measured indirectly by installing a floating evaporation pan. For both precipitation and evaporation determinations, the area of water surface in the pit must be known. This can be determined by periodic land surveys, such as on a monthly basis. Aerial photographs could also be taken at a similar frequency to document the location of water bodies in the pit.

The volume of water entering the pit is more difficult to determine. This is because the water may come both from discrete sources, such as leakage at one location from a stream channel, and diffuse sources, such as seepage. Surveys of operating mines indicate that discrete sources may be prevalent. For these sources, flumes or weirs could be installed near the point of entrance to the pit. Groundwater seepage into the pit from diffuse sources can be calculated if water table slopes and aquifer characteristics are known.

This information would be developed in defining the hydrogeologic situation. Alternatively, the groundwater seepage could be characterized by a network of monitoring wells surrounding the pit. Aquifer tests would be necessary to determine transmissivity and water-level measurements to determine the hydraulic gradient.

Items other than pit inflow and discharge could be measured, including change in storage for water in the pit. A staff gage used in conjunction with aerial photographs, or water surface area surveys could be used to determine change in pit water storage. Additionally, leakage from the pit could be estimated after other water budget items have been determined.

Water samples should be collected from pit water and discrete sources of water entering the pit. For water in the pit, samples could be taken representative of various depth intervals, since the water quality may vary substantially with depth in the pit. A depth-integrated sampler could be used from a small boat which would allow access to various parts of the pond. A composite sampler could be used to continuously monitor the quality of the water removed from the pit for use or dewatering. Grab samples could be collected from discrete sources of inflow to the pit. Sediments beneath the pit water should also be collected for sampling.

For groundwater in the coal seam, overburden, underburden and spoils, wells could be installed at the periphery of the pit to collect water samples. Changes in water quality along flow paths could be determined as groundwater approaches the pit. Generalized data from operating mines indicate that the effects of pit dewatering do not extend out more than a few miles. Thus, these monitor wells should be placed within ¼ mile or less of the pit. For groundwater percolating from streams, water samples could be collected from streamflow. Wells could be installed to allow collection of water samples from the alluvium. Changes in water quality during percolation could be determined as groundwater approaches the pit. Both solid and liquid wastes that could affect the quality of pit water could be sampled for chemical analyses. In general, the latter type of monitoring would generally have the lowest priority, unless sampling of pit water suggested the necessity for this approach.

Water entering the upper part of a pit can traverse significant distances before joining the pit water body. In this case, the water could pick up a number of pollutants from spills, native or disturbed materials, and other sources. In this case, sampling traverses could be made following the course of the water flow.

Monitor wells should be constructed to allow aquifer testing. These tests are advisable for some monitor wells because it allows the optimal determination of aquifer transmissivity. Transmissivity values provide key input for calculating the rate of groundwater flow, which is crucial in placement of monitor wells relative to pollution sources. An 8-inch diameter casing is necessary to provide room for the submersible pump (often 4 to 6 inches in diameter), plus a 1-inch diameter access tube for electric sounder measurements. For aquifer testing the pump is not permanent, and since PVC is the preferred casing material, extra room should be provided so that the casing is not damaged during pump installation and removal. For depths exceeding 100 feet or so, most casing strings are not perfectly straight, thus extra room is advisable. An 8-inch diameter casing is generally adequate for pumping lifts of up to 500 feet, assuming the range of well yield normally encountered in the coal regions. A 3-inch thick gravel pack is generally recommended; however, a 2-inch gravel pack would suffice for shallow wells (i.e., alluvium). Thus, the hole diameter would generally be 14 inches, but possibly 12 inches.

For monitor wells that are not to be pump tested, where water levels are shallow, and where a fixed pump is placed, a 4-inch diameter PVC casing could be used. In cases such as monitoring groundwater quality in alluvium, such a diameter would be feasible. For deeper water levels or where portable pumps are used, a 6- or 8-inch casing is advisable. In many cases, use of a somewhat larger diameter casing is the least expensive procedure in the long term. Larger diameter wells are easier to develop, easier to sample, and provide maximum flexibility for use. For example, a water-level recorder could be more easily installed in a larger well.

An annular seal would be placed opposite the upper 10 to 20 feet of the well. The wells should be properly developed upon completion to remove drilling mud or other foreign materials. The top of the casing should extend several inches above the ground surface and a locking cap should be installed. Barriers should be constructed to prevent destruction. Thus, it may be advisable to deliberately construct the monitor wells in a manner that allows retrieval of the casing at a later date. Obviously as the pit moves, some wells will have to be destroyed and new ones drilled.

The general drilling procedure in the Gillette area is to use the air rotary method for overburden or coal above the water table. Thus, holes are drilled by air until saturated conditions prevail, and then mud is added and the air drilling is by direct rotary, with a drilling fluid circulated. Bentonite is commonly used for drilling below the water table. Clinker is a special case, and may be rather easily drilled above the water table. However, lost circulation commonly occurs below the water table, even when drilling mud is used. Thus bran, fiber, cement, or other materials may be added. For alluvium, a common procedure is to drill an 8-inch diameter hole with a flight auger and install a 4-inch diameter PVC casing, and a 2-inch-thick gravel pack. In general, the alluvium is usually less than 20 feet thick and clay-rich with lenses of sand and gravel. Annular well seals are usually provided by using bentonite.

In general, the methods of well drilling in use are suitable. However, considerable attention should be given to well development. It may also be advisable to use a biodegradable drilling mud. Monitor wells can be swabbed and bailed, air or water jetted, and finally pumped and surged. Use of a larger diameter casing enhances proper well development.

To obtain water samples, a portable submersible pump should be installed in the monitor well. Upon completion of the well, a pump should be installed, pumping commenced, and water samples collected at frequent intervals during the first few hours of pumping. For alluvium, test durations of about 24 hours are generally adequate. For consolidated rock aquifers and clinker, durations of 1 week to 1 month are advisable. A step-drawdown test is advisable during the first part of the test to determine well losses. In general, several observation wells are advisable for consolidated rock aquifers where fractures result in anisotropic conditions. Often other monitor wells can be used for this purpose. Water should be piped a sufficient distance from the pumped well to ensure that no recirculation occurs during the test. A 1-inch diameter sounding line should be provided to allow water-level measurements by electric sounder. Totalizing propeller-type flow meters or orifice plates should be used to measure the flow. Electrical conductivity, pH, and temperature of discharged water should be periodically measured during the pump test. About six water samples should be collected at different times during the test for chemical analysis of parameters to be monitored. Field determinations of pH, EC, oxidation potential, and other parameters can be made. The procedure could be followed simultaneously with aquifer testing to avoid duplication. From such data, the optimum duration of pumping prior to water sample collection can be determined. Proper sample collection procedures are given by Brown, Skougstad, and Fishman (1970) and Thatcher, Janzer, and Edwards (1977).

In general, pumping is the preferred method of sampling where well yields exceeding about ½ gpm can be obtained. Airlifting is commonly used in the Gillette area and may be the most feasible approach where wells yield less than ½ gpm. However, consideration must be given to changes in chemical composition that may be induced by the airlifting process.

A quarterly sampling frequency is adequate for overburden and coal, and semiannual sampling is adequate for deeper materials. In Wyoming, the DEQ specifies sampling monitor wells twice a year. Due to weather conditions and access problems, this is usually done early in the summer and late in the summer. Quarterly sampling is advisable where access is feasible. The greatest constraint to more frequent sampling in many western coal regions is adverse weather conditions.

Samples of water should be examined for the major inorganic chemical constituents, including pH, EC, and TDS (residue at 180°C). Selected samples should be examined for total dissolved solids (ignition 600°F). Such determinations allow comparison of cation-anion sums, total dissolved solids versus electrical conductivity, and calculated total dissolved solids versus residue. Boron, phosphorus, and fluoride should be determined on all samples. Proper sample treatment and filtration techniques should be used (Brown, Skougstad and Fishman, 1970). The various nitrogen forms should occasionally be determined. Trace elements that are recommended for frequent determinations include iron, manganese, cadmium, chromium, arsenic, lead, molybdenum, vanadium, cyanide, and selenium. However, an extensive list of trace elements should be determined early in the program and annually thereafter.

A gross indication of the organic chemical composition can be obtained by total organic carbon and dissolved organic carbon determinations. Oil, grease, gasoline, and selected pesticides should be determined early in the program and annually thereafter. For radiologic composition, the uranium and thorium contents and gross alpha activity, gross beta activity, and radium-226 activity should be determined. For bacteriologic composition, total coliform and fecal coliform should be determined.

Preliminary Recommendations--

A recommended general procedure is to perform the most complete analyses on the pit water. Existing information on discrete and diffuse sources could be compiled and reviewed and these waters entering the pit would not require complete analysis, especially once they are characterized.

For solid materials accumulated at the bottom of the pit water, the nitrogen forms, trace elements, and total organic carbon could be determined on saturated extracts. Proper quality control procedures for laboratory analysis should be utilized.

Grab samples of pit water should initially be collected on a weekly basis. However, prior to initiation of a routine sampling program, the variability in pit water composition with depth and location should be determined. Results of this survey can be used to determine the number of samples required for each sampling round. The sampling frequency may be increased or decreased depending on results of the first several months of sampling. Alternatively, a composite sampling device may be necessary if grab samples prove inadequate. The date and time of sample collection should be determined in light of climatic conditions and operational procedures at the mine that might affect the quality of water sampled.

Labor costs would include inventorying and characterizing discrete and diffuse sources and for field checking water quality and sample collection. Capital expenditures for sampling equipment given in Appendix B, Table B-2, would not be required if these instruments have been obtained to sample sedimentation ponds. Grab samples of solid waste materials found in the pit would not require additional equipment. Operating costs would include those for analysis and transportion and storage of samples.

Define Groundwater Usage

Active coal strip mines require potable water for drinking and bath house operation, and larger quantities of nonpotable water for equipment cleanup, shop housekeeping, and dust suppression. Groundwater wells and seepage and runoff into the pit are the primary sources of these waters.

Monitoring Needs--

Information required to characterize groundwater usage includes the amount of water needed for various mining activities and the locations of water supply wells.

Alternative Monitoring Approaches--

The following nonsampling methods could be used to characterize groundwater usage: determine current efforts by the mine to quantify groundwater usage for various mining activities and collect available water use data; locate water supply wells on a base map (particularly those wells near the sedimentation pond) by contacting the mine operator or State engineer; obtain available data on the capacities of wells on-site; install flow-measuring devices; and estimate pumpage from power consumption data.

Certain of these activities could also be included in future steps. Specifically, locating water supply wells and determining their specifications could be undertaken when the hydrogeology of the site and existing groundwater quality are characterized.

Preliminary Recommendations--

It is recommended that information on the locations and specifications of water supply wells be collected during this step. Total pumpage in the wells would be estimated from power consumption data. The entire cost of the nonsampling program would be for the salary or wages of the project employee collecting the data and required field transportation. These costs are given in Appendix B, Table B-2.

Define Hydrogeologic Situation

The site-specific, and to a lesser degree the regional, hydrogeologic framework of the mine lease area is essential to assessing the overall impact of mining operation on the hydrologic system.

Monitoring Needs--

In order to characterize the hydrogeologic framework, information is required in the following areas: location, extent and interaction of aquifers, piezometric surface and velocities of flow, aquifer characteristics, and local geology.

Alternative Monitoring Approaches--

One nonsampling method would comprise collecting available hydrogeological information from a number of sources, including the mine operator, private consultants, the U.S. Geological Survey, State agencies, etc. Alternative types of information which could be solicited include: well locations, details on well construction (construction methods, depth, diameter, locations of perforations, completion techniques), drillers logs and geophysical data, and results of pumping tests for aquifer properties (including determining the particular test methods). Although information germane to the sedimentation pond area would be given priority, hydrogeologic data on the lease area, as a whole, could be obtained, i.e., to arrive at a regional picture. If necessary to complete the regional hydrogeologic picture, data could also be collected from adjoining mines.

In order to supplement existing groundwater data, a network of wells could be installed within the vicinity of the selected source area. One procedure would be to tie in the network with the existing wells. Alternatively, wells could be installed in a pattern suggested by Mooji and Rovers (1976). This pattern would comprise four wells, with one well upgradient of the source area, one well downgradient, and the remaining two wells within or near the source. Three of the wells would terminate in the same (uppermost) aquifer. The remaining bore hole would comprise a multiple piezometer cluster, with individual piezometers terminating within the same and separate aquifers. The latter unit would identify vertical hydraulic gradients and interaquifer leakage. The other three wells would permit defining the orientation of the potentiometric surface of the uppermost aquifers. This surface would illustrate the possible direction of flow. (Note: in fractured systems, such as coal aquifers, because of anisotropy, flow may not necessarily occur perpendicular to the hydraulic gradient. See Davis and DeWiest (1966, p. 355).)

During construction of the wells, lithological information could be obtained by analyzing drill cuttings for particle-size distribution. The locations of regions of perched groundwater in the vadose zone may be estimated by examining drill cuttings. Similarly, some notion of the hydraulic properties of sediments could be derived from particle-size analysis. Bore holes could be logged with a variety of geophysical tools (e.g., gamma loggers, calipers, etc.).

The test wells could be constructed by several techniques, e.g., cable tool, rotary, etc. Cable tool construction is desirable because drill cuttings are sampled from discrete depths. Well casings may comprise PVC or steel. Perforations may be installed by a variety of techniques, e.g., drilled holes, slots, etc. Well completion may involve using a swedge block and bailing, and/or pumping. Finally, wells may or may not be gravel packed.

The wells could be used in pumping tests to determine aquifer properties, T and S. A number of techniques could be used. Those reviewed by Lohman (1972) include the Theis method and the Jacob straight-line method for confined aquifers, the Hantush modified method for leaking confined aquifers, and Boulton's method for unconfined aquifers.

The wells could also be used as observation wells. Water levels could be routinely measured via an electric sounder or chalked tape, or instrumented with automatic water-stage recorders.

Preliminary Recommendations--

The following preferred approach is recommended for nonsampling hydrogeological studies:

- Collect available data on the hydrogeology of both the source (the sedimentation ponds) area and from the regional system.

- Use available wells to conduct aquifer tests, supplemented by constructing additional wells as necessary to provide a network of at least four wells. Ensure that the well network is arranged such that the potentiometric surface can be defined from water level data for all aquifers that may be affected by mining.

- One bore hole in the network will be used to install piezometer clusters within the uppermost aquifers.

- Construct wells via techniques commonly used in the area (i.e., either rotary or cable tool). Collect drill cuttings for laboratory determination of particle-size distribution. Use PVC wells, perforated by either drilling holes or by slotting. Gravel pack wells if necessary. Develop wells by pumping and surging for a sufficient time to reduce turbidity in pumped water.

- Use aquifer testing procedures appropriate to either confined, unconfined, and/or a leaking aquifer. Determine anisotropic transmissivity values (if the aquifer is fractured).

The costs of this step, as summarized in Appendix B, Table B-2, would be highest of the entire program for the sedimentation pond. However, these costs would be expended only in response to a data set developed from evaluation of infiltration and mobility of pollutants in the vadose zone which indicated a need to monitor pollutant attenuation and migration in the saturated zone. This information would be developed from previous iterations through the monitoring methodology and would justify the large expenditures assigned to the hydrogeologic framework monitoring program. Specific costs for this monitoring step would include the following:

- Labor costs for:

  -- Collecting and evaluating existing hydrogeologic information

  -- Overseeing drilling and well construction and development programs, including collection of drill cuttings

  -- Conducting aquifer tests, including collecting, analyzing, and interpreting data

  -- Routinely sounding observation wells and changing charts on water stage sounders.

- Operating costs will include:

  -- Travel (vehicle operation)

  -- Laboratory costs for determining particle-size analyses of drill cuttings

  -- Miscellaneous costs for materials (e.g., chart paper).

- Capital costs for:

  -- Well construction and development

  -- Well casing

  -- Water-level sounder or tape

  -- Submersible pump used in pumping tests and portable generator.

Study Existing Groundwater Quality

Activities during this step will overlap related steps involving characterizing the hydrogeologic framework and determining the attenuation of pollutants in the zone of saturation. Impact of groundwater quality is also closely associated with infiltration rates and migration of fluids through the vadose zone from the source area.

Monitoring Needs--

Determining the impact of a pollution source on groundwater quality involves determining time trends in the concentrations of pollutants in upgradient and downgradient wells. Ideally, these wells should be relatively close to the source because of the generally slow flow rates of groundwater.

Alternative Monitoring Approaches--

One nonsampling method would consist of collecting available water quality data from every available source, including the mining company, the U.S. Geological Survey, consultants, etc. The interpretations (if any) of these agencies could be used to estimate the quality impact of seepage from the sedimentation pond. Alternatively, the raw quality data from monitor wells near the ponds could be used to construct chemical hydrograms or trilinear diagrams, and isopleth maps for various constituents. Results could be compared with data on source-pollutant characteristics.

A water sampling program could be initiated to characterize the current groundwater quality in the vicinity of the source and downstream washes. Methods include sampling from existing monitor wells, if such wells are near the ponds, installation of supplemental wells, and a combination of the first two methods. The second method would require the construction of monitor wells. Such wells would be constructed during the previous step (define the hydrogeologic situation). Note that the multiple well, installed during that step, could be used to sample from different depths in the uppermost aquifer, and also from different aquifers.

Water samples could be obtained by a variety of alternative techniques: submersible pumps, hand bailing, airlift pump, etc. The submersible pump permits redevelopment of the well and rapid sample collection. The latter feature is desirable in light of the recommendation that at least five casing volumes be removed prior to sample collection (Mooji and Rovers, 1976). Wyoming recommends that one to two casing volumes be exchanged. Hand bailing is a viable method in small-diameter casing. Airlift pumps introduce air into the sample, causing changes in unstable constituents, such as pH, DO, and alkalinity.

Three methods of water sample analysis are possible. Samples could be completely analyzed for constituents listed above (Identify Potential Pollutants) in each of the following categories: major inorganics, trace constituents, organics, and microorganisms. Alternatively, the first few water samples could be examined completely. Once the principal constituents are identified (primarily those occurring in greater-than-permissible levels), subsequent analyses would be for these constituents only. Note that this approach should be used only for trace constituents, organics, and microorganisms. The major constituents should be determined completely for each sample.

A third technique would be to field analyze pH, EC, DO, alkalinity, chloride, and nitrate. When pronounced changes (i.e., above instrument or experimental error) occur, a sample could be collected for laboratory analyses.

Preliminary Recommendations--

The following preferred approach is recommended:

- Examine groundwater samples from available wells and special wells constructed during the previous step (Define Hydrogeolgic Framework). Special attention would be paid to sampling from the multiple-level well.

- Use a submersible pump for sample collection. Pump for a sufficient period of time to remove five casing volumes. Always carry an alternative sampler (e.g., hand bailer) in case of failure of the submersible pump.

For all samples, it is recommended that collection, preservation, and storage be conducted in accordance with recommended methods (Brown, Skougstad and Fishman, 1970).

The preferred monitoring approach would comprise:

- Completely analyze the first five samples from each well. Delineate parameters in excess of recommended limits.

- Field check for such parameters as pH, EC, DO, nitrate, and chloride. Collect a sample for laboratory analyses when marked changes occur between field checks.

- Analyze samples collected during the second item for those trace constituents, organics, and microorganisms delineated during the first item. All samples would be examined for the entire suite of major inorganics.

- Always implement appropriate quality control measures (e.g., submission of duplicate samples to alternative laboratories).

Samples would be collected on a weekly basis until time trends in quality are established. Thereafter, samples would be obtained on a bimonthly basis. Note, however, that unusual events may necessitate a greater sampling frequency, e.g., the introduction of toxic substances into the pond from pit discharge.

The principal cost for characterizing groundwater quality would initially be for sample analyses. Later, as quality trends become apparent, the sampling frequency and analyses would be reduced. The use of field checks to determine when laboratory analyses are necessary represents a cost-effective approach. Specific costs are itemized in Appendix B, Table B-2, and include:

- Labor costs for:
  - -- Collecting, analyzing, and interpreting available water quality data
  - -- Collecting, preserving, and storing groundwater samples.
- Capital costs for:
  - -- Submersible pumps
  - -- Hand bailer
  - -- pH meter
  - -- EC bridge
  - -- DO meter
  - -- Field kit for determining chloride and nitrate.
- Operating costs for:
  - -- Sample analyzer
  - -- Miscellaneous items, such as sample bottles, thermometers, chemicals, storage chest, etc.

The capital items listed above are general project tools, available for the overall TEMPO monitoring program. Note that monitor wells installed to characterize the hydrogeology of the site would also be used for sampling. The capital costs were included in the above step (Define Hydrogeologic Situation.) The analytical costs would be high initially, but would diminish throughout the sampling program as the list of constituents requiring analyses is narrowed and when field checks are used.

<u>Evaluate Infiltration Potential</u>

Herein, infiltration refers to seepage within the sedimentation ponds and in the downstream outflow channel during ponds discharge.

Monitoring Needs--

The primary monitoring need is to determine the quantity of water seeping into the subsurface from the sedimentation pond and outflow channel.

Alternative Monitoring Approaches--

Two alternative methods are possible for estimating pond seepage: the water budget method and a seepage matrix. The water budget method requires determining inflow rates, from all sources, outflow rates, evaporation-rainfall rates, and changes in storage. Inflow rates from the pit and package plant could be determined via weirs or flow meters. Runoff from the watershed draining into the ponds could be estimated from rainfall data and suitable rainfall-runoff relationships, such as developed by Craig and Rankl (1977). Outflow rates may also be determined via weirs or flow meters. The amount of water removed from the ponds for road spraying could be estimated by knowing the capacity and number of truckloads utilized for dust suppression. Evaporation and rainfall rates may be determined by installing rain gages and evaporation pans in the vicinity of the pond by using meteorological data from an on-site station, or by using such data from a nearby station. The most cost-effective approach is to use data from an on-site station. Data from other areas may not be strictly applicable. Changes in storage may be determined by installing either staff gages or an automatic stage recorder. The latter unit would require a stilling well and possibly a platform. Staff gages offer the most cost-effective approach unless rapid changes in water levels are expected.

When all the above components of the water budget have been determined, seepage rates are calculated by differences.

Seepage meters provide point information on seepage. Such meters may be difficult to install and operate in sedimentation ponds. In addition, a large number of observations is required in order to ensure that results are meaningful.

Infiltration in the outflow channel when pond overflow occurs may be determined by using existing flumes, by installing flumes between measuring points, or by current metering different reaches.

Water budget determinations may be made on a continuous or intermittent basis. Continuous determinations would require the installation of recording flow meters, automatic stage recorders, etc. Alternatively, the measurements required to compute a water balance could be obtained on a monthly or seasonal basis. In addition, measurements could be obtained before and after sedimentation removal. The surface mining reclamation and enforcement provisions require that sediment be removed from sedimentation ponds when the volume of sediment accumulates to 60 percent of the sediment storage required. After sediment removal, seepage rates would probably increase.

Preliminary Recommendations--

It is recommended that the water budget approach be used on this project. Although the initial cost of seepage rates via a water budget may be greater than by installing seepage meters, the results would be more accurate. In addition, capital items (e.g., weirs) may be general project items, reducing the cost apportioned to the sedimentation ponds. A cost-effective approach for monitoring infiltration through the outflow channel would be to utilize existing gaging stations, where possible, supplemented with an additional station in an upstream or downstream location.

The preferred approach to conducting a water balance for the sedimentation pond would be to obtain measurements on a monthly basis, until a seepage curve is obtained, and thereafter on a semiannual basis (e.g., in the winter or summer). Measurements would also be obtained before and after sediment removal.

Seepage rates in reaches of the outflow channel would be determined via an existing or project gaging station on a frequency dependent on pond overflow. That is, if overflow is continual, measurements would be obtained on a monthly basis. If overflow is periodic, measurements would also be periodic. Note that seepage rates would also be obtained during snowmelt or thunderstorm runoff.

The principal costs for this effort are given in Appendix B, Table B-2, and include:

- Labor costs for:
  - -- Conducting water balance studies on the sedimentation ponds, i.e., for installing weirs and flow meters
  - -- Installing staff gages on automatic stage records
  - -- Collecting rainfall-evaporation data (or for installing associated equipment)
  - -- Determining rainfall-runoff relationships for the contributing watershed
  - -- Analysis and interpretion of data
  - -- Determining seepage in the outflow channel.
- Capital costs for:
  - -- Weirs or flow meters
  - -- Water stage recorders or staff gages
  - -- Gaging station in the outflow channel.
- Operating funds for travel, chart paper, etc.

The capital items listed above would be general project items, and costs would be apportioned to usage.

Evaluate Mobility in the Vadose Zone

Mobility and attenuation of potential pollutants in the vadose zone will depend entirely on the quantity of infiltration water, defined in the previous step, which enters the zone. Thus, this and subsequent monitoring steps will be implemented only when preceding studies indicate a need for further evaluation.

Monitoring Needs--

Data gaps exist in knowledge of the factors tending to attenuate pollutants within the vadose zone (i.e., dilution, filtration, sorption, chemical precipitation, buffering, oxidation reduction, volatilization, and biological degradation and assimilation), and field data on transformations in waterborne pollutants during flow in the vadose zone.

Alternative Monitoring Approaches--

The potential attenuation of pollutants in the vadose zone may be depicted by constructing a matrix (table) comprising attenuating factors (rows) versus specific pollutants (columns). Each location in the matrix would specify the relative potential of a factor (e.g., sorption) to attenuate a specific pollutant (e.g., zinc). Each position in the table may be filled in by subjective evaluation, or on the basis of actual measurement. Subjective evaluation would involve examining available data and estimating the effect on the mobility of a specific pollutant. Alternatively, actual values from attenuating factors may be obtained from field measurements. For example, drill cuttings obtained during construction of wells may be analyzed to characterize cation exchange, pH, particle size, Eh, etc.

Obviously, completion of the above matrix would be highly complicated because of the interaction (synergistic or antagonistic) of several of the attenuating factors. In addition, some factors may not be easily determined or estimated (e.g., volatilization). Consequently, the recommended approach is to use a mix of subjective estimates supplemented, when possible, with actual data.

Access wells could be constructed through the vadose zone. Water content profiles could thus be obtained using a neutron moisture logger. The vertical movement of water could be inferred by periodically logging in single wells. For example, water content changes between daily logs could be used to calculate the daily rate of moisture accretion to, or drainage from, vertical segments of the vadose zone. In addition, the growth and dissipation of perched groundwater may be manifested on logs. The rate of lateral movement of perched groundwater could be inferred by monitoring water content profiles in a transect of wells. Several construction methods are possible for installing access wells (e.g., rotary percussion, cable tool). However, the method providing the tightest fit should be selected. Access wells could be constructed of steel, PVC, or aluminum. PVC would moderate the thermal neutrons used in moisture detection and result in poor resolution. Aluminum wells could deteriorate under highly saline conditions.

Water movement in the vadose zone underlying the sedimentation ponds may also be estimated by installing tensiometers and using methods described by Bouwer and Jackson (1974). Such units could be installed in several depths below the sedimentation pond. Tensiometers fail at water pressures less than -0.8 atmosphere. Alternatively, moisture blocks could be installed. Blocks function at greater suctions.

In order to characterize water movement beneath the outflow channel during pond overflow or natural discharge, access wells and/or tensiometers and moisture blocks could be installed at two or three locations.

Supplementing the above nonsampling program, field activities could be initiated to monitor the actual movement of pollutants in the vadose zone. Alternative methods include: collecting drill or auger samples for laboratory analysis, installing suction cups, and installing sampling wells within perched groundwater bodies.

Collection of samples of vadose zone sediments would entail using hand or power augers or core samplers. Depending on physical composition of sediments underlying the ponds, hand-augered samples could be obtained to a depth of about 10 feet. If deeper samples were required, power equipment would be needed. Samples may be collected (if possible) within the pond and in a transect away from the pond. Similarly, hand or power auger samples could be collected in the outflow channel. Samples could be taken to a laboratory for analysis.

Suction-cup lysimeters could be installed throughout the vadose zone provided the region consists of alluvium. Installations of cups in shale or sandstone might cause post-operational difficulties. Suction cups can be installed as individual units, in depth-wise increments, or as multiple units in a common bore hole. The cheapest approach is to install separate units to a depth of about 5 to 10 feet, say in 1-foot increments. Beyond 10 feet, borehole installation would be a more efficient alternative. For illustration of suction-cup lysimeter installations and operation procedures, see Fenn et al. (1975). Note that suction-cup lysimeters become inoperable at a soil water pressure less than -0.8 atmosphere.

The presence of perched groundwater could be detected from neutron moisture logs. Perched groundwater regions may yield water in sufficient volume to permit sampling. In this case, PVC wells could be constructed to the perched regions and samples extracted by hand bailing or by pumping.

Water samples collected from suction-cup lysimeters could be analyzed completely or partially. Ideally, a complete analysis includes the major inorganics, trace constituents, and organics listed under Identify Potential Pollutants. (Note that the ceramic suction cups may filter out microorganisms.) Upon examination of the results of complete analysis, it may be opted to analyze subsequent samples only for those trace constituents found present in greater than permissible concentrations. A complete analysis for major constituents is always recommended.

Solid samples could be used to obtain saturated extracts via techniques in Methods of Soil Analysis (Black, 1965). Saturated extracts could be employed to determine particle-size distribution, cation exchange capacity, EC, pH, and specific major and trace constituents, including Ca, Mg, K, Na, CO_2, HCO_3 SO_4, Cl, and B. Additional techniques are available for determining other trace constiuents, such as Cu, Zn, F, Se, Co, and Mo (Black, 1965). Organics could be determined using procedures described by Dunlap et al., 1977.

Water samples pumped from PVC wells within perched layers could be analyzed using alternatives described under Study Existing Groundwater Quality. These alternatives include: complete analysis of each sample; complete analysis of the first five to ten samples, until the water quality is characterized; partial analysis for those constituents found in excessive concentrations; and field checks.

Sampling frequency in suction-cup lysimeters depends on the water pressure within the surrounding porous matrix. Thus, if the system is very dry, water will enter the cups at a very slow rate. A week or more may be required before sufficient sample is available for analyses. In the extreme case, the cups may become inoperable (i.e., when water pressure is less than -0.8 atmosphere). In this case, samples may become available only once or twice a year. In contrast, if the porous system is very wet, samples may be extracted on a daily basis. In other words, the sampling frequency cannot be explicitly defined until field units are installed and operating. For a wet system, it may be desirable to collect samples on a more frequent (e.g., weekly) basis until quality trends are established. Later, samples could be obtained once a month.

Perched groundwater may be available only on a cyclic basis. Samples would then be obtained whenever possible. If perched groundwater is available continuously, samples could be obtained frequently (say, once a week) until quality trends are established. Later, samples could be collected on a monthly basis.

Preliminary Recommendations--

The preferred approach for estimating pollutant movement in the vadose zone would comprise:

- Construct a matrix of attenuation factors versus specific pollutants using available data when possible, supplemented with intuition.
- Install three access wells laterally away from the sedimentation ponds, into the uppermost aquifer.
- Install two networks of shallow tensiometers and moisture blocks in each pond with individual units terminating in foot increments to 5 feet beneath the base of the ponds.
- Install a network of shallow access wells, tensiometers, and moisture blocks at three locations along the outflow channel.

- Install suction-cup lysimeters in 1-foot increments to a depth of 10 feet below the base of the pond and in the outflow channel alluvium. Three sets of suction-cup lysimeters would be installed, one set within or immediately next to the pond, and the remaining sets at intervals along the outflow channel to be determined later. If suction-cup samples show that deep percolation of water is occurring, additional units would be installed at greater depths.

- During installation of suction cup lysimeters and PVC wells, collect solid samples for laboratory analysis of pollutants.

- Collect additional auger samples of solids only as deemed necessary, or when suction cups are inoperable.

- Install one PVC well within each perched groundwater body detected by neutron logging and sample via a submersible pump.

A preferred approach for analyzing solid and water samples collected from the vadose zone would comprise:

- Analyze solid samples for major and trace constituents and organics. Particular attention would be paid to determining those pollutants found in excessive concentrations in the source during the program, Identify Potential Pollutants.

- Analyze the initial five to ten water samples from the suction-cup lysimeters completely for major trace constituents. Subsequently, completely analyze for major constituents, but only for those trace constituents found in excessive concentrations.

- Examine perched groundwater samples completely for major and trace constituents, organics, and microorganisms in the first five samples. Subsequently, only those trace constituents, organics, and microorganisms found in excessive concentrations would be determined. After the initial characterization, field checks would be made of pH, EC, chloride, and nitrate. When substantial changes occur in these constituents, samples would be collected for partial analysis, as described above.

A preferred approach to sampling frequency would be:

- Sample suction cups whenever possible during very dry conditions. For wet conditions, sample weekly until quality trends are established. Thereafter, sample once a month.

- Obtain and analyze solid samples only during installation of suction cups and PVC wells

- Sample PVC wells at a frequency depending upon availability of free, perched groundwater.

Costs associated with the recommended approach for monitoring in the vadose zone are summarized in Appendix B, Table B-2, and include:

- Labor costs would be broken down into the following items:
  - -- Constructing an attenuation factor versus pollutant matrix and interpreting results
  - -- Overseeing the installation of access wells, and subsequently logging the wells
  - -- Installing tensiometers and moisture blocks and collecting and interpreting results
  - -- Obtaining and examining data from neutron moisture logs and tensiometer data to determine the flux of water (and pollutants) in the vadose zone
  - -- Installing suction-cup lysimeters
  - -- Collecting solid samples from the vadose zone
  - -- Collecting water samples from the suction cups and PVC wells (if constructed)
  - -- Conducting field checks on pH, EC, chloride, and nitrate.
- Capital costs would include:
  - -- Access wells
  - -- Neutron moisture logger
  - -- Tensiometers
  - -- Suction-cup lysimeters
  - -- PVC wells
  - -- pH meter, EC bridge, and field kit for measuring chloride and nitrate; these items are general project items and associated costs for this step will be apportioned according to usage
  - -- Hand augers or power augers; again, these would be project items.
- Operating costs would comprise:
  - -- Analytical costs for water samples. This cost would be reduced when field checks are used to determine the need for laboratory analysis. Also, the number of requisite analyses would be reduced throughout the program.

-- Analytical costs for analysis of auger samples.

-- Transportation costs, sample bottles, etc.

Evaluate Attenuation of Pollutants in the Saturated Zone

As pointed out by Todd et al. (1976), the principal processes involved in attenuating pollutants in the zone of saturation include: decay, physical-chemical reactions, or dilution. For pollutants in a source, such as a sedimentation pond, physical-chemical processes and dilution may be of prime significance. Included in the physical-chemical processes are sorption, precipitation, volatilization, oxidation-reduction reactions, etc. Dilution is effected by hydrodynamic dispersion resulting from such effects as convection diffusion, and flow tortuousity.

At the present time, dispersion (or dispersivity) within an aquifer is difficult to determine without careful, extensive field experimentation. A qualitative notion of dilution resulting from dispersion may be obtained from knowledge of the following (see Todd et al., 1976): volume of wastewater reaching the water table, the waste loading, areal head distribution, transmissivity values, vertical hydraulic-head gradients and permeabilities, groundwater quality, quantity and quality of recharge from other sources, and pumpage volumes and patterns.

Monitoring Needs--

Information gaps currently exist in predicting the effect of the following mechanisms on pollutant attenuation within aquifers underlying the sedimentation pond: physical-chemical reactions and dilution.

Alternative Monitoring Approaches--

The relative effect of various physical-chemical mechanisms for attenuation pollutants within the saturated zone could be estimated by constructing a matrix similar to that for the vadose zone. That is, a table could be prepared consisting of attenuating mechanisms (rows) versus pollutants (columns). Attenuating mechanisms would consist of the following physical-chemical factors: sorption, precipitation, volatilization, oxidation-reduction (Eh), decay, and dilution. When completed, the table would show in a mixed qualitative-quantitative sense the pollutants which should be monitored.

Completion of the matrix for the physical-chemical items requires specific information on exchange capacity of aquifer materials, on the Eh and pH of groundwater, as well as on the specific pollutants entering the zone of saturation. Many of the physical-chemical parameters could be quantified from analysis of drill cuttings obtained during well construction (see Define Hydrogeologic Situation), and from field analysis of Eh and pH. Identification of pollutants must await the results of mobility studies in the vadose zone.

Estimating the effect of dilution on pollutant attenuation would require data on items listed previously, i.e., volume of wastewater reaching the water table, the waste loading, areal head distribution, aquifer transmissivity, vertical hydraulic head gradients and permeabilities, groundwater quality, quantity and quality of recharge from other sources, and pumpage volume and patterns. The volume of pond water reaching the water table may be estimated from data on seepage rates (see Evaluate Infiltration Potential). Assumptions are that steady-state seepage has been reached and that the water content of vadose sediments equals or exceeds field capacity. Water content data from access wells installed earlier would be useful in verifying these assumptions. Similarly, neutron moisture logging data in a transect of access wells may indicate the lateral spread of pond water within the vadose zone and, consequently, the waste loading rate. It might be necessary to install additional access wells to obtain adequate resolution. Areal head distributions in the aquifer could be obtained via the set of four wells installed earlier (Define Hydrogeologic Situation). Similarly, piezometer clusters may provide data on vertical hydraulic gradients, and possibly on vertical hydraulic conductivity. Aquifer transmissivity values may also be obtained as a result of earlier pumping tests on the four wells. Groundwater quality could be quantified as a result of activities during the step, Study Existing Groundwater Quality. The quantity and quality of recharge from other sources could be the most difficult items to identify. Available data would be used if possible, e.g., on seepage rates in the outflow channel. Similarly, information on pumping rates in existing wells would be solicited from the mine manager.

In lieu of constructing an attenuation matrix, an alternative method would entail initiating tracer studies to estimate the spread and attenuation of pollutants. For example, a conservative tracer, such as chloride, could be injected in one of the upstream wells installed earlier and water samples extracted periodically from downstream wells. However, in light of possible low T values in the shallow aquifers, the time to obtain a tracer breakthrough in downstream wells could be excessive.

Groundwater samples could be obtained for analysis and ensuing data examined to characterize pollutant attenuation. The network of four wells installed during previous steps could be used in such a program. In actuality, a special sampling program would not be required, because samples would be available from these steps.

It is imperative that vertical samples be obtained within the water-bearing strata being examined. The rationale for this necessity was stated by Mooji and Rovers (1976).

> In the past it was frequently assumed that the monitoring of the upper few feet of an aquifer was adequate as it was assumed that the contaminants migrated vertically to the water table followed by lateral migration in the upper zone of the aquifer. In fact, recent research studies show that the contaminants can migrate to the bottom of the aquifer prior to extensive lateral migration taking place . . . . Therefore the preferred method is to install piezometers at varying depths throughout the thickness of the aquifer.

In lieu of, or to supplement, piezometer clusters, alternative methods for obtaining depth-wise samples from a given water-bearing formation include multilevel samples and groundwater profile samplers. Details of a multilevel sampling well designed by Pickens et al. (1977) are illustrated in Figure 4. This well consists of PVC or steel well casing, ports or openings at desired incremental depths, screened coverings on openings, and polypropane tubing sealed onto the openings, extending to the surface. According to Pickens et al. (1977), this unit may be used to depths of 30 to 40 meters. The advantages of this unit are that depth-wise sampling is facilitated and overall construction costs may be lower than for piezometers. A suitable pumping unit may be such as that used to purge tensiometer units (available from Soil Moisture Equipment Company, Santa Barbara, California).

An alternative depth-wise sampler was designed by Hansen and Harris (1974). The unit, called a "groundwater profile sampler," is shown in Figure 5. Basically, the sampler consists of a 1¼-inch diameter well point, of optional length, with isolated chambers containing fiberglass probes. The individual chambers are filled with sand and separated by caulking compound. Small-diameter tubing provides surface access to the probes. The positioning of probes is optional, depending on aquifer materials, desired sampling frequency, etc. In operation, a vacuum is applied to the lines pulling the sampling flasks. Hansen and Harris (1974) recommended that all samples should be extracted simultaneously and at the same rate to minimize variation in aquifer thickness sampled by the individual probes. Water tables as deep as 30 feet may be sampled by the unit (Hansen and Harris, 1974).

Preliminary Recommendations--

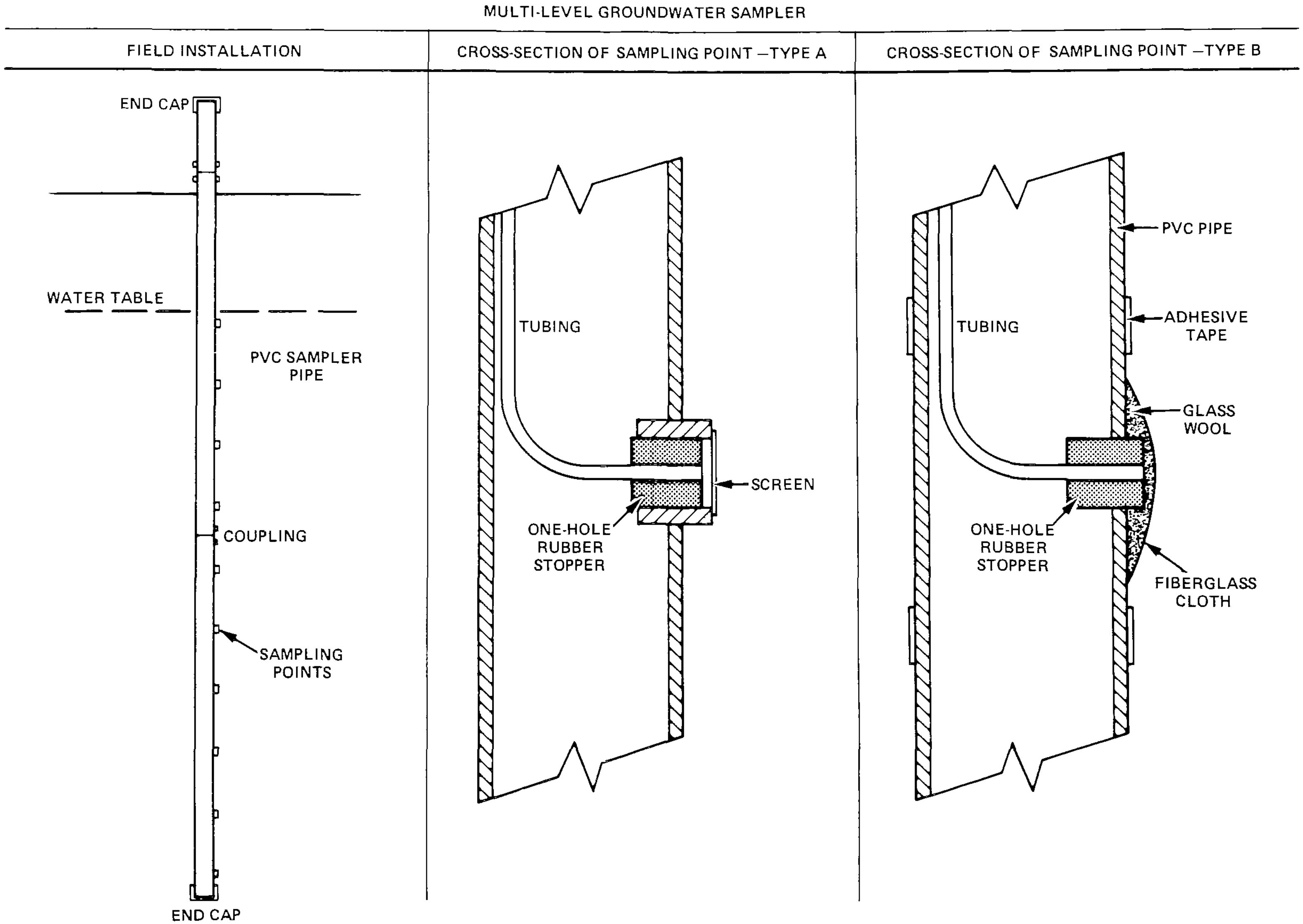
A preferred monitoring approach includes:

- Construct an attenuating mechanism versus pollutant matrix, using available data whenever possible
- Conduct tracer studies if two monitor wells are deemed to be sufficiently close that short-time studies are possible
- Use monitor wells installed during previous steps and install additional piezometer clusters as necessary to obtain samples for characterizing the vertical distribution of quality. (The other methods, multilevel samplers or groundwater profile samplers, are not recommended unless the water table is very shallow.

The costs for the proposed approach are summarized in Appendix B, Table B-2, and would consist of:

- Labor costs for obtaining data necessary to prepare and interpret the attenuation mechanisms versus pollutant matrix. Labor costs for collecting water samples would be accounted for under Study Existing Groundwater Quality.
- Capital costs for additional wells.

Figure 4. Multilevel groundwater sampler (after Pickens et al., 1977).



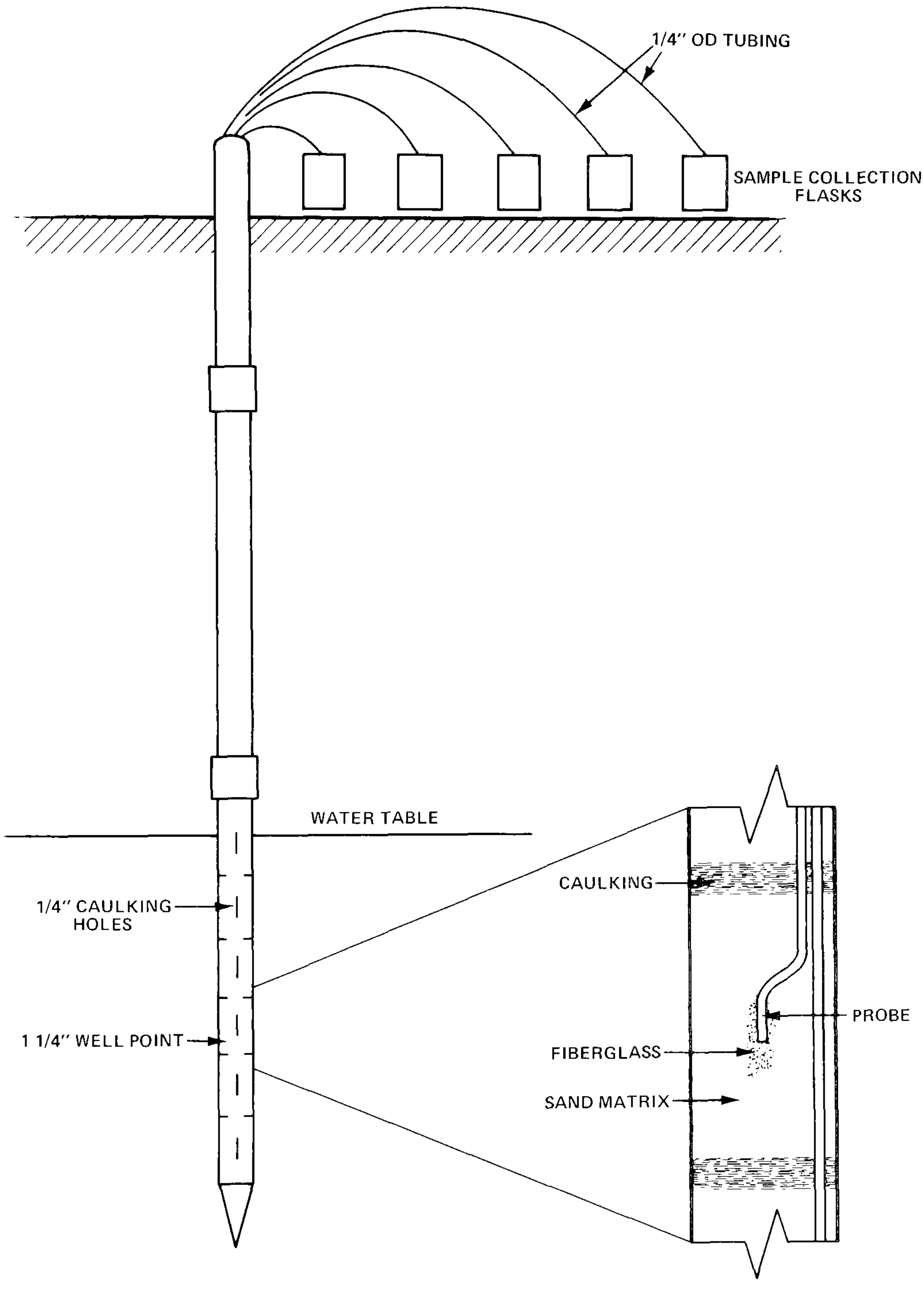


Figure 5. Groundwater profile sampler (after: Hansen and Harris, 1974).

- Operating costs for analyzing water samples would be accounted for in the step, Study Existing Groundwater Quality.

EXAMPLE CASE STUDY--SUN OIL COMPANY'S CORDERO MINE

The following case study is derived from data compiled on an active mine water source (sedimentation ponds) for Sun Oil Company's Cordero Mine.

Identify Potential Pollutants

The Cordero Mining Co. (1976) states that two settling ponds combined in series are designed to receive runoff of source water from the facility area, sewage treatment plant effluent, pit water, and runoff from a 2.8-inch rainfall in a 24-hour period (i.e., 50-year flood). The ponds that typically impound less than 20 acre-feet of water will retain the source waters for approximately 5 days as required by the Wyoming Department of Environmental Quality to settle out suspended solids. The water will meet the other effluent standards, such as pH, iron, manganese, and total suspended solids as well as applicable Wyoming water quality standards. Under normal operating conditions, no discharges are expected from the ponds. However, a sand filter is installed on the second settling pond as a final step in removing any suspended solids. The sedimentation ponds are located in T47N, R71W, S29 (see Figure 6). Note the locations of a sewage treatment plant (package plant) and a proposed supplemental sedimentation pond.

Potential pollutants in the pond water have not been characterized. For a general discussion of pollutants likely to occur in the source waters, see Everett (1979).

Water-borne pollutants in the sedimentation ponds could represent a threat to local groundwater quality should leakage occur. As shown on Figure 6, the sedimentation ponds are located on the floodplain of the Belle Fourche River and, therefore, overflow from the ponds could introduce pollutants into alluvial aquifers underlying the Belle Fourche River.

According to the Cordero Mining Company (1976), the pond water will meet Wyoming quality standards for suspended solids, pH, iron, manganese, and other (unspecified) water quality standards and no overflow is expected under normal operating conditions. In addition, it is stated that ". . . the quality of the water will be monitored." In the event that pond overflow occurs, the standards in the NPDES permit must be fulfilled, again requiring monitoring. Note that except for suspended solids, pH, iron, and manganese, specific parameters to be characterized are not specified.

Define Groundwater Usage

The water table at the site is apparently near the middle of the coal seam. During mining, the pit water is to be pumped into two settling basins capable of holding water from 6 days of normal mine discharge. The water in the settling basins will be used primarily for dust control. The U.S. Geological Survey (1976) states that any discharge to the Belle Fourche River will be minimal. However, an NPDES discharge permit has been obtained. Pit

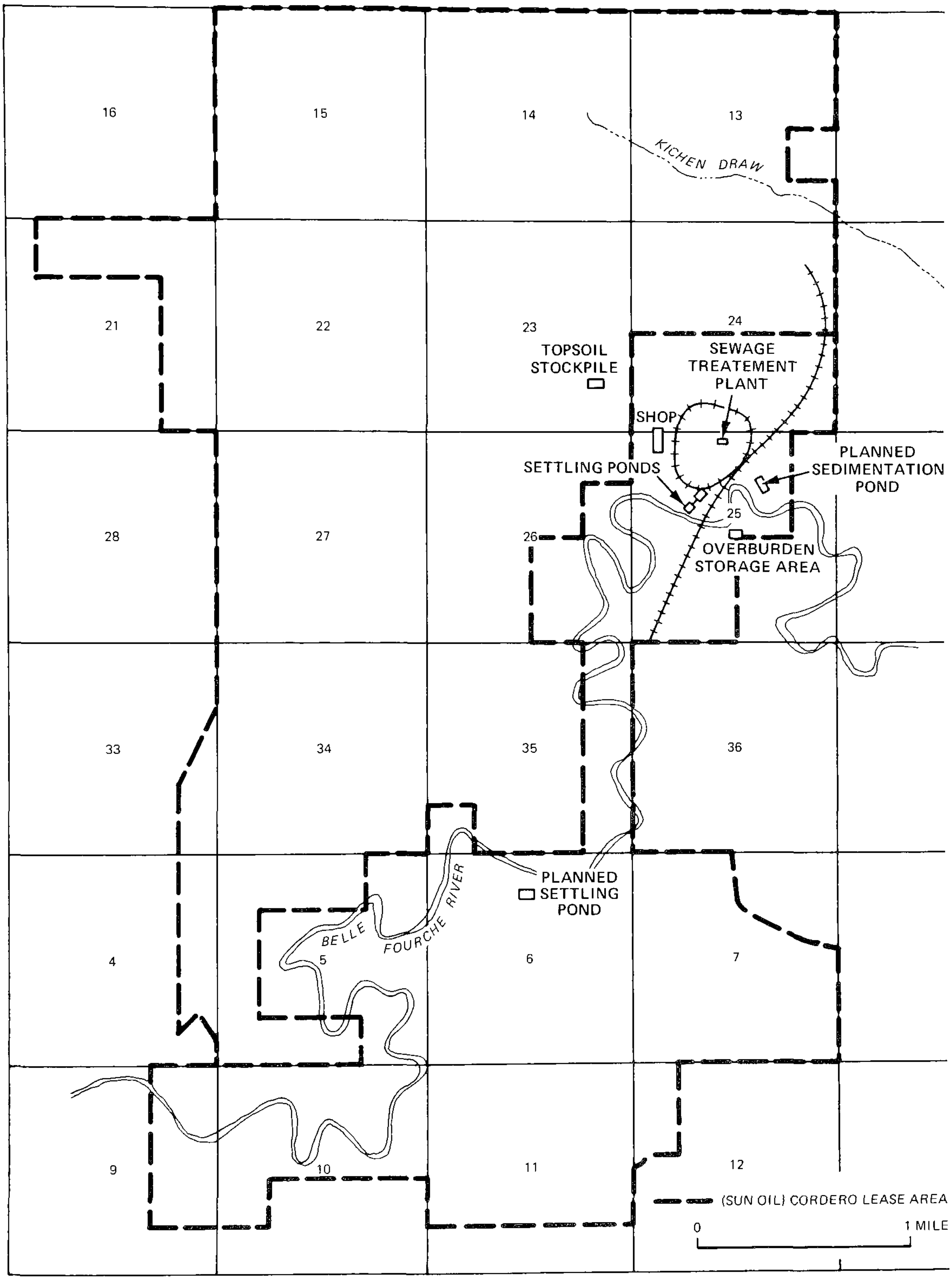


Figure 6. Location of sedimentation pond.

water will come primarily from seepage from the coal aquifer, and secondarily from limited groundwater in the overburden and spoils. Near the Belle Fourche River in the southern part of the site, a substantial portion of the pit discharge may come from percolation of surface water through alluvium. The rate of pit discharge has been estimated to range from 40,000 to 100,000 gpd, and average 70,000 gpd. Groundwater from strata beneath the coal may move upward into the pit during mining.

Surface water runoff will generally be kept from the pit by diversion ditches. To prevent water from the Belle Fourche River from entering the pits, some of the oxbow loops have been eliminated by construction of a new river channel across the heads of the loops.

Mining plans for the Cordero Mine (Sun Oil Co., 1976) indicate that groundwater will be pumped to supply potable water needs of the mine. Pumped water will be stored in a 20,000-gallon tank. Usage is expected to amount to 15,000 gpd. (Note: water for the sedimentation ponds, including package plant effluent, will be used for firefighting and other plant needs.)

A facility layout included in the mine plans (Cordero Mining Company, 1976) shows the location of two water wells in T47N, R71W, S24, and a windmill in T47N, R71W, S23. Reference is also made to the Hayden well, possibly a domestic well near the mine.

Although the locations of wells appear to be well defined on the Cordero mine, data deficiencies exist in the following: volume of groundwater pumped for shop, sanitary, and office needs and for fire protection; volume of groundwater in excess of pit water used for coal preparation; and volume of groundwater in excess of pit water used for irrigation.

<u>Define Hydrogeologic Situation</u>

Information on the hydrogeologic framework of the Cordero Mine was summarized in a report edited by Everett (1979).

> Groundwater exists in the Wasatch Formation, the coal beds, the alluviated areas of the Belle Fourche River, and probably in the scoria . . . . Field observations at the Cordero indicate that the overburden is generally dry, with the exception of several lenticular sandstone beds.

The location of the settling ponds on the floodplain of the Belle Fourche River suggests that they may be underlain by an alluvial aquifer. The extent of current studies by the Cordero Mining Company to characterize the hydrogeology of the lease to date is unknown. The Company has not published pump test results to assist in evaluating the properties of the aquifer's systems. Eleven wells were constructed on the lease in late 1974 (Cordero Mining Company, 1976). Static water levels are routinely measured in these wells, and ostensibly the wells could be used for pumping tests.

Until detailed results of hydrogeologic studies on the Cordero Mine became available, it is presumed that information deficiencies may exist. In particular, the following data gaps may exist relative to the area encompassing the sedimentation ponds: vadose zone properties (geology, lithology, etc.), and saturated zone properties, including locations of aquifers and associated geology and hydraulic head distributions, transmissivities (including anisotropic T) and storage coefficients of aquifers, and direction and velocities of groundwater flow.

Study Existing Groundwater Quality

Although Cordero has been shipping coal since March 1977, its groundwater monitoring program is not well developed. In its mining plan update (Cordero Mining Company, 1976). Cordero officials indicated the existence of only four groundwater quality monitoring stations. These include three water wells and one stock well. All are Wasatch Formation wells. Quality values for these wells are shown on Tables 6 and 7.

Cordero reported that these samples show stable values that that they are useable data. However, the stock well sample was not a pumped sample and no field sampling techniques were discussed. Also, the Hayden well is less than 1000 feet from a major tributary to the Belle Fourche River. The low quantity of dissolved solids in the water is probably due to hydraulic connection with low TDS surface water.

In summary, it appears that monitoring wells on the Cordero Mine are being used to a minimal extent to characterize the regional groundwater quality. Specific monitoring for groundwater quality near the sedimentation pond appears to be minimal or nonexistent at this time.

Data deficiencies exist in the following: current areal distribution of groundwater quality in the vicinity of the sedimentation ponds, time trends in the quality of groundwater beneath the ponds, and vertical distribution of water quality within the uppermost aquifer and differences between adjoining aquifers.

Evaluate Infiltration Potential

The extent that seepage losses in the ponds and downstream river bed are being determined by the Cordero Mining Company is unknown. Presumably, such determinations have been minimial in the past. At the present time, it appears that the following data deficiencies exist: seepage losses in the sedimentation ponds, and seepage losses in the Belle Fourche River during overflow.

Evaluate Mobility in the Vadose Zone

Pollutant mobility in the vadose zone underlying the sedimentation ponds or Belle Fourche River is currently not being monitored on the Cordero Mine.

Evaluate Attenuation of Pollutants in the Saturated Zone

Activities by the Cordero Mining Company to determine the attenuation of pollutants originating from the sedimentation pond during groundwater flow

TABLE 6. GROUNDWATER QUALITY, HAYDEN RESIDENCE, SUN OIL CORDERO LEASE (SUN OIL, 1976)

Date	September 3, 1974	November 25, 1974	February 9, 1975	May 22, 1975
Constituent (mg/l)				
Total dissolved solids	328	360	390	354
Suspended solids		6	-	-
Hardness	44	45	47	85
Bicarbonate				
as HCO_3		377		-
as $CaCO_3$	316		330	415
Carbonate				
as CO_3		0	-	-
- as $CaCO_3$	<1	-	0	0
Sulfate	<5	3	<1	4
Chloride	7	9	10	18
Nitrate	1.5	2.9	1.6	1.5
Fluoride	1.5	1.0	1.9	1.1
Sodium	118	133	150	122
Calcium		10		
Iron		0.24		0.05
Lithium		0.01		0.04
Arsenic		<0.01		0.00
Selenium		0.011		0.00
Boron		0.11		0.00
Zinc		0.14		0.03
Mercury (μg/l)		<0.5		0.000
Cadmium (μg/l)		<5		0
Copper				0.00
Lead		-		0.00
Chromium				0.00
Molybdenum				0.00
Nickel		-		0.00
Aluminum				0.0
pH				
field			7.58	-
lab	7.9	7.8	8.1	-
Alkalinity as $CaCO_3$		309		-

TABLE 7. GROUNDWATER QUALITY, WELL NUMBER 11, SUN OIL CORDERO LEASE (SUN OIL CO., 1976)

Date	November 25, 1974	February 9, 1975	May 22, 1975[a]
Constituent (mg/l)			
Total dissolved solids	(a)	2,000	2,160
Suspended solids			
Hardness	(a)	920	925
Bicarbonate			
as HCO_3	412	770	1,010
as $CaCO_3$			
Carbonate			
as CO_3	0	0	0
as $CaCO_3$			
Sulfate	900	910	959
Chloride	8	12	19
Nitrate	13.2	0.90	0.7
Fluoride	0.58	0.53	0.48
Sodium	415	440	321
Calcium	56		
Iron	0.028		0.03
Lithium			0.10
Arsenic			0.00
Selenium			0.00
Boron	0.14		0.01
Zinc			0.00
Mercury			0.000
Cadmium			0.00
Copper			0.00
Lead			0.00
Chromium			0.00
Molybdenum			0.00
Nickel			0.04
Aluminum			0.00
pH			
field		7.6	
lab	8.1	7.9	
Alkalinity as $CaCO_3$	337		

[a]Sample not sufficient to analyze.

are nonexistent. As pointed out earlier, 11 monitor wells have been installed on the lease. However, none of these wells is close enough to the source to constitute source-specific monitoring wells.

SECTION 4

MONITORING DESIGN FOR MISCELLANEOUS ACTIVE MINE SOURCES

GENERAL CASE CONSIDERATIONS

Identify Potential Pollutants--Explosives

Mining sites with well consolidated overburden and coal seams utilize explosives to dislodge the materials prior to their removal. The principal explosive being used at the mines for blasting is an ammonium-nitrate--fuel oil mixture known as ANFO. Apparently, the water pollution potential of explosives used for strip mining has not been studied in detail in the Western United States. In the case of an incomplete explosion, some ammonium-nitrate and fuel oil residual will occur. Also, spillage of the explosives could create a pollution potential. Such materials could directly affect the quality of pit water. Also, stockpile and spoils could contain these materials and affect groundwater quality.

Monitoring Needs--

Records of blasting operations in the study area are unknown and it is therefore assumed that no direct monitoring of explosives in relation to water pollution potential is performed. There is a need to determine the approximate amounts of residual ammonium-nitrate and fuel oil from explosives. Spills of these materials should also be monitored.

Alternative Monitoring Approaches--

A nonsampling method of monitoring this potential pollutant source would utilize much of the required information available in response to the provisions of the Surface Mining Control and Reclamation Act. Specifically, the location, dates and time of blasting, the type of material blasted, the number of holes and spacing, the depth and diameter of holes, and the type and weight of explosives used are to be recorded. From this information, maps could be prepared illustrating patterns in the use of explosives, such as hole density or tonnage of explosives. Records should also be maintained on location and amounts of spills of explosives and cleanup measures, if any.

Sampling of both overburden and coal could be performed prior to and after blasting. Although the blasted materials are eventually removed from the area, water could contact the materials and drain into the pit prior to its removal. Also, after the overburden is removed and prior to blasting of the coal, the uppermost layers of coal could be sampled for explosives or residual materials. After the coal is removed, the uppermost layers of underburden could be sampled for explosives or residual materials. Water could run over both of these surfaces and pick up potential pollutants.

Because the explosives are used in close proximity to the pit water body, sampling of water in the pit and tributary to the pit is recommended. In general, the direction of groundwater movement in the coal and overburden in areas where explosives are used would be toward the pit water body. Water could pick up residuals from explosives or spilled materials during flow over the surface of the pit. Based on present data, this is the most likely mechanism whereby pollutants from explosives would enter the pit water. Thus, the optimal situation is to monitor explosion residuals and pit water at the same mine, a procedure followed in this monitoring program design. Monitoring water quality in wells completed in "blasted" and replaced spoils will be discussed in a subsequent report dealing with reclaimed mine potential sources of pollution. Water flowing across the pit a significant distance before entering the pit water body could be sampled along the flow path. At the same time, samples of solid materials beneath the flowing water could be sampled for residuals or spilled explosives. If any pollutant transport by groundwater was occurring, the recommended monitoring for groundwater seepage into the pit water (see Section 3) would detect it.

Analyses for explosives and residuals can apparently be limited to the nitrogen forms, fuel oil, and possibly total organic carbon. However, future studies may show the presence of pollutants unknown at present, but formed as residuals. If the inventory of type of explosive indicates that additional potential pollutants are present, then they would also be determined in the water analyses. For solid materials, saturation extract can be utilized for chemical determinations.

Samples of overburden and coal should initially be collected on a weekly basis for determination of explosives and residuals. When water is running over the surface of the pit and into the pit water body, monthly traverses should be made along the flow path. Both the water and the underlying materials should be sampled.

Preliminary Recommendations--

The nonsampling monitoring alternatives described above are recommended. Analysis of pit water, described in Section 3, would indicate if further sampling of potential pollutants from explosives would be required.

Costs for the nonsampling method would include labor for inventorying mining records. Should further sampling be required, additional labor for field sampling and analytical work would accrue. These costs are summarized in Appendix B, Table B-3.

<u>Identify Potential Pollutants--Mine Solid Wastes</u>

Solid waste materials are produced during the construction phase of the mine and to a lesser degree throughout the life of the mine. Four methods exist to dispose of these wastes. One option is on-site landfills which can consist of an open dump or a sanitary landfill where the waste is disposed in great density and covered daily with soil. A second option is off-site disposal--some of the mines have reportedly disposed of premining construction wastes at a nearby city landfill. A third option is incorporation of wastes in the mine spoils. This tends to be haphazard and makes source monitoring difficult; nevertheless, most of the mines are licensed as landfills and this appears to be the principal means of disposal. A fourth option, which may be used to varying degrees, is incineration. The ash is buried in the mine, although some is dispersed through the air to surrounding areas. Potential pollutants are primarily the organic and inorganic chemicals and trace elements; secondary pollutants are heavy metals.

The physical environment of the wastes incorporated in these alternative disposal methods is similar to stockpiles discussed in Section 2. However, they differ in materials, e.g., scrap lumber, paper, metals, cement, etc., in addition to overburden or topsoil used to cover the deposits. It is estimated that an average of one-half cubic yard of solid wastes will be produced per day.

Monitoring Needs--

The extent of monitoring solid waste disposal areas is unknown. Data deficiencies are assumed to exist in the characterization of pollutants in the following categories: major inorganics, trace contaminants (especially heavy metals) organics, and microorganisms.

Alternate Monitoring Approaches--

A nonsampling method for identifying potential pollutants would be to estimate quantities and inventory wastes as they are delivered to the disposal site. The type of wastes entering a landfill is a major determinant of potential groundwater pollutants. The inventory could be made by stationing an inspector at the site, or estimating waste from mine construction materials. Spot checks could be done on an infrequent basis.

Potential pollutants would be concentrated in the disposal site leachate before percolating into the vadose zone. Alternative methods of sampling leachate would be to install a manifold sampling device or have a bulldozer dig to the base of the wastes and have grab samples of the leachate taken.

Samples could be taken from suction-cup lysimeters in the vadose zone and from wells in perched layers and the saturated zone. These would be installed primarily for use in determining mobility and pollutant attenuation in the unsaturated and saturated zones.

Grab samples could be taken of surface runoff entering the landfill. This is a likely source of water for leachate formation. Similarly, grab samples could be obtained of water found discharging into the landfill.

Preliminary Recommendations--

The preferred monitoring approach would be to estimate quantities and type of solid waste from the mine construction materials. The disposal area could be spot checked at infrequent intervals. Grab samples could be taken after precipitation events. Suction-cup lysimeters and wells installed for use during parallel or subsequent monitoring steps could be used to sample the vadose zone, perched water tables, and the saturated zone near the disposal area.

The first few samples would be analyzed for major inorganics, trace contaminants, organics, and microorganisms as described in Section 3 (Identify Potential Polluants--Sedimentation Ponds), until pollutants are defined. Thereafter, partial analysis would focus on identified pollutants.

Sampling frequency of the suction-cup lysimeters and wells would follow data gathering schedules for monitoring steps described in Section 3. Surface runoff grab samples would follow weather patterns.

Costs for identifying potential pollutants from mine solid waste material would include labor for intentorying mine construction waste, infrequent checks of the disposal sites, and collection of field samples. Costs for analytical work would be covered under alternate monitoring steps except for a few grab samples of surface discharges from the disposal site. These costs are summarized in Appendix B, Table B-3.

Identify Potential Pollutants--Liquid Shop Waste

Liquid shop wastes include fluids, such as oils and lubricants, which are used in the repair and maintenance of mining equipment, and soaps and wash water used for cleaning trucks and machinery. Waste oils are probably stored either for recycling or disposal away from the lease area. Other waste products and water may enter some type of a sewer system where oil/water separators are usually employed. Water from equipment washing will probably run onto the ground in a designated equipment-washing area and may be routed to a sedimentation pond with oil and grease skimmers.

Monitoring Needs--

A need exists to determine the amount of potential pollutants in liquid soap wastes. Oils, lubricants, gasoline, wash water, soap, and other substances that may be mixed with these fluids will constitute the primary sources of these pollutants. Disposal methods for these wastes are unknown.

Alternative Monitoring Approaches--

Several nonsampling methods are available for identifying potential pollutants: hold discussions with mine personnel on types and quantities of liquid wastes produced, quantity of waste water used, location of washing areas, use of soaps, etc.--all of the above can be confirmed through field observation; quantities of liquid wastes and wash water used can be measured; an inventory of wastes can be kept on a continuous basis.

There are several alternative sampling methods for identifying potential pollutants. The wastes themselves could be sampled and analyzed completely. Suction-cup lysimeters could be installed in the vadose zone beneath the shop area and sampled for potential pollutants. Wells could be installed in perched layers and sampled. Piezometer clusters could be installed for sampling from the saturated zone.

Wells and suction-cup lysimeters should only be installed where they will be useful in subsequent steps of the monitoring program.

Preliminary Recommendations--

A nonsampling method incorporating discussions with mine personnel to determine type and quantity of liquid waste produced and field observations would be recommended. Grab samples of liquid wastes could be taken if deemed necessary during field checks. These samples would be analyzed for major inorganics, trace contaminants, organics, and microorganisms as described in Section 3. Sampling frequency would be determined by field studies.

Costs would include labor for conducting interviews, making field observations, and collecting grab samples as necessary. Operational costs would include sampling hardware, bottles, storage racks, etc. These costs are summarized in Appendix B, Table B-3.

Identify Potential Pollutants--Spills and Leaks

Mining operations require the movement and storage of a large number of substances, any of which can be spilled or leaked from their containers. Gasoline, diesel fuel, oils, and lubricants are used in the shop area. Ammonium-nitrate and fuel oil are used for blasting. Herbicides are used to clear rights-of-way and pesticides; fertilizers and soil amendments are used in reclamation. Topsoil, overburden, parting materials, and coaly waste are transported to stockpiles, and, of course, coal is transported from the mine pit to storage silos or barns.

Monitoring Needs--

Monitoring needs include characterizing types of substances transported and stored on the lease area and the quantities of these substances. The monitoring for potential pollutants in spills and leaks of an active mine is unknown.

Alternate Monitoring Approaches--

Nonsampling monitoring methods include determination of substances transported and stored at the mine through discussions with mine personnel and field observation. A review of accident records or past spills would indicate potential problem areas that could be watched more closely. Grab samples could be taken if field monitoring personnel are present at a spill or discover a leak; however, these analyses would be required of substances for which existing analyses are not available.

Preliminary Recommendation--

The nonsampling method described for liquid shop wastes is recommended for monitoring spills and leaks.

Labor for conducting interviews with mine personnel, reviewing accident or spillage records, and followup field observations are the only cost likely to accrue from this monitoring step. These costs are given in Appendix B, Table B-3.

Identify Potential Pollutants--Solid Waste for Road Construction

Access and haul roads to the mines in the study area are constructed across a variety of surface materials including coal, topsoil, or reclaimed mine spoils. Roadbeds are often constructed of overburden, and most roads are surfaced with scoria, when it is available. Pit water is applied to the roads on a continuous basis to reduce airborne dust. In addition, Coherex, an oil-water emulsion of petroluem resins, can be mixed with the pit water and applied about once a month to control dust. The extent to which roads may constitute a pollution source is dependent upon construction materials, the quality and quantity of water which comes into contact with the road surface, and the total land area covered by roads.

Monitoring Needs--

Monitoring needs for potential pollutants in road construction materials include major inorganics and trace constitutents leached from these materials and the quality and chemical additives of the water used to control road dust. With the exception of chemical additives, potential pollutants from road construction materials are described elsewhere in this report. The aerial distribution and potential for interaction through surface runoff with local drainage systems are important factors in including these materials as a separate miscellaneous source of potential pollutants.

Alternate Monitoring Approaches--

Interviewing mine personnel to determine mine road construction materials and dust suppression programs would provide the required information for a nonsampling monitoring method. Potential pollutants found in the construction materials, overburden or mine spoils, and pit water used for dust suppression are discussed in Sections 2 and 3, respectively.

Preliminary Recommendations--

The nonsampling monitoring method is recommended to determine location of roads, construction materials, and dust suppression programs. Chemical constituents of the mine road solid wastes will be characterized in parallel or subsequent monitoring steps.

Labor costs for conducting interviews with mine personnel and transportation for field checks would be the only expense for this monitoring step. These costs are summarized in Appendix B, Table B-3.

Identify Potential Pollutants--Septic Tanks

The principal function of a septic tank is to permit settling of solids, flotation of grease, anaerobic stabilization of organic matter, and storage of sludge (Hammer, 1977). The majority of the biological treatment occurs in the leaching field.

Specific pollutants in the specific tank and leach field will primarily be of sanitary origin. However, water (carrier of the wastes) may contain constituents concentrated during usage. Principal among these constituents are the major inorganics (e.g., calcium, magnesium, potassium, sodium, bicarbonate, chloride, and sulfate) and trace contaminants (e.g., iron, manganese, zinc, copper). Organics include stabilized and unstabilized organics, grease, and oils. Microorganisms may include bacteria (e.g., total and fecal coliform, fecal streptococcus, and viruses).

Monitoring Needs--

Presumably, the operation of the septic tank may be checked periodically and possibly samples are taken for analysis. Similarly, the leach field may be checked occasionally to ensure that soil clogging is not occurring.

Until specific data are obtained, it is assumed that data deficiencies exist in monitoring for specific pollutants outlined above.

Alternative Monitoring Approaches--

A nonsampling method leading to a characterization of pollutants in septic tanks and leaching fields is to inventory all sources discharging to the septic tank and estimate their relative quantities. For example, in addition to sanitary wastes, certain shop wastes (possibly including toxic substances) may occasionally be flushed into the system. The number of individuals using the system could also be identified. Engineering plans for the system, showing the size of the septic tanks, distribution of sewer lines, location of leaching field, depth and areal extent of the leach field, etc. could be obtained. Soil data and percolation studies obtained for the leach field area could be reviewed. Such data could show, for example, that the leaching field is in tight clay soils, with slow intake rates, promoting anaerobic conditions (i.e., inhibiting stabilization of organics). Because of slow intake rates, clay soils would also limit the amount of wastewater seeping into the vadose zone.

Sampling of raw sewage entering the septic tank and wastewater discharging from the tank could be collected for analysis. Automatic samplers could be used to collect composite or discrete-time samples. In selecting samplers of either type, guidelines from Harris and Keefer (1976) are useful. Collection of grab samples are another option.

Sampling wastewater in the leach field could involve installing shallow sample PVC or steel wells down to the natural soil interface. Samples could be pumped or bailed from the wells. A Teflon bailer designed by Dunlap et al. (1977) is recommended for collecting water samples for organics and microorganisms.

An alternative method for sampling within the leaching field is to install suction-cup lysimeters. The design and operation of these units are described in by Everett et al. (1979) and Fenn et al. (1975). Note that the ceramic cups may filter out microorganisms.

Potential pollutants in wastewater samples collected by the above could be examined by alternative methods. For example, one method could entail selectively analyzing samples for the major constituents (Ca, Mg, Na, K, HCO_3, Cl, SO_4, PO_4, SiO_2, NH_3-H, NO_3N, total nitrogen, organic nitrogen, pH, and EC). Trace constituents could be examined selectively (B, Se, As, Fe, Hg, Al, Zn, Cu, Cd, Cr, Ni). Organics may be examined by BOD, COD, DOC, TOC, or oil and grease analyses. Microorganisms could be examined for any, all, or some of the following: total coliform, fecal coliform, fecal strep, and viruses. Various combinations of analyses from these constituent groupings create numerous other options.

Preferred approaches include:

- Analyze the first 5 to 10 samples from the septic tank as completely as possible, i.e., for major inorganics, trace constituents, organics, and microorganisms. Subsequently, samples would be analyzed only for those trace constituents, organics, or microorganisms found in excess of recommended limits. All the major inorganics would be analyzed completely in each sample.

- Completely analyze the initial 5 samples from the network of wells in the leaching field. The sampling sites would be selected at random, but would include at least one well near the inlet and one well near the end of the leaching field. After complete analyses (see above), subsequent samples for the leaching field would be examined primarily for those constituents found in excess.

Preliminary Recommendations--

The preferred monitoring approach is as follows:

- Inventory all sources discharging to the septic tank and estimate the related quantities of fluids

- Review data on engineering design, leach field soils, and percolation tests in the leach field

- Install automatic samplers to collect composite samples of wastewater discharging from the tank

- Install a minimum of two shallow wells in the leach field and use Teflon bailer for sampling

- Analyze samples as described earlier.

The costs for this step will initially be high because samples will be completely analyzed. Later, as trends are established and the requisite number of analyses is reduced, the costs will concomitantly decrease. Specific costs for this monitoring step are given in Appendix B, Table B-3, and include:

- Labor costs for:
  - -- Inventorying and characterizing the septic tanks (i.e., collection of engineering data, water quality analysis, etc.)
  - -- Characterizing the leaching field including collection of soil data, results of percolation tests, etc.
  - -- Installation of composite samplers or for grab sampling, and collection of samples
  - -- Installation of shallow wells in the leaching fields.
- Operational costs for:
  - -- Water quality analysis
  - -- Sample bottles, labels, etc.
- Capital costs for:
  - -- Composite samplers
  - -- Leach field wells
  - -- Teflon bailers.

<u>Identify Potential Pollutants--Oxidation Ponds</u>

Raw sewage could be treated by means of a "lagoon-type aeration plant" (Everett, 1979). Some of the lagoons in the study area are developed in permeable sediments, fluvial deposits along diverted creeks. It is not known whether or not these ponds are lined. However, if NPDES permits are not obtained, it is assumed that no discharge will occur and that capacity is maintained by seepage, evaporation, and possibly by pumpage for road spraying. This pond could operate as either a high-rate aerobic pond or as a facultative pond (oxygen provided by algae and wind action), or use mechanical aerators (U.S. EPA, 1974). Treatment capacity of the ponds will depend on size and engineering design for the anticipated loading.

Monitoring Needs--

Potential pollutants associated with normally functioning "aerated" lagoons include major inorganics introduced with incoming sources (including phosphorous and nitrogen); possible trace contaminants; unstabilized organics; bacteria, viruses, and other microorganisms. In the winter, ponds tend to become anaerobic because of restricted biological activity. Anaerobic ponds are not particularly effective in reducing nutrients, BOD, organics, or microorganisms. Note that facultative ponds have an anaerobic benthic region, introducing reduced forms of nitrogen, sulfides, etc. into the underlying vadose zone during seepage. As pointed out by Fuller (1977), the mobilities of heavy metals and trace metals will, in general, be accelerated under anoxic conditions.

The quality of wastewater within the pond will also be affected by disposal practices. For example, if evaporation is the principal mode of sustaining storage capacity, dissolved suspended constituents will tend to increase in concentration. In turn, pollutants entering the vadose zone will become more concentrated.

Alternative Monitoring Approaches--

Nonsampling methods involve collecting and examining pollutant-related information for a source, such as quantity of flows, collection of available quality data, etc. The results of selecting nonsampling methods may indicate that further monitoring activities are unwarranted. For example, it may be found that the pond is lined.

One alternative method would consist of obtaining specific information on the design of the pond, including type of operation (high-rate aerobic pond, facultative pond, mechanically aerated pond); presence or absence of a liner; type of liner, if present; interior dimensions of the pond; loading rates; and plans of the sewer system. (If the pond is found to be lined with a durable material, it may be elected either to cease the monitoring effort, or to bypass intervening steps and determine the infiltration potential. Results of the step would indicate either to cease the effort or to return again to the first step.)

Copies of analytical data for the pond will be solicited from the mine manager to determine the extent of ongoing monitoring and to specify potential pollutants.

Sources contributing to the oxidation pond could be inventoried, including possible shop wastes, portable toilets, etc. One purpose of the inventory would be to judge the possibility that toxic substances may be introduced which could affect pond operation.

If information on the loading rate is unavailable, permission of the mine manager could be requested to install suitable metering equipment (e.g., Palmer-Bowlus flumes) in manholes within the discharge line. The flume could be equipped with a water stage recorder for continuous monitoring of flows.

Information obtained during the above procedures could be examined by a competent sanitary engineer for a judgment on pond operation. Wastewater samples could be collected from all sources discharging into the pond, provided that access is possible, e.g., by manholes. Sources include shop and office sanitary wastes and other discharges. Samples could also be collected from the discharge pipe and at one or two locations within the pond.

Alternative water sampling techniques include grab sampling, automatic composite sampling, and automatic discrete sampling. Grab samples are obtained to determine instantaneous water quality. Composite samplers are used to obtain blended water samples over a certain time interval (e.g., 24 hours). Discrete samplers extract water samples at timed intervals. The relative advantages and disadvantages of these techniques for wastewater sampling are reviewed by Harris and Keefer (1974).

Samples of the benthic solids could be obtained for analysis via a suitable hollow sampling tube.

Samples could be analyzed as described for septic tank wastewater. Field analysis for unstable constituents, such as pH, EC, DO and alkalinity, and additional spot checks for chloride and nitrate could also be performed. This method will require the purchase of a pH meter, EC bridge, DO meter, and a portable field kit (e.g., Hach Engineering Laboratory). When the results of such field checks as pH, EC, chloride, and nitrate indicate a substantial change between testing, samples would be collected for laboratory analysis.

Benthic solids could be examined in the laboratory for trace constituents and organics (grease, etc.).

Preliminary Recommendations--

A preferred monitoring approach for oxidation ponds is as follows:

- Inventory the sources of discharge to the oxidation ponds (utilize data gathered from inventory on sources collected for septic tanks), engineering design, and method of operation
- Install water sampling and flow measuring equipment
- Indicate programs for field analysis, sample collection, and monitor equipment maintenance
- Sampling frequency will be determined by field studies and budget allocations.

The overall costs for this step will be high initially because of the need for complete analysis of source samples. Later, sampling frequency and requisite analyses will be reduced. The process of using field checks to determine sampling frequency is another cost-reducing technique. Costs for monitoring an oxidation pond are given in Appendix B, Table B-3, and include:

- Labor costs for inventorying and characterizing sources, installing and operating water sampling and flow measuring equipment, field checking quality, and collecting and transporting samples.

- Capital costs for purchasing composite or discrete samplers, for equipment for field checking quality (pH meter, EC meter, etc.), and for a sampling tube. These items will be general capital items available for the overall TEMPO monitoring program. Consequently, the proportionate charges against this source will be low.

- Operating costs for analyzing samples. These costs will be high initially but will lower as the list of constituents to examine is narrowed and when field checks are used to guide sampling.

Identify Potential Pollutants--Package Plant

Mining plans indicate that sanitary wastes will be treated in package plants commonly designed with a supplemental surge tank to prevent shock loading.

Chlorinated effluent will be pumped to a sedimentation pond for reuse in road sprinkling or irrigation. Sewage from chemical toilets will be discharged into the package plant. Sludge will be buried in the spoil piles.

Pollutants in package plant effluent could impact on groundwater quality if leakage should occur at the following locations: within the package plant tanks, within the surge tank, within the pipeline transporting wastewater to the sedimentation ponds, and within the sedimentation ponds. An overall approach for monitoring the sedimentation ponds is presented elsewhere in this report (see Section 3, Monitoring Design for Mine Water Sources).

Monitoring Needs--

The following pollutants are normally associated with package plants: organics, in the form of BOD, COD, DOC, or TOC; microorganisms (e.g., total and fecal coliform, viruses, microscopic animals); and major and trace inorganics occurring in concentrations above recommended limits. Also, a problem inherent in package plant operation is that shock loadings tend to interfere with treatment.

In light of limited information on existing monitoring at the package plants, it is presumed that data deficiencies exist in the following categories: major inorganics (Ca, Mg, Na, K, PO_4, Cl, SO_4, CO_3, HCO_3, organic nitrogen, NH_3-N, NO_2-N, NO_3-N, and SiO_2); trace contaminants (Fe, Mn, Zn, Cu, Cd, Cr, As, Pb, V, U, Th, and Se); organics (grease, oils, etc., and those measured by BOD, COD, DOC, and TOC); and microorganics (total and fecal coliform, fecal strep, and viruses).

Alternative Monitoring Approaches--

One nonsampling monitoring method entails obtaining a copy of the specifications of the plant from the mine manager. Similarly, information could be obtained on the design and construction of the surge tank. At the same time, information could be obtained on the chlorination unit, together with data or chlorine usage, chlorine demand, and chlorine residual.

Sources contributing to the package plant could be inventoried, including shop wastes and portable toilets. A purpose of the inventory is to estimate the possibility that toxic substances may be discharged periodically. Such substances interfere with plant operation and introduce exotic pollutants into the waste stream.

Information on the number of personnel using the sanitary and other wastewater facilities in a 24-hour period could be solicited from the mine manager.

Another alternative method comprises obtaining information on the loading rates of the package plant from the mine operator. If such information is unavailable, permission could be requested to install suitable metering devices (e.g., Palmer-Bowlus flumes) in the incoming lines. A flow meter could be installed in the line between the package plant and the surge tank. Interaction of the plant and surge tank could be characterized routinely, particularly relating to the period that the flow is held in storage.

Copies of quality data for the package plant could be requested to specify the extent of ongoing monitoring and to define pollutants. Information on specific analytical techniques of quality control measures could be obtained at this time.

Sampling methods of evaluating raw wastewater entering the plant and treated effluent could be done by alternative methods such as by composite or discrete automatic samplers, or by grab sampling. Composite samplers produce a single blended sample obtained by pumping from the sampling stream at periodic intervals. Discrete samplers provide a series of individual samples collected at timed intervals. Grab samples are obtained by manually dipping the sample container into the source. Guidelines of Harris and Keefer (1974) will be followed in selecting automatic samplers.

Samples of wastewater discharging into the sedimentation ponds could also be obtained via any or all of the above alternative sampling methods.

Samples from the discrete samples could be analyzed completely for the major inorganics (Cu, Mg, K, Na, Cl, SO_4, NH_3-N, NO_2-N, NO_3-N, HCO_3, CO_3, SiO_2, PO_4, etc.); trace constituents (Fe, Zn, V, Cu, No, Cd, Ra, Se, etc.); organics (measured by BOD, COD, TOC, DOC); and microorganisms (total and fecal coliform, viruses, etc.).

Alternatively, samples from the discrete samplers could be analyzed only for BOD until trends are characterized.

A third alternative method for examining discrete samples could be partial analyses for those constituents found in concentrations above permissible limits.

Analyses of composite and grab samples could parallel those above for discrete samples: complete analyses, partial analyses for BOD, or partial analyses for specific constituents.

The discrete samplers could be activated at various timed intervals; for example, hourly, bihourly, etc. Similarly, these samplers could be used on a daily basis, weekly basis, etc. The 24-hour composite samplers could be used on a daily, weekly, or monthly basis. Grab samples could also be obtained at alternative frequencies, e.g., hourly, daily, weekly, etc.

A preferred approach to sampling frequency includes:

- Collect 2-hour samples on the discrete sampler installed in package plant inlet and outlet ports, at daily intervals until trends in BOD have been characterized

- Collect 6-hour discrete samples for complete analysis, once a week, until quality trends are established

- Collect 24-hour composite samples once a month from the inlet and outlet ports in the package plant

- Collect 2-hour water samples at the discharge point into the ponds, using a discrete sampler, at daily intervals until BOD trends are established. Thereafter, sample every 6 hours via the discrete sampler, one day a week until quality trends are established. Thereafter, collect a grab sample once every 2 weeks.

Preliminary Recommendations--

The preliminary monitoring recommendation incorporates both nonsampling and sampling methods. This approach would include the following:

- Obtain available information on the package plant design, including the interaction with the surge tank and chlorinator design and operation.

- Interview mine personnel to determine plant usage, sewer line distribution and drain line to sedimentation pond, toxic substances flushed into the system, loading rates.

- Install an automatic discrete sampler in the inlet and discharge ports, and collect 2-hour samples for BOD and coliform.

- Collect 6-hour discrete samples via the automatic sampler, once BOD and coliform trends have been established.

- Install a 24-hour composite sampler in the inlet and outlet ports once trends in quality (major inorganics, trace constituents, organics, and microorganisms) have been characterized. Activate samples for a 24-hour period once every month.

- Install a discrete sampler in the discharge point to the pond and collect 2-hour samples for BOD. After BOD trends are established, collect 6-hour samples for complete analyses. Once general quality trends are characterized, collect grab samples.

All samples will be collected, preserved, stored, and transported in accordance with recommended techniques.

Cost for the monitoring program would include labor for inventorying plant design and quality data, installing sampling instruments, and collecting and transporting water samples. Operating costs would include analyzing samples, capital costs for sampling equipment, and flow measuring instrumentation. These costs are summarized in Appendix B, Table B-3.

Identify Potential Pollutants--Sludge

Sanitary wastes from the active mines will be treated by the sewage treatment and package plants described herein. In accordance with some of the reviewed mining plants, inert sludge from the treatment plants will be mixed with the topsoil and placed on the graded spoils.

According to Hammer (1977), the mixed liquor in extended aeration (package) plants increases in concentration over a period of several months and is then pumped from the aeration basin. The mixed liquor suspended solids (MLSS) operating range varies from 1000 to 10,000 ppm.

Hammer presented an example of build-up time in a typical small extended aeration plant assuming a loading rate of 170 g/m^3 per day BOD, an aeration period of 24 hours, and a measured suspended solids build-up rate of 30 ppm per day. If the MLSS concentration in this plant were permitted to increase from 1000 ppm to 10,000 ppm before wasting the solids, the build-up time would be 300 days.

In a discussion of extended aeration plants, Vesilind (1976) indicated, ". . . the ecology within the aeration tank is quite diverse and little excess biomass is created, resulting in little or no waste activated sludge to be disposed of . . . ."

In light of the potentially low build-up time prior to sludge disposal and the small amount of sludge produced each year, it is apparent that this source is insignificant vis-a-vis other sources on the mine. Consequently, the possibility of groundwater pollution from pollutants in sludge will be miniscule. This report will, therefore, be limited to source pollutant monitoring.

Monitoring Needs--

Sewage sludge contains the macro plant nutrients (nitrogen, phosphorous, and potassium) in concentrations that are about one-fifth of those found in commercial fertilizers (Wyatt and White, 1975). Of these constituents, nitrogen in the nitrate form is the pollutant of greatest concern. The metal content of sludge is also of importance as a pollutant. In particular, zinc, copper, nickel, and cadmium are likely to be present in excessive concentrations. Previously, it was surmised that high metal concentrations reflected input from industrial waste sources. However, according to the Environmental Protection Agency (1974), metal concentrations are high even in wastewater predominantly of domestic origin. Sludges may also contain pesticides and polychlorinated biphenols (Wyatt and White, 1975), and pathogenic organisms, unless pasteurized.

Until additional information is obtained on monitoring for sludge pollutants, it is assumed that data deficiencies exist in defining: major inorganics, trace constituents, organics (including polychlorinated biphenols and other organic toxins flushed into the sewer system), microorganisms, solid MLSS, and mass of sludge produced each year.

Alternative Monitoring Approaches--

The volume of sludge deposited in the package plant could be estimated each time the aeration basin is pumped. In addition, the frequency of pumping could be noted.

The disposition of sludge could be determined. For example, the location of stockpiles receiving sludge could be noted, together with areas which are spread with soil-sludge mixtures. Such locations could be defined on a base map for the mine.

The sources of wastewater could be determined, particularly to determine the influx of toxic chemicals. Analytical data on wastewater, sludge, and soil-sludge mixtures could be solicited from the mine manager.

Samples of sludge from the package plant could be obtained via a special brass sampler equipped with valves and a pull cord. Alternatively, an inexpensive sampler could be constructed by attaching a wide-mouthed stoppered bottle to the end of a pole. The bottle is positioned at the desired depth in the sludge, and the stopper is uncorked with a cord.

When sludge is being pumped, grab samples of equal size could be obtained at various times. It is recommended that grab samples be obtained at the start, during, and at the end of the pumping period.

Samples of dried sludge could be obtained from the soil piles on which the sludge is disposed. The recommended sampling procedure is to take portions of equal size from scattered points on the bed, taking care not to include sand, mix thoroughly after pulverizing, and use about 500 grams for the laboratory sample.

During rehabilitation of spoil piles, samples of soil-sludge mixtures could be obtained from the spreading area. Possible sampling methods include shovels and augers.

A preferred sampling approach will include:

- Sample sludge from the package plant tanks via a pole and bottle sampler

- Collect grab samples of sludge at the beginning, during, and at the end of pumping periods; the samples will be mixed together

- Collect sludge samples from soil piles using the recommended techniques in Laboratory Procedures for Wastewater Treatment Plant Operations (New York State Department of Health, no date)

- Collect samples of soil-sludge mixture from the spreading areas via a hand auger; collect 5 to 10 samples at random locations.

Collected sludge samples and sludge-soil mixtures could be subjected to any or all of the following analyses: suspended solids, volatile solids, major inorganics, trace contaminants, organics, and microorganisms. The concentration of suspended solids in samples collected from the aeration tank is called mixed liquor suspended solids. If BOD is also determined on the incoming raw sewage, the ratio of BOD to MLSS represents the loading of the system (Vesilind, 1974).

Some of the possible specific techniques for sludge analyses were summarized by Sommers, Nelson, and Yost (1976). These included: gravimetric determination of solids and ash after drying at 105°C (16 hours), followed by igniting at 650°C; gravimetric determination of CO_2 liberated by H_2SO_4-H_3PO_4-$K_2Cr_2O_7$ digestion, as a measure of total C; titremetric determination of inorganic C after treating samples with 2M HCl; determination of organic C by difference; determination of total -N by a modified micro-Kjeldahl procedure; determination of soluble plus exchangeable NH_4^+ and NO_3^- by steam distillation techniques after 2M KCl extraction; determination of organic nitrogen by difference; determination of total P by colorimetry after HNO_3 - $HClO_4$ digestion; determination of inorganic P by colorimetry after 1W HCl extraction; and determination of organic P by difference. According to Sommers, Nelson, and Yost (1976), samples digested with HNO_3 - $HClO_4$ are analyzed for Ca, Mg, Cd, Pb, Ni, Cu, Zn, and Cr by atomic absorption spectrophotometry; K by flume emission; and Fe by colorimetry.

Sludge samples could be obtained from the four sampling sites at highly variable frequencies, e.g., daily, weekly, monthly, or yearly. A preferred approach will be:

- Sample sludge and incoming wastewater in the plant at monthly intervals until trends in the loading rate become apparent; thereafter, sample every 6 months

- Sample pumped sludge once a year

- Sample for soil-sludge stockpile once when sludge is first dumped on the pile and 6 months later (losses in NH_4^+ would be quantified by this technique

- Sample from soil-sludge areas on the reclaimed spoil pile.

Preliminary Recommendations--

A nonsampling monitoring approach is recommended which would consist of the following:

- Corroborate sludge monitoring effort with sewage treatment and package plant studies

- Collect sludge samples at package plant via pole and bottle sampler and grab samples during pumping periods.

Expenditures for sludge monitoring will be kept to a minimum due to the small annual production of this waste material. Labor costs for infrequent sludge sampling during plant pumpage and limited chemical analysis, field transportation, and miscellaneous capital costs would comprise the only expenditures for this monitoring step. These costs are summarized in Appendix B, Table B-3.

Define Groundwater Usage

Liquid and solid miscellaneous mine sources would impact a defined groundwater usage based on its location and physical characteristics. As no one miscellaneous source is representative of this group the reader is referred to sources given in Sections 2 and 3 which most closely fit the miscellaneous source of interest. In most cases, monitoring miscellaneous sources would be incorporated into a monitoring program for another mine source. However, some additional site-specific impact from leaks in the sanitary treatment system or container spills and leaks may require individualized study. For these, the reader should reference a sample similar to the miscellaneous source of interest to develop appropriate monitoring needs, alternative monitoring approaches, and a specific preliminary recommendation to meet his needs.

Define Hydrogeologic Situation

Data required to evaluate the hydrogeologic framework, sources of information, monitoring needs, alternative monitoring approaches, and preliminary recommendations for developing monitoring designs have been described earlier. The reader should refer to Sections 2 and 3 for detailed information for this monitoring step.

Study Existing Groundwater Quality

Defining existing groundwater quality for miscellaneous mine sources would overlap similar monitoring efforts for major sources. Networks of monitor wells or sampling stations should be developed with the location of miscellaneous sources in mind. Defining concentrations of pollutants upgradient and downgradient from the sources would be the ideal situation; however, budgetary restrictions may preclude such detailed results. For a detailed discussion of monitoring needs, approaches, and installation of monitoring equipment see Sections 2 and 3 of this report.

Evaluate Infiltration Potential

The extent to which monitoring of the infiltration potential of miscellaneous mine sources is unknown. Presumably, sources associated with mine sanitary waste treatment facility (e.g., oxidation ponds, leach fields), could have limited infiltration data based on percolation tests. It is assumed that data on other miscellaneous liquid and solid mine wastes are lacking. Information on monitoring designs for these sources can be obtained in Sections 2 and 3 herein.

Evaluate Mobility in the Vadose Zone

No information was available for review on monitoring or potential pollutant mobility in this vadose zone for miscellaneous mine sources. These data are assumed to be nonexistent. Data bases could be generated using monitoring designs described earlier in this volume.

Evaluate Attenuation of Pollutants in the Saturated Zone

Data on pollutant mobility and attenuation in the saturated zone for miscellaneous mine sources are unknown. Monitoring designs for these studies are given in Sections 2 and 3 for solid and liquid potential pollutant source, respectively.

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APPENDIX A

METRIC CONVERSION TABLE*

Nonmetric units	Multiply by	Metric Units
inch (in)	25.4	millimeters (mm)
	2.54	centimeters (cm)
feet (ft)	0.3048	meters (m)
square feet (ft^2)	0.290×10^{-2}	square meters (m^2)
yards	91.44	centimeters (cm)
square yards	0.914	square meters (m^2)
miles	1.6093	kilometers (km)
square miles	3.599	square kilometers
acres	4.047×10^{3}	square meters
	4.047×10^{-1}	hectares (ha)
gallons	3.785×10^{3}	cubic centimeters
	3.785×10^{-3}	cubic meters
cubic feet (ft^3)	3.785	liters
barrels (oil)	1.590×10^{2}	liters
acre/ft	1.108×10^{7}	liters
gallons/square foot per minte	40.74	liters/square meter per minute
cubic feet/second	3.532×10^{2}	liters/second
gallons/minute†	6.308×10^{-2}	liters/second
gallons/day	3.785	liters/day
million gallons/day	28.32	liters/second
	0.028	cubic meters/second
pounds	0.454	kilograms
	4.536×10^{-4}	tons (metric)
tons (short)	9.072×10^{2}	kilograms
	0.907	tons (metric)
pounds/acre	1.122	kilograms/hectare
parts per million (ppm)	1	milligrams per liter (mg/l)

* English units were used in this report because of their current usage and familiarity in industry and the hydrology-related sciences.

† 1 gpm = 1.6276 afa.

APPENDIX B

SUMMARY OF PRELMINARY MONITORING DESIGNS

TABLE B-1. SUMMARY OF PRELIMINARY MONITORING DESIGN FOR TOPSOIL STOCKPILES, FOR OVERBURDEN STOCKPILES, AND FOR COAL, COAL REFUSE AND COALY WASTE STOCKPILES

TEMPO monitoring steps[a]	Monitoring needs	Alternative monitoring approaches	Preliminary recommendations	Monitoring costs
Identify potential pollutants (topsoil stockpiles)	1. Determine volume, location, and anticipated duration of stockpiles 2. Determine undisturbed soil characteristics 3. Determine physical and chemical alterations of soils with time (old stockpiles)	1. Nonsampling method a. Compile data on stockpiles' volume and location from aerial photography or mine engineering and production records b. Determine soil characteristics from soil inventory maps 2. Sampling method a. Compile data on stockpiles' volume and location by field measurements b. Determine soil characteristics by chemical analysis for major inorganics, trace constituents, organics, and microorganisms	1. Obtain soil inventory maps 2. Determine topsoil removal and stockpile locations from mine engineering and production records 3. Sample oil stockpiles (1 year or more) annually for chemical analysis of major inorganics, trace constituents, and organics	1. Labor a. Review soils map (1 week): $300 b. Interview mine personnel (1 week): $200 c. Sample handling, preparation, quality control, etc.: $10/sample 2. Operation a. Chemical analysis: $100/sample b. Air freight, refrigeration, packing, etc.: $10/set of 1 to 3 samples 3. Capital a. Sample container, labels, chemicals, etc.: $2.50/sample b. Hand-driven soil sampler: $500
Identify potential pollutants (overburden stockpiles)	1. Determine chemical composition of in-place overburden 2. Determine volume, composition, and expected life of overburden stockpiles 3. Determine dynamic nature of disturbed overburden through time	1. Nonsampling method a. Review existing data on in-place overburden (i.e., water well or core hole lithologic logs, geophysical logs, core sample analyses, etc.) b. Determine volume and location of overburden stockpiles through engineering production records or aerial photographs c. Determine estimated duration of stockpiling from mine engineering and production records 2. Sampling method a. Compile volumetric and chemical data from field and laboratory analysis	1. Review existing data on chemical constituents of in-place overburden 2. Measure volume of overburden stockpiled 3. Sample stockpiles (a minimum of 2 samples per location or every 10 feet of thickness), 1 hole for every 10 acres of surface area 4. Conduct annual analyses for parameters given in Table 1	1. Labor a. Review existing data (1 week): $300 b. Survey stockpiles (volume), 2 weeks, surveyor and assistant: $1,000 c. Sample handling, preparation, quality control, etc.: $10/sample 2. Operation a. Chemical analysis: $100/sample b. Air freight, refrigeration, packing, etc.: $10/set, 1 to 3 samples c. Field transportation: $2/sample

[a] Subsequent monitoring steps for topsoil are similar to those for overburden and coal, coal refuse, and coaly waste stockpiles

TABLE B-1 (continued)

TEMPO monitoring steps[a]	Monitoring needs	Alternative monitoring approaches	Preliminary recommendations	Monitoring costs
Identify potential pollutants (overburden) (continued)		2. Sampling method (continued) b. Sample new and old (more than 1 year) stockpiles to determine chemical changes, analyze for parameters given in Table 1		3. Capital a. Sample containers, labels, chemicals, etc.: $2.50/sample b. Hand-driver soil sampler: $500
Identify potential pollutant (coal, coal refuse, and coaly waste stockpiles)	1. Determine soluble salts in the coal resource 2. Determine chemical characteristic of coaly wastes	1. Nonsampling method a. Determine method and duration of stockpiling from mine engineering and production reports b. Determine potential pollutants of coal from existing chemical data 2. Sampling method a. Determine method of stockpiling, location, and volume from field surveys, take grab samples b. Analyze grab samples for Ag, Pb, Se, Hg, As, Mo, Cu, Cd, Mn, B, Ge, U, Ni, Zn, Cr, Be, V, F	1. Determine volume of coal and coaly waste from field measurements 2. Review existing data on chemical characteristic of stockpiled materials to estimate volume of potential pollutants therein 3. Utilize sample collection to fill in data gaps found in data review above	1. Labor a. Review chemical data on coal and coaly waste (1 week): $300 b. Survey coaly waste stockpiles (volume), 1 week, surveyor and assistant: $500 c. Sample handling, preparation, quality control, etc.: $10/sample 2. Operation a. Chemical analysis (if required): $100/sample b. Air freight, refrigeration, packing, etc.: $10/set, 1 to 3 samples c. Field transportation: $2/sample 3. Capital a. Sample containers, labels, chemicals, etc.: $2.50/sample
Define groundwater usage (topsoil stockpiles)	1. Determine irrigation water quality and quantities for revegetation	1. Install irrigation metering devices 2. Determine vegetation consumptive water use and water quality tolerances from soil characteristics and selected vegetation cover	1. Determine if irrigation is planned for stockpiles 2. Monitor irrigation water, if required	1. Labor a. Determine irrigation schedule from mining plans (1 day): $40 b. Install monitoring equipment in irrigation system, if required (1 day): $60 2. Operation a. Record water usage, maintain monitoring equipment (if required): $2.50/measurement 3. Capital a. Flow meter: $40

TABLE B-1 (continued)

TEMPO monitoring steps[a]	Monitoring needs	Alternative monitoring approaches	Preliminary recommendations	Monitoring costs
Define hydrogeo-geologic situation	1. Define regional and local geology, aquifer locations, interactions and characteristics, groundwater depths, flow rates, and recharge/discharge relationships (source specific and regional)	1. Nonsampling method a. Compile hydrogeologic data from mine operators, U.S. Geological Survey, State agencies, private consultants (i.e., well construction methods, depth, diameter, producing aquifers, completion techniques, driller's logs, geophysical logs, etc.) 2. Sampling method a. Measure water levels and pump test existing wells	1. Review data defined in nonsampling method 2. Sample existing monitor wells if supplemental data are required 3. Install site-specific monitor wells if further data are required and justified by subsequent monitoring steps	1. Labor a. Compile and review existing hydrogeologic data (2 weeks): $600 b. Sample handling, preparation, quality control, etc.: $5/sample 2. Operation a. Chemical analysis: $200/sample b. Packing and air freight to laboratory: $25/set, 4 to 8 samples c. Field transportation: $2/sample d. Portable pump for sampling: $30/sample 3. Capital a. Electronic sounder: $200 b. Bottles, labels, field books, etc.: $2.50/sample
Study existing groundwater quality	1. Determine chemical quality of groundwater (regionally or site specific)	1. Nonsampling method a. Determine groundwater quality from existing records (i.e., mining companies, U.S. Geological Survey, State agencies, private consultants, etc.) 2. Sampling method a. Sample existing monitor wells via submersible pumps b. Install new monitor wells and sample as above	1. Evaluate existing groundwater quality data 2. Initiate sampling program of existing wells 3. Begin periodic field checks and collect laboratory samples when marked changes occur between field measurements 4. Install site-specific monitor wells if subsequent studies indicate pollutants are entering the saturated zone	1. Labor a. Compile and review existing groundwater quality data (2 weeks): $600 b. Sample existing wells and conduct periodic field checks: $7/hr c. Sample handling, quality control, laboratory preparation: $5/sample d. Drilling labor and supervision for new monitor wells: $93/hr

TABLE B-1 (continued)

TEMPO monitoring steps[a]	Monitoring needs	Alternative monitoring approaches	Preliminary recommendations	Monitoring costs
Study existing groundwater (continued)		c. Analyze samples for major inorganics (Ca, Mg, Na, K, HCO_3, Cl, SO_4, PO_4, SiO_2, NH_3-N, total N, pH, and EC), trace constituents (Fe, Mg, Zn, Cu, Cl, Cr, As, Mo, V, U, Th, Ru, and Se), organics (measured by BOD, DOC), and microorganisms (total and fecal coliform) d. Conduct field analysis of samples collected, including pH, electrical conductivity, dissolved oxygen, alkalinity, chloride, and nitrates		e. Pumping tests (3 persons): \$140/day f. Drill site geologist: \$7/hr 2. Operation a. Chemical analysis: \$200/sample b. Packing and air freight for water quality samples: \$25/set, 4 to 8 samples c. Field transportation: \$2/sample d. Pumping tests (equipment operation): \$3,000/test 3. Capital a. Bottles, labels, chemicals, etc.: \$2.50/sample b. Field kit, bailer, storage chest: \$750 c. Hardware and supplies to complete wells: \$15/ft
Evaluate infiltration potential (topsoil stockpiles)	1. Determine migration of fluids through the stockpiles	1. Sampling method a. Determine water penetration using field infiltrometer for natural and applied water conditions	1. Install 3 or more ring infiltrometers on each stockpile as dictated by variation in stockpiled materials	1. Labor a. Installation of infiltrometer: \$10 b. Conduct infiltration test: \$9/test 2. Operation a. Field transportation and equipment maintenance (included in infiltration test) 3. Capital a. Double-ring infiltrometer: \$150

TABLE B-1 (continued)

TEMPO monitoring steps[a]	Monitoring needs	Alternative monitoring approaches	Preliminary recommendations	Monitoring costs
Evaluate mobility of pollutants in the vadose zone	1. Determine movement and attenuation of pollutants in vadose zone	1. Sampling method a. Determine unsaturated flow beneath stockpiles using neutron probes and tensiometers b. Collect soil solutions in porous cups for chemical analysis, major inorganics, pH, and electrical conductivity	1. Install access tubes for neutron probes and corroborate data with infiltrometer analysis 2. Install lysimeters if neutron probe indicates appreciable fluid movement	1. Labor a. 100-ft neutron probe access hole: $250/site b. Neutron logging survey: $50/site c. Lysimeter installation and tests: $30/sample d. Sample handling, preparation, quality control, collection: $5/sample 2. Operation a. Field transportation, sample collection: $2/site b. Air freight, packing for water quality samples: $10/set, 1 to 3 samples 3. Capital a. Neutron moisture probe and generator: $15,000 b. Lysimeters: $21 each c. Bottles, chemicals, labels, etc.: $2.50/sample d. Seamless steel pipe: $3.12/ft
Evaluate attenuation of pollutants in the saturated zone	1. Determine attenuation of pollutants in the zone of saturation	1. Compare local and regional background data with samples collected near source 2. Install site-specific monitoring wells near potential pollutant source	1. No monitoring would be conducted unless infiltration and neutron probe analyses indicated appreciable flow through the stockpiles and vadose zone	Labor, operation, and capital costs for sampling and well installation: See "study existing groundwater quality" monitoring step

TABLE B-2. PRELIMINARY MONITORING DESIGN--MINE WATER SOURCES

TEMPO monitoring steps[a]	Monitoring needs	Alternative monitoring approaches	Preliminary recommendations	Monitoring costs
Identify potential pollutants (sedimentation ponds)	1. Characterize discrete sources and pollutants entering the sedimentation ponds 2. Determine chemical characteristics and water quality transformations throughout the pond	1. Nonsampling method a. Compile pollutant-specific information relating to sedimentation pond from mining companies (i.e., sewage treatment and package plant operations and discharge characteristics; pit dewatering; runoff from spoils and regraded areas) b. Review National Pollutant Discharge Elimination Systems (NPDES) permits for water quality data c. Determine pollutant loading by measuring discharge into ponds d. Conduct inventories of diffuse sources contributing possible pollutants to ponds (see miscellaneous sources (Section 4) contributing to surface runoff) 2. Sampling method a. Sample pit water discharged into ponds b. Sample package plant effluent and miscellaneous sources on surface runoff at pond inlets c. Sample pond water at various locations, depths and at outfall point to determine water quality transformations d. Sample pond overflow at downstream locations e. Sampling above can be done by grab, automatic composite, and automatic discrete methods f. Samples could be analyzed for major inorganics (Ca, Mg, Na, K, HCO_3, Cl, SO_4, PO_4, SiO_2, NH_3-N, total N, pH, and EC), trace constituents (Fe, Mg, Zn, Cu, Cl, Cr, As, Mo, V, U, Th, Ru, and Se, cyanide), organics (oils, grease, and those measured by BOD, DOC), and microorganisms (total and fecal coliform) g. Determine water quality of the first few samples using (f) above and monitor subsequent samples by analyzing for major organics only	1. Review available water quality data including NPDES permits 2. Sample pit water and sewage effluent via discrete or composite samplers 3. Sample surface runoff at pond inlet (grab) 4. Sample pond water at various locations and and depths 5. Sample pond overflow at outfall and downstream 6. Samples (first five) would be analyzed completely; subsequent samples for major inorganics only; field samples would be analyzed for chlorides and nitrates	1. Labor a. Compile and review water quality data (1 week): $300 b. Sample handling, laboratory preparation, quality control etc.: $5/sample c. Sampling equipment installation: $40/day d. Field checks of water quality: $2.50/sample 2. Operational a. Chemical analysis: $200/sample b. Field transportation: $2/sample c. Packing, air freight for water quality samples: $25/set, 4 to 8 samples 3. Capital a. Automatic sampler: $600 b. Wide-mouth bottle sampler: $10 c. Field kit, storage chest: $730 d. Bottles, labels, chemicals: $2.50/sample

[a] Subsequent monitoring steps for sedimentation ponds are similar to those for a pit water source

TABLE B-2 (continued)

TEMPO monitoring steps[a]	Monitoring needs	Alternative monitoring approaches	Preliminary recommendations	Monitoring costs
Identify potential pollutants (sedimentation ponds) (continued)		h. Define water quality by field analysis for nitrate and chloride i. Sampling interval will be determined through site-specific study and budget allocated for analytical work; a preferred approach to sampling frequencies is given in the text		
Identify potential pollutants (pit water)	1. Determine the quantity and quality of water in the pit 2. Characterize discrete sources contributing to the pit water	1. Nonsampling method a. Compile existing data on discrete pit water sources from mining company records (stream channel leakage, sewage treatment, or package plant effluent), and miscellaneous sources (Section 4) b. Evaluate diffuse sources (seepage and nonchanneled overland flow) into pit from existing hydrogeological and weather data (i.e., water table gradient, aquifer hydraulic characteristics, direct surface runoff, precipitation, etc.) c. Estimate pollutant loading into pit from above data 2. Sampling method a. Install weirs or flumes to measure pit inflow from discrete sources described above b. Install precipitation gages and evaporation pans in the area of the pit c. Install continuous recording flow meters on pit discharge lines d. Survey water surface area and install staff gage to determine change in pit storage e. Collect pit water samples at various depths and representative water samples from discrete sources for chemical analysis described for sedimentation ponds above	1. Compile and review existing data on discrete and diffuse pit water sources 2. Collect small number of pit water samples to be submitted for complete chemical, biochemical, and biological analyses; submit subsequent samples of same for partial analysis focusing on probable pollutants in the pit water 3. Sample solid materials at bottom of pit water for nitrogen forms, trace elements, TOC, etc. on saturated extract	1. Labor a. Compile and review pit water quality data (3 days): $180 b. Monitor equipment installation: $40/day c. Quality control sample handling, preparation, collection, etc.: $5/sample d. Field check of water quality: $2.50/sample 2. Operational a. Chemical analysis: $2/sample b. Field transportation: $2/sample c. Packing, air freight, etc. for water quality samples: $10/set, 1 to 3 samples d. Bottles, labels, chemicals: $2.50/sample
Define groundwater usage	1. Define water usage for mining activities 2. Determine location of groundwater supply wells	1. Nonsampling method a. Interview mine operator or State engineer to determine water usage for mine activities	1. Compile and review data on locations and specifications for water supply wells	1. Labor a. Compile and review water supply data and calculate well pumpage (7 days): $280

TABLE B-2 (continued)

TEMPO monitoring steps[a]	Monitoring needs	Alternative monitoring approaches	Preliminary recommendations	Monitoring costs
Define ground-water usage (continued)		b. Review water well completion records for yields, capacity, location, and aquifers utilized c. Determine well output from power consumption records using calculated power consumption versus discharge relationships	2. Determine well pumpage from discharge versus power consumption	2. Operational a. Field transportation: $0.17/mile 3. Capital a. None
Define hydrogeologic situation	1. Determine geologic framework, location, areal distribution, interaction of aquifers, and direction and flow velocities	1. Nonsampling method a. Compile available hydrogeologic data from mine operators, adjoining mine operators, U.S. Geological Survey, State agencies, private consultants, and local drillers 2. Sampling method a. Measure water levels and pump test well in vicinity of source area (sedimentation ponds) b. Install new monitor wells near source area required by data gaps c. Determine aquifer properties (T and S) from pumping tests d. Install piezometer clusters in uppermost aquifer near source area to determine vertical hydraulic gradient and inter-aquifer leakage e. Develop water-level contour maps or piezometric maps and well hydrographs based on measured data	1. Compile and review available hydrogeologic data for source area (sedimentation pond) and regional system 2. Conduct aquifer tests on existing wells and field check water quality 3. Install monitor wells, collect geological data on penetrated formations, and pump test new wells near source so that the potentiometric surface can be defined by water level data 4. Install piezometer cluster near source area to determine interaquifer leakage and vertical hydraulic gradient	1. Labor a. Compile and review hydrogeologic data (2 weeks): $600 b. Sample existing wells: $5/hr c. Drilling labor and supervision, new monitor wells: $93/hr d. Pumping tests (3 persons): $140/day e. Drill site geologist: $7/hr f. Piezometer installation: $30/site g. Sample handling, quality control, laboratory preparation: $5/sample h. Field checks of water quality: $2.50/sample 2. Operation a. Chemical analysis: $200/sample b. Packing and air freight for water quality samples: $25/set, 4 to 8 samples c. Field transportation: $2/sample d. Soil analysis (cation exchange, soluble salts, particle size): $64/sample

TABLE B-2 (continued)

TEMPO monitoring steps[a]	Monitoring needs	Alternative monitoring approaches	Preliminary recommendations	Monitoring costs
Define hydrogeologic situation (continued)				e. Pump test (equipment rental and operation): $3,000/test f. Field check water quality: $2.50/sample 3. Capital a. Piezometers: $15 each b. Hardware and supplies for monitor well completion: $15/kit c. Field kit (water quality analysis): $700 d. Bailer, storage chest: $50 e. Bottles, labels, field notebooks, chemicals, etc.: $2.50/sample f. Water-level sounder: $200
Study existing groundwater quality	1. Determine chemical quality of groundwater (regionally and site specific) 2. Characterize concentration levels and time trends of poltants entering groundwater system based on upgradient and downgradient wells	1. Nonsampling method a. Compile and review existing water quality data b. Construct isopleth maps, trilinear diagrams, and chemical hydrograms from above data 2. Sampling method a. Utilize existing and new monitor wells installed to characterize hydrogeologic framework for sample collection b. Analyze samples for major inorganics, trace constituents, organics, microorganisms (see "identify potential pollutants," sampling method (f), (g), (h), and (i) above for complete analysis, alternative sampling procedures, and timing of sample collection)	1. Compile, review, and develop existing groundwater quality data 2. Collect groundwater samples from existing and new monitor wells (utilize submersible pumps) 3. Analyze samples using system described in "identify potential pollutants," sampling method part (f), and delineate pollutants which exceed recommended limits 4. Conduct field tests for pH, EC, DO, nitrate, and chloride and collect samples for laboratory analyses when marked changes occur between field checks	1. Labor a. Compile, review, and develop water quality data (2 weeks): $600 b. Sample existing wells: $40/day c. Drilling labor and supervision for new monitor wells: $93/day d. Drill site geologist: $7/hr e. Sample handling, quality control, laboratory preparation: $5/sample 2. Operation a. Submersible pump: $30/site b. Chemical analysis: $200/sample

TABLE B-2 (continued)

TEMPO monitoring steps[a]	Monitoring needs	Alternative monitoring approaches	Preliminary recommendations	Monitoring costs
Study existing groundwater quality (continued)				c. Air freight, packing for water quality samples: $25/set, 4 to 8 samples d. Field transportation: $2.50/sample 3. Capital a. Field kit and storage chest: $730 b. Bailer: $20 c. Bottles, labels, chemicals: $2.50/sample d. Submersible pump and generator: $1,200 e. pH meter: $325 f. EC bridge: $375 g. DO meter: $400
Evaluate infiltration potential	1. Determine quantity of infiltration water from the source (sedimentation ponds)	1. Nonsampling method a. Define a water budget for the source based on available records from the mine operator, and meteorological data (i.e., inflow rates from all mine sources, pond outflow rates, rainfall-evaporation rates, change in pond storage) 2. Sampling method a. Determine infiltration by conducting seepage meter measurements in the source area	1. Utilize water budget approach to determine infiltration at source 2. Use existing gaging stations supplemented by installation of recording flow meters, automatic stage recorders, or staff gages 3. Install rain gages and evaporation pans	1. Labor a. Inventorying sedimentation pond sources (2 weeks): $400 b. Installation of monitoring equipment: $5/hr c. Rain gage and evaporation pan installation: $5/hr 2. Operation a. Field transportation: $0.17/mile b. Field measurements and equipment maintenance: $5/hr 3. Capital a. Weather station (evaporation and precipitation): $800 each b. Flow meter: $40 each

TABLE B-2 (continued)

TEMPO monitoring steps[a]	Monitoring needs	Alternative monitoring approaches	Preliminary recommendations	Monitoring costs
Evaluate infiltration potential (continued)				c. Automatic stage recorder: $375 each d. Staff gage: $50 each
Evaluate mobility in the vadose zone	1. Determine attenuation and migration of pollutants within the vadose zone	1. Nonsampling method a. Construct a table (matrix) comprising specific pollutants (columns) and attenuating factors (rows) and determine or estimate from available chemical or biochemical data pollutant attenuation for each matrix point in the table by evaluating effects of oxidation reduction, sorption, chemical precipitation, buffering, dilution, filtration, volatilization, biological degradation, and assimilation b. Analyze existing monitor well cutting to characterize cation exchange, pH, Eh, particle size distribution, precipitation, or staining on aquifer matrix or materials which comprise the vadose zone 2. Sampling method a. Analyze, as (b) above, auger or core samples from the vadose zone in source area b. Install suction lysimeter for sampling unsaturated flows c. Develop monitor wells in perched water tables where indicated by neutron logging d. Analyze water samples from (b) or (c) above for major inorganics, trace constituents, and organics (see "identify potential pollutants," sampling method part (f) above)	1. Construct table (matrix) of attenuation factors versus specific pollutants using available data 2. Install monitor wells in uppermost aquifer below source (sedimentation pond) 3. Install three sets of tensiometers and moisture blocks at base of pond and along the outflow channel 4. Install suction cups at base of pond and along outflow channel alluvium 5. Collect soil samples for laboratory analysis of pollutants and chemical characteristics when installing tensiometers; collect additional auger or core samples, if necessary 6. Install monitor well in perched groundwater body as indicated by neutron logging 7. Analyze groundwater and soil samples as detailed in text	1. Labor a. Evaluation of attenuation factors versus specific pollutants (3 weeks): $900 b. Drilling labor and supervision for monitor wells: $93/hr c. Drill site geologist: $7/hr d. Sample handling, quality control, laboratory preparation: $5/sample e. Tensiometer installation: $30/site f. Suction cup installation: $30/site g. Neutron logging: $50/site 2. Operation a. Chemical analysis: $200/sample b. Soil analysis (cation exchange, soluble salts, particle size): $64/sample c. Air freight, packing: $25/set, 4 to 8 samples d. Field transportation: $2/sample 3. Capital a. Neutron logger and generator: $15,000 b. Hardware and supplies to complete monitor well: $15/ft c. Bailer, storage chest: $50

TABLE B-2 (continued)

TEMPO monitoring steps[a]	Monitoring needs	Alternative monitoring approaches	Preliminary recommendations	Monitoring costs
Evaluate mobility in the vadose zone (continued)				d. Bottles, labels, chemicals, etc: $2.50/sample e. Tensiometers: $20 each f. Moisture blocks: $5 each g. Moisture meter: $150 h. Suction cups: $4 each
Evaluate attenuation of pollutants in the saturated zone	1. Determine attenuation and migration characteristics of pollutants within aquifers underlying source (sedimentation ponds)	1. Nonsampling method a. Construct a table (matrix) of attenuating mechanisms versus pollutants as was done in the previous monitoring step for the saturated zone to show concentration of the different pollutants which should be monitored 2. Sampling method a. Determine aquifer exchange capacity from analysis of monitor well cuttings b. Characterize Eh and pH of groundwater from field analysis c. Initiate tracer studies to estimate spread and attenuation of pollutants d. Install piezometer clusters in uppermost aquifer below source area to determine vertical movement of pollutants e. Concentrate monitoring effort on pollutants which pass through the vadose zone characterized in the two preceding monitoring steps	1. Construct attenuation mechanism versus pollutant mataix using available data 2. Monitor existing wells and install and sample vertical distribution of groundwater quality using piezometer clusters near source 3. Conduct tracer study if tracer breakthrough time is estimated to be short	1. Labor a. Construct pollutant attenuation matrix (3 weeks): $900 b. Piezometer installation: $30/site c. Sample handling, quality control, laboratory preparation: $5/sample d. Tracer study, if required: $7/hr e. Sample wells: $5/hr 2. Operation a. Chemical analysis: $200/sample b. Air freight, packing, etc: $25/set, 4 to 8 samples c. Field transportation: $2/sample 3. Capital a. Piezometers: $15 each b. Well hardware for piezometer cluster: $5/ft c. Bottles, labels, chemicals, etc.: $2.50/sample d. Bailer, storage chest: $50 e. Portable pump and generator: $1,200

TABLE B-3. SUMMARY OF PRELIMINARY MONITORING DESIGN FOR MISCELLANEOUS ACTIVE MINE SOURCES

TEMPO monitoring steps[a]	Monitoring needs	Alternative monitoring approaches	Preliminary recommendations	Monitoring costs
Identify potential pollutants (explosives)	1. Characterize amount of residual ammonium-nitrate and fuel oil from explosives 2. Evaluate spillage of these materials during handling and blasting operations	1. Nonsampling method a. Inventory records kept in compliance with the Surface Mining Control and Reclamation Act, i.e., type and weight of explosives, number of holes and spacing, location, etc. b. Interview mine personnel regarding spills and cleanup measures for explosives 2. Sampling method a. Sample overburden and coal prior to and following blasting to characterize explosive-related pollutants b. Analyze samples for nitrogen forms, fuel oil, and TOC	1. Inventory mining records 2. Refer to analysis performed in monitoring pit water (Section 3) to determine if further sampling of explosive-related pollutants is required	1. Labor a. Inventory mine records (1 week): $200 b. Sample handling, quality control, laboratory preparation (if samples are taken): $10/sample 2. Operation a. Chemical analysis (if required): $100/sample b. Field transportation: $2/sample 3. Capital a. Sample containers, labels, chemicals, etc. (if required): $2.50/sample
Identify potential pollutants (mine solid wastes)	1. Characterize amount of potential pollutants in premining *construction materials* (scrap lumber, metals, cement, etc.) and mining waste (disposable containers, worn out parts, etc.)	1. Nonsampling method a. Estimate weight and inventory waste *delivered to disposal site by stationing* an inspector at the site or by reviewing mine construction and waste materials 2. Sampling method a. Sample leachate from solid waste disposal site by taking grab samples of leachate at base of waste disposal pile b. Install suction-cup lysimeters to sample water in vadose zone, sample wells in perched water layers, or saturated zone below or near the disposal area (for details see monitoring steps, Evaluate Mobility in the Vadose Zone, and Evaluate Attenuation of Pollutants in the Saturated Zone, for sedimentation ponds, Section 3) c. Grab sampling water inflow and discharge from disposal site to determine quality of source and leachate waters from the site	1. Inventory mine construction materials and infrequently (4 to 6 months) *spot check disposal site* 2. Collect grab sample of surface runoff of landfill discharge after precipitation event 3. Analyze grab sample completely (see Monitoring of Sedimentation Ponds for complete chemical chemical analysis, Table B-2)	1. Labor a. Inventory mine construc*tion and other solid* wastes (1 week): $200 b. Sample handling, quality control, laboratory preparation: $5/sample 2. Operation a. Chemical analysis: $200/sample b. Field transportation: $2/sample 3. Capital a. Miscellaneous supplies, bottles, labels, etc.: $2.50/sample

[a] Subsequent monitoring steps for solid or liquid miscellaneous mine wastes are given in Tables B-1 and B-2, respectively

TABLE B-3 (continued)

TEMPO monitoring steps[a]	Monitoring needs	Alternative monitoring approaches	Preliminary recommendations	Monitoring costs
Identify potential pollutants (mine solid wastes) (continued)		d. Samples would be analyzed completely (see Section 3, Identify Potential Pollutants--Sedimentation Ponds) until pollutants are characterized		
Identify potential pollutants (liquid shop waste)	1. Characterize potential pollutants in oils, lubricants, gasoline, wash water, soap, and other substances incorporated in the liquid shop wastes	1. Nonsampling method a. Interview mine personnel to determine type and quantities of liquid wastes produced, wash areas, soaps, quality of wash water b. Observe sources of liquid shop wastes in field 2. Sampling method a. Collect samples from lysimeters, or wells near shop areas b. Submit samples for complete chemical analysis (For analytical tests see Section 3, Monitoring Design for Mine Sources)	1. Interview mine personnel to determine what liquid shop wastes will be produced 2. Field check shop liquid wastes and collect grab sample if necessary	1. Labor a. Inventory mine personnel (1 week): $200 b. Sample handling, quality control: $5/sample 2. Operation a. Field transportation: $0.17/mile b. Chemical analysis (if required): $200/sample 3. Capital a. Miscellaneous supplies, bottles, etc: $2.50/sample
Identify potential pollutants (spills and leaks)	1. Characterize quantities and chemical quality of substances stored and transported on the lease area and thereby subject to spillage or leakage	1. Nonsampling method a. Interview mine personnel to determine quantities and transportation requirements of substances stored on the lease area b. Review accident reports and records of previous spills or leaks c. Field check storage locations and transportation routes for potential pollutants resulting from spills or leaks	1. Utilize nonsampling method described in Table B-2, Alternative Monitoring Approaches for a Preliminary Monitoring Design	1. Labor a. Inventory mine accident reports and interview mine personnel (1 week): $200 2. Operation a. Field transportation: $0.17/mile 3. Capital: None
Identify potential pollutants (solid waste for road construction and liquids used for dust suppression)	1. Characterize potential pollutants in leachate from solid waste for road construction	1. Nonsampling method a. Interview mine personnel to determine mine road construction materials and dust suppression programs b. Pollutants in solid waste (overburden, mine spoils, etc.) used for road construction and fluids (pit water) used for dust suppression are discussed in Sections 2 and 3, respectively	1. Conduct interviews with mine personnel to determine locations, construction materials, and dust suppression programs 2. Use data gathered in parallel monitoring steps (for stockpiles and mine water sources) to characterize potential pollutants in mine road leachate	1. Labor a. Interview mine personnel (3 days): $120 2. Operation a. Field transportation: $0.17/mile 3. Capital: None

TABLE B-3 (continued)

TEMPO monitoring steps[a]	Monitoring needs	Alternative monitoring approaches	Preliminary recommendations	Monitoring costs
Identify potential pollutants (septic tanks)	1. Characterize pollutants found as major inorganics, trace constituents, organics, and microorganisms in septic tank effluent	1. Nonsampling method a. Inventory all sources discharging to the septic tank and estimate the quantities and quality of fluids involved b. Review engineering design for septic tanks and leach field characteristics c. Compile soil and percolation information for leach field area 2. Sampling method a. Sample septic tank effluent by installing automatic composite sampler b. Sample leach field by installing network of shallow wells or suction-cup lysimeters c. Analyze first few samples completely (see text) and subsequently focus analysis on constituents found to be in excess	1. Inventory all sources discharging to septic tank, data on engineering design, leach field soils, and percolation rates 2. Install automatic composite sampler at tank discharge point (grab samples could also be taken here) 3. Install network of shallow monitoring wells in the leach field 4. Collect and analyze samples as discussed in the text	1. Labor a. Review septic tank engineering data (1 week): $200 b. Install sampling equipment: $40/day c. Sample handling quality control, laboratory preparation: $5/sample d. Install shallow wells in leach field: $5/hr 2. Operation a. Chemical analysis: $200/sample b. Field transportation, equipment maintenance: $2/sample c. Air freight, packing, etc. for water quality samples: $10/set, 1 to 3 samples 3. Capital a. Automatic sampler: $600 b. Leach field well hardware: $10/ft c. Sample bottles, labels, miscellaneous supplies: $2.50/sample d. Bailer: $20 e. Power hole digger: $300
Identify potential pollutants (oxidation ponds)	1. Characterize pollutants found as major inorganics, trace constituents, organics, and microorganisms in oxidation pond effluent	1. Nonsampling method a. Inventory all sources of discharge to oxidation ponds b. Review engineering design (e.g., depth, surface area, lining, etc.) and method of operation (high-rate aerobic, facultative, or mechanically aerated pond)	1. Inventory all sources of discharge to oxidation ponds, engineering specifications for ponds, and method of operation 2. Install water sampling and flow measuring equipment at inlet and discharge points	1. Labor a. Review method of operation and engineering specifications of oxidation ponds: (3 days): $120 b. Installation of sampling equipment: $40/day

TABLE B-3 (continued)

TEMPO monitoring steps[a]	Monitoring needs	Alternative monitoring approaches	Preliminary recommendations	Monitoring costs
Identify potential pollutants (oxidation ponds) (continued)		2. Sampling method a. Collect samples of sources of discharge to ponds, pond effluent, and at various points within this pond b. Utilize alternative sampling techniques (grab, automatic composite, or discrete, etc.) c. Conduct field analysis for water quality d. Sample benthic solids in ponds		c. Field check water quality: $2.50/sample d. Sample handling, quality control, laboratory preparation: $5/sample 2. Operation a. Chemical analysis: $200/sample b. Field transportation: $2/sample c. Air freight, packing, etc. for water quality samples: $10/set, 1 to 3 samples 3. Capital a. Automatic sampler: $600 b. Flow meter: $40 c. Field kit, storage chest: $730 d. Bottles, labels, chemicals: $2.50/sample
Identify potential pollutants (package plant)	1. Characterize package plant water quality (i.e., organics, BOD, COD, DOC, TOC; microorganisms, viruses, total and fecal coliform, microscopic animals; major and trace inorganics)	1. Nonsampling method a. Obtain plant and surge tank specification from mine manager b. Inventory sources to plant including shop waste, portable toilets, and anticipated loading rate c. Compile copies of quality control data and determine analytical techniques utilized 2. Sampling method a. Install composite and discrete automatic samplers at plant inflow and outflow ports, and flow meter on incoming lines b. Collect discrete samples at 2-hour intervals until trends are established for BOD and coliform and 6-hour intervals for complete analysis and source characterization	1. Obtain available information on package plant design, surge tank, and chlorinator design and operation 2. Interview mine personnel to determine plant usage, loading rates, sewer line distribution and drain line to sedimentation pond, etc. 3. Install automatic discrete sampler at inlet and discharge ports 4. Install 24-hour composite sampler at the discharge ports	1. Labor a. Interview personnel and review package plant engineering data (3 days): $120 b. Sampling equipment installation: $40/day c. Quality control, sample handling, laboratory preparation: $5/sample 2. Operation a. Chemical analysis: $200/sample b. Field transportation: $2/sample

TABLE B-3 (continued)

TEMPO monitoring steps[a]	Monitoring needs	Alternative monitoring approaches	Preliminary recommendations	Monitoring costs
Identify potential pollutants (package plant) (continued)		c. Install 24-hour composite sampler for monthly sample collection d. Install discrete sampler at discharge point to sedimentation pond e. Analysis of samples will vary from determining BOD and coliform to complete analysis as described in text	5. Install discrete sampler in discharge point to sedimentation pond 6. Samples will be collected to characterize coliform and BOD trends and at less frequent intervals for complete chemical and biochemical analysis	c. Air freight, packing, etc. for water quality samples: $25/set, 4 to 8 samples 3. Capital a. Automatic sampler (3X): $1,800 b. Bottles, labels, chemicals: $2.50/sample c. Flow meter: $40
Identify potential pollutants (sludge)	1. Characterize organics including polychlorinated biphenols and other organic toxins filtered into sewer system, MLSS, and major and trace inorganics 2. Estimate quantity of sludge produced	1. Nonsampling method a. Estimate volume of sludge produced each time aeration basin is pumped, record pumping frequency b. Characterize sources of wastewater through collaboration with monitoring of sewage treatment and package plants c. Compile data on sludge disposal locations and methods 2. Sampling method a. Sample sludge via special brass sampler or by pole and bottle method b. Grab sample sludge at beginning, during, and at end of pumping periods c. Sample soil piles or spreading areas used for sludge disposal d. Analyze samples as described in text	1. Corroborate sludge monitoring effort with sewage treatment and package plant studies 2. Collect sludge samples at package plant via pole and bottle sampler and grab samples during pumping periods	1. Labor a. Collaborate data on sludge production (2 days): $80 b. Quality control, sample handling, laboratory preparation: $5/sample 2. Operation a. Chemical analysis: $140/sample b. Field transportation: $2/sample c. Air freight, packing, miscellaneous: $10/set, 1 to 3 samples 3. Capital a. Pole and bottle sampler: $10 b. Bottles, labels, chemicals, etc.: $2.50/sample

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15. SUPPLEMENTARY NOTES

16. ABSTRACT

Three potential pollution source categories have been identified for Western coal strip mines. These sources include mine stockpiles, mine waters, and miscellaneous active mine sources. TEMPO's stepwise monitoring methodology (Todd et al., 1976) is used to develop groundwater quality monitoring designs for each source category. These designs include description of monitoring needs, alternative monitoring approaches, and preliminary recommendations. Generic and example case studies are presented for stockpile and mine water sources. General case considerations are given for miscellaneous sources. Unit cost estimates for the monitoring designs, based on preliminary recommendations, are given in Appendix B.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Groundwater	Groundwater movement	43F
Groundwater quality	Monitor wells	44G
Waste management	Monitoring methodology	48A
Coal mining		68C
Sanitary landfills		68D
Strip mining wastes		91A
Septic tanks		

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