SEI012A

DEPARTMENT OF ENVIRONMENTAL QUALITY
LAND QUALITY DIVISION

GUIDELINE NO. 4

IN-SITU MINING

TABLE OF CONTENTS

I. INTRODUCTION

This document is a guideline only. Its contents are not to be interpreted by applicants, operators, or LQD staff as mandatory. Its preparation is the result of numerous requests from applicants and operators for guidance in preparation of a comprehensive application or amendment. If an operator wishes to pursue other alternatives, they are encouraged to discuss these alternatives with the LQD staff.

This guideline is intended to be comprehensive and all headings may not apply to all operators. A table of contents is provided to direct the applicant to the appropriate topic for individual permitting needs.

A. Supporting Documents

Prior to resource inventory or development of an in-situ application, the applicant should review the following documents which can be obtained from the Land Quality Division upon request:

1. Wyoming Environmental Quality Act (as amended).
2. Land Quality Division Rules and Regulations.
3. Water Quality Division Rules and Regulations.
4. Land Quality Division Guidelines:

- No. 1 Soil and Overburden
- No. 2 Vegetation
- No. 3 Parameters for Determining Soil Suitability
- No. 5 Wildlife
- No. 6 Organization and topic outline for an Application for a Permit to Mine or an Amendment
- No. 6A Format and General Content Guideline for Permit Applications, Amendments and Revisions for Coal Mining Operations
- No. 8 Hydrology
- No. 10 Fencing
- No. 11 Cultural Resources
- No. 15 Alternate Sediment Control

B. Application Format

A single application (consisting of 3 copies, 4 copies if BLM surface or mineral) for a permit to mine or a research and development testing license should be submitted to the Administrator of the Land Quality Division. It should consist of two sections.

The first section of the application is the adjudication file, containing the "Permit to Mine" and "License to Mine" forms, bonds notification, receipts, consent forms, and Appendices A through C. The adjudication file should be submitted in a loose form and not be bound.

The second section of the application contains supporting information. Data for this section should be submitted in loose leaf 3 ring binders to allow easy substitution of pages for revisions or additions. It should be printed on 82 x 11 inch paper with standard margins and page numbers on all pages. The paper should be about 20 pound quality. All figures and tables larger than 82 x 11 inch paper should be folded to fit into the application and should be physically attached to the appropriate location in the application. All figures and tables should be numbered and referenced in the text. The Land Quality Division and the Water Quality Division will concurrently review the application and a single permit or license will be granted upon the approval of both administrators of the two divisions.

C. Definitions for Purpose of the Guideline

1. Aquifer". A zone, stratum, or a group of strata that store and transmit water in sufficient quantities for a specific use.

    1a. "Aquitard". A layer of low permeability that can store groundwater and also transmit it slowly from one aquifer to another.

    1b. "Confined Aquifer". An aquifer that is overlain by a confining bed, where the hydrostatic pressure at the top of the aquifer is greater than atmospheric pressure.

    1c. "Unconfined Aquifer". An aquifer in which there are no confining beds between the zone of saturation and the surface, where the hydrostatic pressure at the top of the saturated zone is equal to atmospheric pressure.

2. "Area of Review". The area for which information and analyses will be submitted as part of a groundwater pollution control permit application, and reviewed for issuance of a permit; the extent of the area will never be less than an area within a one-quarter (3) mile radius of the discharge site. The area of review may coincide with a permit area and adjacent lands, or may be determined by use of a mathematical model and formula which have been developed to describe groundwater hydraulics and flow. (Reference Water Quality Division Rules and Regulations, Chapter IX for the formula). The "area of review" definition applies only to groundwater pollution control permit applications.

3. "Background". The constituents or parameters and the concentrations or measurements which describe water quality and quantity variability prior to subsurface discharge, may also be called baseline.

4. "Best Practicable Technology, (BPT)". A technology based process determined by WDEQ as justifiable in terms of existing performance and achievability (in relation to health and safety) which minimizes, to the extent safe and practicable, disturbances and adverse impacts of the operation on human or animal life, fish, wildlife, plant life and related environmental values.

5. "Excursion". Any unwanted and unauthorized movement of recovery fluid (or associated by-products from underground coal gasification operations) out of the production zone as a result of in-situ mining activities.

6. "Groundwater Restoration". The condition achieved when the quality of all groundwater affected by the injection of recovery fluids is returned to a quality of use equal to or better than, and consistent with the uses for which the water was suitable prior to the operation by employing the best practicable technology.

7. "Injection Well". A well or conduit through which recovery fluid is introduced into the subsurface.

8. "In-situ Mining". A method of in-place subsurface mining in which limited quantities of overburden are disturbed to install a conduit or well, and the mineral is mined by injecting and recovering a liquid, solid, sludge, or gas that causes the leaching, dissolution, gasification, liquefaction or extraction of the mineral. In-situ mining does not include the primary or enhanced recovery of naturally occurring oil and gas or any related process regulated by the Wyoming Oil and Gas Commission.

9. "License Area". An area described in the license application within which all affected land and water is contained.

10. "Monitor Well". A well constructed or utilized to measure static water levels and/or to obtain liquid, solid, or gaseous analytical samples or other physical data that would be used for controlling the operation or to indicate potential circumstances that could affect the environment.

11. "Potentiometric Surface". The surface that coincides with the static level of water in an aquifer. The surface is represented by the levels to which water from a given aquifer will rise under its full head.

12. "Production Zone". The geologic interval into which recovery fluids are to be injected or extracted.

13. "Recovery Fluid". Any material which flows or moves, whether semisolid, liquid, sludge, gas or other form or state, used to dissolve, leach, gasify or extract a mineral (the term is the same as lixiviant).

14. "Recovery Well". A well or conduit through which a recovery fluid, mineral or product is produced from the subsurface.

15. "Research and Development Testing". Conducting research and development activities to indicate mine ability or work ability of, and develop reclamation techniques for, an in-situ operation.

16. "Subsidence". The measurable lowering of a portion of the surface or substrata.

17. "Surface Affected Area". The acreage which requires seeding for reclamation purposes and includes disturbances associated with roads.

18. "Trend Well". A well or wells between the well field area and the monitoring wells used for pre-excursion problem area detection.

19. "UCL or Upper Control Limit". The maximum concentration of a chemical parameter in groundwater that can be attributed to natural geochemical fluctuations and analytical variability. Upper control limits are defined statistically from baseline sampling and agreed upon by the administrator and the operator prior to mining initiation.

20. "Well Field Area". The surface area containing injection and recovery wells. This area may be all or a portion of the entire area proposed for the injection and production of recovery fluid throughout the life of the mine.

II. ADJUDICATION FILE - Permit to Mine (In-situ) and Research & Development License (In-situ)

The adjudication file is required for all applications and should be submitted in triplicate to the Division.

A. Form 1 UIC (Underground Injection Control) Mine Application or Form 5 R&D License, In-situ.

These forms contain a list of information to be included in the adjudication file. An original corporate seal is required on this form.

Below are listed the potential legal entities (applicants), with instructions on who can execute the documents associated with the application.

1. Corporations (closed or publicly held)

The corporation and the president should sign all documents unless certified evidence is included to show that the position signing can bind the corporation.

2. Partnership

The partnership is the applicant, but all partners must sign the documents.

3. Joint Venture

Same as partnership.

4. Limited Partnership

The limited partnership itself is the applicant. Each general partner (not the limited partners, they are only investors) must sign the documents.

B. Form 3 License to Mine Application (Not necessary for a R&D License)

An original corporate seal is required.

C. Reclamation Bonds

The following are acceptable types of bonds:

1. Corporate Surety Bond

This bond must be executed on the State of Wyoming form. It must be an original execution and be accompanied by a Power of Attorney for the Surety's Attorney-in-Fact. It is wise to investigate with surety companies the time necessary to process a surety bond. The bond must be approved by the Attorney General's Office and the LQD prior to approval of the application.

2. Federally Insured, Automatically Renewable Certificates of Deposit

These must be made out solely to the Wyoming Department of Environmental Quality - Land Quality Division. Interest is payable to the purchaser.

3. Government Backed Securities

ex: Treasury Bills

4. Self-Bond

See Chapter XII of the Land Quality Rules and Regulations for details on this type of bond.

5. Cash - U.S. Dollars

If a personal or company check is submitted as cash bond, three weeks waiting is required to assure that the check will be paid by the bank. The application cannot be approved until the check has cleared the bank. To avoid any delay in approval, a certified or cashier's check should be used.

6. Letters of Credit

See Chapter XX of the Land Quality Coal Rules and Regulations or Chapter XII of the Land Quality Noncoal Rules and Regulations on details on this type of bond.

D. Surface Owner Consent and Right of Entry

There is no item on the Form 5 to document Surface Owner Consent but Consent and Right-of-Entry are required for Coal R&D Licensing.

Form 8 - Surface Owner Consent Form is required of all surface owners since generally a lease agreement or other legal document does not specifically state that the surface owner has seen and viewed the mine plan.

E. Certificate of Public Liability (Applicable only to Coal In-situ Permit or License)

1. An original certificate with a notarized signature is required.

2. A rider must be attached requiring the insurance company to notify the LQD whenever substantive changes occur or the policy is cancelled or is not renewed.

F. Appendix "A" (For lands within the Permit or R&D License area. Applicable to both In-situ Permit & R&D Licenses)

1. List of names and last known addresses of:

a. Owners of record of the surface rights within Permit or R&D License area.

b. Owners of record of the mineral rights within Permit or R&D License area.

2. Maps showing locations of ownership in 1.a. and 1.b. above.

G. Appendix "B" (for lands adjacent to Permit or R&D License area)

1. List of names and last known addresses of: a. Owners of record of surface rights of lands immediately adjacent to the proposed Permit or R&D License area, b. Any other persons having a valid legal estate of record within one-half (2) mile of the Permit or R&D License area such as water rights and rights-of-way owners, etc.

List of names and last known addresses of owners of record of coal immediately adjacent to the proposed Permit or R&D License area. (Applicable only to coal permit or license.)

2. Maps showing the locations of the ownership in 1. and 2. above.

H. Appendix "C" Tabulation of Lands

1. Lands in the permit area are to be tabulated on LQD Forms C-1 and C-2 and signed by the applicant. The separate tabulations are as follows:

a. Tabulation of lands in the proposed Permit or R&D License area by legal subdivision, section, township, range, county, and municipal corporation, if any, and number of acres for each entry listed. If a bearing and distance description is used, it must be presented in either quadrant bearings or azimuths with horizontal distances. The number of acres in each bearing and distance description must be listed.

b. Separate tabulation of lands in the proposed Permit or R&D License area where no right to mine is claimed with the number of acres for each entry.

c. Tabulation of lands which are located within other Permit or R&D License areas in the state, and a copy of the agreement with the other permittee(s), licensee(s).

2. An original U.S. Geological Survey topographic map, clearly outlining and identifying the lands within the proposed Permit or R&D License area. Photo copies or other similar copies are not acceptable unless prior approval is obtained from the Land Quality Division.

I. Appendix "D"

See No. III of this Guideline

J. Appendix "E"

It is suggested that the applicant compose an Appendix "E" for the R&D License application although it is only required for coal ventures.

A map or maps with the boundary of the proposed Permit area or R&D License area and adjacent area clearly outlined and identified should be submitted that shows:

1. Lands to be affected over the life of the mine.

2. Drainage area within and surrounding the proposed permit area.

3. Location and names, where known, of all existing roads, railroads, public or private rights-of-way and easements, utility lines, pipelines, buildings, lakes, streams, creeks, springs and other surface water courses, oil wells, gas wells, and water wells.

4. Outline of the probable limits of all areas previously disturbed or to be disturbed by underground or surface mining, whether active or inactive, within or adjacent to the proposed permit area.

5. For operations which began prior to November 25, 1990, a map distinguishing operational mining units.

6. Ownership and use of all buildings on or adjacent to the permit area.

7. Political boundaries of special districts such as water, police, fire, conservation; public and private parks; cemeteries; Indian burial grounds; areas mentioned in Chapter XII, Section 1(a)(v)(A) and (B) of the Land Quality Coal Rules and Regulations as applicable.

K. Statement of Compliance (Applicable to Coal Applications)

1. List all notices of violation incurred by the applicant for any U.S. surface coal mine operated during the three years prior to the date of the application.

2. State whether the applicant or entities controlled by or under control with the applicant have had any mining permit suspended or revoked in the last five years. If so, describe the proceedings and identify the regulatory authority.

3. List all licenses, permits and approvals needed to conduct the operation. Include information about what you need to do to comply with requirements for all permits not yet obtained.

4. List your Mine Safety and Health Administration (MSHA) number.

5. Provide copies of all DEQ and State Engineer permits and approvals, or list the identification numbers.

6. State whether the proposed area to be mined is within an area designated, or being studied for designation as unsuitable for surface coal mining. Also state whether the permit or license area is within an area where mining is prohibited.

L. Identification of Interests (Applicable only to Coal Applications)

1. List all owners of record of the property to be mined:

   a. legal and equitable owners
   b. leaseholders
   c. purchasers of record under a real estate contract

2. If the applicant or any surface or mineral owner is a corporation or partnership, list the name and address of every:

   a. officer
   b. partner
   c. director
   d. principal
   e. resident agent

3. List the names and addresses of all principal shareholders of the applicant. (over 5%)

4. List the names of all surface coal mines operated by the applicant or principal shareholders during the preceding five years.

5. List all current, pending (including this application) and previous U.S. surface coal mining permits held by the applicant, partner, or principal shareholder subsequent to 1970. Include the regulatory authority.

6. Provide a statement of all lands, interests in land, options, or pending bids made by the applicant for lands contiguous to the permit area.

M. Proof of Publication (Applicable to Form 1 Applications and Coal R&D Licenses)

Land Quality Division will provide publication notice format. Publication and notification is not to begin until written consent from the Land Quality Division has been received by the applicant.

N. Proof of Filing (Applicable to Form 1 applications & Coal R&D Licenses)

Submit an original, signed affidavit of filing from appropriate county courthouse just prior to start of publication.

O. Proof of Notification (Applicable to Form 1 and Form 5 R&D)*

Applies to all owners of record of the surface and mineral rights within the Permit or R&D License area; owners of record of surface rights of adjacent lands; and all persons within one-half (2) mile having a valid legal estate of record. The notice must be sent within five (5) days after the publication to all above owners of record. The original certified mail receipts (the white post office form PS3800) must be submitted to LQD for validation. The receipts must be affixed to 8 x 10 sheets and placed in either alphabetic order or in the exact same order as the names listed in Appendix A, B, and the water rights owners listed in Appendix D6 who are within 2 mile of the Permit or R&D License area.

* Non-coal Form R&D License requires mailing a letter of notice and provide proof of mailing, but publication is not required.

III. RESEARCH AND DEVELOPMENT TESTING LICENSE - Supportive Information

A. Introduction

The following format assumed the operator will eventually apply for a commercial in-situ permit, and that the Research and Development License will be used to justify future techniques proposed for mining and reclamation.

The Research and Development License application should precisely describe all non-research aspects of the operation, as requested in Parts III.B. through D. Part III.E. is reserved for the research project; a detailed outline of the proposed research is requested. During the experiments, accurate records of the experiments should be kept by the operator. Previous research that a commercial scale permit is based on should be thoroughly discussed and/or referenced in the permit document (see part IV of this document).

Background data collection, Part III.B., should emphasize the site-specific environment of the License Area. Information should be provided to demonstrate that areas outside the License Area will not be affected by the operation.

B. Contents of Appendix D

1. Appendix D-1, Past and Present Land Use of the Area

2. Appendix D-3, Archaeological and Paleontological Resources of the Area

3. Appendix D-4, Climatology

Climatological data from the past year should be obtained from the National Oceanic and Atmospheric Administration station nearest to the license area.

4. Appendix D-5, Geologic Assessment

   a. The regional geology should be briefly described using referenced and published information.

   b. The geology in the License Area should be described using geologic cross-sections and should be confirmed with geophysical logs and field investigation. A 1 acre well field may be described with one north/south and one east/west trending section. Guideline 8 (Part IV.A.1. and Part IV.A.5.d.) should be referenced for the information and the level of detail suggested for the cross-sections. The production zone and confining zones should be identified on the cross-sections. When applicable, the depositional environment should be discussed.

5. Appendix D-6, Hydrology

Methods to identify the groundwater system within the license area of review and reporting procedures are described below.

   a. Potentiometric surfaces

   Potentiometric surfaces with sufficient data points to spatially define affected aquifers should be submitted. The potentiometric surfaces should be superimposed on topographic maps of sufficient scale for analysis. Wells used in developing the potentiometric surface map should all be located and identified on the map with the particular water elevation and date of observation at each well shown.

   b. Baseline groundwater quality

1. Determining regional baseline groundwater quality

Regional groundwater quality should be defined for the license area. Regional groundwater quality data should be collected for a sufficient length of time to identify any important spatial and time variant properties of the affected aquifers, to show the pre-mining hydrogeochemistry of the area, and to identify existing or anticipated impacts of adjacent mines on the groundwater quality within the license area. Generally a minimum of 4 samples per well taken quarterly over a one year time period is necessary (Table 1). Consultation with the appropriate regulatory authorities is recommended prior to beginning the program. A representative number of samples should be collected for each affected aquifer. The number of samples necessary to define groundwater quality varies with the area to be studied. More samples will be necessary for partially confined aquifers and for shallow, water table aquifers which may react more quickly to seasonal changes and to surface affects. The reliability of the data should be evaluated as part of the data gathering program.

2. Determining baseline groundwater quality per mining unit

The importance of properly defining the baseline groundwater quality for individual mining units cannot be overemphasized. The method for detecting excursions and the extent to which aquifers must be reclaimed are dependent on well characterized mining unit aquifers. Table 1 includes baseline monitoring frequency, density, parameters, and QA/QC recommendations and should be referenced during the discussion of this section.

All monitoring wells per mining unit should be sampled four times (minimum of 2 weeks between samplings) during baseline characterization. The first monitor well sampling should include analyses for parameters listed in Appendix 1, parts III and IV of Guideline No. 8.

Wellfield wells (injection and production) should be sampled four times (minimum of 2 weeks between samplings) during baseline characterization at a recommended density of 1 well per 3 acres of mining unit. The first and second sampling events should include analyses for all Guideline 8, Appendix 1, parts III and IV parameters. The third and fourth sampling events can be analyzed for a reduced list of parameters as defined by the results of the previous samplings (e.g., if certain elements are not detected during the first and second samplings, then those elements need not be analyzed for during the third and fourth sample outings).

Upper control limits (UCLs) are used to define excursions at monitoring wells and are determined from baseline sampling results. Attachment I of this guideline includes the recommended statistical method for determining UCL values. Well field baseline values are used to determine aquifer restoration goals (see Reclamation section of this guideline, part III.D.1.g.).

TABLE 1
Minimum Baseline Sampling Recommendations for In-situ Mining Operations

Area to be Sampled	**Purpose of Sampling**	**Frequency**	**Density**	**Parameters Sampled for**	**QA/QC**
Regional or Permit Wide	LQD review of regional groundwater quality for initial permitting and for obtaining UIC permit	Quarterly for 1 year	1 well per mi^2 in the ore zone aquifer as a general rule	Guideline 8	1 duplicate per quarter 1 blank per quarter, and 1 standard reported from the lab per quarter
Mining Unit Monitoring Wells	To establish UCLs and To characterize the geochemical environment of the buffer zone in case major excursions alter the buffer zone such that restoration is required	4 samples taken at a minimum of 2 weeks apart	All monitoring wells	1st sampling Guideline 8 Next 3, UCL parameters only	1 duplicate, 1 standard & 1 blank for Guideline 8 parameter set only
Well Field Wells	To establish restoration goals	4 samples taken at a minimum of 2 weeks apart	1 well per 3 acres as a general rule	First 2 samplings, Guideline 8 Second 2 samplings "short list" as defined by results of previous regional or mining unit samplings	1 duplicate per outing 1 blank per outing 1 standard per outing

c. Pump tests

Generally, pump tests utilizing the Neuman-Witherspoon method of analysis or other method yielding equivalent information are recommended. Multiwell pump tests are necessary to define aquifer properties. The testing should be designed to define aquifer properties within the affected area, hydrologic boundary conditions, layering effects, directional permeability, and the vertical confinement of the production zone. Transmissivity data should be of sufficient detail to confidently identify axes of directional transmissivities in the production zone.

d. Water rights

Locations and present owners of all wells inside and within 2 mile of the license area should be included. Information concerning plugging and well completion and producing interval(s) (to the extent such information is available in the public record or by a reasonable inspection of the property) is also requested.

e. Surface water

Surface water quality and quantity should be monitored only if the surface or the alluvial water quality and quantity of the stream could be affected by the mining operations. The contributing drainage area to the license area should be mapped and its acreage identified. Any ground water/surface water interactions should be identified and discussed.

f. Abandoned drill holes

A report which identifies all known premining wells and drill holes in the license and adjacent area should be filed. To ensure proper abandonment procedures were used, plugging should be verified.

6. Appendix D-7, Soil Assessment

a. Ten acres or less disturbance

For surface disturbance of ten acres or less within the license area, at a minimum, the following soils information should be submitted:

1. A soil inventory map should be provided with soil units and surface affected lands clearly outlined.

2. Soil mapping unit and profile descriptions should be provided.

3. Quantitative estimates of all suitable topsoil as described in Guideline 1, should be made for those areas where significant disturbance will occur (i.e. building construction or wellfield leveling).

b. Disturbances greater than Ten Acres

For surface disturbances greater than ten acres within the license area, more detailed soils information should be provided including chemical analysis of soils per LQD Guideline No.1.

7. Appendix D-8, Vegetation Inventory

a. Mapping and data collection

The area to be permitted for the R&D license should be mapped according to plant communities. The area to be affected should be delineated on this map. If the area to be affected (surface affected acreage is that which requires seeding for reclamation purposes and includes disturbances associated with roads) is less than 10 acres in size, a qualitative description of the vegetation communities is adequate. However, if the R&D will disturb more than 10 acres, quantitative sampling of the affected lands will be necessary. Parameters to be measured include % cover for each species (or life form categories), total cover and a species list. Vegetation production sampling may be required depending on the nature of the communities to be disturbed and whether production information exists for the area from other sources (Soil Conservation Service publication or adjacent permit areas). Measurements should be conducted in accordance with the current LQD Guideline No. 2.

b. Extended reference areas

A parcel of land representative of the area to be affected and scheduled to remain undisturbed during the life of the project shall be delineated for bond release evaluation purposes. This parcel of land which is usually greater than 10 acres in extent is referred to as an extended reference area (ERA). The ERA should be identified in the field in conjunction with LQD personnel prior to vegetation sampling. This area should be representative of the vegetation communities to be disturbed by the R&D operations. The ERA should also be quantitatively sampled as described above. The ERA and surface affected areas can either be sampled as a unit according to vegetation types or each can be sampled individually. A decision regarding these options should be made between LQD and the operator prior to conducting the vegetation survey.

c. Threatened or endangered plant species, noxious weeds

A survey of the area to be affected (regardless of the size of disturbance) should be conducted to note the presence of any threatened or endangered plant species, and any noxious weeds. The relative abundance of any species noted should be described.

d. Photographs

Original photographs of the vegetation communities to be disturbed as well as a view of the ERA should be included in the application.

8. Appendix D-9, Wildlife

a. Vertebrate distribution

Potential vertebrate distribution on the license area should be listed.

b. Vertebrate observations and habitat affinity

Actual vertebrate observation on the license area should be described, including information on dates, extent of field studies conducted and observations. Habitat affinity of animals on the license area, and an identification of unique habitat types or known migration routes on the area should be submitted.

c. Rare, threatened or endangered species

The occurrence of rare, threatened, or endangered species, including eagles, on or within one-half mile of the license area should be noted, along with information on surveys/literature searches conducted for presence/absence determination.

C. Minerals Extraction Plan

1. Introduction

The Research and Development License application should include the experimental techniques to be tested and a prediction of the expected results. During mining, on-site data collected should be in sufficient detail so that an analysis may be performed for the predictions made in the application. The experiments and predictions could include: performance of equipment under operating conditions, well completion, well development and boring techniques, excursion prediction and control, lixiviant chemistry, identification of best restoration methods, subsidence research, or any other research topics. The license area should be limited to the minimum acreage possible.

2. General Discussion Contents

A general discussion and description of the operation should be included which identifies the goals of the operation, the life of the project, the mineral to be mined, the mining methods, equipment to be used for mining, and any research and development activities to be tested during the operation. This discussion should indicate the areal extent of disturbance within the area. The proximity of mineral, oil, gas or other resources that could be affected by the operation should also be identified in this section.

3. Site Preparation Activities

a. Location map

A location map at 1" = 500', or more detailed, identifying all areas of surface disturbance should be submitted. The map should be superimposed on a topographic map of sufficient detail to accurately locate topsoil and spoil stockpiles, erosion and sediment control methods, support facilities, well fields, monitor wells, hydrologic control features (septic systems, diversions, evaporation ponds, culverts, etc.), roads, power and telephone lines, all waste disposal sites, and fencing or other surface control methods.

b. Topsoil removal

A description and a timetable identifying the extent of topsoil removal, the depth of removal, and the quantity of topsoil in each stockpile should be included. Any other surface disturbances, appropriate timetables, and the dimensions of other stockpiles should be described.

c. Wildlife and archeology mitigation

Mitigating measures that are to be taken to alleviate impacts to wildlife and archeology should be placed in the application. This should include measures taken to prevent wildlife use of evaporation ponds.

d. Hydrologic control features

The designs and engineering of surface water hydrologic control features should be placed within this section. Appropriate permits should be obtained from the Water Quality Division with notice of application provided to the Land Quality Division.

The applicant should consult with DEQ-WQD concerning obtaining a National Pollution Discharge Elimination System (NPDES) discharge permit.

4. Production Process and Timetables

a. Description of special fluid and chemical flow paths

Major chemical reactions or physical processes anticipated at each step in the process should be described. This section should identify the composition and average and maximum volume of fluid to be injected during operation. Special processes and reactions, such as those involved in reverse osmosis, burn initiation, or high pressure water injection should also be identified in this section. The anticipated volume and composition of waste waters or materials generated by the mining operation should be described.

The potential for surface spills should be discussed along with an indication of likely contaminants involved. Spill control and cleanup procedures should be outlined.

b. Surface hydraulic equipment

A map locating the typical configuration of the piping planned for the well field area, and a description of the system should be submitted. General pipe and pump specifications should be described. Typical connections between cells (for gasification projects) should be described. Winterization techniques should be discussed. This information will be used primarily for bonding purposes.

c. Production zone location

A series of geologic cross-sections (reference Part III,B.4.) along with the geophysical logs should be used to accurately locate the limits of the production zone in three dimensions.

d. Production zone confinement

Down hole injection pressures should be identified, including the maximum injection pressure. The fracture pressure of the production zone and any confining zones surrounding the production zone should be defined. Fracture information, and data received from the pump tests should identify the extent of lithologic confinement of the production zone. Areas of diminished confinement should be delineated (where known). Special techniques that may be used for production zone confinement should also be described.

e. Well completion

Well completion, development, redevelopment and drilling techniques should be described; the drilling fluid and any additives used should be identified. The methods and materials to be used for well completion, including casing type, jointing and specifications, grouting methods, and the information requested in LQD Guideline No. 8 part III, A. 5. should be

reported for production, injection, and monitor wells. Well development methods and any anticipated well redevelopment methods should be described.

f. Mechanical integrity of wells

A schedule and procedures to check the integrity of all injection and production wells should be provided. An inflatable packer pressure test is recommended for all injection and production wells. Tests procedures used to check mechanical integrity of wells must at a minimum be approved by the EPA. The test should be performed following any down-hole insertion of drilling tools. All tests are required to be repeated at least every 5 years. Results of all integrity tests should be submitted to the Land Quality Division quarterly.

5. Excursions

a. Introduction

Excursion detection, control, and cleanup procedures should be identified in this section, considering both horizontal and vertical excursions. The monitoring network should be described and parameters used to detect and confirm excursions should be identified.

b. Monitoring well network. (See also discussion under Reclamation Plan)

The monitoring well network used for excursion detection should be outlined. Wells should be installed in aquifers which show the potential for being affected above, within, and below the production zone, and should be used for identifying excursions from the production zone. Monitor well spacings should reflect directional transmissivity and other conditions identified through on-site pump tests.

The monitoring network should be superimposed on a topographic map identifying the well field area. The extent of the ore zone, faults and other hydrogeologic boundaries should be identified on the map. The application should contain a commitment to maintain the integrity of all monitoring wells to the extent possible until their removal and reclamation (see LQD Guideline No. 8, Appendix 2).

A site specific, technically sound method for emplacement of monitor wells, including but not limited to: gradient consideration, dispersivity of recovery fluids, the initial excursion recovery measures employed by the operator, the normal mining operational flare (the lateral and vertical extent of affected area under normal operating conditions), and the recoverability within the allowable regulatory time frame, as specified in Chapter XVIII, Section 2.(e) of the Land Quality Coal Rules and Regulations or Chapter XI, Section 2.(e) of the Land Quality Noncoal Rules and Regulations, should be employed. Monitor wells may be located using a groundwater flow model, or other technically justified method. Monitor well spacing may be increased if trend wells are used. (See Attachment 1).

All wells completed in the production zone must be in hydraulic communication with the mining zone. The completed interval should include the mineralized zone. Additional wells with lesser spacing may be necessary in preferred flow path zones. It is recommended that trend wells be monitored and the data maintained on site for inspection. For trend wells, unless an excursion occurs at the monitor well ring, remedial action is not required.

The width of the buffer zone (the area between the production field and the monitor wells) should be such that the monitor wells are within the zone of control of pumping wells which would be used to control excursions. (See Attachment 2).

The operator is responsible for restoring all groundwater affected by the mining process, including the buffer zone if it has been affected. It is therefore in the operator's best interest to establish as small a buffer zone as is operationally feasible. Monitor wells should be completed in the lower portion of the first aquifer above the ore and in the upper portion of the first aquifer below the ore. Placement of these wells should be based upon knowledge of the nature and extent of the confining layer and the presence of drill holes, hydraulic gradient, and abandonment procedures utilized.

Monitor wells should have upper control limits established on a well by well basis for an R&D. A wellfield average may be used for a commercial permit with upper control limits determined using the procedures outlined in Attachment 1.

c. Frequency of monitoring UCLs during mining

Monitoring frequency is somewhat dependent on hydraulic conductivity. Sampling and analysis for UCLs should be done twice monthly and at least 10 days apart. If UCLs are exceeded (e.g. 2 or more), then the analysis should be repeated within 24 hours of receipt of analytical data. If that second sample does not indicate the UCLs have been exceeded, a third sample shall be collected within 48 hours of receipt of the second sampling data. If neither the second nor the third sample indicate the UCLs were exceeded, the first sample shall be considered in error. If confirmed by either the second or third sample, the well will be considered to be on excursion status and should be reported verbally to the agency within 24 hours. The operator should implement the recovery plan and continue monitoring. Samples will be collected and analyzed on a weekly basis until the excursion is controlled. If the excursion lasts longer than 30 days, a suite of samples should be analyzed for Guideline 8 parameters. At the time UCLs are no longer exceeded, a suite of samples should again be analyzed for Guideline 8 parameters.

d. Parameters

A parameter set should be developed for the detection of excursions. Excursion parameters are process specific. Factors that should be considered in the selection of excursion parameters include the potential of constituents to participate in reactions such as sorption, oxidation/reduction, and precipitation.

Possible excursion parameters may include the following:

For Uranium:

TDS or conductivity
Chloride
Sulfate
Bicarbonate or Total Alkalinity
Sodium

For Underground Coal Gasification:

TDS	Cyanide
TOC	CO
Ammonia	HS

Phenols CH_4
Boron

Water level measurements should be part of any excursion monitoring program, since pressure changes due to an imbalance in injection and production rates is transmitted quickly through the aquifer system.

e. Corrective actions

The applicant should describe the actions to be implemented to correct and control an excursion event. The actions should be identified for both horizontal and vertical excursions.

Samples should be collected and analyzed on a weekly basis until the excursion is controlled.

f. Reporting procedures

(See Chapter XVIII, Section 2.(e) of the Land Quality Coal Rules and Regulations or Chapter XI, Section 2.(e) of the Land Quality Noncoal Rules and Regulations.)

In the event of an excursion, the Land and Water Quality Divisions should be verbally notified within 24 hours. Written notification describing implementation of the approved plan is required within 7 days. A plan outlining appropriate corrective actions should be included within the license. Record keeping methods and responsibilities should also be described.

6. Subsidence

An estimate of the amount of subsidence and a monitoring plan should be outlined in the license application. Costs associated from backfilling subsidence areas should be included in the bond estimation. If subsidence is not a problem for the type of mining, indicate so in the application.

7. State Permits

Copies of requested approved state and federal permits associated with this application (e.g. well permits, pond construction permits, discharge permits, fish and wildlife service permits) should be placed in the license application. It is not necessary to include the documentation associated with these permits. A copy of the WQD/SEO approved pond design does not have to be included in the original license application but should be inserted later after WQD/SEO approval.

D. Reclamation Plan

1. Aquifer restoration

a. Introduction

Aquifer reclamation activities, including procedures, chemistry, facilities, equipment required and the expected final water quality should be briefly summarized. The timetables for restoration activities should be discussed.

b. Methodology

Aquifer restoration procedures should be detailed in this section. Process description and chemistry should be specifically described. The anticipated volume and composition of water generated during restoration should be identified.

Restoration water quality and water levels should be monitored and sampled at the very beginning and at the very end of restoration. Parameters to be analyzed should include the full suite as listed in LQD Guideline No. 8, Appendix 1.

c. Monitor network groundwater restoration

A specific monitoring plan for both active and stability phases of restoration should be outlined. This may have to be modified depending on excursion events during mining. An updated plan should be submitted to Land Quality Division prior to beginning groundwater restoration.

d. Stability

Wells initially selected and listed in the reclamation plan will be used to determine restoration success. Both injection and production wells should be selected. When the restoration goal is achieved, active restoration should be discontinued and a stability period of at least 6 months will begin. The end of the 6 months period is a decision making point for the DEQ, i.e., more restoration, longer stability period, or overall success.

Based on the reclamation plan and the restoration success, the restoration sampling wells should be selected for monitoring during stability. (These wells should be identified in the reclamation plan to ensure appropriate baseline information is available, however, it is recognized that some wells may need to be changed or redesignated due to mining activities).

The restoration sampling wells should be monitored during the stability period on a monthly basis for a full suite of LQD Guideline No. 8, Appendix 1 parameters except those shown to be unaffected by mining and restoration processes.

e. Evaluation of Stability Data

1. The data should be analyzed on the basis of well field averages. In no case will wells of different baseline class be averaged together.

2. The data should be examined on a parameter by parameter basis.

3. The data should be examined over time (the six month period) to identify any trends - techniques such as scatter plots, trend, regression analysis and standard statistics should be used. A determination of aquifer stability should be made upon the "trends" in the data; i.e., a stable aquifer should not exhibit rapid upward or downward trends or be oscillating back and forth over a wide range of values.

4. The data should be evaluated against baseline quality and variability to determine if the restoration goal is met - the primary restoration goal is always baseline. The secondary goal is to restore the water within class of use. The secondary goal of restoration within class of use is applicable for "problem" parameters <u>if and only if BPT has been demonstrated</u>.

Statistical methods should be used to compare the restored aquifer data with the baseline, e.g. analysis of variance and t-test. It is important to address all of the assumptions inherent in the particular statistical method chosen. The restoration success will be evaluated on the basis of statistically equivalent populations between baseline and post-restoration data.

Potentiometric surface maps should be developed to reflect aquifer conditions at the end of the stability monitoring period. This information will be used to determine if the groundwater flow pattern is stabilizing.

Following a decision that the aquifer geochemistry is stable, data should be evaluated on a parameter by parameter basis to determine if:

- parameters have met baseline.

- parameters are above baseline but below class of use.

- parameters are above class of use.

f. Determination of Best Practicable Technology (BPT)

The following items should be discussed:

1. Type of Technology - The type of technology may be different for different circumstances.

2. Application of Technology - Has the technology been used correctly? As an example, reverse osmosis evaluation should include:

   - Number of gallons and/or pore volumes pumped

   - Number of gallons reinjected

   - Demonstration of balance of well field

   - Bleed stream split

   - Quality of water produced vs. reinjected

   - Pond capacity

   - There should be evidence that active restoration was discontinued at the appropriate timer

   - Proper maintenance and operation of equipment

3. Economics - Consider the amount it would cost to gain further reduction in parameters, (e.g., if it requires a very large expenditure for a relatively small gain in water quality). Consideration of economics only applies if parameters fall within the class of use.

NOTE: If parameters are above class of use, then further restoration may be required.

g. Determination of groundwater restoration success at the end of the stability period.

At the end of the stability period, groundwater restoration success will be determined based on the following criteria:

1. All parameters are at baseline AND the aquifer is stable, then restoration is successful.

2. All parameters are within Class of Use Standards AND the aquifer is stable AND BPT has been applied, then restoration is successful.

3. If any parameters remain above Class of Use, then restoration is Unsuccessful. Further restoration may be required in the appropriate areas.

4. If the baseline water quality is suitable for domestic use (Class I) with the use of economically reasonable treatment devices and groundwater has not been returned to a quality within the range of such devices, then restoration is Unsuccessful.

2. Surface Reclamation

a. Post-mining land use.

The proposed post-mining land use should be specified.

b. Disposal of buildings and facilities.

The plan should include procedures for disposing of buildings and other facilities.

c. Toxic materials

The procedures for permanently disposing of any toxic or acid forming materials should be provided.

d. Topography

The plan should demonstrate that surface affected lands will blend with adjacent topography and land uses and that drainages will be re-established.

e. Surface preparation

The plan should indicate any surface preparation to be undertaken before topsoiling. Topsoil replacement methods and schedules should be included. Minimum depth of topsoil replacement should be specified. Any erosion control practices and addition of soil amendments that are planned should be indicated.

f. Revegetation

The plan for revegetation should include species to be seeded, rate of seeding, and method and time of seeding. If cover crops, mulch, fertilizer, or irrigation will be used, this should be discussed in detail including methods and timing, rates, locations, and water quality.

g. Protection of newly seed areas

The plan should include measures and specifications to be used for protecting newly revegetated areas from grazing animals.

A site maintenance plan which includes contingencies to correct weed establishment or erosional instability should be included.

3. Reclamation schedule and cost

The plan should include a schedule for reclamation and costs broken down by different types of disturbance and different phases of reclamation work. Costs should be based on reclaiming the entire affected area after the first year as if the mine were to shut down at that time and be completely reclaimed including the removal of all facilities. Cost estimates should include restoration of the anticipated affected groundwater as well as surface reclamation.

E. Research Section

1. Introduction

The research and development license is available to allow testing of new technology or tried technology in a new geologic setting. Therefore, operations under the license should identify procedures to be tested and evaluated.

The purpose of this section is to identify the research aspects of the research and development license. This section is meant to justify the areas in the license where exact mining and reclamation procedures, timetables, methods or results can only be generally described.

2. Identification and Description of Research Methods

A description of each research area proposed in the mine and reclamation plan should be written. The description should define the anticipated techniques to be tested, the expected manner of implementation of the techniques, and the expected results.

3. Records and Reporting

A plan should outline the records that will be kept by the operator to identify the procedures actually used in the research areas and to identify the dates those procedures were implemented. For example, record keeping of the chemical composition of fluids, the volumetric water balance, injection pressures and volumes, burn intervals, and other standard operating procedures should be described in an efficient technical manner. The daily logs describing normal operational procedures may be reviewed by Division personnel on site visits.

4. Disposal of Product

A plan should be outlined for disposal of any product produced by the research project.

F. Reporting Procedures

A plan for submitting technical summaries of research results and the present status of the operation should be submitted as described in the license application. At the cessation of operations, the

operator should submit a final technical report of all research results, logs, procedures, conclusions, etc., to the LQD.

G. Confidential Material

Materials or record requests for confidential status will be reviewed pursuant to W.S. ' 35-11-1101.

IV. SUPPORTIVE INFORMATION - Commercial Scale Permit

A. Introduction

In general, the same information as recommended for a Research and Development License is required for a Commercial Scale permit. Listed below are some additional items considered necessary. Organization of the permit document would be similar. In using Section III for a commercial scale permit substitute the word "permit" for "license". The operator may choose to take a two-tiered approach to the commercial scale permit; i.e. obtain the mine permit for a large area using more general information with commitments to provide the more specific detailed information on a mine-unit by mine-unit basis. Approval of each mine-unit would then be necessary prior to lixiviant injection. This approach should be discussed with Land Quality Division prior to permit submittal.

B. Supportive Information in Addition to R&D License Requirements

1. Water Rights

A list and map of all adjudicated water rights inside and within three miles of the permit area boundary must be provided. The locations and present owners of all wells within three miles of the license area (including plugging techniques, well completion techniques, and producing intervals) must be provided, to the extent such information is available in the public records and from a reasonable inspection of the property.

2. Site Preparation Activities

A description and timetable identifying the extent of topsoil removal, the depth of removal, and the quantity of topsoil in each stockpile should be included. Any other surface disturbances, appropriate timetables, and the dimensions of the stockpiles should be described.

3. Groundwater Restoration

It should be clearly demonstrated that successful groundwater restoration is being achieved in early mine units before additional mine units can be mined, according to the approved mine plan. Long term monitoring may be required in already mined and restored units throughout the progression of the mine sequence, if stability has not been demonstrated.

4. Vegetation Inventory

a. Vegetation community map

A vegetation map of the entire permit area and 2 mile buffer surrounding the boundary is required. Aerial photos can be used for mapping purposes. This map should depict the distribution of plant communities, potential surface affected areas, extended reference area

(ERA), sample locations and any other information pertinent to the area. The map scale should be from 1" = 400' to 1" = 700'.

b. Qualitative description

A qualitative description of each plant community should be provided in the Appendix D-8 text of the application.

c. Cover and production data collection

Vegetation information of primary importance is cover data. Therefore, quantitative sampling should include % cover for individual species (or life form categories) and % total cover. Measurements should be conducted according to the current version of LQD Guideline No. 2. Vegetation production sampling may be required depending on the nature of the communities to be disturbed. However, if existing data from other sources (Soil Conservation Service publications or adjacent permit areas) can be provided and demonstrated to be applicable to the permit area communities in question, the collection of production data may be waived.

Sampling should be conducted on the permit area or a reduced area as approved by the Administrator. Quantitative sampling should also be conducted on the native land which is designated as the ERA to be used for bond release evaluation purposes. The ERA should be undisturbed by mining/exploration activities for the life of the operation, be of sufficient size (no less than 10 acres) to include the major plant communities to be affected and be representative of their general nature. The ERA should be reviewed and approved by LQD personnel prior to vegetation sampling.

d. Sampling design

The surface affected areas and ERA can either be sampled as one unit according to vegetation types or sampled separately depending on the nature of the permit area and the in-situ operation. A decision concerning which option would be most appropriate should be made by the operator and LQD prior to initiating the vegetation sampling study.

e. Other information to be included

1. A species list including a survey for the presence of any threatened or endangered plant species.

2. Description of any areas containing noxious weeds to include the aerial extent and their relative abundance.

3. Description of tree densities or any proposed disruption of tree communities.

4. Independent shrub density studies will not be required. However, it should be indicated whether plant communities are shrub dominated (20% cover contributed by shrub and sub-shrub species).

5. Pre-mining land uses of the area and grazing history should be provided.

6. If shrubs are not to be included in the reclamation seed mixtures because of a landowner's request, a letter verifying this from the landowner should be included.

7. Original photographs of the vegetation communities to be disturbed and a view of the ERA should be included.

ATTACHMENT 1 - SAMPLING, ANALYSIS AND UPPER CONTROL LIMIT CALCULATION

I. Discussion

A. Sampling and Analysis (S&A) Plan

In an effort to improve the consistency and quality of water-quality data submitted to the Land Quality Division, a groundwater sampling and analysis plan is recommended to be prepared and implemented as part of each research and development (R&D) and commercial scale in-situ mining permit. Although a very good discussion of an S&A plan is covered in the Resource Conservation and Recovery Act guidance document (EPA, 1986) on pages 97-128, the following points are presented to emphasize or elaborate on information provided in the RCRA guidance document. A S&A plan should include, but not be limited to, information on:

1. Sample Collection Protocol

- Static water elevation and total depth of the well to the bottom of the completed interval should be measured to 0.1 foot and recorded in the samplers report for each water quality sampling event.

- The sample withdrawal technique should be selected based on a consideration of the stability of the parameters of interest.

- Procedures for evacuating each well prior to sample collection should be documented.

2. In-Situ or Field Analyses

- The following parameters should be analyzed in the field during baseline and stability periods: pH, temperature, and conductivity.

3. Sample Preservation and Handling

- Because many parameters are unstable after sample collection and cannot be analyzed in the field due to logistical constraints, sample preservation is recommended as stated in Guideline 8, Appendix I.

4. Chain of Custody

- An adequate chain-of-custody program is to be described.

- All sample containers are to have durable labels affixed to them which contain pertinent information such as time and date of sampling, well ID, and name of collector.

5. Analytical Methods

- Methods to analyze water-quality parameters should be consistent and follow EPA approved test procedures according to 40 CFR 136 (See References).

6. Field and Lab QA/QC

- Quality assurance and quality control recommendations are discussed in III,B.5.b.

- The frequency and method of standardizing or calibrating test equipment brought into the field needs to be documented; typically this equipment includes pH, and conductivity meters.

- The results of all field and lab QC samples are to be included along with the analytical reports submitted to the DEQ/LQD.

B. Selection of UCL Parameters

Excursions are detected through the use of systematic water-quality sampling at monitoring wells surrounding the active mining zone, both laterally and vertically. Available data on R&D and commercial scale in-situ mining operations indicate that certain parameters are typically good excursion indicators, while others are good only under certain geologic settings. The following parameters have been shown to be reliable excursion-detection parameters:

Parameters	**Units**
Conductivity	umhos/cm @ 25^{B}C
Chloride	mg/L as Cl
Total Phenols (For UCG operations)	ug/L as total phenols

Additional parameters that have demonstrated an ability to detect excursions are as follows:

Parameters	**Units**
Calcium	mg/L as Ca
Sodium	mg/L as Na
Sulfate	mg/L as SO_4
Total Alkalinity	mg/L as $CaCO_3$
Total Dissolved Solids	mg/L residue @ 180^{B}C
Total Organic Carbon (for UCG operations)	mg/L as TOC
Ammonia (for UCG operations)	mg/L as NH_3

C. Statistical Assumptions

This attachment recommends various statistical methods for analyzing water quality data bases. These methods may be sensitive to (1) significant departures from a normal distribution, (2) serial dependence, and (3) temporal trends. A good review of this topic is found in Harris et al. (1987). In general, the skewness coefficient is a recommended test for normality; a sampling frequency no shorter than every two weeks is recommended to reduce serial dependence; and at least a two month sampling (4 samples per well) period is recommended to incorporate temporal variability into a water quality data base for UCL determination.

D. Screening the UCL Parameter Data Base for Errors and Outlier Populations

Data bases should be routinely screened through the use of (1) quality control (QC) checks and (2) checking and correcting any transcription errors. In addition to these data-screening steps, a baseline data base should be statistically evaluated for outliers.

Outliers are anomalously high or low values relative to the other values comprising a data base. An outlier can result from one or more of the following conditions:

- Transcription errors.
- Sampling errors.
- Analytical errors.
- Incorrect units of measurements.
- Natural water quality variability.
- Differences in geology within the sampled aquifer.

If the source of error responsible for an outlier is detected, then the anomalous value can possibly be corrected. However, there is often insufficient information available to evaluate an error source. The inclusion of an outlier in a data base can have a disproportionately large influence on statistical analyses of water quality data. Because there are no reliable methods for evaluating whether an outlier is due to an error or the result of natural water quality variability, a technique for discarding outliers from a data base is needed. The proposed screening technique accounts for wide variations in parameter values while still being capable of detecting outliers that fall outside of a statistically calculated interval. The following tolerance-limit formula (Loftis et al., 1987) is recommended for screening outliers from baseline data used to calculate UCL values:

x = k S alpha = 0.05, p = 0.99

where:

x = mean of observations in sample
k = tolerance limit factor
S = standard deviation of sample

The tolerance limit factor (k) is a function of sample size (n), confidence level (1 - alpha), and proportionality values (p).

Consider the following total alkalinity concentrations:

Total Alkalinity, mg/L as $CaCO_3$

Well 37	100.8	93.6	97.0	87.4	86.3
Well 38	85.3	93.0	87.2	85.5	85.1
Well 39	98.0	92.5	92.0	87.8	85.7
Well 40	76.6	80.3	66.0	86.3	73.0
Well 41	91.5	91.0	92.2	85.1	87.4
Well 42	93.0	94.5	93.8	84.9	79.4
Well 43	94.5	93.5	105.0	84.7	86.3
Well 44	92.0	94.0	94.0	85.7	89.6
Well 45	85.7	88.1	89.5	81.3	95.0
Well 46	86.6	85.5	92.2	92.0	84.2
Well 47	91.3	93.2	93.2	84.7	85.1

Step 1. There are no hard and fast rules regarding the initial selection of potential outliers. A recommended method is to visually screen the data base for anomalous values or groups of values, then subjectively identify whether these values are especially high or low relative to the other values in the data base.

Initial Outlier Estimate: 105.0, 66.0

Step 2. Calculate the tolerance interval, excluding the use of the two potential outliers (i.e., 105.0 and 66.0). See Appendix A for "k" values.

x = 88.83
S.D. = 5.38
k(n = 53) = 3.094

$x \pm k\ S$
88.83 $\pm$ (3.094 x 5.38)
(72.2 to 105.5)

Step 3. An evaluation of the tolerance interval indicates that the value <u>105.0</u> is marginally acceptable and therefore should be included in the baseline data base for statistical calculations.

Step 4. Recalculate the tolerance interval including the value 105.0, but excluding the value 66.0.

x = 89.13
S.D. = 5.77
k(n=54) = 3.094

$x \pm k\ S$
$89.13 \pm (3.094 \times 5.77)$
(71.3 to 107.0)

At an alpha = 0.05 and p = 0.99, one can assert with a degree of confidence (1 -alpha) that the proportion of the population of possible alkalinity values contained between 71.3 and 107.0 mg/L as $CaCO_3$ is at least 99 percent. The use of an alpha - 0.05 is based solely on the historical use of this alpha value for statistical evaluations of hydrology data, while the 99% proportionality value is used because it is the highest value for which k values are available.

Note: For a given sample size (n) of 100, only one value should be expected to be discarded as an outlier when it may actually be a representative value.

Step 5. At this point, the iterative process of calculating tolerance intervals for outlier detection is complete. The conclusion is that the value 66.0 is considered an outlier and will be discarded from the data base.

Note: If one or more wells have parameter values that contain a relatively large number of outliers (See Appendix E), then these wells should be treated separately as an additional baseline data base for one or more UCL parameters.

F. Calculation of UCL Values

Upper control limits are needed to detect the uncontrolled migration of contaminants outside of a well field in either a lateral or vertical direction. The use of UCLs for conservative parameters provides a reliable basis for determining when an excursion occurs.

The establishment of UCL values based on the variability of the baseline data base is recommended. The use of a baseline mean value plus three standard deviations for calculating NPDES standards was proposed by the National Academy of Science (1977) in a report to the EPA. Using parameter values that follow a normal distribution, the probability of a single observation falling beyond the boundary designated as X + 3 S.D. is 0.00135, or 0.135 percent. Such an occurrence is considered so rare that in the event the upper boundary is exceeded, the operating company is determined to be in violation of the effluent regulation. However, if different methods or laboratories are used to analyze collected water samples after the baseline data base has been established, then the calculated probability of exceeding UCL values may be less accurate.

The rationale used to evaluate the adequacy of various methods to calculate UCLs is based on two criteria:

(1) the UCL for any parameter should not be exceeded in the baseline data base after it has been screened for outliers, and (2) the UCL for any parameter should be capable of detecting an excursion event within one or two sample collections (based

on a 2-week sampling interval). These criteria are based on minimizing the probability of committing a Type I and Type II error. In general, the preferred method is one that results in the highest UCL value while still being capable of detecting an excursion event.

A method that uses the baseline mean plus 5 standard deviations is the recommended method for calculating UCLs. Use of this proposed method should result in adequate excursion control, yet minimize the possibility of incorrectly placing wells in excursion status.

For situations where chloride values are very low and show little variation during baseline data collection, the LQD is willing to consider allowing the upper control limit for chloride to be set at the average baseline value plus 15 mg/L if that value is greater than the average baseline value plus five standard deviations. This option will only be considered for chloride..

G. Trend Wells

The use of trend wells has enabled in-situ operators to detect an excursive groundwater plume prior to the plume reaching excursion monitoring wells. Parameter value changes in a trend well can signal a water balance problem in the active well field that may not be otherwise evident to the operator. These wells are typically located between the injection/production wells and the monitor wells in the active well field. Water-quality analyses of samples collected from trend wells will not result in regulatory corrective action. Their use is as a preventive measure to allow greater operational control of wellfield fluids and to decrease the possibility of having to halt production to restore a much more extensive plume of mine fluids had an excursion been detected at the excursion-monitoring wells.

CONCLUSIONS AND RECOMMENDATIONS

The following is a list of recommendations relating to the use of baseline data for calculating UCLs.

1. A detailed groundwater sampling and analysis (S&A) plan should be included in each uranium mine permit application.

2. UCL parameters should be selected based on their reliability to detect an excursion event. At least three parameters are recommended to be included in each excursion monitoring program.

3. For UCL determination, a sampling frequency of 4 samples taken at a minimum of 2 weeks apart, is recommended.

4. Baseline data bases should be screened for outliers. A recommended method of outlier detection is discussed in this guideline.

5. A well (or wells) that produces anomalous water-quality data, for any UCL parameter, should be treated separately for UCL calculations.

6. The use of an empirically-derived method for calculating UCL values is proposed. The formula is: baseline mean plus 5 standard deviations, after the baseline data base has been screened for outliers.

7. The beneficial use of trend wells located between the active well field and the excursion monitoring wells is recommended. Trend well water quality data need not be submitted to the LQD.

8. A review of water-quality changes during an excursion event indicates that an excursion-status criteria could reliably be based on the exceeding of two out of three UCL parameters.

ATTACHMENT II - SUGGESTED PROCEDURE FOR SELECTING DISTANCE BETWEEN HORIZONTAL EXCURSION MONITORING WELLS AND AN IN-SITU WELL FIELD

Goals:

1. To determine acceptable distances between an in-situ well field and its associated horizontal excursion monitoring wells.

2. To demonstrate that a theoretical excursion can be controlled at these monitoring locations within 60 days of detection using the excursion control procedures outlined in the permit.

Procedure:

1. Simulate mine induced drawdown of the regional potentiometric surface using an appropriate groundwater flow model. This includes **gradient, estimated transmissivities,** estimated aquifer storage, estimated leakage (if applicable), hydrologic boundary conditions, well field size (areal extent), bleed rate including distribution of bleed rate in space and time (individual injection and production may also be simulated), expected life of well field (or, life of monitor well(s), etc.) Acceptable groundwater flow models include Theis (1935), Hantush (1960), Jacob-Hantush (1955), Neuman (1974), etc.

2. Show on a map the estimated potentiometric surface, the locations of important nodes used during simulation (injection, production, bleed, hydrologic boundaries, and selected drawdown calculation nodes). Locate horizontal monitoring wells on the map within the zone of control.

3. Verify that an excursion can be "controlled" within sixty days of detection using the excursion control procedures proposed in the permit. This verification should involve the following procedures and assumptions:

   a. Calculate the hydraulic gradient at the monitor well on excursion, at the time of the excursion. Assume it took 28 days for lixiviant to move thirty feet beyond the monitor well by the time the excursion is called. For example, using the equation for average linear velocity:

$$v = 1 * t = \frac{-K\, dh}{n\, dl}$$

Where:

K	=	hydraulic conductivity
dh/dl	=	hydraulic gradient
l	=	distance beyond monitor well = 10 feet
t	=	time for lixiviant to move 10 feet past the monitor well = 28 days
n	=	effective porosity
v	=	average linear velocity

Solving for dh/dl:

$$\frac{dh}{dl} = \frac{1*t*n}{-K}$$

   b. Raise head at the bleed node which is causing the simulated excursion enough to achieve the calculated gradient between the monitor well on excursion and that node.

c. Run model again using the elevated bleed rate and the estimated potentiometric surface from the first modeling run with the adjusted head value(s) calculated in the previous step. Run the model in ten or twenty day time steps for 60 days. At the end of each time step do the following:

* Obtain the hydraulic gradient at the monitor well
* Calculate the average linear velocity
* Calculate how far the excursion has traveled back towards the well field based on the time elapsed since bleed was adjusted (time steps) and the calculated velocity **OR**
* Calculate the time it would take for excursion to travel the ten feet back to the monitor well assuming the above velocity.
* Answer the questions: 1) Has the hydraulic gradient at the monitor well been reversed by the increased bleed rate at this time? 2) If so, is the present hydraulic gradient sufficient to move the contaminated water back to the monitor well in a reasonable time frame, (e.g., 100 days)?
* If the answers to both questions are "yes" then there is no need to simulate the next time step.

4. To ensure that excursion wells are not placed within the normal operational flare, the following optional steps might be taken:

* Consider two wells in a line: one production well and one injection well.
* Calculate the change in head due to each of the two wells separately at various distances from the wells (e.g. 50' intervals) using the Theis equation, for example.
* The calculation point is beyond the normal operational flare if the change in head due to the recovery well is equal to, or greater than, the change in head due to the injection well.

ATTACHMENT III - TOPSOIL AND SUBSOIL MANAGEMENT AND THE ASSOCIATED EROSION CONTROL AT URANIUM IN SITU LEACHING OPERATIONS

This attachment intends to assist all interested parties in the management of topsoil and subsoil at In Situ Leaching Operations (ISL).

Permittees may propose alternative methods to achieve the basic performance standards embodied in the Wyoming Environmental Quality Act and Chapter XI, "In Situ Mining", Noncoal Rules and Regulations. However, the procedures provided in this attachment are those recommended by the LQD. If any permittee proposes alternative handling procedures, the LQD staff and permittee must agree that alternative procedures are acceptable before using the procedures in the field or before approval of any permitting actions.

I. Objectives

The objective of topsoil and subsoil management plans at In Situ Leaching (ISL) operations is to **minimize** disturbance to the topsoil/subsoil and premine vegetation resource, thereby allowing the postmining land use conditions to be established. This objective is accomplished by limiting areas of disturbance during each wellfield delineation, construction, and operation. Limiting the disturbance and reestablishing the land use is accomplished by minimizing temporary access roads, and segregating topsoil and subsoil during mud pit, pipeline, wellfield construction and other excavations. To minimize disturbance below the surface, preserve soil structure, and to facilitate the reestablishment of native vegetation, topsoil and subsoil are generally not stripped and stockpiled for the entire wellfield area. However, soil stripping in specific wellfield areas where traffic is concentrated (e.g., wellfield pattern area as defined below) may be necessary in site specific situations. The physical and biological characteristics should be considered in all decisions to strip the soil resource. These characteristics should be considered when evaluating the potential for soil erosion or soil contamination.

It is important that the operators protect vegetation, topsoil, and subsoil by reducing traffic routes and promptly replacing the soil where necessary to minimize the impact of mining and help the recovery of vital soil and vegetation. Timely revegetation of affected areas assists in protecting the topsoil/subsoil resource from erosion. Erosion control is essential. Aggressive revegetation efforts should be initiated following completion of any construction activities. Any areas where the topsoil/subsoil or vegetation are stripped should be reseeded before the next growing season. Where vegetation is effected by vehicular traffic, the need for reseeding will be evaluated on a site-by-site basis.

II. Applicable Non Coal Rules and Regulations

The following list of Non Coal Rules and Regulations should be reviewed for handling of topsoil/subsoil at all in situ mining operations.

<u>Definitions</u>
Chapter I, 2. (ay); ARoads@
Chapter I, 2. (bj); ASubsoil@
Chapter I, 2. (bn); ATopsoil@

Environmental Protection Performance Standards
Chapter III, 2. (c)(i); Topsoil
Chapter III, 2. (c)(ii); Subsoil

In Situ Mining (Proposed Rules)
Chapter XI, 3. (a)(ii)(B); A soil survey ...
Chapter XI, 3. (a)(ii)(C); A description of the nature and depth of the topsoil...
Chapter XI, 3. (a)(iii)(G); The procedure(s) used to protect the topsoil...
Chapter XI, 3. (a)(iii)(M); Procedures for insuring that all acid-forming, or toxic materials...
Chapter XI, 3. (a)(iv)(H); Procedures for ground surface preparation, depth of topsoil replacement.

III. Definitions

The following definitions are included to assist both the industry and LQD in assessing the adequacy of topsoil and subsoil management plans and provide consistent nomenclature that operators and regulatory personnel can use.

A. Soil

Topsoil - means the A and E Horizons or any combination thereof (Non Coal Rules and Regulations (R&R), Chapter 1, Sec. 2(bn).

Subsoil - means the B and C Horizons excluding consolidated bedrock material (R&R, Chapter 1, Sec. 2(bj).

Suitable Topsoil and Subsoil - means topsoil and subsoil that meets or exceeds the criteria established in the WDEQ/LQD Guideline No. 1, "Topsoil and Overburden", or those criteria otherwise authorized by the LQD Administrator.

Long-Term Topsoil/Subsoil Stockpile - means a stockpile that exists for a period greater than six months. These stockpiles are associated with more extensive and permanent facilities, such as plant areas, satellite facilities, office areas and primary access roads. These stockpiles might not be used for reclamation of these areas for 10 years or more after stockpile construction.

Short-Term Topsoil/Subsoil Stockpile - means a stockpile that exists for a period less than six months. These small stockpiles are associated with drilling mud pits, pipeline or utility line construction, and similar activities where topsoil/subsoil will be quickly reapplied.

B. Roads

Primary Access Road - means a road constructed at an ISL facility that may necessitate cut and fill with gravel surfacing, or other material, and is constructed for long-term use. These roads are typically used for routine access to the main facility areas including office areas, satellite facilities and includes all haul roads as defined in Chapter 1, Sec. 2.(ay)(i).
2. Secondary Access Road - means a road constructed at an ISL facility that provides access to wellfield headerhouses with limited cut and fill construction. These roads are used for long-term traffic.

They may be surfaced with small sized aggregate or other appropriate material.

3. Temporary Wellfield Access Road - means a road used at an ISL facility for temporary access to drilling sites, wellfields in development, or ancillary areas assisting wellfield development. These roads are temporary in nature (generally in use 2-6 months) and consist of designated two track trails where the land surface is not typically modified to accommodate the road.

4. Well Access Roads (i.e., used to access production, injection, and monitor wells within the monitor ring or wellfield pattern area) - means roads used at an ISL facility for access to wells within the wellfield. These roads are used for limited travel and consist of designated two-track trails where the land surface is not modified to accommodate the road. They are used until they are no longer needed to access the desired location within the wellfield.

C. Wellfields

1. Wellfield Area - means the area located within the monitor well ring.

2. Wellfield Pattern Area - means the area within the wellfield that contains the wellfield patterns of injection and production wells, headerhouses, and associated pipelines and buried electrical lines.

Facilities

1. Permanent or Long-Term Facilities - means office complexes, satellite buildings, main plant facility areas, wellfield headerhouse buildings, construction equipment, evaporation ponds, and oxygen and other gas or chemical storage areas.

2. Temporary Structures and Storage Areas - means those structures or areas used to support short-term construction (less than six months) activity. These activities include equipment (cement, bentonite, piping, vehicles, trailers, etc.) storage or staging areas.

IV. Baseline Characterization of the Soil Resource

A. Generally, all soils within the permit areas at ISL operations should be surveyed at an Order 3 level using methods of the Natural Resource Conservation Service (NRCS). This level of soil survey should be done before the permit is approved. For all areas that will have soil stripped or displaced, including wellfields, salvageable soil depths should be confirmed in the field by a qualified soil scientist or reclamation specialist before initiation of any disturbance. This confirmation may be accomplished by conducting an Order 1-2 soil survey or by digging verification holes on 3 acre grid spacing across the disturbance area. The Order 1-2 soil survey is a standard level of soil characterization used for mining impacts. The information gathered from the more detailed delineation of soil depth should be submitted in the wellfield approval package, before wellfield development. Please refer to Guideline No.1, "Soils and Overburden" for more information on soil baseline characterization.

V. Access During Wellfield Development, Including Delineation Drilling Activities

A. Minimize the number of Temporary Wellfield Access Roads. Strategically locating roads such that they offer the most direct route between operations will result in minimizing these roads. Road placement should avoid drainages, wet or low areas, and take advantage of desirable surface conditions (i.e., ridge line, sandy soils, etc.).

B. Minimize the extent of Temporary Wellfield Access Roads. Vehicles should stay within designated travel ways of minimal width. Topsoil/subsoil is are not generally salvaged from these Temporary Wellfield Access Roads.

C. Vehicle tracks within the wellfield area are unavoidable. However, the operator should limit the disturbance to the vegetation within the wellfield. Patches of undisturbed vegetation on this area will enhance the reestablishment of vegetation both during the producing stages and for final reclamation. Non-essential activities should be reduced or suspended during adverse weather conditions. For example, reduction of activities should occur during very wet periods when soils are saturated and travel is difficult. This recommendation may assist in limiting deep rutting of native areas inside and outside the Wellfield Pattern Area.

D. Minimize vehicular activity during wellfield construction outside the areas that will undergo wellfield development (i.e., outside of Wellfield Pattern Areas). The wellfield area between the wellfield pattern area and the ring of monitoring wells should have limited designated travel routes during the installation process. Multiple two-tracks cris-crossing the undisturbed vegetation outside the wellfield pattern area is detrimental to the vegetation and soil. The LQD recommends planned access to desired areas of the wellfield pattern area.

VI. Topsoil/Subsoil Protection at Facilities Areas and Roads

Most soils in Wyoming have a limited depth of topsoil from 1 to 2 inches. However, subsoil can be deeper than the 60 inch maximum criteria for sampling as described in the LQD Guideline No. 1. The amount of subsoil that should be stripped from facilities and roads, as discussed below, should be evaluated on a site specific basis as allowed by Chapter III, Section 2 (c)(ii)(A) and (B).

A. Permanent or Long-Term Facilities. Suitable topsoil and subsoil should be salvaged from permanent or long-term facilities areas, associated pad (parking) areas, and long-term storage areas. Salvaged topsoil/subsoil should be stored in long-term stockpiles.

Temporary Structures and Storage Areas. Temporary structures used for short- term construction activity or storage (less than six months) are generally not stripped of topsoil/subsoil. However, topsoil and perhaps subsoil should be stripped where it is likely that the soil will be adversely affected by compaction due to repetitive traffic or contaminated by fuel, oil, grease, drilling mud or other such construction materials. The LQD should be consulted when these materials are planned for storage. The conditions, characteristics, duration, and types of items to be stored should be considered before a decision is made to strip the soil from these storage areas.

C. Primary Access Roads. All suitable topsoil and subsoil should be salvaged from the Primary Access Roads that service the permanent/long-term facilities. Salvaged topsoil/subsoil is stored in long-term stockpiles.

D. Secondary Access Roads. Suitable topsoil (A and E Horizons) and possibly all or part of the subsoil should be salvaged from the Secondary Access Roads that service the wellfields and headerhouses. The depth of soil stripped should be **site specific** as determined by the soil horizons, texture, and other factors that will effect erosion or road stability. These soils are stockpiled in long-term stockpiles.

Secondary access roads are constructed progressively as headerhouses are located and wellfield installation proceeds. These roads usually include a gravel surface. During reclamation, an effort should be made to remove the gravel before ripping, in preparation of topsoil/subsoil replacement. Furthermore, gravel road

surfaces containing aggregate of greater than 1.5 inches should be removed before preparing for soil replacement. Any remaining gravel should be ripped and disced into the road base before final topsoil/subsoil application.

E. Monitoring Well Access Roads. The topsoil and subsoil are generally not salvaged from these roads. These designated travel ways are typically two-track trails that are located such that the number and length of roads are minimized. Sensitive areas such as springs and wetlands are avoided. Travel should be limited to light-duty vehicle use.

F. Long-term topsoil/subsoil stockpiles are constructed and designed in accordance with Chapter III, Sec.2 (c)(i)(B) of the LQD Noncoal Rules and Regulations. These stockpiles should have containment berms or ring ditches to conserve the resource.

VII. Drilling Mud Pit Construction

A. Drilling mud pits are constructed to minimize disturbance to the topsoil and subsoil resource. This construction is accomplished by limiting the size of these excavations, segregating suitable topsoil/subsoil to the extent practicable and reapplying the material in the reverse order after activities are completed.

During mud pit construction for delineation drilling activities or pilot hole drilling and well installation, topsoil/subsoil is removed from the excavation and placed in a temporary stockpile. Soil material is stockpiled separately from the material underlying the topsoil/subsoil. This topsoil/subsoil stockpile should be located such that it is not mixed with the pile of deeper earthen material and placed to ensure that it is protected from contamination. Compaction by vehicular traffic should be avoided after stockpiling is completed. Upon completion of wellfield development activities (well installation, pipeline and electrical installation), this stockpiled soil is replaced. Seeding should be accomplished at the earliest appropriate season, either fall or early spring.

Care should be taken during delineation drilling, pilot hole drilling, and well installation to minimize the spilling and/or splashing of drilling fluids, cuttings, or cement on areas outside the mud pit.

When mud pits are backfilled, soils are replaced in the reverse order they were removed. Parent material or subsoils last removed are replaced first. Topsoil/subsoil is placed on the surface of the pit.

VIII. Pipeline Construction

A. Pipelines should be constructed to minimize disturbance to the topsoil and subsoil resource. This construction should be accomplished by limiting, the size (width) of the pipeline trench, segregating topsoil/subsoil and reapplying this soil after activities are completed.

B. During pipeline trench construction, suitable topsoil/subsoil should be removed from the trench and temporarily stockpiled along the trench. The deeper earthen material is piled separately from topsoil/subsoil, to the extent practicable.

C. When pipeline trenches are backfilled, soils are replaced in the reverse order they were removed. Parent material (or in some situationsAC@ horizon subsoils) are replaced first, with topsoil/subsoil being placed on the surface of the excavation. If topsoil is segregated from the subsoil, then topsoil is replaced over the surface of the subsoil. Seeding should be accomplished at the earliest appropriate season, either late fall or early spring.

IX. Wellfield Operations

A. During operation, routine access in wellfields should be limited to Secondary Access Roads and Monitoring Well Access Roads. Traffic off these roads should be restricted to necessary well maintenance, field work and ancillary activities.

B. Access to each wellhead is a necessary part of the day-to-day operations of an ISL facility. Traffic should be limited to the established designated wellfield access and well access roads to reach all pattern wells. During adverse weather, particularly wet ground conditions, activities in vegetated areas of wellfields should be limited when rutting and impact of the soil structure will occur. If rutting occurs, the ruts should be raked out and seeded as soon as conditions will allow.

X. Revegetation and Erosion Control

To avoid the loss of the soil resource during exploration, delineation, development, production, and monitoring phases, it is important that ISL operators practice appropriate measures to limit wind and water erosion. The following practices should be considered:

A. The primary means of erosion control at ISL operations is to minimize impact to vegetation and swiftly reestablish vegetation on disturbed areas. Revegetation is accomplished in two ways: 1) In wellfield areas, quick reestablishment should be accomplished by minimizing the impact to the native vegetation, so vegetation can be reestablished from existing plants and root stock the following growing season; 2) In those areas where the native vegetation is stripped of vegetative cover, seeding with an approved seed mix, at the earliest appropriate season either late fall or early spring, is recommended.

The affected areas within ISL wellfields, temporary wellfield access roads, drill sites, backfilled pipeline corridors, and any ancillary disturbances, should all be seeded at the earliest appropriate season. All reclaimed roads should be ripped or disced before seeding. Seedbed preparation and seeding operations should be conducted on the contour or perpendicular to the prevailing wind direction on flat or level ground. Traffic is restricted on areas that have been reseeded.

C. Drainage bottoms require special consideration. Drainage bottoms should be avoided in all phases of operation where practicable. Erosion control measures are essential to protect all drainages. Erosion control measures are dependent on the following: how much disturbance will occur, expected flows, channel geometry and gradient, soil type, and associated conditions. A fast growing cover crop, mulching, erosion netting, or straw hay bales should be considered to minimize soil erosion and promote revegetation.

D. Long-term topsoil/subsoil stockpiles are constructed to conserve the salvaged soil. This stockpiling is accomplished by constructing the pile with gentle side slopes, which permits seeding with mechanical equipment, promotes revegetation, and reduces potential erosion. A ditch and/or berm is constructed around stockpiles to assist in maintaining the soil in the pile. Topsoil and subsoil stockpiles should be seeded at the earliest appropriate season, either late fall or early spring. Long-term topsoil/subsoil stockpiles should entail fencing, if potential damage from livestock is a concern.

Primary Access Roads and Secondary Access Roads should be designed and constructed to assure adequate drainage to protect the road surface, base, and surrounding undisturbed areas using best available engineering practices such as energy dissipaters, adequate ditches, and culverts. Turnouts should be used in ditches, where appropriate, to minimize the velocity of runoff and reduce potential ditch erosion.

The Storm Water Discharge Plan, or elements comparable to this plan should be attached to the LQD

permit to address run-off control concerns for all roads and wellfields to areas within and adjacent to the operation. Controlling run-off helps to ensure erosion of the soil is minimized.

REFERENCES

American Public Health Association. 1985. Standard Methods for the Examination of Water and Wastewater. 16th Ed. APHA, AWWA, WPCF. Washington, DC.

EPA. 1986. Federal Register 40 CFR 136: Guidelines Establishing Test Procedures for the Analysis of Pollutants Under the Clean Water Act; Technical Amendments and Notice of Availability of Information. Vol. 51, No. 125/Monday, June 30, 1986 Rules and Regulations.

EPA. 1986, September. RCRA Ground Water Monitoring Technical Enforcement Guidance Document. EPA Series.

EPA. 1977. Incorporating Uncertainty into Environmental Regulations in Environmental Monitoring Volume IV. National Academy of Sciences. Washington, DC. pp.139-153.

Harris, J., J.C. Loftis, and R.H. Montgomery. 1987. Statistical Methods for Characterizing Ground-Water Quality. GROUND WATER - March-April. Vol. 25, No. 2 pp. 198-193.

Loftis, J.C., J. Harris, and R.H. Montgomery. 1987. Detecting Changes in Ground Water Quality at Regulated Facilities. Ground Water Monitoring Review - Winter 1987. pp. 72-76.

Miller, I. and J.E. Freund. 1977. Probability and Statistics for Engineers. Prentice-Hall, Inc. Englewood Cliffs, New Jersey. p. 505.

APPENDIX A

Values of "k" for various sample sizes

			$1\ \alpha = 0.95$			$1\ \alpha = 0.99$
n	0.90	0.95	0.99	0.90	0.95	0.99
2	32.019	37.674	48.430	160.193	188.491	242.300
3	8.380	9.916	12.861	18.930	22.401	29.055
4	5.369	6.370	8.299	9.398	11.150	14.527
5	4.275	5.079	6.634	6.612	7.855	10.260
6	3.712	4.414	5.775	5.337	6.345	8.301
7	3.369	4.007	5.248	4.613	5.488	7.187
8	3.136	3.732	4.891	4.147	4.936	6.468
9	2.967	3.532	4.631	3.822	4.550	5.966
10	2.839	3.379	4.433	3.582	4.265	5.594
11	2.737	3.259	4.277	3.397	4.045	5.308
12	2.655	3.162	4.150	3.250	3.870	5.079
13	2.587	3.081	4.044	3.130	3.727	4.893
14	2.529	3.012	3.955	3.029	3.608	4.737
15	2.480	2.954	3.878	2.945	3.507	4.605
16	2.437	2.903	3.812	2.872	3.421	4.492
17	2.400	2.858	3.754	2.808	3.345	4.393
18	2.366	2.819	3.702	2.753	3.279	4.307
19	2.337	2.784	3.656	2.703	3.221	4.230
20	2.310	2.752	3.615	2.659	3.168	4.161
25	2.208	2.631	3.457	2.494	2.972	3.904
30	2.140	2.549	3.350	2.385	2.841	3.733
35	2.090	2.490	3.272	2.306	2.748	3.611
40	2.052	2.445	3.213	2.247	2.677	3.518
45	2.021	2.408	3.165	2.200	2.621	3.444
50	1.996	2.379	3.126	2.162	2.576	3.385
55	1.976	2.354	3.094	2.130	2.538	3.335
60	1.958	2.333	3.066	2.103	2.506	3.293
65	1.943	2.315	3.042	2.080	2.478	3.257
70	1.929	2.299	3.021	2.060	2.454	3.225
75	1.917	2.285	3.002	2.042	2.433	3.197
80	1.907	2.272	2.986	2.026	2.414	3.173
85	1.897	2.261	2.971	2.012	2.397	3.150
90	1.889	2.251	2.958	1.999	2.382	3.130
95	1.881	2.241	2.945	1.987	2.368	3.112
100	1.874	2.233	2.934	1.977	2.355	3.096
150	1.825	2.175	2.859	1.905	2.270	2.983
200	1.798	2.143	2.816	1.865	2.222	2.921
250	1.780	2.121	2.788	1.839	2.191	2.880
300	1.767	2.106	2.767	1.820	2.169	2.850
400	1.749	2.084	2.739	1.794	2.138	2.809
500	1.737	2.070	2.721	1.777	2.117	2.783
600	1.729	2.060	2.707	1.764	2.102	2.763
700	1.722	2.052	2.697	1.755	2.091	2.748
800	1.717	2.046	2.688	1.747	2.082	2.736
900	1.712	2.040	2.682	1.741	2.075	2.726
1000	1.709	2.036	2.676	1.736	2.068	2.718
4	1.645	1.960	2.576	1.645	1.960	2.576

Source: Table 14 on page 505 of Probability and Statistics for Engineers by Miller, I., and J.E. Freund, 1977. Second Edition, Prentice-Hall, Inc. New Jersey