GUIDE TO SPECIFICATION PREPARATION FOR SLURRY WALLS AND CLAY LINERS AS A COMPONENT OF A COLORADO MINED LAND RECLAMATION PERMIT

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Colorado Department of Natural Resources
Division of Minerals and Geology
Michael B. Long, Director
H. Bruce Humphries, Minerals Program Supervisor
Allen Sorenson, Contact Person for this Guide
1313 Sherman Street, Room 215
Denver, Colorado 80203
303/866-3567
http://mining.state.co.us/

INTRODUCTION

It has become a common practice to reclaim gravel pits to a developed water resource land use through the installation of clay pit liners or slurry walls. The purpose of these installations is to isolate the constructed water storage reservoir from the surrounding ground water system. The State Engineer's Office has established design and performance standards for pit liners and slurry walls (see sections on *Post Construction Testing* below). It is the responsibility of the Mined Land Reclamation Board to hold sufficient bond to assure that the State Engineer's performance standard can be met if the Operator of a pit were to default and the state of Colorado were to reclaim the site with the forfeit bond. Under the Division of Minerals and Geology policy on lined pits dated March 29, 2000, Operators may choose the option to bond for 100 percent installation or replacement cost of a slurry wall or pit liner or may select a regulated construction option and become eligible for a 20 percent installation or replacement bond. Operators are free to design and install the liner or slurry wall with relatively minimal design information, specifications and quality assurance detail in the permit application under the 100 percent bonding option. The assurance that the pit will be reclaimed to developed water resources is primarily managed through the amount of bond held by the Board. For an Operator to be eligible for the 20 percent bonding option, the Division must have a high degree of assurance that the liner or slurry wall installed by the Operator will meet the State Engineer's performance standard. This assurance is provided through inclusion of design documents, plans and specifications, and a quality assurance program as enforceable components of the reclamation permit.

This memorandum provides an outline that is intended to guide reclamation permit Applicants that are pursuing the 20 percent bonding option. Applicants that intend to bond for 100 percent of the installation or replacement cost of a slurry wall or clay liner do not have to provide the information

discussed in the following sections in their permit applications. A general plan for liner or slurry wall installation is sufficient for permitting under the 100 percent bond option. Included below are discussions and lists of those elements of designs, plans, and specifications that the Division will look for in applications for lined pits seeking the lower bond amount. The discussion and lists provided are necessarily generalized, and must be tailored to site specific operations and conditions. The examples provided are not intended to be Standard Specifications. Numerical information in the example specifications are typical for the vast majority of slurry wall and clay liner installations, but may be modified if justified to suit specific site conditions. The Mined Land Reclamation Board and the Division of Minerals and Geology want to emphasize that this is a guidance document only and is not a rule or regulation. Any time the Division provides guidance to reclamation permit Applicants, the information is intended to simplify and streamline the permitting process and minimize the need to extend decision dates or involve Applicants in extended adequacy review processes. The guidance provided is not intended to stifle the flexibility Applicants have to design their mining and reclamation plans and is not intended to serve as a template for any future rule making. Applicants may use this guidance to their benefit or may provide an application that does not follow the guidance and propose a different, innovative plan for permitting a slurry wall or clay liner. The Division and the Board will consider each application individually under the terms of the Mined Land Reclamation Act, and no Applicant will ever be penalized for, or encouraged to use the permitting guidance provided in this document.

SLURRY WALLS

The factors that may influence the performance of a slurry wall, and that should be addressed in a reclamation permit application are:

- Design (including construction plans and appropriate drawings)
- Technical Specifications
- Construction Quality Control/Construction Quality Assurance (CQA)
- Final Construction Report including the CQA Engineer's Certification

The design documents and drawings must be sufficient to describe the major construction activities involved in building a soil-bentonite (S-B) slurry wall, which are:

- Preparation of the site
- Slurry mixing and hydration
- Trench excavation
- Backfill preparation
- Backfill placement
- Site cleanup

The slurry is used to hold the trench open until backfill can be placed. Slurry is composed of water with 4-8 percent sodium bentonite. The S-B backfill typically consists of a minimum of 2 percent

bentonite, 20-40 percent fines, and has a moisture content of 25-40 percent. The density of the slurry in the trench must be at least 15 pounds per cubic foot less than the density of the S-B backfill to displace the slurry in the trench during backfilling.

Working Platform and Layout Drawing

An S-B slurry wall generally cannot be constructed in areas with a slope greater than 2 percent along the alignment. Site preparation may require the construction of a clear and stable working platform 40 to 60 feet wide and at least 5 feet above the ground water level. The layout of the slurry wall should be illustrated on a 1"=100' or other appropriately scaled drawing showing property lines, coordinates, contours, existing facilities, and drill hole locations. The erosion control plan should also be illustrated and described. It is important to route runoff away from the trench to protect the purity of the slurry.

Bentonite

The design documents or other preconstruction submittals should include the bentonite manufacturer's certificate of compliance. If these are unavailable during permitting they may be provided with the final construction report and certification, but the standards to be met must be in the technical specifications. Bentonite standards are described in American Petroleum Institute (API) Standard 13A. The following example specification is typical for bentonite.

YP/PV ratio	API Std. 13A	less than 3
Viscometer		greater than 30
Filtrate Loss		less than 15 cm^3
Moisture Content	ASTM D 2216	less than 10 percent

Test results for each lot of bentonite must be provided. The specification should describe how the bentonite will be stored at the site.

Water

Suitable water must be used in the preparation of the bentonite slurry. Water that does not meet specifications must be treated or conditioned or another source of water located. An example of a typical water specification follows:

pH	6-8
Hardness	less than 200 ppm
Total Dissolved Solids	less than 500 ppm
Oil, organics, acids, alkali	less than 50 ppm each
Chloride	report

Bentonite Slurry

The initial bentonite slurry must be tested prior to placement in the trench. The slurry may be mixed in high shear mixers or mixed and hydrated in slurry hydration ponds. In general, a minimum hydration time of 8 hours will allow the bentonite slurry to meet all criteria. The following is an example specification for the bentonite slurry prior to placement in the trench. As a rule of thumb, a minimum bentonite content of 6 percent in the slurry by weight will assure that the requirements will be met.

Viscosity	Measured w/ Marsh Funnel (API RP 13B-1)	less than 40 seconds
Density		less than 64 pcf
Filtrate Loss		less than 20 cm^3
pH		6.5 to 10

The tests listed above should be run 1 or 2 times per shift and at least once per batch of slurry.

The slurry must be further tested after placement in the trench. The tests conducted are for viscosity, density, sand content, and pH. A typical plan would call for two sets of tests per shift at two locations in the trench (approximately 2 feet below the slurry surface and 2 feet above the bottom of the trench). If the density of the slurry in the trench exceeds 85 pcf the excess solids must be removed by desanding or the slurry replaced with fresh slurry. The slurry level must be maintained at least 3 feet above the ground water elevation and no more than 2 feet below the top of the working platform. An example of a specification for slurry in the trench follows:

Unit Weight		1.03 to 1.40 gm/cm^3
Sand Content	ASTM D 4381-84(1993)e1	0 to 20 percent by volume

Soil-Bentonite Backfill

The design should include a slurry trench implementation plan describing the general work sequence and layout of operations. Borings are taken along the proposed alignment of a slurry wall, preferably before the development of plans and specifications. These borings are spaced 100-200 feet apart, depending on the geologic uniformity and nature of the layer the slurry wall will be keyed into. The geotechnical information gleaned from the borings is important to the determination of the suitability of the key layer and potential for the material to be excavated from the trench to be used in the S-B backfill. To obtain a low permeability S-B backfill mixture, plastic soils with an appreciable amount of fines are needed. Two examples of S-B backfill specifications follow:

Example #1

65 to 100 percent passing 3/8” sieve
40 to 85 percent passing #20 sieve
25 to 40 percent passing #200 seive

Roll soil to 1/8 inch thread

Example #2

Screen (US Standard)	Percent by Dry Weight
3 inch	100
# 4	40-80
#40	25-60
#200	20-40
Minimum Plasticity Index of 10	

The design documents should include an S-B backfill testing report. This report should include a description of test results used to prepare the S-B backfill mix design and should include proposed mix proportions, gradations, slumps, densities, permeabilities, and moisture contents. Typically, the only permeability testing to be required would occur during the mix design and testing phase. If the mix is prepared and placed in accordance with the specifications, it can be assumed that the target permeability will be met.

Mixing S-B backfill must be done in such a manner that the material is consistent. This can be done on a separate mixing pad or alongside the slurry trench. It is important that all soil particles are coated with slurry and that clods are broken down. There should be a description of the S-B backfill mixing protocol in the design documents, and the specifications should address minimum mixing standards. Once S-B backfilling operations have begun, it is recommended that trench excavation precede the toe of the S-B backfill slope by at least 30 feet but not more than 100 feet.

Quality control test results for permeability (if needed), slump, density, and moisture content should be supplied by the Contractor as required by the specifications and quality control plan for the S-B backfill. Third party quality assurance testing should also be specified. Placement of S-B backfill should be done such that there are no pockets of trapped slurry. The plans and specifications should describe acceptable backfilling methods and prohibit free dropping of S-B backfill. An example specification and quality assurance protocol for S-B backfill mix is provided below.

S-B backfill slump	ASTM C 143	1 set per 100 cu. yds.	Slump 2-6 inches
S-B backfill gradation	(various standards)	1 set per 300 cu. yds.	-65 to 100 percent passing 3/8” sieve -40 to 85 percent passing #20 sieve -25 to 40 percent passing #200 sieve

Key Trench and Slurry Wall Cap

During excavation, soundings should be obtained to determine the elevations of the top of the key layer, the bottom of the excavation, and the bottom of the trench prior to backfilling. If sediments in excess of 2 inches have accumulated it is necessary to clean the trench bottom by airlift pumps or excavation equipment to remove the sand and sediment that has settled. The trench bottom should be cleaned, as a minimum, at the beginning of each shift. Soundings should be obtained approximately every 20 feet.

Many of the leakage issues with slurry walls can be traced back to inadequate keying in the S-B backfill to an impermeable layer at the base of the wall. The design documents should include a description of the key in layer and describe how trench cuttings or other observations will be used to assure that the slurry wall will be adequately keyed. At most gravel pits, slurry walls are keyed into shale underlying the sand and gravel. If the shale is weathered, fractured, or contains sand lenses, it may be necessary to provide a deeper key trench. This should be addressed in the design.

The specifications should call for temporary slurry wall protection in the form of a noncompacted soil cover placed within one day over each backfilled 100 foot reach. The temporary cover is removed after settlement (approximately 2 weeks) and replaced with a compacted clay cover over the completed slurry wall.

Post Construction Testing

Typically, post construction testing will be conducted in accordance with the "State Engineer Guidelines for Lining Criteria for Gravel Pits," August 1999, section 3.1. This document is available from the Office of the State Engineer or online at http://water.state.co.us/pits.htm. Once an Operator can document that the State Engineer has determined the lined pit meets performance standards, the Division of Minerals and Geology can release the portion of the bond that covers slurry wall installation.

As-Built Drawings and Final Report

Under the regulated construction option, Operators are required to provide a final construction report detailing the installation of the slurry wall, describing any problems that occurred, and listing the results of testing that was conducted under the approved quality assurance/quality control plan. An example table of contents for the final report is provided below.

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CLAY BACKFILL PIT LINERS

Applicants seeking the lower bond amount available under the regulated construction option for a reclamation plan that includes a clay lined reservoir must provide a design for the liner. The intent of the design can be effectively conveyed through plan and section views of the pit perimeters where a liner will be installed. The liner cross section should illustrate the dimensions and shape of the liner fill to be installed, the location, size, and shape of the keyway, and the dimensions of liner cover fill that will protect the liner soil from desiccation and erosion. The design should address the following elements that may affect the performance of the liner.

Liner Fill Mixture

- *Fines* - The liner fill should contain at least 20 percent fines defined as the percentage, on a dry weight basis, of material passing the No. 200 sieve.
- *Plasticity Index* – The soil should have a plasticity index of at least 10 percent, although some soils with a slightly lower index may be suitable. Soils with plasticity indices less than about 10 percent have very little clay and usually will not produce the necessary low permeability. Soils with plasticity indices greater than 30 to 40 percent are difficult to work with, as they form hard chunks when dry and sticky clods when wet.
- *Percentage of Gravel* – The percentage of gravel (material retained on the No. 4 sieve) should in general not exceed 10 percent. Larger percentages are acceptable if it can be demonstrated that the design standard for permeability can be achieved and that segregation of gravel into pockets that contain little or no fines will not occur during installation.
- *Stones and Rocks* – No rocks larger than 2 inches should be present in the liner material.

If two or more materials will be blended to prepare the liner fill, a description of the mixing process should be included in the design documents. For example, an Operator may choose to prepare the liner fill by mixing 50 percent weathered shale ripped from the floor of the pit with 50 percent overburden. The mixing may be accomplished by a number of methods such as windrowing of the materials and multiple passes of mixing equipment such as a road reclaimer.

Water Content

The molding water content at which the maximum dry unit weight is observed for a given compactive energy is termed the optimum water content. Soils compacted wet of the optimum water content tend to have lower permeability. This is because a soil that is slightly wet of optimum will more readily mold into a homogeneous mass that is free of clods. For liner fill, moisture content slightly wet of optimum should be specified. For example:

> Material represented by the samples tested having a water more than 1 percent dry of the optimum water content, or more than 3 percent wet of the optimum water content will be rejected and shall be removed or reworked until the water content is between these limits.

> Supplementary water, if required, shall be added to the material by sprinkling on the earth fill, and each layer of earth fill shall be conditioned by disking or other approved methods so that the water is distributed uniformly throughout the layer.

Mechanical mixing to distribute water evenly in the soil is particularly important for highly plastic soils that form large clods.

Compactive Energy

The energy of compaction is an important variable controlling the engineering properties of soil liner materials. Increasing the energy of compaction increases the dry unit weight of the soil, decreases the optimum moisture content, and reduces permeability. The compactive energy delivered to soil depends on the weight of the compaction equipment, the number of equipment passes, and the thickness of the loose lift of soil being compacted. The best combination of these factors to use when compacting low permeability soil liners depends on the targeted maximum permeability, equipment availability, economic feasibility, experience on similar projects, and test results with the site specific soils. For a typical soil liner fill composed of weathered shale, the specifications may call for a minimum of 5 passes over a maximum 9 inch thick loose lift with a 40,000 pound or greater compactor.

Size of Clods

Highly plastic soils almost always form large clods. For soils that form clods, they must be remolded into a homogeneous mass that is free of large inter-clod pores if low permeability is to be achieved. As discussed previously, when the soil is compacted wet of optimum that clods are sufficiently soft to be easily remolded. If dry clods must be reduced in size prior to compaction, which may be the case when using ripped shale as a liner material, a road reclaimer or other similar equipment may be used to pulverize the material.

Bonding of lifts

Proper bonding of lifts is important in achieving low permeability in soil liners. Poorly bonded lifts result in high horizontal permeability at lift interfaces. Water moving through a liner will spread laterally along these interfaces increasing the likelihood of leaking at any permeable zones that may be present in the underlying lift. To bond lifts together, the surface of the previously compacted lift should be roughened so that the new lift can blend into the surface. The design should address lift bonding by specification of discing lift surfaces or using compactors with tamping feet long enough to fully penetrate the specified loose lift thickness.

Keyway

The wedge of soil liner fill that will form the impermeable barrier around the perimeter of a reservoir must be keyed into a competent impermeable strata at the floor of the pit. The keyway is installed by

first excavating a trench with a flat floor and sloping sides around the perimeter of the reservoir at the midpoint of the wedge of soil liner fill that will be installed. Trench excavation continues until impermeable material is penetrated to the depth listed in the specifications. The keyway is backfilled with soil liner fill that is compacted in accordance with the specifications.

Soil Liner Cover Fill

The design should describe the materials that will be used to bury the soil liner and the depth of burial to prevent desiccation, freeze-thaw effects, and erosion. Typically, the wedge of soil liner fill may by covered by several feet of random fill, and the reservoir perimeter protected from wave erosion by a layer of pit run gravel or riprap depending on the size of the water surface and the anticipated wave generation.

Specifications

The Division of Minerals and Geology does not require that Applicants provide the complete set of technical specifications for a soil liner project. However, certain elements of the specifications should be incorporated into the reclamation permit to become eligible for the lower bond under the regulated construction option. These elements are outlined in the following list of typical examples:

- Submittals - Provide a basic earthwork operations plan and schedule for the installation of the soil liner and the soil liner cover fill. Include a description of the equipment and quality control procedures to be used, including lift thickness control, composite material preparation, and methods for moisture conditioning.
- Materials – Soil liner and soil liner cover fill shall be free of organic matter, debris, frozen material, and other deleterious materials. Soil liner fill shall be excavated from approved borrow areas and conform to the following (example) specification:

U.S. Standard Sieve Size	Percent Passing by Dry Weight
3/4-inch	100
3/8-inch	70-100
No. 4	50-100
No. 40	20-50
No. 200	20-50
Plasticity Index	10 minimum

- Excavations – Excavations shall be graded and properly maintained to provide adequate drainage at all times. Work shall be suspended when the site is overly wet, muddy, or otherwise unsuitable for proper maintenance. In excavations where soil liner fill is to be placed on slopes steeper than

3H:1V, horizontal benches shall be excavated into the slope to allow fill to be placed in horizontal lifts and to eliminate potential weak interfaces between the fill and native ground. Embankment material shall be continuously benched and keyed into the existing material a minimum of 2 feet.

- Fill Placement –
  - ✓ The distribution of materials shall be such that the fill is free from voids, lenses, pockets, streaks, or layers of material differing substantially in texture or gradation from the surrounding material.
  - ✓ The fill surface shall be at or near the same elevation at all times during construction; the maximum permissible difference in elevation between fill surfaces shall be 3 feet. At all times during construction, the surface of the fill shall be graded to prevent ponding of water and maintained for storm water drainage.
  - ✓ Fill placement shall occur by routing the hauling and spreading units approximately parallel to the axis of the fill. As far as practical, hauling units shall be so routed that they do not follow in the same paths, but split their tracks evenly across the surface of the fill to enhance compaction.
  - ✓ Water required for moisture conditioning shall be applied on the fill or in the borrow areas using water trucks with spray bars for even distribution of water. Adjustments in moisture content shall be made principally in the borrow area. Fill materials shall be maintained within the moisture content range required to permit proper compaction to the specified density with the equipment being used. The moisture content of the fill materials, prior to and during compaction, shall be uniform throughout each layer of the material. Mixing of wet and dry material on the fill to obtain the proper moisture content shall not be allowed.
  - ✓ After each layer of fill has been placed, spread, and moisture conditioned, the layer shall be compacted by passing compaction equipment over the entire surface of the layer a sufficient number of times to obtain the required density. Prior to placement of subsequent lifts, the previous lift shall be thoroughly scarified to a depth of 2-inches to provide good bonding between lifts. Scarification shall be accomplished by discing, raking with a grader, or approved alternative method.
  - ✓ Soil liner fill shall be placed and compacted to achieve a coefficient of permeability of less than $1x10^{-6}$ cm/sec.
  - ✓ Compact the soil liner fill to at least 95 percent of the maximum dry density as determined by the Standard Proctor density test (ASTM D 698) at a moisture content between 1 percent below and 3 percent over the optimum moisture content.
  - ✓ In order to resume soil liner fill placement or other operations following an occurrence of inclement weather, unsuitable material shall be removed and dried.
  - ✓ Desiccation and crusting of the soil liner lift surface shall be avoided as much as possible. Cracked areas and swelling, heaving, or other similar conditions shall be replaced or reworked to remove such defects.

Construction Quality Assurance Plan

This plan addresses the construction quality assurance (CQA) procedures for the installation of the earthworks components for a clay liner reservoir project. The CQA program is developed to assure that the construction of the soil components are in compliance with the project specifications and to demonstrate achievement of the construction regulatory requirements.

The CQA monitor is the firm or individual responsible for performing the quality assurance tasks. The specific responsibilities of the CQA monitor include:

- review the drawings, specifications, and related guidance documents;
- observe excavation activities and backfilling operations;
- obtain preconstruction and construction samples and perform material evaluation testing as required;
- monitor and document material placement, including soil type, clod and particle size, loose lift thickness, moisture conditioning process, compaction equipment and methods, number of passes, uniformity of compaction coverage, compacted lift thickness, bonding of lifts and in-place moisture content and dry density is as required by the specifications;
- assure that testing equipment used and tests performed are conducted according to specifications and industry standards;
- document and report test results;
- report any deficiencies in the construction and their resolution;
- prepare a construction certification report describing the construction, any deviations from specifications or drawings and details (with reasons and resolutions), field and laboratory test data and results, and will include professional certification that construction was completed in accordance with the plans and specifications.

The following table is an example of a CQA testing protocol for a clay liner project.

SOIL LINER TESTING FREQUENCY
VOLUME PER TEST[1]

Test and ASTM Designation	Soil Liner Fill (cy)
Compaction (ASTM D 698)	5,000
Particle Size (ASTM D 422)	5,000
Atterberg Limit (ASTM D 4318)	5,000
Moisture Content (ASTM D 2216)	500
Permeability (ASTM D 5084/2434)	15,000
Nuclear Density[2]	500

1. Specified frequency or one per material type, whichever is greater.
2. Specified frequency or minimum of four per day, whichever is greater.

Post Construction Testing

Typically, post construction testing will be conducted in accordance with the "State Engineer Guidelines for Lining Criteria for Gravel Pits," August 1999, section 3.1. This document is available from the Office of the State Engineer or online at http://water.state.co.us/pits.htm. Once an Operator can document that the State Engineer has determined the lined pit meets performance standards, the Division of Minerals and Geology can release the portion of the bond that covers clay liner installation

PERMITTING OPTIONS

Frequently, the process of permitting a gravel pit and lined reservoir project precedes the design phase making it difficult and costly to prepare and application that will qualify for the regulated construction option and the reduced bond amount. The following list describes permitting mechanisms that may be employed to allow application approval prior to design and specification preparation and preserve the option to post the reduced bond amount available under the regulated construction option.

- An application could include a general description of the clay liner or slurry wall installation, similar to what would be sufficient under the 100 percent performance bonding option. The application would be approved with a commitment stating that a liner or slurry wall design, specifications, and quality assurance plan would be submitted as a technical revision and the revision would be approved prior to the exposure of ground water in the pit.
- An applicant may find it difficult to design a clay liner mix and specifications for gradation and plasticity until after a pit has been opened up and representative samples of overburden and underlying bedrock can be collected. In order to permit and bond for a clay liner when the liner soil specifications have not yet been developed, an Applicant may include in the bond a cost for mixing bentonite into the liner soil. This will assure that a low permeability material can be created from virtually any fine grained overburden, even if the overburden is non-plastic. The amount of bond dedicated to adding and mixing in of bentonite may be released once the pit soils have been tested and demonstrated to be suitable for lining.
- There are circumstances where an Applicant proposes to install a slurry wall prior to initial excavation in the pit. This method has the advantage minimizing water inflows and dewatering costs during mining. If an Applicant commits to complete installation of the slurry wall prior to exposing ground water in the pit, and can demonstrate that the slurry wall performs up the standards established by the State Engineer, bonding for the slurry wall may be waived. However, it may be difficult to demonstrate that the slurry wall is performing up to standard until after the pit has been excavated and the rate of any inflows can be measured over time. If an Operator can provide the Division with a construction report and engineer's certification of the slurry wall prior to the exposure of ground water, and the Division accepts that the report and certification demonstrate that the slurry wall will function up to standard, then the operation would be eligible for the reduced (20 percent of replacement cost) slurry wall bond.

SUMMARY

Applicants proposing a developed water resources post mining land use through installation of slurry walls and clay liners may post a smaller reclamation bond through selection of the regulated construction option. If the factors that relate to the performance of slurry walls and clay liners discussed in this memo are addressed in the permit application, Operators will be eligible for the lower bond amount. These factors are addressed by supplying design plans, drawings, specifications, and a quality assurance plan that will be enforceable components of the reclamation permit. Applicants must also provide a statement that the plans and specifications, once approved, could not be altered without consent by the Division. The operator would be required to advise the Division of the schedule for construction so that inspections could be scheduled at appropriate times during installation. The operation would be further required to provide a construction report detailing the installation of the slurry wall or liner, describing any problems that occurred, and listing the results of testing that was conducted under the approved quality assurance/quality control plan. A certification would be required to accompany the construction report with a statement from the quality assurance engineer that the facility was constructed in accordance with the approved plans and specifications. The Division of Minerals and Geology encourages Applicants to use permit commitments and contingencies to reduce the amount of bond required for permitting of slurry walls and clay liners. The basis of any bonding scheme is predicated on the basis for all reclamation bonding; that at any point in the life of the operation of a pit, the state must hold sufficient bond to implement the approved reclamation plan and establish the approved beneficial post mining land use.

ATTACHMENTS: Policy memo dated 3/29/00 on lined sand and gravel pits, 6 pages.
Addendum to the 3/29/00 policy memo, dated 5/9/00, 2 pages.

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STATE OF COLORADO

DIVISION OF MINERALS AND GEOLOGY
Department of Natural Resources

1313 Sherman St., Room 215
Denver, Colorado 80203
Phone: (303) 866-3567
FAX: (303) 832-8106

DIVISION OF MINERALS & GEOLOGY
RECLAMATION MINING·SAFETY

MEMO

MINERALS PROGRAM POLICY

TO: Minerals Staff

FROM: HBH

DATE: March 29, 2000

RE: Policy On Application Reviews Involving Lined Sand and Gravel Pits

The Division has received comments from applicants and their consultants concerning Division request for design information related to lined sand and gravel pits. These comments questioned the need for such information, as well as the Division's technical ability to review it.

It is clear that the Division has a need for such design information in order to calculate an appropriate reclamation bond. It is also clear that the Division has the technical expertise necessary to review the engineering evaluations and designs. However, it is correct that the actual authority to review and approve such designs rests with the Office of the State Engineer (SEO). This review and approval authority is clearly stated in their "Proposed Guidelines for Lining Criteria For Gravel Pits"(8/16/99), and verified through conversations with personnel in the Office of the State Engineer.

Therefore, the Minerals Program will no longer approve engineering designs for installing liners that are intended to meet SEO water rights protection criteria. An applicant, however, shall be required to provide DMG any of the following in order to demonstrate compliance with Section 3.1.6 of the Construction Material Rules:

- A copy of the SEO's letter approving the proposed liner design and a copy of the design and specifications for inclusion into the applicant's application prior to the Division's approval or recommendation date, or
- A commitment to stay at least two feet above the historic highest ground water level together with an adequate means to monitor compliance, or
- A bond adequate to backfill the pit to two feet above the historic highest ground water elevation, or
- A letter from the SEO stating that the applicant has satisfied the SEO requirements for an augmentation plan or substitute supply plan for ground water exposed to evaporative loss and has an associated well permit.

An applicant must still provide the Division an adequate analysis of the hydrologic impacts to surrounding property owners and well owners as part of DMG application process. In addition, the SEO approved plans and designs shall be used to calculate an appropriate financial warranty.

Where there is no SEO approved liner plan, the applicant will need to supply an interim reclamation plan. Such a plan will describe a reclamation plan for a site that does not include a lined pit. Once SEO approval is obtained for the liner design and construction, the applicant/operator may submit a permit modification to the application in order to change the reclamation plan. Based on the degree of difference between the interim reclamation plan and the reclamation plan for a lined pit, the Division will determine if the change is a Technical Revision or an Amendment to the application or permit.

An Illustrative Example:

Introduction

An applicant proposes the installation of a slurry wall around the pit area prior to commencement of mining. Design details and SEO approval letter are provided but no specifications or quality control/quality assurance plan is included in the application. The applicant proposes to bond for the cost to install the slurry wall. Such a bond should serve as a contingency if leakage were to occur in excess of criteria established by the Office of the State Engineer or if the slurry wall were to be damaged by pit slope failure. The unit cost supplied by the applicant in Exhibit L used to establish the amount of required bond is ($X) per square foot of slurry wall assuming a wall depth of (Y) feet.

Lined reservoirs that employ slurry walls to prevent hydrologic communication with ground water are a viable water storage alternative and are adequate to meet the developed water resources post mining land use. However, leakage of ground water through or around the slurry wall into the pit at a rate in excess of SEO requirements would constitute a failure to achieve the designated post mining land use. If an operator were to mine out a pit within the perimeter of a previously installed slurry wall, and it were subsequently determined that ground water was leaking into the pit at a rate in excess of SEO requirements, the operator would be faced with the following three options:

- Improve the seal in the pit to meet the State Engineer's leakage criteria.
- Change the post mining land use and provide water to augment for ground water leaking into the pit that is lost to evaporation.
- Backfill the pit so that water is no longer exposed to the atmosphere.

In the event the Division were to assume responsibility for reclamation of the pit through bond forfeiture, we may be confronted with the same situation and the same three options. Of these options, water augmentation in the river basin and back filling of the pit with inert fill would be the most costly. Also, neither of these options would result in reclamation to the developed water resources use. This leaves the option of assuring that leakage into the pit is less than SEO requirements through reinstallation or repair of the slurry wall.

The Division would propose two permitting options suitable for assuring that the post mining land use of developed water resources will be established at the site through the installation of slurry walls. These options are described below.

Regulated Construction Option

The applicant may provide design drawings and specifications for the installation of the slurry wall along with a quality assurance/quality control plan. These documents would be binding under the terms of the permit, and the Division would require a statement that the plans and specifications, once approved, could not be altered without consent by the Division. The operator would be required to advise the Division of the schedule for construction of the slurry wall so that inspections could be scheduled at appropriate times during installation. The operator would be further required to provide a construction report detailing the installation of the slurry wall, describing any problems that occurred, and listing the results of testing that was conducted under the approved quality assurance/quality control plan. A certification would be required to accompany the construction report with a statement from the quality assurance engineer that the slurry wall was constructed in accordance with the approved plans and specifications.

With the level of regulatory control over the installation of the slurry wall described above, the State would gain a high degree of assurance that the SEO required design standard leakage criterion is attainable. With this level of assurance, contingency bonding for repair or replacement of 20 percent of the total linear feet of slurry wall is acceptable. The number of linear feet of slurry wall and the slurry wall installation costs for the site are discussed below. A table summarizing a typical specification and quality control plan is attached.

Performance Bonding Option

In this option, the operators are left to their own devices in the design, installation, and testing of the slurry wall, but would be required to demonstrate that the slurry wall limits leakage into the pit in accordance with the State Engineer's criteria. In this case, the Division would not have regulatory control over construction of the slurry wall, and would bond for the cost to install a complete replacement slurry wall. The performance bonding option considers the worst case scenario where the slurry wall has been installed and the pit has been mined out, but it is determined that the slurry wall leaks in excess of SEO requirement. Another consideration that enters into bonding for this worst case scenario is the potential for leakage into the pit through the bedrock pit floor. Unless the applicant can provide a geological evaluation of the proposed pit floor bedrock that demonstrates that leakage will not occur, the Division should bond for sealing fractured or sandy bedrock that may be uncovered during mining and that may leak in excess of SEO established criteria at this time.

Reservoir Filling

Past practices by the Division in permitting lined reservoirs included a requirement to provide bond sufficient to purchase enough water from a reliable source to fill the reservoir one time. Numerous gravel pits have been reclaimed or are proposed to be reclaimed as lined storage reservoirs since the passage of Senate Bill 120 in 1989. It has become clear that there is a great demand for lined storage in over appropriated basins. It is no longer a substantial concern to the Division that lined reservoirs will not be filled and put to their intended beneficial use along the Front Range. In the worst case, virtually any reservoir along the Front Range could be filled

eventually by using junior water rights in priority. For these reasons, the Division will not require bonding to fill reservoirs for operations along the Front Range. However, the Division will require a statement from the applicant describing their conceptual plan for filling the reservoir.

Slurry Wall Costs

Slurry wall installation costs include geotechnical investigation and testing, design and quality control, mobilization and setup, excavation of regolith, excavation of the bedrock key, delivery of bentonite and water, mixing of slurry, mixing of soil/bentonite, backfilling of soil/bentonite, clean up and demobilization, and testing and quality assurance. Specialized equipment is required to excavate deep slurry trenches, and the cost of excavation increases dramatically for trenches deeper than 35 feet and/or if the bedrock into which the slurry wall will key is hard or otherwise difficult to excavate. However slurry wall costs may or may not be substantially increased by depth to bedrock or by excessive difficulty in excavating the key trench, depending on mine site location.

The following slurry wall cost references are illustrative:

- The U.S. Army Corps of Engineers installed slurry walls in an extensive levee improvement project in the Pocket area near Sacramento, California. These slurry walls were 30 feet deep with a reported unit installation cost of $5.00 per square foot.
- The Federal Remediation Technologies Roundtable "Remediation Technologies Screening Matrix and Reference Guide" reports slurry wall installation costs of between $5.00 and $7.00 per square foot.
- Environmental Protection Agency document EPA 542-R-98-005, "Evaluation of Subsurface Engineered Barriers at Waste Sites," August 1998 reports slurry wall installation costs of between $5.00 and $15.00 per square foot.

  The costs to install slurry walls at waste containment sites are higher than the costs to line clean water reservoirs using a slurry wall. This is partially due to the need to conduct chemical compatibility testing and the higher degree of quality control used at waste containment sites.

In a recent case, the applicant proposed a unit cost of $3.00 per sq. ft for slurry wall installation, and based on our review of recent bids for slurry walls around gravel pits on the Front Range, this is believed to be appropriate at this point in time. The slurry wall bond, whether it is for installation around the entire reservoir perimeter or is a 20 percent contingency bond as discussed above, should not be released until DMG is provided written confirmation from the OSE that the specified leakage criteria has been met.

As stated above, it is pertinent to the bond amount that the depth to bedrock used in estimating the extent of the slurry wall required is accurately determined and that nature of the bedrock is investigated. The applicant should provide information from bore holes at the site showing the depth to gravel and the type of bedrock present, any variability in the bedrock encountered, and the depth of weathering in the bedrock. It is implicit to the proposed slurry wall plan that the bedrock is a competent seepage barrier, and this is most likely to be the case. However, if fractured zones, sandy lenses or layers, or deeply weathered bedrock are present, pit floor lining or a deeper bedrock keyway for the slurry wall may be required. Either solution would increase

the reclamation cost that may be imposed upon the State in a financial warranty forfeiture, and must be covered by the reclamation bond. Assuming that the bore hole information demonstrates that the bedrock is no more than 36 feet below the surface and is an adequate seepage barrier, the following estimate is provided as an example calculation for a sand and gravel mining operation slurry wall:

36'depth x 8222' length x $3.00/sq.ft. = $887,976.00 direct costs

If the 20% regulated construction bond is selected the required bond for slurry wall installation would be $177,595.00.

Regulatory Responsibility

The final approval and success criteria for the performance of the slurry wall to seal and isolate the reservoir-storage from the surrounding alluvial aquifer lies with the State Engineer. The Division of Minerals and Geology is required to hold financial warranties sufficient to assure that the State Engineer's standards will be met in the event the state becomes responsible for the site. To release a slurry wall financial warranty, an operator must provide the Division documentation of compliance with the State Engineer's lined reservoir performance standards. (The Memorandum of Understanding between the Division of Minerals and Geology and the Office of the State Engineer describes in detail the division of responsibilities between the two agencies.)

attachment(s)

C:policy/policy on lined gravel pits

TABLE 1
Materials Quality Control Program
Soil/Bentonite Slurry Trench Cut-Off Wall

SUBJECT		*STANDARD*	*TYPE OF TEST*	*MINIMUM FREQUENCY*	*SPECIFIED VALUES*
Material	Water	----	-pH -Total Hardness	Per water source or as changes occur	As required to properly hydrate bentonite with approved additives
	Additives	----	Manufacturers certificate of compliance with stated characteristics	One time	As approved by Engineer
	Bentonite	API Std 13A	Manufacturers certificate of compliance	One time	Premium grade sodium cation montmerillonite
	Backfill Soils	----	Selected soils obtained from a borrow area approved by the Engineer	Per borrow source or as changes occur	-65 to 100% passing 3/8" sieve -40 to 85% passing #20 sieve -25 to 40% passing #200 sieve Roll to 1/8" thread
Slurry	Prepared for Placement into the trench	API Std 13B	-Unit Weight -Viscosity -Filtrate Loss -pH	1 set per shift or per batch (pond)	Unit weight ≥ 1.03 gm/cc V ≥ 40 sec-March @ 68° Loss ≤ 30 cc in 30 min. @ 100 psi pH ≥ 8
	In Trench	API Std 13B 1	-Unit Weight -Sand Content	1 set per shift at point of trenching	Unit weight = 1.03 - 1.40 gm/cc - Sand content = 0 to 20% by volume
Backfill Mix	At Trench	ASTM C 143	-Slump -Gradation	1 set per 100 cu/yds. 1 set per 300 cu/yds.	-Slump 2 to 6 inches -65 to 100% passing 3/8" sieve -40 to 85% passing #20 sieve -25 to 40% passing #200 sieve

STATE OF COLORADO

DIVISION OF MINERALS AND GEOLOGY
Department of Natural Resources

1313 Sherman St., Room 215
Denver, Colorado 80203
Phone: (303) 866-3567
FAX: (303) 832-8106

DIVISION OF MINERALS & GEOLOGY
RECLAMATION MINING·SAFETY

MEMO

MINERALS PROGRAM POLICY

TO: Minerals Staff

FROM: HBH

DATE: May 9, 2000

RE: Addendum To The Minerals Program Policy On Application Reviews Involving Lined Sand and Gravel Pits, Original Policy Dated march 29, 2000

This addendum was prepared by Division staff at the request of a consulting company, and is intended to address specific concerns that have been raised by users of the 3/29/00 policy.

1. Under the regulated construction option, an Operator is required to provide a construction report detailing the construction of a slurry wall or pit liner. The report would typically include a project description, construction summary, a description of any problems that occurred and their resolution, a discussion of construction quality assurance observations and a tabulation of test results. The report would also include a certification from the quality assurance engineer that the facility was constructed in accordance with the approved design plan. The regulated construction option also requires Operators to provide a commitment that approved plans and specifications will not be altered without the Division's consent and to provide a construction schedule to facilitate inspections by the Division. With this level of regulatory control over the installation of the slurry wall and pit liner, the Division would not typically require submittal of any interim construction reports. A final construction observation report submitted following completion of the facility is sufficient. Operator's must summarize the progress on installation of slurry walls and pit liners that take more than one year to complete in the annual reclamation report required under 34-32.5-116(3)(a), C.R.S. However, the level of detail required in the annual reclamation report is much less than in the final construction observation report. Information required in the annual report includes a discussion and a map showing the extent of current disturbances to affected land, liner or slurry wall installation accomplished to date and during the preceding year, new disturbances that are anticipated to occur during the upcoming year, liner or slurry wall installation that will be performed during the coming year, and the dates the liner or slurry wall installation occurred during the report year.

2. The discussion and example specifications and quality assurance plan included in the 3/29/00 policy are not intended to be exhaustive. The 3/29/00 policy memo example includes no discussion of pit liners and does not go into detail on the necessary quality assurance

observations for slurry wall installations. For example, the policy memo includes no discussion of critical slurry wall installation observations such as trench key confirmation and no discussion of important slurry wall installation practices such as cleaning of the trench bottom to remove sediments. The policy memo is not a guideline to design and permitting of slurry wall and pit liner installations.