From: Wyoming Mining Association [mailto:wma@vcn.com]
Sent: Monday, December 13, 2010 5:34 PM
To: zzMSHA-Standards - Comments to Fed Reg Group
Subject: Fw: WMA Comments regarding RIN 1219-AB70 1 of 3 emails

2010 DEC 13 P 6:20

Please find the first email regarding Comments on RIN 1219-AB70. 1 of 3

Pat Morran
Office Manager
Wyoming Mining Association
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AB70-COMM-24

WYOMING MINING ASSOCIATION

December 13, 2010

MSHA
Office of Standards, Regulations, and Variances
1100 Wilson Boulevard, Room 2350,
Arlington, Virginia 22209–3939

Subject: **RIN 1219–AB70 - Comments on Advance Notice of Proposed Rulemaking (ANPRM) Metal and Nonmetal Dams Federal Register / Volume 75, Number 156 / Friday, August 13, 2010 / Proposed Rules pages 49429 to 49432**

The Wyoming Mining Association (WMA) is an industry association representing mining companies, contractors, vendors, suppliers and consultants in the State of Wyoming. Among its mining industry members are uranium recovery licensees, including in-situ and conventional uranium recovery operators, several companies planning new uranium recovery operations and several companies conducting final reclamation/restoration operations. The Association has reviewed the **Advance Notice of Proposed Rulemaking (ANPRM) Metal and Nonmetal Dams Federal Register / Volume 75, Number 156 / Friday, August 13, 2010 / Proposed Rules pages 49429 to 49432** and has the following comments on it as it pertains to uranium recovery in Wyoming::

Applicability to Uranium Recovery Operations

The applicability of any Mine Safety and Health Administration (MSHA) regulations to uranium recovery operations in Wyoming is discussed below in terms of the three (3) types of uranium recovery operations that either exist or could exist in the State

In-situ Uranium Recovery Operations

This document is not directly applicable to in-situ uranium recovery operations in Wyoming, since such operations in Wyoming are regulated by the Wyoming Department of Employment Division of Occupational Safety and Health.

Conventional Uranium Mills and Heap Leaching Operations

Conventional uranium mills in Wyoming are inspected by the State Mine Inspector under an agreement with the Wyoming Department of Employment Division of Occupational Safety and Health. The State Mine Inspector enforces Mine Safety and Health Administration (MSHA) rules hence any rules applying to impoundments would impact conventional uranium mills and associated tailings impoundments and fluid retention impoundments.

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Conventional (underground and surface) Uranium Mines

These are regulated by both the Mine Safety and Health Administration (MSHA) and the State Mine Inspector and any changes to Mine Safety and Health Administration (MSHA) rules would impact them directly.

Types of Impoundments Present in Different Aspects of the Uranium Recovery Industry

The types of impoundments likely to be found at the three (3) different types of operations are described below:

- **In-situ Uranium Recovery Operations**
  These operations generally possess fluid retention impoundments such as evaporation ponds and fluid storage ponds.

- **Conventional Uranium Mills and Heap Leaching Operations**
  These operations have both tailings impoundments or heap leach pads (which would be treated like tailings impoundments) and fluid retention impoundments such as evaporation ponds and fluid storage ponds.

- **Conventional (underground and surface) Uranium Mines**
  These operations can have sediment retention ponds and fluid retention impoundments such as evaporation ponds and fluid storage ponds.

Primary Federal and State Regulatory Jurisdiction over Uranium Recovery Operations

The following Federal and State agencies have regulatory jurisdiction over the three (3) types of uranium recovery operations in Wyoming:

- **In-situ Uranium Recovery Operations**
  - Nuclear Regulatory Commission
  - Department of Environmental Quality (DEQ)
  - Bureau of Land Management (BLM) (If operations are conducted on public lands administered by that agency)
  - U.S. Forest Service (USFS) (If operations are conducted on public lands administered by that agency)
  - State Engineers Office
  - Wyoming Department of Employment Division of Occupational Safety and Health

- **Conventional Uranium Mills**
  - Nuclear Regulatory Commission
  - Department of Environmental Quality (DEQ) (As associated with a Permit to Mine since 11(e).2 byproduct material is subject to pre-emptive federal jurisdiction and as related to groundwater)
  - Bureau of Land Management (BLM) (If operations are conducted on public lands administered by that agency)
  - Environmental Protection Agency (EPA)
  - U.S. Forest Service (USFS) (If operations are conducted on public lands administered by that agency)
  - State Engineers Office
  - Wyoming Department of Employment Division of Mine Inspection and Safety

- **Conventional (underground and surface) Uranium Mines**
  - Department of Environmental Quality (DEQ)
  - Bureau of Land Management (BLM) (If operations are conducted on public lands administered by that agency)

- U.S. Forest Service (USFS) (If operations are conducted on public lands administered by that agency)
- State Engineers Office
- Mine Safety and Health Administration (MSHA)
- Wyoming Department of Employment Division of Occupational Safety and Health

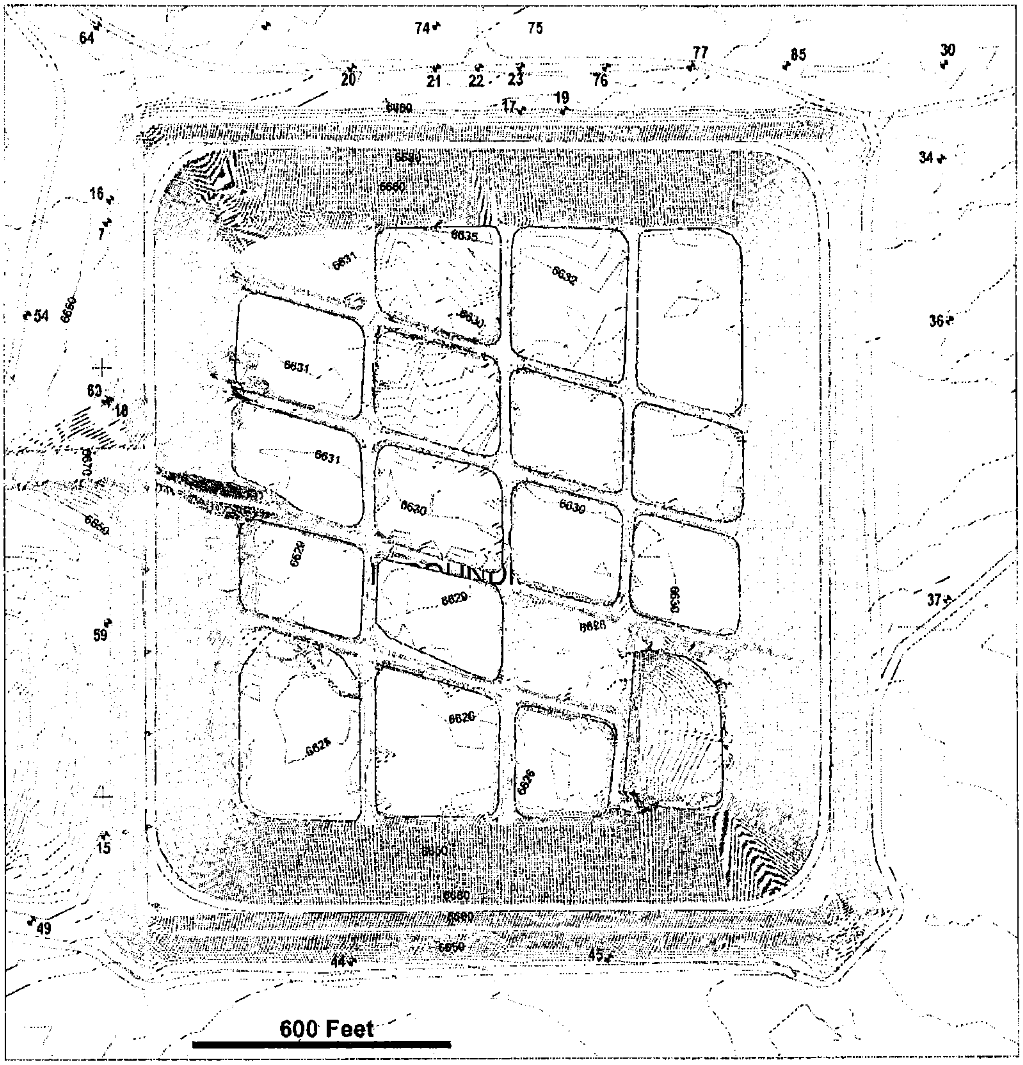
The above lists are not all inclusive. They list only the primary regulatory agencies.

The comprehensive regulation to which uranium processing and mining is subject means that additional regulation of uranium processing and mining is not required.

Conventional Uranium Mills in Wyoming

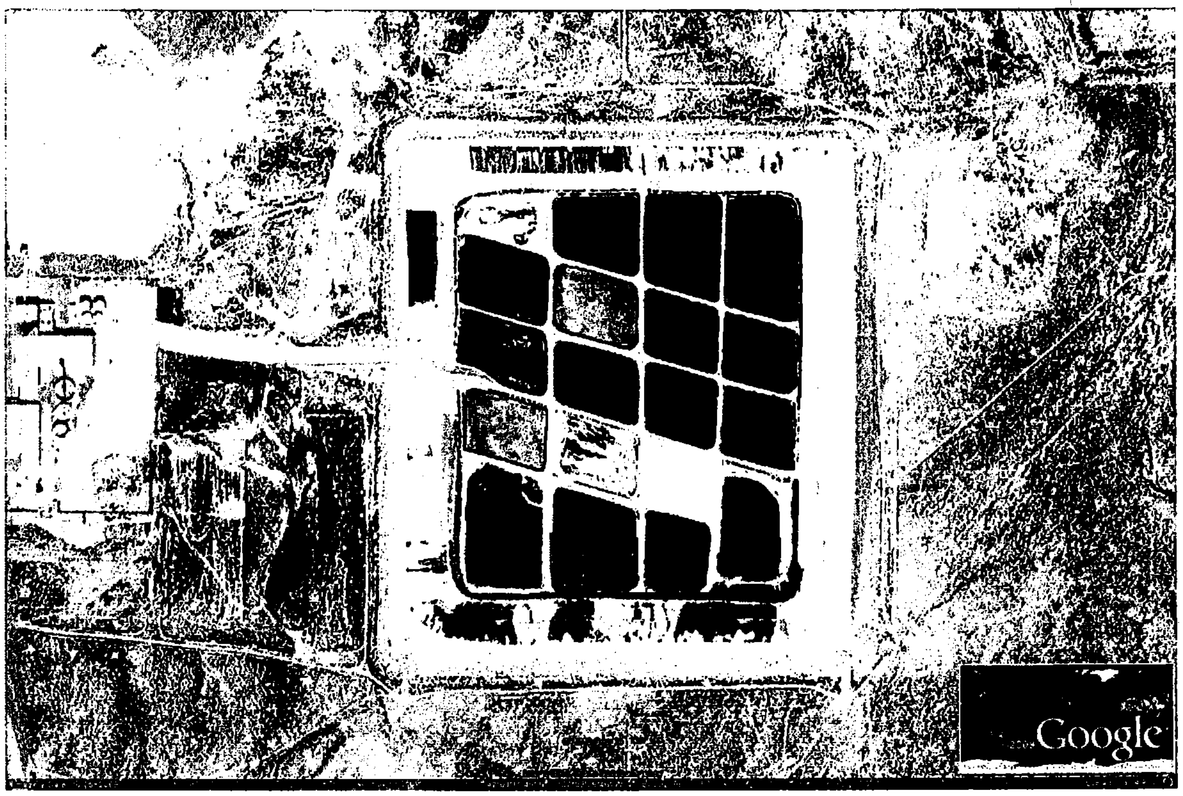
There is a single conventional uranium mill (the Sweetwater Mill in Sweetwater County, Wyoming). This facility is on standby but possesses an operating Nuclear Regulatory Commission (NRC) license. This facility possesses a mill tailings impoundment that is a partially below grade impoundment and created via a balanced cut and fill with a top area of approximately sixty (60) acres and a bottom area of approximately forty (40) acres. The impoundment is lined with a single 30 mil Hypalon liner. It contains over 2.5 million tons of uranium mill tailings regulated as 11(3).2 byproduct material. The tailings are all below grade (ground surface).

A map of the impoundment as it currently appears (August 9, 2010) is shown below:



The tailings in the sixty (60) acre lined impoundment have been leveled and a series of small lined evaporation ponds constructed on top of the regraded tailings. The blue shaded areas are the evaporation lagoons.

A Google Earth image of the impoundment taken on July 5, 2009 is provided below:



The impoundment also has a diversion channel east of it to protect it from surface runoff.

The impoundment is inspected as follows:

- Daily visual check
- Weekly inspection of liner integrity within five (5) feet of the tailings fluid surface
- Annual inspection by a Registered Professional Engineer of:
    - The embankment
    - The impoundment
    - The diversion channel
- In addition, every two (2) years on even numbered years a sample of the liner material is collected and sent to a laboratory for testing.

In addition to the existing impoundment the facility's Nuclear Regulatory Commission (NRC) license permits it to construct up to one (1) additional forty (40) acre tailings impoundment and up to eight (8) ten (10) acre evaporation impoundments. This is described in License Condition 10.3 which states in part:

> *The licensee is currently authorized to construct up to eight evaporation ponds and one new impoundment. An additional two evaporation ponds and an additional five impoundments, as described in the above documents, may be constructed after: 1) notification of NRC; 2) submittal*

of data confirming the proposed design; and 3) an increase in the surety amount, based on the NRC-approved cost estimate for reclaiming the additional structures.

In-Situ Uranium Recovery Operations in Wyoming

There is a single operating in-situ uranium recovery operation in Wyoming, the Smith Ranch/Highland Mine, one (10 on standby, the Irrigary/Christiansen Ranch Mine, one that has just (October 1, 2010) received an Nuclear Regulatory commission (NRC) license, the Moore Ranch Project and several in advanced stages of permitting. Impoundments at these operations are or will be limited to lined fluid retention impoundments.

Regulation of Impoundments at Uranium Recovery Operations in Wyoming

As stated above, uranium mining and processing is subject to a comprehensive regulatory scheme. At least four (4) agencies play an active role in regulating impoundments at uranium facilities. In addition, the Mine Safety and Health Administration (MSHA) is currently inspecting dams at metal/non-metal mines under Procedure Instruction Letter (PIL) Number 109-IV-01, which is attached in Appendix 1. The agencies and the roles they play in the regulation of impoundments at uranium recovery operations in Wyoming are as follows:

Nuclear Regulatory Commission (NRC)

The primary Nuclear Regulatory Commission (NRC) regulation impacting tailings and fluid retention impoundments is 10 CFR part 40 Appendix A Criterion 4 and 5 which are included in Appendix 4.

The Nuclear Regulatory Commission (NRC) also addresses impoundment construction and operation in the following two Regulatory Guides attached as Appendices 2 and 3 respectively:

REGULATORY GUIDE 3.13 - DESIGN, CONSTRUCTION, AND INSPECTION OF EMBANKMENT RETENTION SYSTEMS AT FUEL CYCLE FACILITIES

REGULATORY GUIDE 3.11 - DESIGN, CONSTRUCTION, AND INSPECTION OF EMBANKMENT RETENTION SYSTEMS AT URANIUM RECOVERY FACILITIES

NUREG-1910 - Generic Environmental Impact Statement for In-Situ Leach Uranium Milling Facilities address impoundment design at in-situ uranium recovery facilities when it states in Section 2.3.2:

> *Evaporation ponds may be constructed to dispose of effluent from the processing circuit or from aquifer restoration activities. These impoundments are designed and constructed with liners and leak detection systems installed in accordance with applicable NRC guidance (NRC, 2008a). Embankments for these evaporation ponds are constructed to resist erosion from wave action. The size and shape of the ponds are designed based on the amount of water that must be managed and the evaporation rates for the region. Sufficient space is provided so that the contents of one pond may be transferred to another to allow any identified pond system leaks to be repaired while meeting freeboard requirements from possible wave action.*

The Nuclear Regulatory Commission (NRC) also has specific standards for impoundments in **NUREG-1569 - Standard Review Plan for In Situ Leach Uranium Extraction License Applications**. Section 4.3.2 (2) of this document is included in Appendix 6.

Environmental Protection Agency (EPA)

The Environmental Protection Agency (EPA) also regulates mill tailings impoundments at conventional uranium mills under 40 CFR part 61 Subpart W which states in part:

> *(b) After December 15, 1989, no new tailings impoundment can be built unless it is designed, constructed and operated to meet one of the two following work practices:*
>
> *(1) Phased disposal in lined tailings impoundments that are no more than 40 acres in area and meet the requirements of 40 CFR 192.32(a) as determined by the Nuclear Regulatory Commission. The owner or operator shall have no more than two impoundments, including existing impoundments, in operation at any one time.*
>
> *(2) Continuous disposal of tailings such that tailings are dewatered and immediately disposed with no more than 10 acres uncovered at any time and operated in accordance with §192.32(a) as determined by the Nuclear Regulatory Commission.*

40 CFR Part 61 Subpart W references 40 CFR Part 192.32 which states in part:

> ***§ 192.32 Standards.***
>
> *(a) Standards for application during processing operations and prior to the end of the closure period. (1) Surface impoundments (except for an existing portion) subject to this subpart must be designed, constructed, and installed in such manner as to conform to the requirements of §264.221 of this chapter, except that at sites where the annual precipitation falling on the impoundment and any drainage area contributing surface runoff to the impoundment is less than the annual evaporation from the impoundment, the requirements of §264.228(a)(2) (iii)(E) referenced in §264.221 do not apply.*

40 CFR Part 192.32 references 40 CFR Part 264.221. These regulations are included in Appendix 5 due to their length.

State of Wyoming State Engineer's Office

The State Engineer's Office regulates surface water in the State of Wyoming. The Surface Water and Engineering Division is responsible for reviewing permit applications for any request for putting surface waters of the state to a beneficial use. Permits are issued for, 1) transporting water through ditch or pipelines; 2) for storage in reservoirs; 3) storage in smaller (under 20 acre-feet of capacity and a dam height less than 20 feet) reservoir facilities for stockwater or wildlife purposes; 4) enlargements to existing ditch or storage facilities; and 5) for instream flow purposes.

The State Engineer's Office regulates impoundments under the Safety of Dams Legislation enacted by the 1977 Session of the Wyoming State Legislature. This Act affects the processing of applications for certain sized dams, reservoirs and diversion systems and also affects the construction of certain dams and diversion systems, in that it requires inspections to be performed and reports to be submitted during construction. This Act defines a dam as:

"... any artificial barrier, including appurtenant works use dot impound or divert water and which is or will be greater than twenty 920) feet in height or with an impounding capacity of fifty (50) acre-feet or greater..."

Wyoming Department of Environmental Quality (DEQ)

Department of Environmental Quality (DEQ) regulations (**CHAPTER 3 NONCOAL MINE ENVIRONMENTAL PROTECTION PERFORMANCE STANDARDS)** state the following regarding impoundments:

(g) Permanent water impoundments. Permanent water impoundments shall be constructed in accordance with the following requirements:

(i) Dams must contain an overflow notch and spillway so as to prevent failure by overfilling and washing. Overflow notches and spillways must be riprapped with rock or concrete to prevent erosion;

(ii) The slopes around all water impoundments must be gentle enough so as not to present a safety hazard to humans or livestock and so as to accommodate revegetation. Variations from this procedure may be approved by the Administrator based on the conditions present at the individual locality;

(iii) Mineral seams and other sources of possible water contamination within the impoundment area must be covered with overburden or stabilized in such a manner to prevent contamination of the impounded water; and

(iv) Bentonite or other mire-producing material within the impoundment basin shall be removed or covered with materials which will prevent hazards to man or beast.

(h) Tailings impoundments, tailings disposal areas, heap leach facilities, and spent ore disposal areas, excluding uranium mill tailings facilities regulated by the United States Nuclear Regulatory Commission.

(i) Tailings impoundments, tailings disposal areas, heap leach facilities and spent ore disposal areas shall be designed, constructed, and operated in accordance with established engineering principles using best technology currently available to ensure long term stability and to prevent contamination of surface or groundwater. Appropriate leak detection and groundwater monitoring systems shall be installed to detect any movement of contaminated fluids from the facility. Any leakage or movement of contaminated fluids shall be promptly controlled and remediated using the best technology currently available subject to the Administrator's approval. Impoundments shall be permitted by the Wyoming State Engineer's Office and copies of the State Engineer's permits shall be attached to the application.

As can be seen from the citations provided above all forms of uranium recovery operations (in-situ uranium recovery, conventional mills and conventional mines are already heavily regulated with regard to the design and construction of impoundments, in all cases by the State Engineer's Office and depending upon the situation by the Department of Environmental Quality and/or the Environmental Protection Agency (EPA) so further regulation is not required.

Responses to Specific Question in the Advance Notice of Proposed Rulemaking (ANPRM)

What measures do mine operators currently take to design, construct, operate, and maintain safe and effective dams?

Uranium recovery operators are required to take those measures required of them by the State Engineer's Office, Department of Environmental Quality (DEQ), Environmental Protection Agency (EPA) and the Nuclear Regulatory commission (NRC) depending upon which agencies have jurisdiction over their facilities. The applicable regulations have already been cited.

What measures do mine operators currently take to safely abandon their dams?

Tailings impoundments at conventional uranium mills must be reclaimed in accordance with the requirements of:

10 CFR Part 40 Appendix A and;

NUREG-1620 - Standard Review Plan for the Review of a Reclamation Plan for Mill Tailings Sites Under Title II of the Uranium Mill Tailings Radiation Control Act of 1978

Uranium mill tailings impoundments must be reclaimed so that the reclamation *be effective for 1,000 years, to the extent reasonably achievable, and, in any case, for at least 200 years* (10 CFR Part 40 Appendix A)

Impoundments at in-situ uranium recovery operations and at conventional underground and open pit uranium mines must be removed and the surface reclaimed upon cessation of operations.

What non-Federal authority regulates the safety of dams at metal and nonmetal mines in your state, territory, or local jurisdiction?

This question has been addressed in the preceding text.

Does a competent engineer inspect your mine's dam? If so, at what frequency?

The sole remaining uranium mill tailings impoundment in Wyoming is inspected annually by a Registered Professional Engineer as described in the preceding text.

In summation, the Wyoming Mining Association (WMA) believes that additional regulation of impoundments at uranium recovery facilities is not required in Wyoming due to the current pervasive multi-agency regulatory scheme already in place.

The Association appreciates the opportunity to provide these comments. If you have any questions please do not hesitate to contact me.

Sincerely yours,

Marion Loomis

Marion Loomis
Executive Director

Cc: Katie Sweeney – National Mining Association (NMA)

Appendix 1

Attachment 1

EFFECTIVE DATE: 09/14/09 EXPIRATION DATE: 03/31/2011
(Reissue of I08-IV-1)

PROCEDURE INSTRUCTION LETTER NO. I09-IV-01

FROM: NEAL MERRIFIELD *Neal H Merrifield*
Acting Administrator for Metal and Nonmetal
Mine Safety and Health

SUBJECT: Procedures for Documenting Inspections of Dams on Initial and Subsequent Regular Inspections

Scope

This Procedure Instruction Letter (PIL) applies to all Metal and Nonmetal enforcement personnel conducting inspections of dams at mines and mills during regular (E01) inspections.

Purpose

This PIL provides guidance for Metal and Nonmetal enforcement personnel in documenting inspections of dams at metal and nonmetal mines and mills during regular inspections. This includes dams that impound water, tailings, or sediment. Information on dams meeting the hazard potential or size criteria explained below should be documented using approved MSHA forms "Metal and Nonmetal Tailings and Water Impoundment Inspection" (Form 4000-127) and "Water, Sediment, or Tailings Dam Inspection Checklist" (Form 4000-127a). Information on dams meeting the hazard potential or size criteria is also to be entered into MSHA's Dam Inventory in the MSIS database.

Procedure Instruction

The "Metal and Nonmetal Tailings and Water Impoundment Inspection" form (4000-127 – Attachment 1) and "Water, Sediment, or Tailings Dam Inspection Checklist" form (4000-127a – Attachment 2) are to be completed for all dams which meet any of the following criteria-

1. Dams classified as having "High Hazard Potential." These are dams, regardless of their condition or size, whose failure will probably cause loss of life;
2. Dams classified as having "Significant Hazard Potential." These are dams, regardless of their condition or size, whose failure would result in no probable

loss of life but would disrupt important utilities or cause significant economic loss or significant environmental damage; or

3. Dams classified as having "Low Hazard Potential." These are dams which meet either of the size criteria given below whose failure would not be expected to cause loss of life, disrupt important utilities, or cause significant economic loss or significant environmental damage. The dam must either:

    a. Equal or exceed 25 feet in height and can or does store a volume of more than 15 acre-feet, <u>or</u>
    b. Exceed 6 feet in height and can or does store 50 or more acre-feet.

The attached spreadsheet (Attachment 3) can assist enforcement personnel in determining whether a dam meets the size criteria established in item number 3 above. Enforcement personnel are reminded that any portion of a retaining structure that is incised, meaning it is excavated below undisturbed natural ground so as to preclude that portion of the structure from being released, should not be included in the volume or the dam height used in the size criteria specified in item No. 3 above. A dam at a metal and nonmetal mine or mill meeting any of the three criteria above should also be entered into MSHA's Dam Inventory on MSIS.

The "Metal and Nonmetal Tailings and Water Impoundment Inspection" form (4000-127) is to be completed the first time a dam that meets any of the three criteria is inspected (during or after construction). Information included on the form should reflect the conditions of the dam at the time of the inspection and not planned future conditions. During subsequent MSHA inspections, any changes from those originally noted, such as a change in dam height, should be noted by updating form 4000-127.

The "Water, Sediment, or Tailings Dam Inspection Checklist" form (4000-127a) is to be completed every time a dam meeting any of the three criteria above is inspected. This form is intended to inform the Agency of conditions that could have an adverse effect on the safety of the dam.

Regardless of whether a dam meets the three criteria above, all dams on mine or mill property are to be inspected during mandated inspections for conditions that could present a safety or health hazard to miners, such as inadequate berms along roads on top of the dam. However, the MSHA forms mentioned above are required to be completed only for dams meeting the specified hazard-potential or size criteria in this PIL.

One of the items of information on both forms is the "hazard potential classification" of the dam. This classification should be determined and assigned by the dam designer, because dams are designed to different safety standards depending on their hazard potential classification. For example, a high hazard potential dam should be designed to accommodate a much larger storm than would a low hazard potential dam. Enforcement personnel should ask mine operators what hazard-potential classification has been assigned in the design of the dam. If a classification has been assigned, enforcement personnel should examine the dam and its downstream area to determine whether the classification appears to be reasonable.

Hazard potential classifications can change over time, such as due to increased development in the downstream area. If the classification appears reasonable, it should be entered on MSHA Form 4000-127. If the classification does not appear to be reasonable, or if no classification has been assigned by the dam designer or mine operator, then enforcement personnel should make a judgment of the hazard potential classification. This classification should be reported on form 4000-127. Where the classification is uncertain, the District Dam Safety Representative should be contacted for assistance in determining the appropriate hazard potential classification and discussing the classification with the mine operator. Assistance can also be requested from MSHA's Directorate of Technical Support's Mine Waste and Geotechnical Engineering Division.

Enforcement personnel should also request a copy of "Emergency Action Plans" that mine operators may have for dams on the property. These plans are required by many state agencies.

Completed Form 4000-127a and an updated (if applicable) Form 4000-127 should be attached to every regular inspection report. A copy of Form 4000-127a (and form 4000-127 if applicable) should be forwarded to the District Dam Safety Representative after each regular inspection is concluded at mines or mills having these structures. District Dam Safety Representatives should also be provided with a copy of the dam's "Emergency Action Plan" if one was obtained from the mine operator.

The District Dam Safety Representatives should enter new or changed information noted on Form 4000-127 into the MSIS Dam Inventory database as soon as practical. District Dam Safety Representatives must also retain indefinitely the completed 4000-127 forms and, if provided, the mine's latest "Emergency Action Plan" relevant to any dam. Form 4000-127a must be maintained for three years for dams meeting the above criteria at mines or mills in the respective district.

Field office supervisors must assure that all dams are inspected during every regular inspection. They should also assure that observations made by enforcement personnel during those inspections are noted on the appropriate forms for dams meeting the hazard potential or size criteria. Further, supervisors should assure that completed forms are forwarded to the District Dam Safety Representative as noted above.

Background

This PIL provides guidance to assure that congressionally mandated inspections of dams are performed in accordance with applicable provisions of the Federal Mine Safety and Health Act of 1977 and that these inspections are appropriately documented.

Authority
Federal Mine Safety and Health Act of 1977, as amended, 30 U.S.C § 801 et seq.; 30 C.F.R. §§ 56/57.20010

Filing Instructions
This instruction letter should be filed behind the tab marked "Procedure Instruction Letters" in the binder for Program Policy Handbooks and Procedure Instruction Letters.

Issuing Office and Contact Persons
Lawrence Trainor, MNM Division of Safety and Health, 202-693-9644 E-mail address: trainor.lawrence@dol.gov

Distribution
All Program Policy Manual Holders
Metal and Nonmetal enforcement personnel
Attachment 1 (4000-127)
Attachment 2 (4000-127a)
Attachment 3 (Spreadsheet for Impoundment Size Determination)

MSHA METAL AND NONMETAL
TAILINGS AND WATER IMPOUNDMENT INSPECTION FORM

Note: This form should be completed for all dams classified as having high or significant hazard potential and for low-hazard-potential dams which either are 25 feet or more in height (and can store more than 15 acre-feet) or can store 50 acre-feet or more (and exceed 6 feet in height). For the same Mine ID Number, report each dam that meets any of these criteria on a separate form. Fill out as much information as can be obtained from the operator or directly determined.

MINE ID ____________________ Inspector ____________________________
Date ________________________
Mine Name ____
Mining Company ____
Mine Product _______________________ MSHA District _______________
MSHA Field Office ____
Name of Dam or Impoundment____
Dam ID Number _________________

(The Dam ID Number is assigned by the District and is the MSHA Mine ID Number followed by -01, -02, etc., so that individual mines at the mine that meet the hazard potential or size criteria have unique numbers.)

State___________________ County_________________________________
Does a state agency regulate this dam? Yes ___ No____
If So, which State Agency?____

Type of information provided on this form: New___ Update___
Is impoundment currently under construction? Yes____ No____

Dam owner's contact person ___________________ Phone # ______________
The dam was designed by ____

IMPOUNDMENT FUNCTION:
_____ Tailings/Mine Waste Disposal _____Sediment Control
_____ Fresh Water Supply _____Water Treatment _____Other

Nearest Downstream Town Name: ____________________________________
Distance from the Dam ____miles
Dam Location (coordinates of center of dam crest or point along dam crest for diked dams):
Longitude (as decimal) __________ (or as ____Degrees ____Minutes____ Seconds)
Latitude (as decimal) __________ (or as ____Degrees ____Minutes ____Seconds)

Note: Longitude or latitude as a decimal equals [(degrees) + (minutes/60) + (seconds/3600)]. Longitude and latitude are input into MSIS as decimal values, with the longitude being negative.

Does the dam have an Emergency Action Plan (EAP)? YES ___ NO ___

HAZARD POTENTIAL CLASSIFICATION: The hazard potential classification depends solely on the consequences of failure of the dam and not on the condition of the dam. Check with the mine operator for what classification has been assigned to the dam. If one has been assigned, determine whether it appears reasonable - classifications can change as downstream conditions change. If it appears reasonable, indicate the classification on this form below. If it does not appear reasonable, or no classification has been assigned, then judge the appropriate hazard potential classification and indicate it below. For uncertain cases, the District Dam Safety Representative can be consulted or further assistance can be requested from Technical Support.)

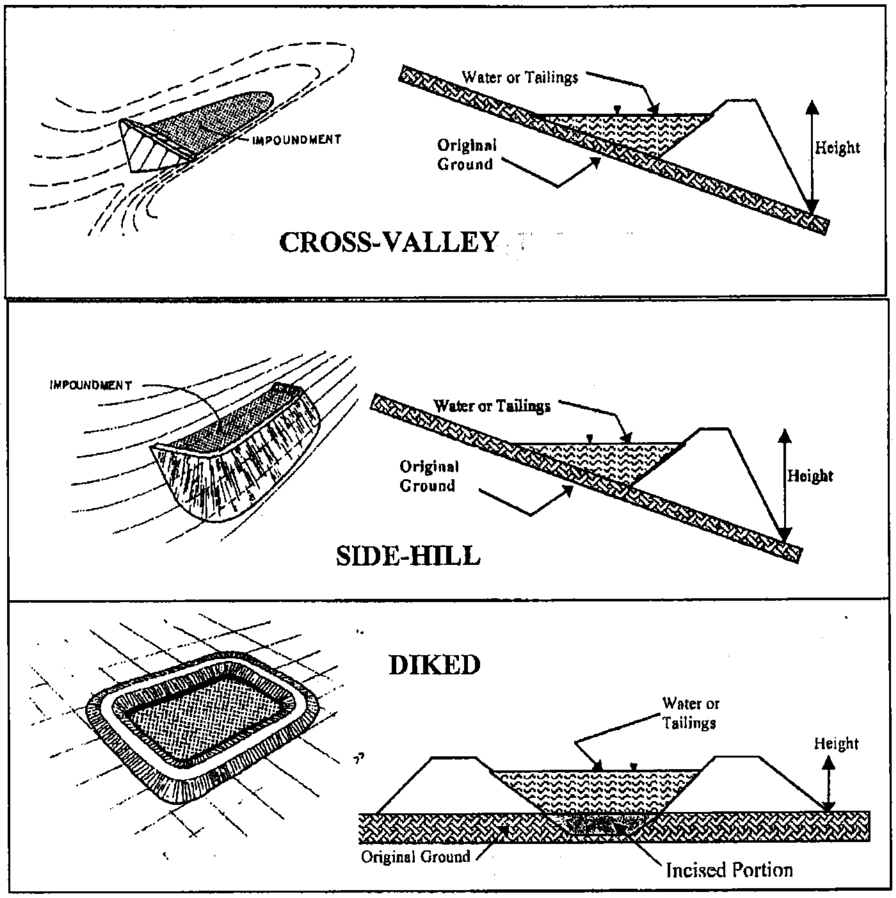
______ High: Dams, regardless of their condition or size, whose failure will probably cause loss of life.

______ Significant: Dams, regardless of their condition or size, whose failure would result in no probable loss of life but would disrupt important utilities or cause significant economic loss or significant environmental damage.

______ Low: Dams whose failure would result in no probable loss of life and only slight property damage such as to farm buildings, forest or agricultural land, or minor roads.

DESCRIBE REASONING FOR HAZARD RATING INDICATED:

CONFIGURATION:



Cross-Valley_____ Side-Hill_____ Diked_____

Note that any portion of an impoundment that is "incised," meaning it is excavated below undisturbed natural ground such that release of that portion of the impoundment is precluded, should not be considered in the storage capacity or in the dam height reported on this form.

Type of dam construction: ___ upstream ___ downstream ___ centerline

Dam Height (above downstream toe): _____ feet Dam Crest Length: _____ feet

Reservoir Area: Width _____feet Length _____ feet or ______ Acres (W x L / 43560)

Current Freeboard: ___________ feet Drainage Area: _______ square miles

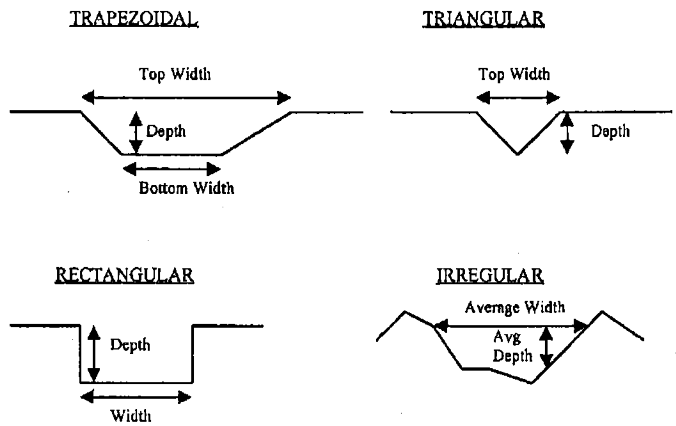
Normal Storage Capacity: ____acre-feet Maximum Storage Capacity: ____acre-feet

TYPE OF OUTLET: (Mark all that apply)

Open Channel Spillway:
Yes____ No_____

_____ Trapezoidal
_____ Triangular
_____ Rectangular
_____ Irregular

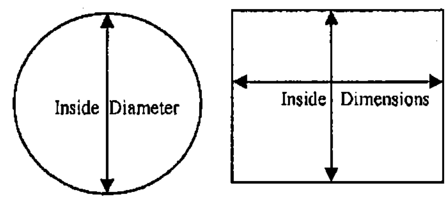
_____ Channel Depth
_____ Bottom (or average) width
_____ Top width



Decant Conduit: Yes____ No____

Size of conduit: Inside diameter:______inches

or Width: ____inches x Height: ____ inches



Conduit Material
_____ corrugated metal
_____ welded steel
_____ concrete
_____ plastic (HDPE, PVC, etc.)
_____ other (specify) ____________________

Is water flowing through the decant? Yes___ No____

Other Type of Outlet (specify, e.g. floating pump system) __________________

____

____

Has the dam been totally removed or breached or has the impoundment been filled in so that the impounding capability has been eliminated? Yes___ No____
If "Yes," as of what date?_________

Has there ever been a failure or incident at this site that resulted in a partial or complete loss of the dam or any of its hydraulic components or a partial or complete unintentional release from the reservoir? YES _____ NO _____

If so, when? ___________________________

If so, please describe: ____

Notes to assist with completing form: **Freeboard** is the vertical distance between the pool level and the lowest point on the dam. **Normal Storage Capacity** can be estimated as the Reservoir Area times the Normal Reservoir Depth. **Maximum Storage Capacity** can be estimated as the Reservoir Area times the Maximum Reservoir Depth. **Drainage Area** is the area that contributes runoff into the impoundment – it must be obtained from the operator's information or a topographic map.

Attachment 2

Water, Sediment, or Tailings Dam Inspection Checklist Form

US Department of Labor
Mine Safety & Health Administration

Site Name:	Date:
Mine Name:	Operator's Name:
Mine I.D.:	Hazard Potential Classification: High Significant Low
Inspector's Name:	

Check the appropriate box below. Provide comments when appropriate. If not applicable or not available, record "N/A". Any unusual conditions or construction practices that should be brought to the attention of the field office supervisor or the district dam safety representative should be noted in the comments section. For large diked embankments, separate checklists may be used for different embankment areas. If separate forms are used, identify approximate area that the form applies to in comments.

	Yes	No		Yes	No
1. Frequency of Company's Dam Inspections?			18. Sloughing or bulging on slopes?		
2. Pool elevation (operator records)?			19. Major erosion or slope deterioration?		
3. Decant inlet elevation (operator records)?			20. Decant Pipes:		
4. Open channel spillway elevation (operator records)?			Is water entering inlet, but not exiting outlet?		
5. Lowest dam crest elevation (operator records)?			Is water exiting outlet, but not entering inlet?		
6. If instrumentation is present, are readings recorded (operator records)?			Is water exiting outlet flowing clear?		
7. Is the embankment currently under construction?			21. Seepage (specify location, if seepage carries fines, and approximate seepage rate below):		
8. Foundation preparation (remove vegetation,stumps, topsoil in area where embankment fill will be placed)?			From underdrain?		
9. Trees growing on embankment? (If so, indicate largest diameter below)			At isolated points on embankment slopes?		
10. Cracks or scarps on crest?			At natural hillside in the embankment area?		
11. Is there significant settlement along the crest?			Over widespread areas?		
12. Are decant trashracks clear and in place?			From downstream foundation area?		
13. Depressions or sinkholes in tailings surface or whirlpool in the pool area?			"Boils" beneath stream or ponded water?		
14. Clogged spillways, groin or diversion ditches?			Around the outside of the decant pipe?		
15. Are spillway or ditch linings deteriorated?			22. Surface movements in valley bottom or on hillside?		
16. Are outlets of decant or underdrains blocked?			23. Water against downstream toe?		
17. Cracks or scarps on slopes?			24. Were Photos taken during the dam inspection?		

Major adverse changes in these items could cause instability and should be reported to the District Manager for further evaluation. Adverse conditions noted in these items should normally be described (extent, location, volume, etc.) in the space below and on the back of this sheet.

Inspection Issue #	Comments

Appendix 2

Attachment 2

U.S. NUCLEAR REGULATORY COMMISSION

July 2010
Revision 1

REGULATORY GUIDE

OFFICE OF NUCLEAR REGULATORY RESEARCH

REGULATORY GUIDE 3.13

(Draft was issued as DG-3040, dated February 2010)

DESIGN, CONSTRUCTION, AND INSPECTION OF EMBANKMENT RETENTION SYSTEMS AT FUEL CYCLE FACILITIES

A. INTRODUCTION

This guide describes some engineering practices and methods generally considered by the U.S. Nuclear Regulatory Commission (NRC) to be satisfactory for the design, construction, and inspection of embankment retention systems used for retaining solid and liquid effluent from nuclear fuel cycle facility operations other than uranium recovery and milling operations. These practices and methods are the result of NRC review and action on a number of specific cases, and they reflect the latest general engineering approaches that are acceptable to the NRC staff. If future information results in alternative methods, the NRC staff will review such methods to determine their acceptability.

Title 10, Section 20.1101, "Radiation Protection Programs," of the *Code of Federal Regulations* (10 CFR 20.1101) (Ref. 1) requires licensees who possess, process, refine, or use uranium ores and oxides in fuel cycle facilities to use, to the extent practical, procedures and engineering controls based on sound radiation protection principles to maintain occupational radiation exposure and radiation exposure to members of the public that are as low as is reasonably achievable (ALARA). In addition, Subpart B, "Environmental Standards for the Uranium Fuel Cycle," of 40 CFR Part 190, "Environmental Radiation Protection Standards for Nuclear Power Operations" (Ref. 2) requires that the annual dose equivalent not exceed $25x10^{-5}$ sieverts (Sv) (25 millirem (mrem)) to the whole body, $75x10^{-5}$ Sv (75 mrem) to the thyroid, and $25x10^{-5}$ Sv (25 mrem) to any other organ of any member of the public as the result of exposures to radiation (radon and its daughters excepted) from nuclear fuel cycle operations, including planned discharges of radioactive materials to the general environment. Liquid and solid wastes generated at fuel cycle facilities typically contain radioactive materials in excess of the discharge limits

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The NRC issues regulatory guides to describe and make available to the public methods that the NRC staff considers acceptable for use in implementing specific parts of the agency's regulations, techniques that the staff uses in evaluating specific problems or postulated accidents, and data that the staff needs in reviewing applications for permits and licenses. Regulatory guides are not substitutes for regulations, and compliance with them is not required. Methods and solutions that differ from those set forth in regulatory guides will be deemed acceptable if they provide a basis for the findings required for the issuance or continuance of a permit or license by the Commission.

This guide was issued after publication of the draft regulatory guide for public comment.

Regulatory guides are issued in 10 broad divisions: 1, Power Reactors; 2, Research and Test Reactors; 3, Fuels and Materials Facilities; 4, Environmental and Siting; 5, Materials and Plant Protection; 6, Products; 7, Transportation; 8, Occupational Health; 9, Antitrust and Financial Review; and 10, General.

Electronic copies of this guide and other recently issued guides are available through the NRC's public Web site under the Regulatory Guides document collection of the NRC's Electronic Reading Room at http://www.nrc.gov/reading-rm/doc-collections/ and through the NRC's Agencywide Documents Access and Management System (ADAMS) at http://www.nrc.gov/reading-rm/adams.html under Accession No. ML101470167. The regulatory analysis may be found in ADAMS under Accession No. ML101470350.

and are generally confined by an embankment retention system to allow the solids to precipitate. The liquid is sampled for radiological or hazardous contents prior to release to the environment.

The NRC issues regulatory guides to describe to the public methods that the staff considers acceptable for use in implementing specific parts of the agency's regulations, to explain techniques that the staff uses in evaluating specific problems or postulated accidents, and to provide guidance to applicants. Regulatory guides are not substitutes for regulations and compliance with them is not required.

This regulatory guide contains information collection requirements covered by 10 CFR Part 20, Part 40, and Part 70 that the Office of Management and Budget (OMB) approved under OMB control numbers 3150-0014, 3150-0020, and 3150-0009 respectively. The NRC may neither conduct nor sponsor, and a person is not required to respond to, an information collection request or requirement unless the requesting document displays a currently valid OMB control number.

B. DISCUSSION

Background

The manufacture of nuclear fuel results in the production of liquid and solid wastes. Fuel cycle facilities have used embankment retention systems for both temporary and long-term storage of solid and liquid discharge. Effluent from the various processes dictates the requirement for release or retention. Factors pertaining to safety, contamination, and environmental damage determine the minimum requirements in planning and constructing retention systems.

Uranium hexafluoride (UF_6) production and fuel fabrication effluent does not contain constituents of long-lived radionuclides (e.g., radium-226) associated with uranium recovery processes. Environmental processing facilities associated with the fuel production and fabrication are able to treat liquid effluent and release it to the environment in compliance with the requirements of Appendix B, "Annual Limits on Intake (ALIs) and Derived Air Concentrations (DACs) of Radionuclides for Occupational Exposure; Effluent Concentrations; Concentrations for Release to Sewerage," to 10 CFR Part 20, "Standards for Protection against Radiation" (Ref. 3). The variation in construction to allow for release to the environment or to retain and not release is the prerogative of the applicant. The NRC staff reviews such variations on a case-by-case basis, or a State reviews them in accordance with the terms contained in the applicant's Ground Water Discharge Permit.

1. General Planning, Siting, and Design Considerations

The following general design considerations are based on the requirements of Appendix A, "Criteria Relating to the Operation of Uranium Mills and the Disposition of Tailings or Wastes Produced by the Extraction or Concentration of Source Material from Ores Processed Primarily for Their Source Material Content," to 10 CFR Part 40, "Domestic Licensing of Source Material," (Ref. 4).

Because the prime functions of the retention system are to store radioactive solids and/or to provide temporary storage of contaminated water, the system must be designed and constructed to remain stable for its intended life. The retention system must be designed to provide sufficient storage capacity at any given time during its intended life, and it must provide sufficient control of seepage to prevent unacceptable contamination of adjacent land, waterways, and ground waters. The retention system must also be designed to be resistant to wind and water erosion during and after facility operations. The design and construction considerations, along with the sound evaluation and inspection principles in this guide, should be used in embankment retention systems associated with fuel production facilities.

The planning, siting, and design of each retention system must comply with any other regulatory and permitting requirements for a proposed impoundment that exist outside of the NRC's regulations in Appendix A to 10 CFR Part 40.

1.1 Site Evaluation

In selecting any site for fuel cycle facility effluent retention, local conditions, including climate, ground water and surface water hydrology, geology, and seismology, should be assessed and their impacts evaluated. In site selection, features that should be considered include (1) hydrologic and other natural conditions as they contribute to continued immobilization and isolation of contaminants from ground water sources, (2) potential for minimizing erosion, disturbance, and dispersion by natural forces over the long term, and (3) security in the form of a fence to restrict access by animals and unauthorized individuals.

1.2 Field Exploration

Subsurface investigations at the site of the retention system should be of adequate scope to determine the suitability of the foundation and characteristics of embankment materials. Borings should be drilled along the axis of the retention structure and at critical locations perpendicular to the axis to establish geologic sections and ground water conditions. Borings should extend to a depth in the natural soils at least equal to the height of the planned embankment section. The investigations should cover classification, physical and chemical properties, location, and extent of soil and rock strata, and variations in ground water conditions. Evaluation of ground water should be focused on the uppermost aquifer. The field exploration should identify this aquifer, its flow direction, and the distance from the impoundment to potential downgradient users. In addition, the preoperational background quality of ground water in the uppermost aquifer should be ascertained. Observation of ground water conditions should be recorded over a sufficient period to permit the ground water depths and range of seasonal fluctuations to be established.

The foundation conditions should be evaluated to assess the ability of subsurface materials to support the embankments without failure and without excessive total or differential settlement. The permeability of foundation soils and rocks should be ascertained to estimate the seepage potential. Information is needed on the characteristics of the underlying soil as they will control transport of contaminants and solutions.

1.3 Laboratory Tests

Testing soil samples of foundation and embankment materials from the field investigation should provide detailed information on the physical and mechanical properties such as classification, gradation, shear strength, consolidation, permeability, sedimentation, compaction, piping and cracking susceptibility, and wind-water erosion characteristics.

2. Design Analysis

Design analysis should consider stability, settlement, seepage, hydrologic analyses, liner stability, and liner compatibility. Specifically, the design should ensure that retention system failure will not occur. Historical records indicate that most failures associated with retention systems have been caused by overtopping by floodwaters, erosion, piping in the retention embankment or the foundation, foundation failure, slope failure, or liquefaction.

2.1 Stability and Failure Analyses

2.1.1 Slope Stability

Stability analyses involve comparing the shearing stresses along potential failure surfaces with the available shearing resistance along those surfaces. The factor of safety is the ratio of the available shear strength to the developed maximum shear stress. A number of computer programs can be used to perform slope stability analyses. Commercially available programs also may allow calculation of the factor of safety. The output from a computer program should be checked carefully to verify that the critical surface with the lowest factor of safety has been identified, the critical surface represents a possible or realistic scenario, and computational problems resulting from the parameters used are minimized. In EM 1110-2-1902, "Engineering and Design Slope Stability," issued October 2003, the U.S. Army Corps of Engineers describes pertinent basic design considerations, methods of stability analysis, and minimum factors of safety that provide an acceptable design basis for a safe settling or retention basin structure, (Ref. 5).

2.1.2 Liquefaction

The impact of liquefaction on stability should be considered, if potentially liquefiable soils exist below the site of a retention system. Evaluation of liquefaction potential should include laboratory testing, in situ testing, and comparisons to similar soil deposits. The U.S. Environmental Protection Agency report EPA/600/R-95/051, "RCRA Subtitle D (258): Seismic Design Guidance for Municipal Solid Waste Landfill Facilities," issued April 1995, elaborates on five criteria for determining whether a site has potentially liquefiable soils—(1) geologic age and origin, (2) fines content and plasticity index, (3) saturation, (4) depth below ground surface, and (5) soil penetration resistance (Ref. 6). If liquefaction potential exists at a retention system site, additional subsurface investigation may be necessary.

2.1.3 Settlement

If the foundation beneath an embankment retention system consists of layers of compressible soils or weathered rock, or if the bedrock profile is very irregular, differential settlements could result from uneven loading or variable thicknesses in the compressible soils. Total settlement and differential settlements may cause cracking and/or excessive strain in the embankments or other retention system components that could lead to system failure.

After settlement analyses have been performed, the engineered components of the waste retention system, such as geotextiles, geomembranes, clay liners, drainage layers, effluent collection piping, and waste piping, should be analyzed for tensile strain. The analysis should verify that the components can maintain their integrity when subjected to the induced strain associated with the settlement determined in the total and differential settlement analyses. If analysis indicates that settlement along any cross-section is likely to damage an engineered component, or to cause the engineered component to be unable to meet the minimum design criteria, then the retention system must be redesigned to eliminate the adverse effects of total and differential settlement. Methods such as overbuilding, surcharging, removal of the material causing the problem, or engineered reinforcement may be used to mitigate the effects of settlement.

2.2 *Water Control and Management*

2.2.1 Impoundment Storage Capacity

Some catchment areas contribute runoff into the retention system. This generally will be the area of the system itself, and the runoff will result from precipitation. This does not present a problem, as it only further dilutes any potential activity in the embankment retention system. Grading and diversion channels should be provided to enhance natural drainage if necessary.

When the probability of occurrence of large floods on small drainage basins in arid regions is small and onsite personnel are available to repair any minor damage that could occur, the NRC staff may accept less conservative options for determining the design-basis flood. For small retention systems built in isolated areas where failure would neither jeopardize human life nor create damage to property or the environment beyond the licensee's legal liabilities and financial capabilities, the design need not use extremely conservative flood design criteria. However, the selection of the design flood should be at least compatible with the hazard category guidelines set forth by the U.S. Army Corps of Engineers (Ref. 7).

2.2.2 Seepage Control

When retention systems are lined, seepage analysis for embankment stability purposes is unnecessary. However, special design features, such as impervious liners and collection systems, are needed to maintain the quality and quantity of seepage from the retention system within tolerable limits of water supply and pollution control requirements. If a clay liner is proposed, seepage into this layer must be assessed to ensure that seepage will not occur through the liner (Criterion 5 of Appendix A to 10 CFR Part 40).

The potential for seepage at an embankment retention system can be controlled through installation of a liner system. The interior of each retention or settling basin should be lined with an essentially impervious synthetic lining material designed to prevent seepage. The number of construction joints and penetrations of the liner should be minimized, and protection from mechanical damage should be provided. The liner can be constructed of earthen material, such as compacted clay, or synthetic material, such as a high-density polyethylene geomembrane. The design of a liner system should consider subgrade material, type of liner system (earthen or synthetic), liner system protection, and leak detection. Both types of liner systems have advantages and disadvantages, and the choice of the liner system should consider several factors. A key factor is the liner material's physical and chemical inertness when exposed to the materials within the retention system. The chemical qualities of the effluent must be assessed to determine the impacts on liners and/or the environment (Criterion 5 of Appendix A to 10 CFR Part 40).

The advantages of a synthetic liner system include a significantly reduced thickness, a greater resistance to cracking, and a much lower hydraulic conductivity (typically several orders of magnitude lower than that of an earthen liner system). The design of a synthetic liner system should consider the method of placement, the seaming techniques, and the puncture resistance. Theory and design methods to evaluate puncture resistance have been developed and can be used to evaluate the puncture resistance of synthetics for different conditions (Refs. 8-10).

3. Construction Considerations

The construction of embankment retention systems generally involves both excavation and filling in some specified order. Successful embankment retention system construction requires understanding the moisture/density relationships of the soils, providing adequate compaction, and preventing poor-quality soils from being incorporated into the embankment retention system fill materials. Clearing and stripping operations provide much additional information on the characteristics of foundations, and this information may confirm or contradict design assumptions based on earlier geotechnical investigations. Weather and ground water conditions during construction may significantly alter water contents of proposed fill material or create seepage and/or hydraulic conditions necessitating modifications in design. Projects should be evaluated and "reengineered" continuously during construction to ensure that the final design is compatible with conditions encountered during construction. Construction supervision, management, and monitoring of the embankment and associated structures are a critical part of the overall project management plan. Once the facility is placed into operation, observations, surveillance, inspections, and continuing evaluation are required to ensure the satisfactory performance of the retention system (Criterion 12 of Appendix A to 10 CFR Part 40).

4. Inspection and Maintenance

Conditions can change throughout the life of the embankment retention system. Such changes can significantly affect the factors governing the stability of a retention system. Therefore, a continuous program of inspection of the retention system is strongly recommended, beginning at the start of construction. Each site and structure has its own characteristics and its own susceptibilities to problems, and the inspection program should be tailored to consider these. Thorough physical examination is an essential part of the inspection program. The optimal frequency of inspections depends on the size and condition of the facilities, the character of the foundation, the regional geological setting, and the consequences of failure, such as jeopardizing human health and safety and inflicting property and environmental damage. Monitoring and analysis of performance data are necessary to ensure detection of adverse conditions (Criterion 12 of Appendix A to 10 CFR Part 40).

Before the operational use of the system begins, records of ground water levels (including seasonal fluctuations), ground water quality, ground elevations, and background radioactivities at the site should be compiled and compared with the operational conditions of the impoundment. Once operational activities begin, inspection should be performed at regular intervals to check the condition of the retention systems and associated facilities and to evaluate their structural safety and operational adequacy. A detailed, systematic inspection program should consist of, but not necessarily be limited to, the elements described in the sections below (10 CFR 40.27(b)(2)).

4.1 Engineering Data Compilation

Engineering data related to the design, construction, and operation of the retention systems should be compiled and, to the extent practicable, included in the initial inspection report. Most engineering data are readily available in documents filed for the license application. A detailed reference to the original documents kept at the project site should be adequate. These data should include the following items, as available and applicable:

- general project data, including regional vicinity maps showing the project location and the upstream and downstream drainage areas and as-built drawings and photographs of the retention system

- hydrologic and hydraulic data, including drainage area and basin characteristics, storage volume, surcharge capacity for floods, rate of inflow, elevation of the maximum design pool, and freeboard height

- foundation data and geological features, including boring logs, geological maps, profiles, and cross-sections

- properties of embankment and foundation materials, including results of laboratory and field tests, and assumed design material properties

- principal design assumptions and analyses, including hydrologic and hydraulic analyses, stability and stress analyses, and seepage and settlement analyses

- pertinent construction photographs and records, including construction control tests, construction problems and modifications, and maintenance repairs

4.2 Inspection Programs

The embankment retention system inspection program should be established and conducted systematically to minimize the possibility of overlooking any significant features. A checklist should be developed and followed to document the observations of each significant feature. Photographs for comparison of previous and present conditions may be used as a part of the inspection program. The inspection program should include, but not be limited to, the following as appropriate:

- Semiannual Inspection

  - Pond water elevations should be examined and recorded to ensure that minimum freeboard is maintained.

  - The transport system should be examined for any evidence of obstruction of the pipes or pumps caused by clogging or ice accumulation. The pipe couplings should be examined for leakage, and any flow rate sensor should be tested.

  - The liner system should be visually inspected to identify any damage to the liner and any operating practices that may contribute to liner damage.

  - Channels should be examined for channel bank erosion, bed aggradation or degradation and siltation, obstruction to flow, undesirable vegetation, or any unusual or inadequate operational behavior.

  - Any installed instrumentation, such as survey monuments, settlement plates or gauges, and/or piezometers, should be examined and tested for proper functioning. The available records and readings of these instruments should be reviewed to detect any unusual performance or distress of the structure.

  - The top of the embankment and downstream toe areas should be examined and surveyed, if necessary, for any evidence of unusual localized or overall settlement or depressions.

  - Embankment slopes should be examined for irregularities in alignment and variance from originally constructed slopes, unusual changes from original crest alignment and elevation, evidence of movement at or beyond the toe, erosion, and surface cracks that indicate movement.

- The slope protection should be examined for erosion-formed gullies and wave-formed notches and benches. The adequacy of slope protection against waves and surface runoff that may occur at the site should be evaluated.

- The maintenance of operating facilities and features (such as pumps and valves) that pertain to the safety of the retention system should be examined to determine the adequacy and quality of the maintenance procedures followed in maintaining the retention system in a safe operating condition.

- The general long-term performance of the liner, such as its resistance to degradation, should be examined.

• Periodic Inspection (preferably bi-annual) should be performed by an independent geotechnical consultant to ascertain the condition of the embankment, which protects the retention basins.

• Special Inspections

  - Unscheduled inspections should be performed after the occurrence of significant earthquakes, tornadoes, floods, intense local rainfalls, or other unusual events.

  - The NRC's implementation of the National Dam Safety Program and its associated guidelines may require special inspections of any uranium fuel cycle facility embankments that fall within the scope of the program.

4.3 Technical Evaluation

The existing conditions of the retention system should be evaluated annually unless changing conditions dictate a shorter period. This evaluation should include an assessment of the hydraulic and hydrologic capacities, water quality, and structural stability and should take into account both existing conditions and any changing conditions. In addition, surface water and ground water sampling data should be collected at the time of the technical evaluation to detect any patterns that could be a sign of failure of seepage control measures or foundation distress.

4.4 Inspection Reporting

A report should be prepared to present the results of each technical evaluation and the inspection data accumulated since the last report. These documents should be kept at the project site for reference purposes, available for inspection by regulatory authorities, and retired only upon termination of the project. Any abnormal hazardous conditions observed during the inspection should be reported immediately to the NRC staff.

4.5 Inspection Personnel

An experienced professional who is thoroughly familiar with the investigation, design, construction, and operation of these types of facilities should direct the planning and conduct of the inspections and evaluations. At each facility, this individual should ensure that all field inspectors are trained to recognize and assess signs of possible distress or abnormality.

C. REGULATORY POSITION

The following describes acceptable criteria for proposed construction, inspection, and performance of a fuel cycle facility waste retention system. If an applicant proposes the use of an alternative method or new information that may be developed in the future, the NRC will review the proposal and, if acceptable, approve its use.

1. Basic Design Criteria

a. The stability of the retention system is fundamental to design for construction and operation. In ensuring structural integrity, it should not be presumed that the liner system will function without leakage during the active life of the impoundment.

b. Consider total and differential settlement within tolerable limits that will not result in harmful cracking and embankment instability.

c. A liner's design, construction, and installation should limit any uncontrolled migration of effluent out of the impoundment to the adjacent subsurface soil, ground water, or surface water.

d. Recommended liner characteristics (Criterion 5 of Appendix A to 10 CFR Part 40):

(1) The liner must be constructed of materials that have appropriate chemical properties and sufficient strength and thickness to prevent failure from pressure gradients, physical contact with the effluent to which they are exposed, climatic conditions, the stress of installation, and the stress of daily operation.

(2) The liner must be placed on a foundation or base capable of providing support to the liner and resistance to pressure gradients above and below the liner to prevent failure of the liner from settlement, compression, or uplift.

(3) The liner must be installed in such a way that it will cover all surrounding earth likely to be in contact with effluent.

e. Consideration for installation of a leakage detection system to ensure that major liner failures are detected if they occur.

f. Allow sufficient freeboard to minimize overtopping by flood inflows and wind-generated waves and should include an allowance for settlement of the foundation and embankments.

g. Minimize upstream rainfall catchment areas to limit erosion potential and the size of the floods that could erode or wash out sections of the retention system.

2. Methods of Analysis

a. Wave runup may be determined using procedures discussed in the U.S. Army Corps of Engineers "Coastal Engineering Manual," issued April 2002 (Ref. 11).

b. The static stability of the embankment should be analyzed using commonly accepted detailed stability methods. The analysis should use appropriate static soil and rock properties established on tested representative samples over anticipated in situ and placement conditions.

c. Evaluation of liquefaction potential should include laboratory testing, in situ testing, and comparisons to similar soil deposits. Screening criteria should be used to determine whether there are potentially liquefiable soils at a site. The factor of safety for liquefaction potential should be greater than 1.0.

d. Appropriate laboratory test results should be used to estimate the rate and magnitude of settlement.

3. Construction Methods

a. Conventional acceptable engineering practices of construction control for water retention dams (e.g., controls on foundation preparation, suitability of materials, proper placement, field moisture, and density).

b. Installation of a synthetic liner system should focus on minimizing liner damage. Damage can occur in the form of wrinkles, improper seaming techniques, poor synthetic panel orientation, and punctures caused by construction equipment.

4. Inspection and Maintenance

a. A systematic inspection and maintenance program should be established to detect and repair damage that might lessen the integrity of the retention system. Generally, visual inspections performed on a regular basis and supplemented by adequate instrumentation are acceptable.

b. Semiannual inspections of retention systems should be planned, conducted, evaluated, and documented under the direction of an experienced professional who is familiar with the design, construction, and operation of these types of facilities. The licensee should retain documentation (i.e., a record) of each inspection for 3 years after the documentation is made.

c. Unscheduled inspections should be performed after the occurrence of significant earthquakes, tornadoes, floods, intense local rainfalls, or other unusual events. The NRC's implementation of the National Dam Safety Program and its associated guidelines may require special inspections of any fuel cycle facility embankments that fall within the scope of the program.

d. The inspection and maintenance program should start at the beginning of construction and continue at least through the operation of the facility.

D. IMPLEMENTATION

The purpose of this section is to provide information to applicants and licensees regarding the NRC's plans for using this regulatory guide. The NRC does not intend or approve any imposition or backfit in connection with its issuance.

In some cases, applicants or licensees may propose or use a previously established acceptable alternative method for complying with specified portions of the NRC's regulations. Otherwise, the methods described in this guide will be used in evaluating compliance with the applicable regulations for license applications, license amendment applications, and amendment requests.

GLOSSARY

This guide uses the following definitions:

Embankment: A dike or ridge of either natural or man-made materials used to prevent the movement of liquids, sludges, solids or other materials.

Earthen Embankment Retention System: A watertight system of one or more settling and/or retention basins, including their associated engineered safety features.

Retention Basin: A watertight basin in which liquid, sludge, or solid wastes are held for one or more of the following reasons – (1) analysis to verify activity levels permitting release, (2) evaporation, and (3) recycle for treatment.

Settling Basin: A watertight basin designed for separating sludges and sediments as a layer on the bottom. The liquid is disposed of by overflow to the environment, transfer to a retention basin, or solar evaporation.

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1. 10 CFR 20.1101, "Radiation Protection Programs," U. S. Nuclear Regulatory Commission, Washington, DC.

2. 40 CFR Part 190, "Environmental Radiation Protection Standards for Nuclear Power Operations," U. S. Nuclear Regulatory Commission, Washington, DC.

3. Appendix B, "Annual Limits on Intake (ALIs) and Derived Air Concentrations (DACs) of Radionuclides for Occupational Exposure; Effluent Concentrations; Concentrations for Release to Sewerage," to 10 CFR Part 20, "Standards for Protection against Radiation," U.S. Nuclear Regulatory Commission, Washington, DC.

4. Appendix A, "Criteria Relating to the Operation of Uranium Mills and the Disposition of Tailings or Wastes Produced by the Extraction or Concentration of Source Material from Ores Processed Primarily for Their Source Material Content," to 10 CFR Part 40, "Domestic Licensing of Source Material," U.S. Nuclear Regulatory Commission, Washington, DC.

5. EM 1110-2-1902, "Engineering and Design Slope Stability," U.S. Army Corps of Engineers, Washington, DC, October 2003.[2]

6. EPA/600/R-95/051, "RCRA Subtitle D (258): Seismic Design Guidance for Municipal Solid Waste Landfill Facilities," U.S. Environmental Protection Agency, Washington, DC, April 1995.[3]

7. ER 1110-2-106, "Recommended Guidelines for Safety Inspection of Dams," Table 3, U.S. Army Corps of Engineers, Washington, DC, September 1979.

8. R.F. Wilson-Fahmy, D.B. Narejo, and R.M. Koerner, "Puncture Protection of Geomembranes, Part I—Theory," *Geosynthetics International*, 3(5), 1996.[4]

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10. R.M. Koerner, R.F. Wilson-Fahmy, and D.B. Narejo, "Puncture Protection of Geomembranes, Part III—Examples," *Geosynthetics International*, 3(5), 1996.

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[1] Publicly available NRC published documents are available electronically through the Electronic Reading room on the NRC's public Web site at: http://www.nrc.gov/reading-rm/doc-collections/. The documents can also be viewed on-line or printed for a fee in the NRC's Public Document Room (PDR) at 11555 Rockville Pike, Rockville, MD; the mailing address is USNRC PDR, Washington, DC 20555; telephone 301-415-4737 or (800) 397-4209; fax (301) 415-3548; and e-mail PDR.Resource@nrc.gov.

[2] Electronic copies of public U.S. Army Corps of Engineers (USACE) publications are available for free download from the Internet at http://www.usace.army.mil/inet/usace-docs/. This site is the only repository for all official USACE engineer regulations, circulars, manuals, and other documents originating from HQUSACE. Publications are provided in portable document format (PDF).

[3] Electronic copies of publicly available U.S. Environmental Protection Agency (EPA) publications are available for free download from the Internet at http://www.epa.gov/nscep/. Hard copies are available for purchase from the EPA National Library Network at US EPA, Mail Code 3404T, 1200 Pennsylvania Avenue NW, Washington, DC 20460; telephone 202-566-0556.

[4] Copies of listed Geosynthetics International journal articles are available for purchase from the Institute of Civil Engineers, Thomas Telford Ltd., 40 March Wall, London, England, E14 9TP, telephone: +44 (0) 20 7665 2460 / 2418, or e-mail at Orders@icevl.com.

11. EM 1110-2-1100, "Coastal Engineering Manual," U.S. Army Corps of Engineers, Washington, DC.

12. NUREG/BR-0216, "Radioactive Waste: Production, Storage, and Disposal," Rev. 2, U.S. Nuclear Regulatory Commission, Washington, DC, May 2002.

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1. Regulatory Guide 3.11, "Design, Construction, and Inspection of Embankment Retention Systems at Uranium Recovery Facilities," US Nuclear Regulatory Commission, Washington, DC.

2 Regulatory Guide 1.127, "Inspection of Water-Control Structures Associated with Nuclear Power Plants," US Nuclear Regulatory Commission, Washington, DC.

3. Regulatory Guide 1.132, "site Investigations for Foundations of Nuclear Power Plants," US Nuclear Regulatory Commission, Washington, DC.

4. Regulatory Guide 1.138, "Laboratory Investigations of soils and rocks for Engineering analysis and Design of Nuclear Power Plants," US Nuclear Regulatory Commission, Washington, DC.

5. Regulatory Guide 1.198, "Procedures and Criteria for Assessing Seismic soil Liquefaction at Nuclear Power Plants," US Nuclear Regulatory Commission, Washington, DC.

6. Regulatory Guide 1.59, "Design Basis Floods at Nuclear Power Plants," US Nuclear Regulatory Commission, Washington, DC.

Appendix 3

Attachment 3

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REGULATORY GUIDE

OFFICE OF NUCLEAR REGULATORY RESEARCH

REGULATORY GUIDE 3.11

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DESIGN, CONSTRUCTION, AND INSPECTION OF EMBANKMENT RETENTION SYSTEMS AT URANIUM RECOVERY FACILITIES

A. INTRODUCTION

This guide describes some engineering practices and methods generally considered by the U.S. Nuclear Regulatory Commission (NRC) to be satisfactory for the design, construction, and inspection of embankment retention systems used for retaining liquid and solid wastes from uranium recovery operations. These practices and methods are the result of NRC review and action on a number of specific cases, and they reflect the latest general engineering approaches that are acceptable to the NRC staff. If future information results in alternative methods, the NRC staff will review such methods to determine their acceptability. Separate guidance (Refs. 1–3) addresses the closure of retention systems.

Licensees who process or refine uranium ores in a milling operation are required by Title 10, Section 20.1101, "Radiation Protection Programs," of the *Code of Federal Regulations* (10 CFR 20.1101) to use, to the extent practical, procedures and engineering controls based on sound radiation protection principles, to maintain occupational radiation exposure and radiation exposure to members of the public that are as low as is reasonably achievable (ALARA). In addition, Subpart B, "Environmental Standards for the Uranium Fuel Cycle," of 40 CFR Part 190, "Environmental Radiation Protection Standards for Nuclear Power Operations," requires that the annual dose equivalent not exceed 25×10^{-5} sieverts (Sv) (25 millirem (mrem)) to the whole body, 75×10^{-5} Sv (75 mrem) to the thyroid, and 25×10^{-5} Sv (25 mrem) to any other organ of any member of the public as the result of exposures to radiation (radon and its daughters excepted) from uranium fuel cycle operations, including planned discharges of radioactive

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materials to the general environment. Liquid and solid wastes generated in uranium recovery operations typically contain radioactive materials in excess of the discharge limits and are generally confined by an embankment retention system.

This regulatory guide contains information collection requirements covered by 10 CFR Part 20 and 10 CFR Part 40 and that the Office of Management and Budget (OMB) approved under OMB control numbers 3150-0014 and 3150-0020, respectively. The NRC may neither conduct nor sponsor, and a person is not required to respond to, an information collection request or requirement unless the requesting document displays a currently valid OMB control number.

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B. DISCUSSION

Background

The milling of uranium ores results in the production of large volumes of liquid and solid wastes (tailings). These tailings are usually stored behind manmade retaining structures, following the practice of the nonuranium mining industry. In addition, other liquid wastes from operations and ground-water corrective action activities at uranium recovery facilities are often retained behind evaporation pond embankments. The design and construction of early tailings retention structures were based largely on mining experience, with little use of design concepts. These empirical approaches resulted in various mining dam mishaps and failures (Refs. 4 and 5). The 1972 failure of Buffalo Creek Dam in West Virginia resulted in the U.S. Congress passing a national dam safety law affecting all water-impounding structures in excess of either 7.62 meters (25 feet) in height or 61,674 cubic meters (50 acre-feet) in impoundment capacity (Ref. 6).

Wastes from uranium recovery operations, unlike most nonuranium mine wastes, contain concentrations of radioactive materials in excess of allowable discharge limits (Ref. 7). Furthermore, the most significant radioactive element in the wastes is radium-226, which has a half-life of about 1600 years (Ref. 8). Therefore, it is necessary to confine such wastes to prevent or control their release to the environment, not only during the operation of the uranium recovery facility, but also for generations after operations have ceased. The embankments, foundation, and any abutments need to be stable under all conditions to prevent the uncontrolled release of the retained liquid or semifluid wastes. Seepage from the tailings cell or evaporation pond, which contains dissolved radium and other toxic substances (Ref. 8), needs to be controlled under normal and severe operating conditions to prevent the possibility of unacceptable contamination of the ground water or nearby streams. The impoundment and embankments need to be designed to prevent wind and water erosion during operation, and after facility closure in the case of reclaimed tailings impoundments.

Factors pertaining to safety, contamination, and environmental damage determine the basic requirements in planning and constructing retention systems. To achieve the basic requirements, the design must be based on a thorough understanding of both the geotechnical and hydrological problems involved and the requirements of the uranium recovery operation.

The latest advances in geotechnical engineering, together with engineering experience and knowledge in the field of water storage dams and retention structures, can be used in the design and construction of uranium recovery retention systems. The basic concepts of conventional water storage impoundments can be suitably modified to produce economical designs that will ensure the stability of the retention system and minimal contamination.

1. General Planning, Siting, and Design Considerations

Because the prime functions of the retention system are to store radioactive solids and/or to provide temporary storage of contaminated water for clarification and evaporation, the system must be designed and constructed to remain stable for its intended life. It must provide the required storage at any given time, and it must provide sufficient control of seepage to prevent unacceptable contamination of adjacent land, waterways, and ground waters. It must also be designed to be resistant to wind and water erosion during and after facility operations.

The planning, siting, and design of uranium recovery retention systems need to ensure that such systems meet any other regulatory and permitting requirements for a proposed impoundment that exist outside NRC's regulations (10 CFR Part 40, Appendix A) and regulatory process.

The siting and design should consider the requirements of the U.S. Environmental Protection Agency's (EPA) national emission regulations at Subpart W, "National Emissions Standards for Radon Emissions from Operating Mill Tailings," of 40 CFR Part 61, "National Emission Standards for Hazardous Air Pollutants." Subpart W requires that "... no new tailings impoundment can be built unless it is designed, constructed, and operated to meet one of the two following work practices: (1) Phased disposal in lined tailings impoundments that are no more than 40 acres in area and meet the requirements of 40 CFR 192.32(a) as determined by the Nuclear Regulatory Commission. The owner or operator shall have no more than two impoundments, including existing impoundments, in operation at any one time. (2) Continuous disposal of tailings such that tailings are dewatered and immediately disposed with no more than 10 acres uncovered at any time and operated in accordance with 40 CFR 192.32(a) as determined by the Nuclear Regulatory Commission." Furthermore, the design should consider the requirements of 40 CFR 264.221 addressing surface impoundment design and operation. An applicant or licensee should consider these EPA regulations during the preliminary design and planning stages of the tailings retention system.

1.1 Site Evaluation

The goal in the siting and design of uranium recovery retention systems is to achieve permanent isolation of tailings and associated contaminants by minimizing disturbance and dispersion by natural forces and to do so without ongoing maintenance. In the selection of alternative tailings disposal sites or in the evaluation of the adequacy of existing tailings sites, all site features that will contribute to this goal should be considered, including (1) remoteness from populated areas, (2) hydrologic and other natural conditions as they contribute to continued immobilization and isolation of contaminants from ground-water sources, and (3) potential for minimizing erosion, disturbance, and dispersion by natural forces over the long term. In the selection of disposal sites, primary emphasis must be given to the isolation of tailings or wastes, a matter having long-term impacts, as opposed to the consideration of only short-term convenience or benefits, such as minimization of transportation or land acquisition costs. While isolation of tailings will be a function of both site conditions and engineering design, siting features are the primary consideration for ensuring permanent isolation of wastes given the long-term nature of the tailings hazards.

To the extent possible, sites should be selected that are at or near the top of local drainage divides and/or are not located in floodplains or flood-prone areas. Such site selection will avoid the need for diversion channels or extensive riprap protection to prevent erosion of the toes and slopes of the embankments.

The "prime option" for the disposal of tailings is placement below grade. Where full below-grade burial is not feasible, the size of retention structures, as well as the size and steepness of slopes associated with exposed embankments, must be minimized by excavation to the maximum extent reasonably achievable given the geologic and hydrologic conditions at a site. In these cases, it must be demonstrated that an above-grade disposal program will provide equivalent isolation of the tailings from natural erosion forces.

In selecting any site for uranium recovery waste retention, detailed local conditions, including climate, ground-water and surface-water hydrology, geology, and seismology, need to be assessed and their impacts evaluated.

1.2 Field Exploration

Subsurface investigations at the site of the retention system and at possible borrow areas need to be of adequate scope to determine the suitability of the foundation and the availability and characteristics of embankment materials. Borings should be drilled along the axis of the retention structure and at critical locations perpendicular to the axis to establish geologic sections and ground-water conditions. Generally, borings should extend to a depth in the natural soils at least equal to the height of the planned embankment section. A minimum of 4.57 meters (15 feet) into natural soils is required for small retention structures. The investigations should cover classification, physical and chemical properties, location, and extent of soil and rock strata, and variations in ground-water conditions. Evaluation of ground water should be focused on the uppermost aquifer. The field exploration should identify this aquifer, its flow direction, and the distance from the impoundment to potential down-gradient users. In addition, the background ground-water quality of the uppermost aquifer should be obtained in accordance with the preoperational guidance in Regulatory Guide 4.14, Revision 1, "Radiological Effluent and Environmental Monitoring at Uranium Mills," issued April 1980. Observation of ground-water conditions should be recorded over a sufficient period to permit the ground-water depths and range of seasonal fluctuations to be established.

The foundation conditions must be determined to assess the ability of subsurface materials to support the embankments without failure and without excessive total or differential settlement. The permeability of foundation soils and rocks must be ascertained to estimate the seepage potential. The availability of suitable borrow material for retention system construction must be assessed with consideration of the construction sequence and schedule.

Information is needed on the characteristics of the underlying soil and geologic formations, particularly as they will control transport of contaminants and solutions. This includes detailed information concerning extent, thickness, uniformity, shape, and orientation of underlying strata. Hydraulic gradients and conductivities of the various formations must be determined. This information must be gathered from borings and field survey methods taken within the proposed impoundment area and in surrounding areas where contaminants might migrate to ground water. Hydrologic parameters such as permeability may not be determined on the basis of laboratory analysis of samples alone; a sufficient amount of field testing (e.g., pump tests) must be conducted to ensure an adequate understanding of actual field properties.

1.3 Laboratory Tests

Testing soil samples of foundation and embankment materials from the field investigation should result in detailed knowledge of such physical and mechanical properties as classification, gradation, shear strength, consolidation, permeability, sedimentation, compaction, piping and cracking susceptibility, and wind-water erosion characteristics.

2. Design Analysis

Design analysis should consider stability, settlement, seepage, hydrologic analyses, liner stability, and liner compatibility. Specifically, the design must ensure that retention system failure will not occur. Historical records (Refs. 9–12) indicate that most failures associated with tailings retention systems have been caused by overtopping by flood waters, erosion, piping in the retention embankment or the foundation, foundation failure, slope failure, or liquefaction.

2.1 Stability and Failure Analyses

2.1.1 Slope Stability

Slope failure occurs when an outer portion of an embankment slides downward and outward with respect to the remaining part of the embankment. The slide generally occurs along a fairly well-defined slip surface.

2.1.1.1 Methods of Analyses

Stability analyses involve comparing the shearing stresses along potential failure surfaces with the available shearing resistance along those surfaces. The factor of safety is the ratio of the available shear strength to the developed maximum shear stress.

A number of computer programs can be used to perform slope stability analyses. Computer programs provide an easier means to (1) consider complex slope geometries and subsurface soil layering, (2) use a number of different types of soil in the analysis, (3) search for circular, wedge, and noncircular failure surfaces, (4) consider different models to represent soil strength, and (5) consider different loading conditions. When used properly, these programs can allow a designer to consider a significant number of potential slip surfaces. Commercially available programs also may allow calculation of the factor of safety using several of the methods identified below. Despite these advantages, the output from a computer program needs to be checked carefully to verify that the critical surface with the lowest factor of safety has been identified, the critical surface represents a possible or realistic scenario, and computational problems resulting from the parameters used are minimized. For complicated situations, it may be prudent to verify the analysis with a second computer program or a hand calculation.

2.1.1.2 Static Stability Analysis

Limit Equilibrium

Conventional limit equilibrium methods of slope stability analysis evaluate the equilibrium of a soil mass tending to move down slope under the influence of gravity. Many methods use the limit equilibrium approach. Various publications (Refs. 13–15) offer detailed discussions. The following provides a brief overview of several of these methods:

- *Friction Circle Method*—This method considers the entire sliding block as a rigid free body and makes assumptions regarding the distribution of normal stresses along the failure surface. It can be used only to evaluate failure surfaces that are circles or single straight lines and is most suited to homogeneous soil conditions. The Logarithmic Spiral Method is a different version of this method.

- *Method of Slices*—This method divides the free body into many vertical slices, and the equilibrium of each slice is considered. The best known and most widely used versions of this method are the Ordinary Method of Slices, the Swedish Circle Method, Modified Swedish Method, Simplified Bishop Method, Spencer's Method, and Morgenstern-Price Method. Although this method can be used to analyze wedge and noncircular slip surfaces, certain methods, such as the Ordinary Method of Slices and Simplified Bishop Method, require a circular slip surface. The analyses should consider both shallow slip surfaces that run through the embankment as well as deep slip surfaces that run beneath the embankment (Refs. 16 and 17).

- *Wedge Method*—This method is used whenever the failure surface can be satisfactorily approximated by a series of straight lines (usually two or three).

- *Special Cases*

  - Infinite Slope—This analysis is suited to cases in which a slip surface may form parallel to the face of the slope. This type of failure can be approximated using a circular surface with a large radius. However, a simple approach has been developed based on equilibrium of forces. Several publications (Refs. 15–18) discuss this situation in detail.

  - Geomembranes—If a geomembrane is to be used as a component of a retention system, a stability analysis of a layer of cover soil on top of the geomembrane may be needed. This type of analysis can be sensitive to the slope angle and the interface friction between the cover soil and the geomembrane (Refs. 19 and 20).

Deterministic versus Probabilistic Analyses

In traditional deterministic approaches to slope stability analysis, the foundation soil properties, pore pressure, geometry, and loading conditions are held constant, and one of the analysis techniques identified above is used to calculate the factor of safety. In this approach, the numerical values used in the analysis do not account for the inherent variability of material properties, pore pressures, and loading conditions that can exist within a given slope. Probabilistic methods make it possible for a slope stability analysis to consider the variability of these parameters. While the use of probabilistic methods is not required when designing an embankment or retention system, it can aid in the interpretation of an analysis. Reference 21 further discusses probabilistic methods in slope stability analysis.

Finite Element Method

The finite element method (FEM) is most useful when calculating the stresses, pore pressures, and deformation of a slope. FEM can be used to calculate a factor of safety in a slope stability analysis, but this requires additional steps beyond the typical FEM output. FEM usually requires information about the stress-strain behavior of soil to provide a reasonable answer. This can require complex laboratory testing. Because of the considerable time and effort required to develop an accurate and representative understanding of the soil conditions, FEM is best suited to aiding the interpretation of difficult slope stability problems. Examples of situations in which FEM may be applicable include (1) pore pressure dissipation and corresponding strength gain in tailings slimes, (2) settlement of an embankment as it is raised, (3) consolidation of soft soils beneath an embankment, and (4) identifying areas of displacement near critical structures. References 15 and 22 further discuss FEM.

2.1.1.3 Dynamic (Seismic) Stability Analysis

In areas where embankments are subjected to seismic disturbances, seismic stability analyses should be performed. Seismic vibrations can cause liquefaction of saturated or nearly saturated loose sands and sensitive silts (Ref. 4). The dynamic shearing stresses induced during the seismic events can cause excessive deformation, distortion, or even shear failure of the embankment (Refs. 23 and 24).

Seismic stability analyses of embankments are conventionally made using pseudostatic methods (Ref. 25). In this approach, the stability of a potential sliding mass is determined assuming static loading conditions, and the computation accounts for the effects of an earthquake by including an equivalent horizontal force acting on the potential sliding mass. The horizontal force representing earthquake effects is expressed as the product of the weight of the sliding mass and a seismic coefficient. The value of the seismic coefficient is normally selected on the basis of the seismicity of the region in which the embankment is to be constructed.

During earthquakes, large cyclic inertia forces are induced in embankments. In certain zones of an embankment, the inertia forces may be sufficiently large and may occur often enough to cause permanent displacements. Newmark (Ref. 26), Goodman and Seed (Ref. 23), and Makdisi and Seed (Refs. 27 and 28) have proposed procedures for estimating the magnitude of these displacements. These approaches are more involved than conventional methods and have been used successfully to predict the surface displacements of embankments. Other approaches may be used; however, good engineering judgment should be exercised in the selection of soil characteristics, the application of the approach to the soil type and saturation conditions, and the evaluation of the results obtained.

In dealing with saturated, cohesionless soils, the dynamic analysis procedures developed by Seed et al. (Ref. 29) provide a basis for assessing the stability and deformation of the embankment during earthquakes. This type of analysis may be used to predict the development of the liquefaction zone and the anticipated movements, deformation, and stability of the embankment and its foundation. However, good engineering judgment based on adequate data must be exercised in the selection of soil characteristics for use in the analyses, the detailed steps followed to conduct the analyses, and the evaluation of the results obtained.

Reference 30 contains a detailed discussion and applicable guidelines for seismic analysis and design of tailings embankments.

2.1.1.4 Loading Conditions and Factors of Safety

A tailings embankment and its foundation are subjected to shear stresses imposed by the weight of the embankment, the filling of the impoundment, seepage, or earthquake forces. The cases for which stability analyses are necessary include the following:

- *End of construction*—Analyses of the upstream and downstream slopes are needed for the end-of-construction conditions if the embankment and its foundation are partially or entirely composed of impervious soils. The unconsolidated undrained shear strength should be used in the analyses for slow-draining soils, while consolidated drained shear strength should be used for free-draining soils in which excess pore pressures would not develop.

- *Partial pool with steady seepage*—Analyses of the upstream slope are needed for several intermediate pool stages with corresponding steady seepage conditions. The analyses account for a reduction in effective normal stresses when pore water pressure that developed during construction or filling did not dissipate before the subsequent partial pool condition. The lower strength from either the consolidated undrained shear test or consolidated drained shear test is used in the analyses. The minimum factor of safety should be determined as a function of pool elevations.

- *Maximum storage pool with steady seepage*—This condition may develop and may be critical to downstream slope stability. A flow net would be helpful in determining the phreatic line and seepage forces. Shear strength selection should be the same as for the partial pool with steady seepage condition.

- *Earthquake*—In areas subject to seismic shocks, appropriate earthquake forces need to be added onto the previous loading conditions in the stability analyses.

The use of a factor of safety in stability analyses should allow sufficient margin for variations between the parameters used in the design and those existing in the field, as well as consideration of the limits of strains. Many soils undergo relatively large plastic strains as the applied shear stresses approach the shear strength of the soil.

When choosing the factor of safety, the analyst needs to consider the consequence of a failure, the tolerable limits of strains, and the degree of confidence in engineering parameters used in the analyses. The minimum factor of safety suggested in the regulatory position of this guide presumes that the stability analysis has been sufficient to locate the critical failure surface and that parameters used in the analysis are known, with reasonable certainty, to represent actual conditions of the dam and its foundation. Otherwise, higher factors of safety would be required.

2.1.2 *Liquefaction*

Liquefaction impacts on stability need to be considered, if potentially liquefiable soils exist below the site of a retention system. Evaluation of liquefaction potential should include laboratory testing, in situ testing, and comparisons to similar soil deposits. The following five screening criteria should be used to determine whether there are potentially liquefiable soils at a site (Ref. 31):

(1) *Geologic age and origin*—If a soil layer is a fluvial, lacustrine, or aeolian deposit of Holocene age, a greater potential for liquefaction exists than for till, residual deposits, or older deposits.

(2) *Fines content and plasticity index*—Liquefaction potential in a soil layer increases with decreasing fines content and plasticity of the soil. Cohesionless soils having less than 15 percent (by weight) of particles smaller than 0.005 millimeters, a liquid limit less than 35 percent, and an in situ water content greater than 0.9 times the liquid limit may be susceptible to liquefaction (Ref. 32).

(3) *Saturation*—Although soils with low water content have been reported to liquefy, at least 80- to 85-percent saturation is generally deemed to be a necessary condition for soil liquefaction. The highest anticipated temporal phreatic surface elevations should be considered when evaluating saturation.

(4) *Depth below ground surface*—If a soil layer is within 15.24 meters (50 feet) of the ground surface, it is more likely to liquefy than deeper layers.

(5) *Soil penetration resistance*—Seed et al. (Ref. 33) state that soil layers with a normalized standard penetration test (SPT) blowcount [(N1)60] less than 22 have been known to liquefy. Marcuson et al. (Ref. 34) suggest an SPT value of [(N1)60] less than 30 as the threshold to use for suspecting liquefaction potential. Liquefaction also has been shown to occur if the normalized cone penetration test cone resistance is less than 1.59 megapascals (157 tons per square foot) (Ref. 35).

If three or more of the above criteria indicate that liquefaction is not likely, the potential for liquefaction can be dismissed. Otherwise, a more rigorous analysis of the liquefaction potential at a facility is required. However, even if three or more of the liquefaction evaluation criteria indicate that liquefaction is unlikely, historical evidence of past liquefaction or sample testing data collected during the subsurface investigation may raise enough of a concern that a full liquefaction analysis still should be done.

If liquefaction potential exists at a retention system site, additional subsurface investigation may be necessary. Once all testing is complete, a factor of safety against liquefaction should be calculated for each critical layer that may liquefy. Seed and Idriss (Ref. 36) outline one procedure for evaluating liquefaction potential. A liquefaction analysis should, at a minimum, include the following:

- development of a detailed understanding of site conditions, the soil stratigraphy, material properties and their variability, and the areal extent of potential critical layers
- development of simplified cross-sections amenable to analysis
- calculation of the force required to liquefy the critical zones (resisting force), based on the characteristics of the critical zone(s) (e.g., fines content, normalized standardized blow count, overburden stresses, level of saturation)
- calculation of the design earthquake effect (driving force) on each potentially liquefiable layer using the site-specific, in situ soil data and an understanding of the earthquake magnitude potential for the facility
- computation of the factor of safety against liquefaction (resisting force divided by driving force) for each liquefaction susceptible critical layer

2.1.3 *Settlement*

If the foundation beneath an embankment retention system consists of layers of compressible soils or weathered rock, or if the bedrock profile is very irregular, differential settlements could result from uneven loading or variable thicknesses in the compressible soils. Total settlement and differential settlements may cause cracking and/or excessive strain in the embankments or other retention system components that could lead to system failure.

The magnitude of the anticipated settlement can be estimated from the results of laboratory consolidation tests on samples recovered from the compressible foundation strata and remolded embankment materials. The rate of settlement also can be estimated. However, the potential error in estimating the time for settlement to occur is significant, since settlement is influenced by soil drainage, which is controlled by minute geological details that may not be detected during the geotechnical investigation. Predictions based on laboratory data can be modified by actual measurements to provide reasonably accurate long-term estimates. Settlement should be calculated along as many cross-sections as are necessary to ensure that the expected amounts of overall and differential settlement that the engineered components of the facility will experience have been adequately estimated.

After total and differential settlement analyses have been performed, the engineered components of the waste retention system, such as geotextiles, geomembranes, clay liners, drainage layers, leachate collection piping, and waste piping, should be analyzed for tensile strain. The analysis should verify that the components can maintain their integrity when subjected to the induced strain associated with the settlement determined in the total and differential settlement analyses. If analysis indicates that total and differential settlement along any cross-section is likely to damage an engineered component, or to cause the engineered component to be unable to meet the minimum design criteria, then the retention system must be redesigned to eliminate the adverse effects of total and differential settlement. Methods such as overbuilding, surcharging, removal of the material causing the problem, or engineered reinforcement can be used to mitigate the effects of settlement.

2.2 Water Control and Management

2.2.1 *Impoundment Storage Capacity*

Some catchment area will always contribute runoff into the tailings retention system. This generally will be the area of the system itself, given requirements for below-grade impoundments, but might, in some cases, be a larger area incorporating the drainage area of streams entering a valley in which a retention embankment is constructed. Substantial runoff volumes and flows can result from heavy precipitation or snowmelt over relatively small catchment areas.

Because the probability of occurrence of large floods on small drainage basins in arid regions is very small and onsite personnel should be available to repair any minor damage that could occur, the staff may accept less conservative options for determining the design-basis flood. For small retention systems built in isolated areas where failure would neither jeopardize human life nor create damage to property or the environment beyond the licensee's legal liabilities and financial capabilities, the design need not use extremely conservative flood design criteria. However, the selection of the design flood needs to be at least compatible with the hazard category guidelines set forth by the U.S. Army Corps of Engineers (Ref. 37). If impoundments are designed to contain only direct precipitation that falls into the reservoir area, a single occurrence of the 6 hour probable maximum precipitation (PMP) may be used to determine storage capacity and freeboard requirements. If the tailings retention system has some external drainage area, and hydraulic structures (such as diversion channels) are needed to safely divert the probable maximum flood (PMF), the peak PMF inflows and runoff used to design such structures should be determined in accordance with the suggested flood design criteria in NUREG-1623, "Design of Erosion Protection for Long-Term Stabilization," (Ref. 2).

If decant or other reclaim systems have not been designed specifically to handle the design flood, other measures need to be taken. Those other measures may be one or a combination of the following:

- The whole volume of flood runoff is stored. Sufficient freeboard should always be available to provide the necessary storage capacity without overtopping the embankment, as well as adequate protection against wave runup.

- Diversion channels are provided to convey runoff water safely past the retention system.

Determination of the freeboard necessary at any time to store flood runoff will require information on pond storage versus elevation, anticipated embankment settlement versus time, and the expected runup of wind-generated waves. Reference 38 presents procedures for determining wave runup. It is important that the embankment construction schedule ensure that the required freeboard is always available.

Adequate slope protection is needed to guard the embankment against wind and water erosion, weathering, and ice damage. Methods for protecting slopes include dumped riprap, precast and cast-in-place concrete pavements, bituminous pavement, soil cement, tailings beaches, sodding, and planting. The necessary upstream slope protection depends on the expected wind velocity and duration and the size and configuration of the reservoir at the water-surface elevation. Reference 38 provides methods and criteria for the selection and design of slope protections. If the toe of the embankment is subject to flooding or erosion from nearby streams or arroyos, it may be necessary to provide erosion protection for the toes and exterior side slopes. NUREG-1623 (Ref. 2) provides guidance for determining design floods and erosion protection.

2.2.2 *Diversion Channel Design*

Any channels that are needed to protect against flooding and erosion of embankments or tailings should be designed to safely pass a PMF with minimal, if any, damage to the channel. The essential criterion is that no release of tailings or contaminated materials should occur during a PMF, with the recognition that onsite personnel can repair minor damage within a short period of time. For example, a channel could be designed to pass only a 100-year flood, so long as the PMF does not result in the release of contaminated material.

2.2.3 *Seepage and Hydrostatic Uplift Analyses*

Since regulations require retention systems to be lined, seepage analysis for embankment stability purposes is unnecessary. However, special design features, such as impervious liners and collection systems, are needed to maintain the quality and quantity of seepage from the retention system within tolerable limits of water supply and pollution control requirements. Section 2.2.4 of this regulatory guide details seepage control considerations.

Hydrostatic uplift may affect the subbase or engineered components of a waste containment facility anytime ground water exists at a facility. When an excavation or a portion of a waste containment facility is to be constructed at a depth at which a phreatic surface of ground water or piezometric pressures are present, the potential adverse effects on the waste containment facility need to be taken into account. An unstable condition caused by hydrostatic uplift may develop when the hydrostatic uplift force overcomes the downward force created by the weight of the overlying soil. If the area acted on by the hydrostatic force is sufficiently great, excess water pressure may cause overlying soil to rise, creating a failure known as "heave." Although heave can take place in any soil, it will most likely occur at an interface between a relatively impervious layer (such as a clay liner) and a saturated, relatively pervious base.

2.2.4 *Seepage Control*

The potential for seepage at an embankment retention system can be controlled through two means. The first is to employ a system to provide a method to dewater tailings after they are placed in the retention system. The other means is to install a liner system.

Regulations focus on using synthetic liners for the retention systems. However, a design should consider that, with an impervious bottom, process liquids and/or infiltration into the impoundment can result in excessive buildup of liquids after closure. The minimization of this potential for "bathtubbing" should be addressed through discussion of mitigative design aspects, including plans for operational dewatering (see 2.2.4.1 below) and future construction of an infiltration barrier in the closure cover.

2.2.4.1 Dewatering

Regulations require that new tailings impoundment retention systems be dewatered by a drainage system installed at the bottom of the impoundment. The goal of the drainage system is to lower the phreatic surface within the waste materials to reduce the head acting on the liner system. This can be accomplished by several methods. One method is to include a highly permeable layer immediately above the liner system and slope the liner system to a low point. A pump or gravity drain system can then be used to remove the collected liquids from this low point. An alternative method would be to pump liquids out of vertical wells within the tailings. In either case, the potential clogging of the drainage materials should be addressed. The U.S. Department of Agriculture (USDA) Engineering Handbook (Ref. 39) offers examples of design methods for soil filters. References 40 and 41 outline methods for designing synthetic filters.

2.2.4.2 Liners

An embankment retention system for uranium recovery wastes is required to have a liner to prevent the migration of wastes to surrounding soil, ground water, or surface water during its operation and closure period. The design of a liner system should consider subgrade material, type of liner system, liner system protection, and leak detection. A complete liner system design also should address anticipated installation techniques and operating practices. Sections 3 and 4 of this regulatory guide present specific items related to construction and operation respectively.

Subgrade

Proper design and understanding of the subgrade soils is very important to the success of a liner system. Design of the subgrade should consider the available soils, focusing on their gradation and moisture/density relationships. The subgrade surface needs to be competent and able to withstand the anticipated construction traffic. As previously mentioned in Section 2.1.3, a settlement analysis should be performed on the subgrade soils. The purpose of this analysis is to demonstrate that the anticipated settlement of the subgrade will not damage the liner system. The amount of settlement will depend on several factors, including the soil type, subgrade drainage condition, the depth and weight of the material that will be placed on the liner, and the rate of placement of the material on the liner system.

As discussed in Section 2.2.3, the subgrade design should consider the location and potential changes in the ground-water table. If a retention system is located in an area where the water table could rise above the bottom of the liner system, an underdrain may be required to prevent the development of upward water pressure on the liner.

Liner System Selection

The choice of the liner system should consider several factors. A key factor is the liner material's physical and chemical inertness when exposed to the waste materials within the retention system. The chemical qualities of the tailings, slurry, and/or liquid wastes must be assessed to determine the impacts on liners and/or the environment, if contamination resulting from seepage or surface water runoff occurs.

One issue specific to earthen liner layers is the potential for the hydraulic conductivity to increase with time (Ref. 42). Excessive settlement or desiccation can lead to the development of cracks within an earthen layer. This increases the hydraulic conductivity which in turn decreases the effectiveness of the liner system. The subgrade design should address settlement, and desiccation should be handled through an understanding of the subgrade soil conditions and an identification of the proper moisture content range during design.

The advantages of a synthetic liner system include a significantly reduced thickness, a greater resistance to cracking, and a much lower hydraulic conductivity (typically several orders of magnitude lower than an earthen liner system). The design of a synthetic liner system should consider the method of placement, the seaming techniques, and the puncture resistance. Lupo and Morrison (Refs. 43 and 44) outline current design approaches using synthetic materials for mining applications. Theory and design methods to evaluate puncture resistance have been developed and can be used to evaluate the puncture resistance of synthetics for different conditions (Refs. 45–47).

Protection of the Liner System

Ultraviolet radiation, wave action, surface runoff, foot traffic, animals, ice, wind, and construction equipment may damage a liner system. Therefore, a liner system design should consider various protective measures to prevent damage. Protective measures may be particularly important when a synthetic liner is used. Possible protection methods include soil covers, sand bags, game-proof fences, and access restrictions.

Soil covers can protect against ultraviolet radiation, wave action, animals, wind, and construction equipment. The design should address certain aspects of soil covers, including sloughing during heavy precipitation or during rapid drawdown of the liquid within the retention system and erosion during high-precipitation events. The stability of soil covers placed over synthetic liners may need to be analyzed. A series of properly arranged sandbags can be an effective method of protecting a synthetic liner from wind damage. The sandbags need to have an appropriate weight, spacing, and anchoring system to provide the required resistance to wind forces. Use of sandbags as protection has the added benefit of preserving access to the liner for visual inspection and repair. A game-proof fence may need to be installed around the perimeter of the embankment system. The fence should be designed to prevent entry of sharp-hoofed animals such as antelope, deer, and cattle. The fence should be of sufficient height and strength to preclude entry of species known to be in the area.

Leak Detection

A leak detection system is required with a synthetic liner. The leak detection system should be designed to identify the approximate locations of leaks so repairs can be made and to isolate leaks so that they can be controlled. The leak detection system generally consists of either a highly permeable soil or synthetic material such as a geonet located immediately beneath the synthetic liner. This highly permeable layer should be designed to drain to sumps where the leakage can be monitored. Consideration should be given to developing a contoured grading plan that has a series of peaks and valleys for the liner and leak detection system to identify the approximate location of any leak. The design of a leak detection system also should establish an allowable leakage rate (ALR). The ALR should take into account anticipated defect rates in the synthetic layer, hydraulic head conditions on the liner system, and flow rates within the detection layer. If leakage is found in the detection system at a rate greater than the ALR, remedial action is necessary.

3. Construction Considerations

Construction approaches for impoundments are closely related to the specific site and operational conditions. As discussed in Section 1.1 of this guidance, the prime option identified in Criterion 3 of Appendix A, "Criteria Relating to the Operation of Uranium Mills and the Disposition of Tailings or Wastes Produced by the Extraction or Concentration of Source Material from Ores Processed Primarily for Their Source Material Content," to 10 CFR Part 40, "Domestic Licensing of Source Material," is to locate an impoundment below grade. However, certain geologic or hydrogeologic features at a site may make it impractical to locate an impoundment entirely below grade. Given the flexibility provided by Criterion 3, three possible construction scenarios exist:

(1) *Full excavation*—In this scenario, the impoundment would be constructed by excavation to a depth sufficient to accommodate the tailings volume. Depending on the topography of the site, a small perimeter embankment may be required to prevent storm-water runoff from entering the impoundment. This scenario would result in excess soil that would have to be disposed of or used elsewhere.

(2) *Partial excavation*—Under this scenario, the site conditions prevent full excavation of the impoundment. A portion of the retention system would be excavated and an embankment would be built around the excavated cell to create the required disposal capacity. In this scenario, the depth of excavation and height of the perimeter embankment will dictate whether there will be a balanced soil cut and fill, some excess soil to use elsewhere, or a need for some additional borrow material.

(3) *No excavation*—This scenario should be considered only when adverse site conditions exist, such as a high ground-water table or bedrock near the ground surface. The impoundment would be created by constructing an embankment around its perimeter. This scenario would require that a borrow source for embankment material be located in the general vicinity of the impoundment.

The construction of embankment retention systems generally involves both excavation and filling in some specified order. For any of the construction scenarios identified above, successful embankment retention system construction requires understanding the moisture/density relationships of the soils, providing adequate compaction, and preventing poor-quality soils from being incorporated into the embankment retention system fill materials. Much additional information on the characteristics of foundations is obtained during clearing and stripping operations, which may confirm or contradict design assumptions based on earlier geotechnical investigations. Weather and ground-water conditions during construction may significantly alter water contents of proposed fill material or create seepage and/or hydraulic conditions, necessitating modifications in design. Projects must be evaluated and "reengineered" continuously during construction to ensure that the final design is compatible with conditions encountered during construction. Construction supervision, management, and monitoring of the embankment and associated structures are a critical part of the overall project management plan. Once the facility is placed into operation, observations, surveillance, inspections, and continuing evaluation are required to ensure the satisfactory performance of the retention system (see Section 4 of this regulatory guide).

Installation of a synthetic liner system should focus on minimizing liner damage. Damage can occur in the form of wrinkles, improper seaming techniques, poor synthetic panel orientation, and punctures caused by construction equipment. The potential for wrinkle development can be minimized by orienting panels properly, seaming within the allowable range of temperatures, and compacting the subgrade properly. Synthetic liner manufacturers often provide specific guidance on proper techniques for minimizing wrinkles. Seams typically constitute the weakest portion of a synthetic liner system. Therefore, the layout of the synthetic panels should minimize the location of seams in high-stress areas. Punctures can be minimized by following manufacturer recommendations for allowable ground pressures and minimum protective cover requirements for construction equipment working on a synthetic liner. Quality assurance practices during synthetic liner installation need to be rigorous, and a leak location survey after synthetic liner installation may be beneficial.

The construction plans should include construction specifications for excavation, embankment construction, subgrade preparation, liner placement, and the like. The general construction considerations for earthwork listed below should be considered as minimum guidelines, with the understanding that additional or more stringent specifications may be required depending on individual site conditions:

- A geotechnical or construction inspector should be on site during embankment construction.
- Fill material should be taken from an approved, designated borrow area. It should be free of roots, stumps, wood, rubbish, stones greater than 6 inches, and frozen or other objectionable materials.

- Areas on which fill is to be placed should be scarified before its placement.

- The compaction requirements for the fill material should include the percent of maximum dry density for the specified density standard, allowable range of moisture content, and maximum loose lift thickness.

- Fill material should be compacted with appropriate compaction equipment such as a sheepsfoot, rubber-tired, or vibratory roller. The number of required passes by the compaction equipment over the fill material may vary with soil conditions.

- Fill material should contain sufficient moisture to allow the required degree of compaction to be obtained with the equipment used.

- Field density tests should be performed regularly throughout the embankment construction. Many factors influence the frequency and location of control tests. Typically, a routine control test should be performed for every 764.5 to 2293.6 cubic meters (1000 to 3000 cubic yards) of compacted material or as directed by the geotechnical engineer.

- Proper subgrade preparation during construction is necessary for the installation of a liner system. The site of the retention system should be cleared of all debris, vegetation, and potential root systems. The surface should be graded so that it is smooth and free of protruding rock particles. The soil may need to be moisture conditioned to prevent it from drying out before the liner is put into use.

- To the extent possible, synthetic liner seams should run up and down and not across a slope. They should not be located near the crest of a slope. Seams should be tested for integrity along their entire length using methods recommended by the manufacturer. Seaming should be performed only under the supervision of experienced personnel.

In general, widely accepted construction standards and specifications for embankments, such as those developed by the USDA Soil Conservation Service or the U.S. Army Corps of Engineers, should be followed (Refs. 48 and 49).

4. Inspection and Maintenance

Different conditions can develop throughout the active life of the retention system. Such changes can significantly affect the conditions governing the stability of a retention system. Therefore, a continuous program of inspection of the retention system is needed, beginning with the start of construction, through the waste disposal, and, in the case of tailings disposal areas, continuing after reclamation. Each site and structure has its own characteristics and its own susceptibilities to problems, and the inspection program should be tailored to consider these. Thorough physical examination is an essential part of the inspection program. The optimal frequency of inspections depends on the size and condition of the facilities, the character of the foundation, the regional geological setting, and the consequences of failure in jeopardizing human health and safety and inflicting property and environmental damage. Monitoring and analysis of performance data are necessary to ensure detection of adverse conditions.

Before the start of waste disposal, records of ground-water levels (including seasonal fluctuations), ground-water quality, ground elevations, and background radioactivities at the site should be compiled and compared with the operational conditions of the impoundment. Data gathered in accordance with Regulatory Guide 4.14 will be useful in these comparisons. As soon as waste disposal begins, inspection should be performed at regular intervals to check the condition of the retention systems and associated facilities and to evaluate their structural safety and operational adequacy. A detailed, systematic inspection program should consist of, but not necessarily be limited to, the elements described in the sections below.

4.1 Engineering Data Compilation

Engineering data related to the design, construction, and operation of the retention systems should be compiled and, to the extent practicable, included in the initial inspection report. Most engineering data are readily available in documents filed for the license application. A detailed reference to the original documents kept at the project site should be adequate. These data should include the following items, as available and applicable:

- general project data, including regional vicinity maps showing the project location and the upstream and downstream drainage areas, and as-built drawings and photographs of the retention system
- hydrologic and hydraulic data, including drainage area and basin characteristics, waste storage volume, surcharge capacity for floods, rate of waste inflow, elevation of the maximum design pool, and freeboard height
- foundation data and geological features, including boring logs, geological maps, profiles, and cross-sections
- properties of embankment and foundation materials, including results of laboratory and field tests, and assumed design material properties
- principal design assumptions and analyses, including hydrologic and hydraulic analyses, stability and stress analyses, and seepage and settlement analyses
- pertinent construction photographs and records, including construction control tests, construction problems and modifications, and maintenance repairs

4.2 Inspection Programs

The retention system inspection program should be established and conducted systematically to minimize the possibility of overlooking any significant features. A detailed checklist should be developed and followed to document the observations of each significant feature. Photographs for comparison of previous and present conditions should be used as a part of the inspection program. The inspection program should include, but not be limited to, the following as appropriate:

- Daily Inspection
  - Pond water elevations should be examined and recorded to ensure that minimum freeboard is maintained.
  - The slurry transport system should be examined for any evidence of obstruction of the pipes or pumps caused by waste clogging or ice accumulation. The pipe couplings should be examined for leakage of waste, and any flow rate sensor should be tested.

- The retention embankments should be visually inspected for signs of erosion, cracking, slumping, movement, or concentration of seepage.

- The liner system should be inspected to identify any damage to the liner and any operating practices that may contribute to liner damage. The inspection should include a visual check of the presence of animals and the accumulation of water in the leak detection system.

- Monthly Inspection

  - Slurry transport pipes should be examined using an ultrasonic device at locations where pipes cross streams or other natural water courses or where a rupture of the pipe could be expected to affect the stability of the retention system.

  - Channels should be examined for channel bank erosion, bed aggradation or degradation and siltation, obstruction to flow, undesirable vegetation, or any unusual or inadequate operational behavior.

- Quarterly Inspection

  - The top of the embankment and downstream toe areas should be examined and surveyed, if necessary, for any evidence of unusual localized or overall settlement or depressions.

  - Embankment slopes should be examined for irregularities in alignment and variance from originally constructed slopes, unusual changes from original crest alignment and elevation, evidence of movement at or beyond the toe, erosion, and surface cracks that indicate movement.

  - The downstream embankment slopes and toes, and other downstream areas, should be examined for evidence of existing or past seepage, springs, and wet or boggy areas.

  - The slope protection should be examined for erosion-formed gullies and wave-formed notches and benches. The adequacy of slope protection against waves and surface runoff that may occur at the site should be evaluated. The condition of vegetation or any other types of protective covers should be evaluated, when pertinent.

  - Any installed instrumentation, such as survey monuments, settlement plates or gauges, and/or piezometers, should be examined and tested for proper functioning. The available records and readings of these instruments should be reviewed to detect any unusual performance or distress of the structure. Immediately following installation or the discovery of an unusual condition, all instrumentation readings should be taken more frequently than once a quarter (e.g., daily or weekly) until the patterns of the structural behaviors are stabilized.

  - The maintenance of operating facilities and features (such as pumps and valves) that pertain to the safety of the retention system should be examined to determine the adequacy and quality of the maintenance procedures followed in maintaining the retention system in a safe operating condition.

  - The general long-term performance of the liner, such as its resistance to degradation, should be examined.

- Special Inspections

  - Unscheduled inspections should be performed after the occurrence of significant earthquakes, tornadoes, floods, intense local rainfalls, or other unusual events.

  - The NRC's implementation of the National Dam Safety Program and its associated guidelines may require special inspections of any uranium recovery site embankments that fall within the scope of the program. The Federal Emergency Management Agency guidelines for dam safety (Ref. 50) specifically include tailings dams in its program and define a dam in the following manner:

    > Any artificial barrier, including appurtenant works, which impounds or diverts water, and which (1) is twenty-five feet or more in height from the natural bed of the stream or watercourse measured at the downstream toe of the barrier or from the lowest elevation of the outside limit of the barrier if it is not across a stream channel or watercourse, to the maximum water storage elevation or (2) has an impounding capacity at maximum water storage elevation of fifty acre-feet or more.

4.3 Technical Evaluation

The existing conditions of the retention system should be evaluated annually unless changing conditions dictate a shorter period. This evaluation should include an assessment of the hydraulic and hydrologic capacities, water quality, and structural stability and should take into account both existing conditions and any changing conditions. In addition, surface-water and ground-water sampling data collected in accordance with Regulatory Guide 4.14 should be examined at the time of the technical evaluation to detect any patterns that could be a sign of failure of seepage control measures or foundation distress.

4.4 Inspection Reporting

A report should be prepared to present the results of each technical evaluation and the inspection data accumulated since the last report. These documents should be kept at the project site for reference purposes, available for inspection by regulatory authorities, and retired only upon termination of the project. Any abnormal hazardous conditions observed during the inspection should be reported immediately to the NRC staff.

4.5 Inspection Personnel

An experienced professional who is thoroughly familiar with the investigation, design, construction, and operation of these types of facilities should direct the planning and conduct of the inspections and evaluations. At each facility, this individual should ensure that all field inspectors are trained to recognize and assess signs of possible distress or abnormality.

C. REGULATORY POSITION

Basic design criteria generally are drawn from 10 CFR Part 40, Appendix A, and describe the latest approaches approved by the NRC for compliance with the applicable regulations. Information related to the investigation, engineering design, proposed construction, inspection, and performance of a uranium recovery waste retention system should address all applicable areas discussed in Section B of this regulatory guide. If an applicant proposes the use of an alternative method or new information that may be developed in the future, the NRC will review the proposal and, if acceptable, approve its use.

1. Basic Design Criteria

a. The "prime option" for disposal of tailings is placement below grade. Where full below-grade burial is not practicable, the size of retention structures and the size and steepness of slopes associated with exposed embankments must be minimized by excavation to the maximum extent reasonably achievable or appropriate, given the geologic and hydrologic conditions at a site (10 CFR Part 40, Appendix A, Criterion 3).

b. Stability of the retention system should be ensured under all conditions of construction and operation. In ensuring structural integrity, it must not be presumed that the liner system will function without leakage during the active life of the impoundment (10 CFR Part 40, Appendix A, Criterion 5A(5)).

c. The magnitude of total and differential settlement should be within tolerable limits that will not result in harmful cracking and embankment instability.

d. Unless exempted under the regulations in Criterion 5A(3) of Appendix A to 10 CFR Part 40, liners and leak detection systems need to be included in the design of retention systems per 10 CFR Part 40, Appendix A, Criteria 5A(1), 5A(2), and 5E(1), and considering EPA requirements in 40 CFR 264.221.

e. Freeboard must be sufficient at all times to prevent overtopping by flood inflows and wind-generated waves and should include an allowance for settlement of the foundation and embankments (10 CFR Part 40, Appendix A, Criterion 5A(4)). Adequate slope protection should be provided for the embankment against wind and water erosion, weathering, and ice damage.

f. Upstream rainfall catchment areas must be minimized to decrease erosion potential and the size of the floods that could erode or wash out sections of the tailings retention system (10 CFR Part 40, Appendix A, Criterion 4(a)). The surcharge capacity of the retention system must be adequate to store a PMF, calculated using the 6-hour PMP.

2. Methods of Analysis

a. The PMF should be based on the 6-hour PMP and should be developed in accordance with procedures provided in NUREG-1623 (Ref. 2).

b. Wave runup may be determined using procedures discussed in the U.S. Army Corps of Engineers "Coastal Engineering Manual," issued April 2002 (Ref. 38).

c. The static stability of the embankment should be analyzed using commonly accepted detailed stability methods. The analysis should use appropriate static soil and rock properties established on tested representative samples over anticipated in situ and placement conditions. Results of a manual check of the computer stability analysis outcome should be presented to illustrate adopted design procedures and criteria.

d. Conventional pseudostatic analysis may be considered acceptable if the seismic coefficient appropriately reflects the geologic and seismologic conditions of the site and if the materials are not subject to significant loss of strength under dynamic loads. Liquefaction potential and the dynamic stability of the tailing dam and foundation should be assessed using appropriate state-of-the-art methods. Reference 30 will be used to determine the extent of the required dynamic analyses. The analyses should employ appropriate dynamic material properties established on representative materials through adequate field and laboratory testing.

e. The loading conditions to be evaluated in embankment stability analyses and corresponding minimum factors of safety are as follows:

Loading Condition	Minimum Factor of Safety
End of construction	1.3
Partial pool with steady seepage	1.5
Maximum pool with steady seepage	1.5
Earthquake (in combination with the above conditions)	1.0

f. Evaluation of liquefaction potential should include laboratory testing, in situ testing, and comparisons to similar soil deposits. Screening criteria should be used to determine whether there are potentially liquefiable soils at a site. The factor of safety for liquefaction potential should be greater than 1.0.

g. Appropriate laboratory test results should be used to estimate the rate and magnitude of settlement.

3. Construction Methods

a. Mill tailings embankment retention systems should use conventional acceptable engineering practices of construction control for water retention dams (e.g., controls on foundation preparation, suitability of materials, proper placement, field moisture, and density).

b. Installation of a synthetic liner system should focus on minimizing liner damage. Damage can occur in the form of wrinkles, improper seaming techniques, poor synthetic panel orientation, and punctures caused by construction equipment.

4. Inspection and Maintenance

a. A detailed, systematic inspection and maintenance program should be established to detect and repair damage that might lessen the integrity of the retention system. Generally, visual inspections performed on a regular basis and supplemented by adequate instrumentation are acceptable. A detailed checklist should be developed and followed to document the observations of each significant feature. The inspection program should use photographs to compare previous and present conditions. In addition, the program should include radiometric and water quality surveys.

b. Daily inspections of tailings or waste retention systems should be planned, conducted, evaluated, and documented under the direction of an experienced professional who is thoroughly familiar with the investigation, design, construction, and operation of these types of facilities. The licensee should retain documentation (i.e., a record) of each daily inspection for 3 years after the documentation is made. The NRC must be immediately notified of any failure in a tailings or waste retention system that results in a release of tailings or waste into unrestricted areas or of any unusual conditions (conditions not contemplated in the design of the retention system) that, if not corrected, could indicate the potential for, or lead to, failure of the system and result in a release of tailings or waste into unrestricted areas.

c. Unscheduled inspections should be performed after the occurrence of significant earthquakes, tornadoes, floods, intense local rainfalls, or other unusual events. The NRC's implementation of the National Dam Safety Program and its associated guidelines may require special inspections of any uranium recovery site embankments that fall within the scope of the program.

d. The inspection and maintenance program should start at the beginning of construction and continue at least through the operation of the facility.

D. IMPLEMENTATION

The purpose of this section is to provide information to applicants and licensees regarding the NRC's plans for using this regulatory guide. The NRC does not intend or approve any imposition or backfit in connection with its issuance.

In some cases, applicants or licensees may propose or use a previously established acceptable alternative method for complying with specified portions of the NRC's regulations. Otherwise, the methods described in this guide will be used in evaluating compliance with the applicable regulations for license applications, license amendment applications, and amendment requests.

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49. Unified Facilities Guide Specification UFGS-31, "Division 31—Earthwork," U.S. Army Corps of Engineers, Washington, DC, July 2006.

50. "Federal Guidelines for Dam Safety, FEMA 93," U.S. Department of Homeland Security, Federal Emergency Management Agency, Washington, DC, April 2004.

Appendix 4

Attachment 4

Criterion 4--The following site and design criteria must be adhered to whether tailings or wastes are disposed of above or below grade.

(a) Upstream rainfall catchment areas must be minimized to decrease erosion potential and the size of the floods which could erode or wash out sections of the tailings disposal area.

(b) Topographic features should provide good wind protection.

(c) Embankment and cover slopes must be relatively flat after final stabilization to minimize erosion potential and to provide conservative factors of safety assuring long-term stability. The broad objective should be to contour final slopes to grades which are as close as possible to those which would be provided if tailings were disposed of below grade; this could, for example, lead to slopes of about 10 horizontal to 1 vertical (10h:1v) or less steep. In general, slopes should not be steeper than about 5h:1v. Where steeper slopes are proposed, reasons why a slope less steep than 5h:1v would be impracticable should be provided, and compensating factors and conditions which make such slopes acceptable should be identified.

(d) A full self-sustaining vegetative cover must be established or rock cover employed to reduce wind and water erosion to negligible levels.

Where a full vegetative cover is not likely to be self-sustaining due to climatic or other conditions, such as in semi-arid and arid regions, rock cover must be employed on slopes of the impoundment system. The NRC will consider relaxing this requirement for extremely gentle slopes such as those which may exist on the top of the pile.

The following factors must be considered in establishing the final rock cover design to avoid displacement of rock particles by human and animal traffic or by natural process, and to preclude undercutting and piping:

Shape, size, composition, and gradation of rock particles (excepting bedding material average particles size must be at least cobble size or greater);

Rock cover thickness and zoning of particles by size; and

Steepness of underlying slopes.

Individual rock fragments must be dense, sound, and resistant to abrasion, and must be free from cracks, seams, and other defects that would tend to unduly increase their destruction by water and frost actions. Weak, friable, or laminated aggregate may not be used.

Rock covering of slopes may be unnecessary where top covers are very thick (or less); bulk cover materials have inherently favorable erosion resistance characteristics; and, there is negligible drainage catchment area upstream of the pile and good wind protection as described in points (a) and (b) of this Criterion.

Furthermore, all impoundment surfaces must be contoured to avoid areas of concentrated surface runoff or abrupt or sharp changes in slope gradient. In addition to rock cover on slopes, areas toward which surface runoff might be directed must be well protected with substantial rock cover (rip rap). In addition to providing for stability of the impoundment system itself, overall stability, erosion potential, and geomorphology of surrounding terrain must be evaluated to assure that there are not ongoing or potential processes, such as gully erosion, which would lead to impoundment instability.

(e) The impoundment may not be located near a capable fault that could cause a maximum credible earthquake larger than that which the impoundment could reasonably be expected to withstand. As used in this criterion, the term "capable fault" has the same meaning as defined in section III(g) of Appendix A of 10 CFR Part 100. The term "maximum credible earthquake" means that earthquake which would cause the maximum vibratory ground motion based upon an evaluation of earthquake potential considering the regional and local geology and seismology and specific characteristics of local subsurface material.

(f) The impoundment, where feasible, should be designed to incorporate features which will promote deposition. For example, design features which promote deposition of sediment

suspended in any runoff which flows into the impoundment area might be utilized; the object of such a design feature would be to enhance the thickness of cover over time.

Criterion 5--Criteria 5A-5D and new Criterion 13 incorporate the basic ground-water protection standards imposed by the Environmental Protection Agency in 40 CFR Part 192, Subparts D and E (48 FR 45926; October 7, 1983) which apply during operations and prior to the end of closure. Ground-water monitoring to comply with these standards is required by Criterion 7A.

5A(1)--The primary ground-water protection standard is a design standard for surface impoundments used to manage uranium and thorium byproduct material. Unless exempted under paragraph 5A(3) of this criterion, surface impoundments (except for an existing portion) must have a liner that is designed, constructed, and installed to prevent any migration of wastes out of the impoundment to the adjacent subsurface soil, ground water, or surface water at any time during the active life (including the closure period) of the impoundment. The liner may be constructed of materials that may allow wastes to migrate into the liner (but not into the adjacent subsurface soil, ground water, or surface water) during the active life of the facility, provided that impoundment closure includes removal or decontamination of all waste residues, contaminated containment system components (liners, etc.), contaminated subsoils, and structures and equipment contaminated with waste and leachate. For impoundments that will be closed with the liner material left in place, the liner must be constructed of materials that can prevent wastes from migrating into the liner during the active life of the facility.

5A(2)--The liner required by paragraph 5A(1) above must be--

(a) Constructed of materials that have appropriate chemical properties and sufficient strength and thickness to prevent failure due to pressure gradients (including static head and external hydrogeologic forces), physical contact with the waste or leachate to which they are exposed, climatic conditions, the stress of installation, and the stress of daily operation;

(b) Placed upon a foundation or base capable of providing support to the liner and resistance to pressure gradients above and below the liner to prevent failure of the liner due to settlement, compression, or uplift; and

(c) Installed to cover all surrounding earth likely to be in contact with the wastes or leachate.

5A(3)--The applicant or licensee will be exempted from the requirements of paragraph 5A(1) of this criterion if the Commission finds, based on a demonstration by the applicant or licensee, that alternate design and operating practices, including the closure plan, together with site characteristics will prevent the migration of any hazardous constituents into ground water or surface water at any future time. In deciding whether to grant an exemption, the Commission will consider--

(a) The nature and quantity of the wastes;

(b) The proposed alternate design and operation;

(c) The hydrogeologic setting of the facility, including the attenuative capacity and thickness of the liners and soils present between the impoundment and ground water or surface water; and

(d) All other factors which would influence the quality and mobility of the leachate produced and the potential for it to migrate to ground water or surface water.

5A(4)--A surface impoundment must be designed, constructed, maintained, and operated to prevent overtopping resulting from normal or abnormal operations, overfilling, wind and wave actions, rainfall, or run-on; from malfunctions of level controllers, alarms, and other equipment; and from human error.

5A(5)--When dikes are used to form the surface impoundment, the dikes must be designed, constructed, and maintained with sufficient structural integrity to prevent massive failure of the dikes. In ensuring structural integrity, it must not be presumed that the liner system will function without leakage during the active life of the impoundment.

In addition, *NUREG-1569 - Standard Review Plan for In Situ Leach Uranium Extraction License Applications* which specifically governs in-situ uranium recovery operations states:

The design, installation, and operation of surface impoundments at the site used to manage 11e.(2) byproduct material meet relevant guidance provided in Regulatory Guide 3.11, Section 1 (NRC, 1977). The impoundments should have sufficient capacity that the entire contents of one impoundment can be transferred to the other surface impoundments in the event of a leak. (See Section 2.7.3 of this standard review plan for additional discussion of design and evaluation of retention systems and diversion facilities.) Inspections of impoundments will be done consistent with Regulatory Guide 3.11.1, "Operational Inspection and Surveillance of Embankment Retention Systems for Uranium Mill Tailings" (NRC, 1980).

The surface impoundment must have sufficient capacity and must be designed, constructed, maintained, and operated to prevent overtopping resulting from (i) normal or abnormal operations, overfilling, wind and wave actions, rainfall, or run-on; (ii) malfunctions of level controllers, alarms, and other equipment; and (iii) human error. If dikes are used to form the surface impoundment, the dikes must be designed, constructed, and maintained with sufficient structural integrity to prevent massive failure of the dikes. In ensuring structural integrity, the applicant must not assume that the liner system will function without leakage during the active life of the impoundment.

Controls should be established over access to the impoundment, including access during routine maintenance. A procedure should be provided that assures that unnecessary traffic is not directed to the impoundment area.

(4) The design of surface impoundments used in the management of 11e.(2) byproduct material meets or exceeds the requirements in 10 CFR Part 40, Appendix A, Criterion 5(A).

The design of a clay or synthetic liner and its appurtenant component parts should be presented in the application or related amendment applications for a uranium recovery operation. At a minimum, design details, drawings, and pertinent analyses should be provided. Expected construction methods, testing criteria, and quality assurance programs should be presented. Planned modes of operation, inspection, and maintenance should be discussed in the application. Deviation from these plans should be submitted to and approved by the staff before implementation.

The liner for a surface impoundment used to manage 11e.(2) byproduct material must be designed, constructed, and installed to prevent any migration of wastes out of the impoundment to the subsurface soil, ground-water, or surface-water at any time during the active life of the surface impoundment. The liner may be constructed of materials that allow wastes to migrate into the liner provided that the impoundment decommissioning includes removal or decontamination of all waste residues, contaminated containment system components, contaminated subsoils, and structures and equipment contaminated with waste and leachate.

The liner must be constructed of materials that have appropriate chemical properties and sufficient strength and thickness to prevent failure because of pressure gradients, physical contact with the waste or leachate, climatic conditions, and the stresses of installation and daily operation. The subgrade must be sufficient to prevent failure of the liner because of settlement, compression, or uplift. Liners must be installed to cover all surrounding earth which is likely to be in contact with the wastes or leachate.

Tests should show conclusively that the liner will not deteriorate when subjected to the waste products and expected atmospheric and temperature conditions at the site. Applicant test data and all available manufacturers test data should be submitted with the application. For clay liners, tests, at a minimum, should consist of falling head permeameter tests performed on columns of *liner material obtained during and after liner installation. The expected reaction of the impoundment liner to any combination of solutions or atmospheric conditions should be known before the liner is exposed to them. Field seams of synthetic liners should be tested along the entire length of the seam. Representative sampling may be used for factory seams. The testing should use state-of-the-art test methods recommended by the liner manufacturer. Compatibility tests that document the compatibility of the field seam material with the waste products and expected weather conditions should be submitted for staff review and approval. If it is necessary to repair the liner, representatives of the liner manufacturer should be called on to supervise the repairs.*

Proper preparation of the subgrade and slopes of an impoundment is very important to the success of the surface impoundment. The strength of the liner is heavily dependent on the stability of the slopes of the subgrade. The subgrade should be treated with a soil sterilant. The subgrade surface for a synthetic liner should be graded to a surface tolerance of less than 2.54 cm [1 in.] across a 30.3 cm [1 ft] straightedge. NRC Regulatory Guide 3.11, Section 2 (NRC, 1977) outlines acceptable methods for slope stability and settlement analyses, and should be used for design. If a surface impoundment with a synthetic liner is located in an area where the water table could rise above the bottom of the liner, under drains may be required. The impoundment will be inspected in accordance with Regulatory Guide 3.11.1 (NRC, 1980).

A quality control program should be established for the following factors: (i) clearing, grubbing, and stripping; (ii) excavation and backfill; (iii) rolling; (iv) compaction and moisture control; (v) finishing; (vi) subgrade sterilization; and (vii) liner subdrainage and gas venting.

To prevent damage to liners, some form of protection should be provided, including (i) soil covers, (ii) venting systems, (iii) diversion ditches, (iv) side slope protection, or (v) game-proof fences. A program for maintenance of the liner features should be developed, and repair techniques should be planned in advance.

A leak detection system should be installed at all sites using natural or synthetic liners. The system should be designed to perform the following functions: (i) detect accidental leaks from the impoundment, (ii) identify the location of the leak so that liner repair can be implemented immediately, and (iii) isolate the leakage and control it.

Appendix 5

Attachment 5

§ 264.221 Design and operating requirements.

(a) Any surface impoundment that is not covered by paragraph (c) of this section or §265.221 of this chapter must have a liner for all portions of the impoundment (except for existing portions of such impoundments). The liner must be designed, constructed, and installed to prevent any migration of wastes out of the impoundment to the adjacent subsurface soil or ground water or surface water at any time during the active life (including the closure period) of the impoundment. The liner may be constructed of materials that may allow wastes to migrate into the liner (but not into the adjacent subsurface soil or ground water or surface water) during the active life of the facility, provided that the impoundment is closed in accordance with §264.228(a)(1). For impoundments that will be closed in accordance with §264.228(a)(2), the liner must be constructed of materials that can prevent wastes from migrating into the liner during the active life of the facility. The liner must be:

(1) Constructed of materials that have appropriate chemical properties and sufficient strength and thickness to prevent failure due to pressure gradients (including static head and external hydrogeologic forces), physical contact with the waste or leachate to which they are exposed, climatic conditions, the stress of installation, and the stress of daily operation;

(2) Placed upon a foundation or base capable of providing support to the liner and resistance to pressure gradients above and below the liner to prevent failure of the liner due to settlement, compression, or uplift; and

(3) Installed to cover all surrounding earth likely to be in contact with the waste or leachate.

(b) The owner or operator will be exempted from the requirements of paragraph (a) of this section if the Regional Administrator finds, based on a demonstration by the owner or operator, that alternate design and operating practices, together with location characteristics, will prevent the migration of any hazardous constituents (see §264.93) into the ground water or surface water at any future time. In deciding whether to grant an exemption, the Regional Administrator will consider:

(1) The nature and quantity of the wastes;

(2) The proposed alternate design and operation;

(3) The hydrogeologic setting of the facility, including the attenuative capacity and thickness of the liners and soils present between the impoundment and ground water or surface water; and

(4) All other factors which would influence the quality and mobility of the leachate produced and the potential for it to migrate to ground water or surface water.

(c) The owner or operator of each new surface impoundment unit on which construction commences after January 29, 1992, each lateral expansion of a surface impoundment unit on which construction commences after July 29, 1992 and each replacement of an existing surface impoundment unit that is to commence reuse after July 29, 1992 must install two or more liners and a leachate collection and removal system between such liners. "Construction commences" is as defined in §260.10 of this chapter under "existing facility".

(1)(i) The liner system must include:

(A) A top liner designed and constructed of materials (e.g., a geomembrane) to prevent the migration of hazardous constituents into such liner during the active life and post-closure care period; and

(B) A composite bottom liner, consisting of at least two components. The upper component must be designed and constructed of materials (e.g., a geomembrane) to prevent the migration of hazardous constituents into this component during the active life and post-closure care period. The lower component must be designed and constructed of materials to minimize the migration of hazardous constituents if a breach in the upper component were to occur. The lower component must be constructed of at least 3 feet (91 cm) of compacted soil material with a hydraulic conductivity of no more than 1×10^{-7} cm/sec.

(ii) The liners must comply with paragraphs (a) (1), (2), and (3) of this section.

(2) The leachate collection and removal system between the liners, and immediately above the bottom composite liner in the case of multiple leachate collection and removal systems, is also a leak detection system. This leak detection system must be capable of detecting, collecting, and removing leaks of hazardous constituents at the earliest practicable time through all areas of the top liner likely to be exposed to waste or leachate during the active life and post-closure care period. The requirements for a leak detection system in this paragraph are satisfied by installation of a system that is, at a minimum:

(i) Constructed with a bottom slope of one percent or more;

(ii) Constructed of granular drainage materials with a hydraulic conductivity of 1×10^{-1} cm/sec or more and a thickness of 12 inches (30.5 cm) or more; or constructed of synthetic or geonet drainage materials with a transmissivity of $3 \times 10^{-4} m^2$ sec or more;

(iii) Constructed of materials that are chemically resistant to the waste managed in the surface impoundment and the leachate expected to be generated, and of sufficient strength and thickness to prevent collapse under the pressures exerted by overlying wastes and any waste cover materials or equipment used at the surface impoundment;

(iv) Designed and operated to minimize clogging during the active life and post-closure care period; and

(v) Constructed with sumps and liquid removal methods (e.g., pumps) of sufficient size to collect and remove liquids from the sump and prevent liquids from backing up into the drainage layer. Each unit must have its own sump(s). The design of each sump and removal system must provide a method for measuring and recording the volume of liquids present in the sump and of liquids removed.

(3) The owner or operator shall collect and remove pumpable liquids in the sumps to minimize the head on the bottom liner.

(4) The owner or operator of a leak detection system that is not located completely above the seasonal high water table must demonstrate that the operation of the leak detection system will not be adversely affected by the presence of ground water.

(d) The Regional Administrator may approve alternative design or operating practices to those specified in paragraph (c) of this section if the owner or operator demonstrates to the Regional Administrator that such design and operating practices, together with location characteristics:

(1) Will prevent the migration of any hazardous constituent into the ground water or surface water at least as effectively as the liners and leachate collection and removal system specified in paragraph (c) of this section; and

(2) Will allow detection of leaks of hazardous constituents through the top liner at least as effectively.

(e) The double liner requirement set forth in paragraph (c) of this section may be waived by the Regional Administrator for any monofill, if:

(1) The monofill contains only hazardous wastes from foundry furnace emission controls or metal casting molding sand, and such wastes do not contain constituents which would render the wastes hazardous for reasons other than the toxicity characteristic in §261.24 of this chapter; and

(2)(i)(A) The monofill has at least one liner for which there is no evidence that such liner is leaking. For the purposes of this paragraph, the term "liner" means a liner designed, constructed, installed, and operated to prevent hazardous waste from passing into the liner at any time during the active life of the facility, or a liner designed, constructed, installed, and operated to prevent hazardous waste from migrating beyond the liner to adjacent subsurface soil, ground water, or surface water at any time during the active life of the facility. In the case of any surface impoundment which has been exempted from the requirements of paragraph (c) of this section on the basis of a liner designed, constructed, installed, and operated to prevent hazardous waste from passing beyond the liner, at the closure of such impoundment, the owner or operator must remove or decontaminate all waste residues, all contaminated liner material, and contaminated soil to the extent practicable. If all contaminated soil is not removed or decontaminated, the owner or operator of such impoundment will comply with appropriate post-closure requirements, including but not limited to ground-water monitoring and corrective action;

(B) The monofill is located more than one-quarter mile from an "underground source of drinking water" (as that term is defined in 40 CFR 270.2); and

(C) The monofill is in compliance with generally applicable ground-water monitoring requirements for facilities with permits under RCRA section 3005(c); or

(ii) The owner or operator demonstrates that the monofill is located, designed and operated so as to assure that there will be no migration of any hazardous constituent into ground water or surface water at any future time.

(f) The owner or operator of any replacement surface impoundment unit is exempt from paragraph (c) of this section if:

(1) The existing unit was constructed in compliance with the design standards of sections 3004 (o)(1)(A)(i) and (o)(5) of the Resource Conservation and Recovery Act; and

(2) There is no reason to believe that the liner is not functioning as designed.

(g) A surface impoundment must be designed, constructed, maintained, and operated to prevent overtopping resulting from normal or abnormal operations; overfilling; wind and wave action; rainfall; run-on; malfunctions of level controllers, alarms, and other equipment; and human error.

(h) A surface impoundment must have dikes that are designed, constructed, and maintained with sufficient structural integrity to prevent massive failure of the dikes. In ensuring structural integrity,

it must not be presumed that the liner system will function without leakage during the active life of the unit.

(i) The Regional Administrator will specify in the permit all design and operating practices that are necessary to ensure that the requirements of this section are satisfied.

Appendix 6

Attachment 6

(2) On-site evaporation systems are designed and operated in a manner that prevents migration of waste from the evaporation system to the subsurface.

The following discussion provides guidelines for an acceptable application section dealing with surface impoundments.

The monitoring and inspection program consists of documented daily checks of impoundment freeboard and the leak detection system. Because small amounts of condensation can accumulate in leak detection sumps, samples for chemical analysis are not commonly collected until water levels greater than a specified amount are detected. NRC has found 15 cm [6 in.] to be an acceptable level. When significant water levels are detected, the water in the standpipes must be sampled for indicator parameters to confirm that the water in the detection system is from the impoundment. The applicant should specify and provide the basis for selecting the indicator parameter(s) used to verify leaks.

Corrective actions should commence on leak confirmation and should consist of transferring the solution to another impoundment so that liner repairs can be made. Thus, sufficient freeboard capacity should be maintained in the surface impoundments such that any one impoundment could be transferred to the remaining impoundments in the event of a leak. An additional freeboard requirement is that water levels should be kept far enough below the top of the impoundment to prevent waves from overtopping during high wind conditions.

Actions to be taken in the event that surface impoundment water analyses indicate leakage include

(i) notifying NRC by telephone within 48 hours of verification,
(ii) analyzing standpipe water quality samples for leak parameters once every 7 days during the leak period and once every 7 days for at least 14 days following repairs, and
(iii) filing a written report with NRC within 30 days of first notifying NRC that a leak exists. (This report includes analytical data and describes the corrective actions and the results of those actions.)

(3) The design, installation, and operation of surface impoundments at the site used to manage 11e.(2) byproduct material meet relevant guidance provided in Regulatory Guide 3.11, Section 1 (NRC, 1977). The impoundments should have sufficient capacity that the entire contents of one impoundment can be transferred to the other surface impoundments in the event of a leak. (See Section 2.7.3 of this standard review plan for additional discussion of design and evaluation of retention systems and diversion facilities.) Inspections of impoundments will be done consistent with Regulatory Guide 3.11.1, "Operational Inspection and Surveillance of Embankment Retention Systems for Uranium Mill Tailings" (NRC, 1980).

The surface impoundment must have sufficient capacity and must be designed, constructed, maintained, and operated to prevent overtopping resulting from
(i) normal or abnormal operations, overfilling, wind and wave actions, rainfall, or run-on;
(ii) malfunctions of level controllers, alarms, and other equipment; and
(iii) human error.

If dikes are used to form the surface impoundment, the dikes must be designed, constructed, and maintained with sufficient structural integrity to prevent massive failure of the dikes. In ensuring structural integrity, the applicant must not assume that the liner system will function without leakage during the active life of the impoundment. Controls should be established over access to the impoundment, including access during routine maintenance. A procedure should be provided that assures that unnecessary traffic is not directed to the impoundment area.

(4) The design of surface impoundments used in the management of 11e.(2) byproduct material meets or exceeds the requirements in 10 CFR Part 40, Appendix A, Criterion 5(A). The design of a clay or synthetic liner and its appurtenant component parts should be presented in the application or related amendment applications for a uranium recovery operation. At a minimum, design details, drawings, and pertinent analyses should be provided. Expected construction methods, testing criteria, and quality assurance programs should be presented. Planned modes of operation, inspection, and maintenance should be discussed in the application. Deviation from these plans should be submitted to and approved by the staff before implementation.

The liner for a surface impoundment used to manage 11e.(2) byproduct material must be designed, constructed, and installed to prevent any migration of wastes out of the impoundment to the subsurface soil, ground-water, or surface-water at any time during the active life of the surface impoundment. The liner may be constructed of materials that allow wastes to migrate into the liner provided that the impoundment decommissioning includes removal or decontamination of all waste residues, contaminated containment system components, contaminated subsoils, and structures and equipment contaminated with waste and leachate.

The liner must be constructed of materials that have appropriate chemical properties and sufficient strength and thickness to prevent failure because of pressure gradients, physical contact with the waste or leachate, climatic conditions, and the stresses of installation and daily operation. The subgrade must be sufficient to prevent failure of the liner because of settlement, compression, or uplift. Liners must be installed to cover all surrounding earth which is likely to be in contact with the wastes or leachate. Tests should show conclusively that the liner will not deteriorate when subjected to the waste products and expected atmospheric and temperature conditions at the site. Applicant test data and all available manufacturers test data should be submitted with the application. For clay liners, tests, at a minimum, should consist of falling head permeameter tests performed on columns of liner material obtained during and after liner installation. The expected reaction of the impoundment liner to any combination of solutions or atmospheric conditions should be known before the liner is exposed to them. Field seams of synthetic liners should be tested along the entire length of the seam. Representative sampling may be used for factory seams. The testing should use state-of-the-art test methods recommended by the liner manufacturer. Compatibility tests that document the compatibility of the field seam material with the waste products and expected weather conditions should be submitted for staff review and approval. If it is necessary to repair the liner, representatives of the liner manufacturer should be called on to supervise the repairs.

Proper preparation of the subgrade and slopes of an impoundment is very important to the success of the surface impoundment. The strength of the liner is heavily dependent on the stability of the slopes of the subgrade. The subgrade should be treated with a soil sterilant. The subgrade surface for a synthetic liner should be graded to a surface tolerance of less than 2.54 cm [1 in.] across a 30.3 cm [1 ft] straightedge. NRC Regulatory Guide 3.11, Section 2 (NRC, 1977) outlines acceptable methods for slope stability and settlement analyses, and should be used for design. If a surface mpoundment with a synthetic liner is located in an area where the water table could rise above the bottom of the liner, under drains may be required. The impoundment will be inspected in accordance with Regulatory Guide 3.11.1 (NRC, 1980).

A quality control program should be established for the following factors:
(i) clearing, grubbing, and stripping;
(ii) excavation and backfill;
(iii) rolling;
(iv) compaction and moisture control;
(v) finishing;
(vi) subgrade sterilization; and
(vii) liner subdrainage and gas venting.

To prevent damage to liners, some form of protection should be provided, including

(i) soil covers,
(ii) venting systems,
(iii) diversion ditches,
(iv) side slope protection, or
(v) game-proof fences.

A program for maintenance of the liner features should be developed, and repair techniques should be planned in advance.

A leak detection system should be installed at all sites using natural or synthetic liners. The system should be designed to perform the following functions:
(i) detect accidental leaks from the impoundment,
(ii) identify the location of the leak so that liner repair can be implemented immediately, and
(iii) isolate the leakage and control it.