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JUN 14 1985

MEMORANDUM FOR: Leo B. Higginbotham, Chief
Low-Level Waste and Uranium
Recovery Project Branch
Division of Waste Management

FROM: John T Greeves, Chief
Engineering Branch
Division of Waste Management

SUBJECT: STANDARD REVIEW PLAN FOR RAP DOCUMENTS -
GEOTECHNICAL STABILITY SECTION

In accordance with your Technical Assistance Request of April 12, 1985, (WMLU TAR 85022), we have revised the draft Standard Review Plan (SRP) for the civil/geotechnical aspects of UMTRAP which was transmitted with my memo to you dated November 30, 1984. The revised draft SRP is attached to this memo.

As per the WMLU requirement, the revised draft SRP addresses only geotechnical stability aspects of the UMTRAP. Evaluation of geotechnical stability of the site requires review of geologic and seismotectonic data, and WMGT is responsible for this review. WMGT's input for the geological/seismotectonic portion of this SRP will be provided to WMLU for incorporating relevant material into this draft SRP; this arrangement was suggested by WMLU. We would like to review the integrated version of this draft SRP before it is finalized.

This draft SRP was prepared by Dr. Banad Jagannath of my staff and he may be contacted at extension 74629.

ORIGINAL SIGNED BY
John T. Greeves

John T. Greeves, Chief
Engineering Branch
Division of Waste Management

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DATE	6/13/85	6/17/85	6/17/85	6/14/85			

SECTION 2 - GEOTECHNICAL STABILITY

I. AREAS OF REVIEW

The Remedial Action Plan (RAP) and/or its supporting documents must contain geotechnical information and design details related to all materials to be stabilized including soil and rock cover and foundation materials associated with the RAP to meet the EPA standards established by 40 CFR, Part 192, Subpart A. For any embankments under the proposed RAP, both short-term and long-term stability under static and dynamic conditions must be established.

The remedial action involves stabilizing the uranium mill tailings, to comply with the above stated EPA standards, either in-place in the general vicinity of its present location or at a different disposal site. The information that should be presented in the RAP and the specific areas of review by the staff are mentioned below.

1. Geological/Geotechnical Site Characterization:

Information on the geologic and geotechnical characteristics of the site and the uranium mill tailings designated for stabilization should be presented in the site characterization report. Information on the site geologic features should discuss: geologic features in the vicinity of the site, including areas of actual or potential surface or subsurface subsidence, solution activity, uplift, or collapse; rocks or soils that may be unstable because of the mineralogy, underconsolidation; history of deposition and erosion. Information on geotechnical characteristics of the site should include: site exploration data; test results; subsurface stratigraphy; physical properties and both static and dynamic engineering properties of the materials at the site; ground water conditions for all critical subsurface strata at the site including information on its annual fluctuation for both pre and post remedial action state. Geotechnical characterization of the uranium mill tailings designated for stabilization should be similar in scope to that mentioned above for the site.

2. Seismotectonic Site Characterization

(To be developed by WMGT)

3. Slope Stability: Information on exploration data, test results, slope characterization, and analyses concerning the stability of all natural and man-made earth and rock slopes whose failure, under any of the conditions to which they could be exposed throughout the design period, could adversely affect the integrity of the remedial action plan should be presented.

4. Settlement: The results of investigations and analyses conducted for both subsurface materials and uranium mill tailings to calculate anticipated deformation and differential settlement under both static and seismic conditions should be presented.

5. Liquefaction Potential: An analysis of the liquefaction potential of subsurface and pile material should be presented. Consequences of liquefaction of subsurface soils and/or uranium mill tailings affecting the stability of cover materials and erosion control blanket should also be analysed.

6. Soil Cover Engineering Properties: Information presented on the soil cover material should include details of field explorations, laboratory testing, and both physical and performance parameters needed for radon barrier cover design.

7. Construction Considerations: Information on the geotechnical aspects of the remedial action construction should be presented. These may include details such as: mixing of slimes with sand, placing slime and sand in alternate layers, drying out slime, compaction criteria, quality control aspects of construction, etc.

The Geotechnical Branch (WMGT) and the Engineering Branch (WMEG) will coordinate the review of the geotechnical stability aspects of the Remedial Action Plans as follows. The Geotechnical Branch will review:

- The adequacy of the geologic and seismic information cited in support of the conclusions on the suitability of the site.

- The seismological and geological investigations carried out to establish the ground motion environment for seismic design of the remedial action plan, and the procedures and analyses used by the applicant in establishing the

magnitude, intensity and peak effective acceleration of the maximum credible earthquake at the site.

The Engineering Branch will review:

- The engineering design and earth work plans for stabilizing the pile and constructing the retention system, if needed. The geotechnical parameters and method of analysis of soil response to ground motion environment. Also, the site specific soil amplification aspects of the analysis performed to determine the maximum credible earthquake at the site.

II. ACCEPTANCE CRITERIA

A. Regulation and Guidance

The basic acceptance criterion pertinent to the geotechnical stability aspects of these reviews is provided in EPA's 40 CFR Part 192, Subpart A. 40 CFR 192.02 states that:

"Control shall be designed to:

(a) Be effective for up to one thousand years, to the extent reasonably achievable, and in any case, for at least 200 years and,...."

Control is defined in the regulation as "any remedial action intended to stabilize, inhibit future misuse of, or reduce emissions or effluents from residual radioactive materials."

There are presently no NRC regulations or regulatory guides pertinent to the geotechnical stability aspects of the UMTRCA program. However, the following references provide recommendations and guidance generally applicable to geotechnical reviews of this type, although the required level of detail and extent of investigation and analyses would be expected to vary on a case-by-case basis.

1. Regulatory Guide 1.132, "Site Investigations for Foundations of Nuclear Power Plants." This guide describes programs of geotechnical engineering site investigations that would normally meet the needs for evaluating the performance of earthworks under anticipated static and dynamic loading conditions. It provides general guidance and recommendations for developing

site-specific investigation programs as well as specific guidance for conducting subsurface investigations, the spacing and depth of borings, and sampling.

2. Regulatory Guide 1.138, "Laboratory Investigations of Soils for Engineering Analysis and Design of Nuclear Power Plants." This guide describes laboratory investigations and testing practices acceptable for determining soil and rock properties and characteristics needed for geotechnical engineering analysis and design.

3. Regulatory Guide 3.11, "Design, Construction, and Inspection of Embankment Retention Systems for Uranium Mills." This guide describes some engineering practices and methods generally considered satisfactory for the design, construction, and inspection of earth and rockfill embankments used for retaining uranium mill tailings.

B. Specific Criteria

A thorough evaluation of the geotechnical stability aspects of the remedial action plan must be presented along with the basic data supporting all conclusions. The site investigations must be adequate in scope and technique to provide the necessary data. Specific criteria relevant to an assessment of the acceptability of information submitted pertinent to each of the seven areas of review listed in Section I are as follows:

1. Geological/Geotechnical Site Characterization: The discussions of the site characterization aspects of the remedial action design is considered acceptable if the information provided is adequate to enable a determination of whether or not the design (coupled with the site characteristics) is a feasible plan from a geotechnical standpoint for meeting the EPA criteria (40 CFR, 192, Subpart A). The information should include:

   - The section defining geologic features is acceptable if the discussions on geologic maps, profiles of the site stratigraphy, structural geology, geologic history and engineering geology are complete and are supported by investigations sufficiently detailed to obtain a representation of the site geology.

- In meeting the general regulatory positions of Regulatory guides 1.132 and 1.138, the description of properties of underlying materials at the site, uranium mill tailings and borrow materials is considered acceptable if state-of-the-art methods are used in characterizing these materials. The test data obtained should be consistent with the needs of the proposed remedial action at the site. These test methods are described, for example, in geotechnical journals published by the American Society of Civil Engineers (Reference 5), applicable standards published by the American Society for Testing and Materials (Reference 6), publication of the Institution of Civil Engineers (Reference 7), and various research reports prepared by Universities (Reference 8). The properties of these materials must be supported by field and laboratory test records.

Normally, a complete field investigation and sampling program must be performed to define the occurrence and properties of the underlying materials at the site, uranium mill tailings as it exists at the site, and borrow materials. The presentation of the investigation program is acceptable if it includes:

- Plot plan(s) showing the locations of all site explorations such as borings, trenches, seismic lines, piezometers and geologic profiles, with the location of the remedial action plan superimposed thereon.

- Profiles and cross section of mill tailings as it exists and of the site illustrating the detailed relationship of the proposed remedial action plan to the subsurface materials.

- Logs of core borings, geophysical investigations and/or test pits.

Summary tables must be provided which catalog the important test results; test results should be plotted when appropriate. Also, a detailed discussion of laboratory sample preparation must be given when applicable. For critical laboratory tests, details such as, how saturation of the sample was determined and maintained during testing, or how the pore pressures changed must be given.

The applicant should provide a detailed and quantitative discussion of the criteria used to determine that the samples were properly taken and tested in sufficient number to define all the critical soil parameters for the site. For sites that are underlaid by saturated soils and sensitive clays, it should be shown that all zones which could become unstable due to liquefaction or strain-softening phenomena, have been adequately sampled and tested. Dispersive characteristics of the soil should be investigated, if applicable. The applicant must also show that he has adequately defined the consolidation behavior of the soils as well as their static and dynamic strength parameters. The discussion should explain how the developed data is used in the analyses, how the test data is enveloped for design, and why the design envelope is conservative, and should present a table indicating the value of the parameters used in the analyses.

The analysis of ground water conditions, as they relate to geotechnical aspects of the remedial action plan, is acceptable if the following are included:

- o Discussion of critical cases of ground water conditions relative to the stability of the proposed plan
- o Analyses and interpretation of seepage and potential piping conditions during construction
- o Records of any field and laboratory permeability test
- o History of ground water fluctuations.

2. Seismotectonic Site Characterization:
(To be developed by WMGT)

3. Slope Stability: - The discussion of slope stability is considered acceptable if the information presented (exploration data, test results, slope characteristics, and analysis) is sufficient to demonstrate the dynamic and static stability of the slopes of the tailings embankment and any other slopes at the site whose failure could adversely affect the short-term and/or long-term effectiveness of the remedial action plan.

The borings and soil testing carried out for slope stability studies should be discussed. The discussion of characteristics

of both tailings embankment slope and in situ slopes at the site (obtained from the borings and testing) is acceptable if it includes:

o. Cross sections and profiles of the slope in sufficient numbers and detail to represent the slope and foundation conditions.

o. A summary and description of static and dynamic properties of the soil and rock comprising the slope and a discussion of procedures used to estimate, from the available field and laboratory data, conservative soil properties and profiles to be used in the analysis.

o. A summary and description of the ground water conditions within or beneath the slope.

The discussion of the stability analyses is acceptable if valid static and dynamic analyses have been presented to demonstrate that there is an adequate margin of safety. A number of different methods of analysis are available in the literature. To be acceptable, the static analyses should include calculations with different assumptions and methods of analysis to assess the following factors:

o. The uncertainties with regard to the shape of the slope, boundaries of the several types of soils within the slope and their properties, the forces acting on the slope, and pore pressures acting within the slope.

o. Failure surfaces corresponding to the lowest factor of safety.

o. The effect of the assumptions inherent in the method of analysis used.

To be acceptable, the dynamic analyses must account for the effect of cyclic motion of the earthquake on soil strength properties. Similar to the static analyses, the various parameters such as geometry, soil strength, and hydrodynamic and pore pressure forces should be varied to show that there is an adequate margin of safety. Pseudostatic analyses in lieu of the dynamic analysis is acceptable if the strength parameters used in the analyses are conservative, the materials are not subject

to significant loss of strength under dynamic loads, and the resulting minimum factor of safety suggests an adequate margin.

4. Settlement: The discussion of the settlement analyses is acceptable if the settlement of subsurface materials and the tailings embankment has been analyzed to include: rebound, settlement, and differential settlements (caused by zones of slimes of varying material thicknesses and heterogeneous nature of embankment) under deadload of fill and seismic loading. Field and laboratory tests procedures and results must be included to document soil and rock properties used in the analyses.

5. Liquefaction Potential: If the foundation materials at the site of the remedial action are saturated soils, then an analysis of the liquefaction potential of the saturated soils at the site is required. The need for a detailed analysis is determined on a case-by-case study of the site stratigraphy, critical soil parameters and consequences of liquefaction induced failure. Undisturbed samples obtained at the site and appropriate laboratory tests may be required to show if the soils are likely to liquefy. When the need for an in-depth analysis is indicated, an assessment of the potential adverse effects that complete or partial liquefaction could have on the stability of the embankment may be based on cyclic triaxial test data obtained form undisturbed soil samples taken from the critical zones in the site area.

6. Soil Cover Engineering Properties: The discussions on the engineering properties of the cover soil should include detailed information on: in situ density and moisture content; permeability characteristics of the soil cover; detailed calculations on determination of radon diffusion coefficient and long-term moisture content of the soil cover.

7. Construction Consideration: Discussions should include: placement procedures and records including locations and detailed configuration of slimes, clays, silts, sands, and other materials in the uranium mill tailings in its existing condition and in its stabilized condition as proposed in the remedial action plan; construction sequence planed to accomplish the intended zoning or selective placement of various materials within the embankment; quality assurance and quality control program to be implemented during construction.

III. REVIEW PROCEDURES

The following is a brief description (by review area) of the general procedures for review conducted by the staff in evaluating the geotechnical engineering aspects of the remedial action plan supporting a proposed UMTRA plan. NRC publications (NUREGs) that are used in this review are listed in the reference section of this Standard Review Plan.

1. Geological/Geotechnical Site Characterization: The geologic and geotechnical site characterization aspects of the remedial action plan are reviewed to assess whether or not the general design coupled with the site characteristics provides a feasible plan to meet the EPA standards.

   Using pertinent references listed at the end of this SRP, and other sources, the staff reviews the geological/geotechnical investigations conducted at the site. The following questions are considered:

   - Are the exploratory techniques used by the site-investigator representative of the present state-of-the-art? Do the samples represent the in situ soil conditions?

   - Do the investigations provide adequate coverage of the site area and borrow material site in sufficient detail to define the specific subsurface conditions with a high degree of confidence?

   - Have all areas or zones of actual or potential surface or subsurface subsidence, uplift or collapse, deformation, solution cavities or structural weakness, unrelieved stresses in bedrock, and soils that might be unstable because of their physical or chemical properties been identified and adequately evaluated?

   - (input on seismotectonic investigations from WMGT to be incorporated)

   - Are the investigations performed (including laboratory and field testing) sufficient to establish the engineering properties of borrow materials, tailings and underlying soil and rock materials at the site?

o Are the ground water conditions evaluated by studying the records of the historic fluctuations of ground water at the site as obtained by monitoring local wells and springs and/or by analysis of piezometer and permeability data from tests conducted at the site?

The borrow material exploration program is reviewed for adequacy to support determination of the suitability of borrow material for the intended use. Provisions for restoration of the borrow area are reviewed for its effect on the performance of the stabilized tailings pile, particularly its effect on the site drainage, ground water table, and overall long-term stability of the tailings embankment.

To determine whether sufficient investigations were performed, the staff evaluates the effectiveness of the boring, sampling and testing program in defining the specific site conditions pertinent to all analyses and design necessary to demonstrate that the remedial action plan meets the stability standards. If it is the staff's judgment that the investigations or testing are inappropriate or insufficient, additional investigations may be requested. The final conclusion is based in part on professional judgment, considering the complexity of the site subsurface conditions. As part of the review, the staff must ascertain, that appropriate laboratory and field techniques and equipment are employed in determining the material properties.

2. Seismotectonic Site Characterization

(Input to be provided by WMGT)

3. Slope Stability: Plot plans, cross sections, and profiles of slopes of the tailings embankment and all nearby slopes, the failure of which could adversely affect the effectiveness of the remedial action plan, are reviewed and compared with exploratory records and provisions of the RAP to ascertain that the most critical conditions have been addressed and that the characteristics of all slopes have been defined. The soil and rock tests data are reviewed to determine if there is sufficient relevant test data to support the selection of the soil strength characteristics used in the slope analysis. The review also considers whether appropriate soil and rock characteristics derived form the investigations have been completely and conservatively incorporated into the design. If the safety

factors resulting from the analysis are not appropriate for the hazards posed by a slope failure, or if clearly unconservative soil properties and profiles were used, a request is made for additional data to verify the assumptions.

The criteria and method of analysis are reviewed to ascertain that the state-of-the-art techniques are being employed. The design analyses are reviewed to determine that an appropriately conservative approach has been used, and that all adverse conditions to which the slope might be subjected have been considered. The dynamic stability of slopes are reviewed considering the design maximum credible earthquake and potential site amplification of ground motions. No single method of analysis is entirely acceptable for all stability assessments; thus, no single method of analysis can be recommended. Relevant manuals issued by public agencies (such as the U.S. Navy Department, U.S. Army Corps of Engineers, and U.S. Bureau of Reclamation) are often used in reviews to ascertain whether the analyses performed are reasonable (see list of References). If any of the important interaction effects cannot be included in a given analysis, such effects must be treated in some approximate but conservative fashion. Engineering judgment is an important factor in the staff's review of the analyses and in assessing the adequacy of the resulting safety factors.

If the staff review indicates that questionable assumptions have been made or some nonstandard or inappropriate method of analysis has been made, the staff may model the slope in a manner consistent with the data, and perform an independent analysis.

4. Settlement: The settlement of the tailings embankment as a result of volume change of the soils and rock beneath the embankment, and volume change of the tailings embankment as a result of its self weight and weight of cover materials are to be evaluated by state-of-the-art methods. In general, the review procedure includes:

   o Determining whether the soil and rock properties used in the settlement analyses represent the in situ conditions at the site. The site investigation, sampling, and laboratory test programs must be adequate to support this determination. The stratigraphy used in the analysis,

particularly the location of slimes zones within the embankment, is reviewed.

- o Determining whether the methods of settlement analyses are appropriate for the tailings embankment, and soil conditions at the site. Contribution to settlement by drainage of mill tailings and by compression of slimes and/or sands are reviewed. Both instantaneous and time dependent component of total and differential settlements are verified. An analysis of the potential for development of cracks in the earth cover (radon barrier) as a result of differential settlements is reviewed.

- o Determining whether the total settlement, differential settlement and tilt estimates represent conservative and tolerable behavior of the remedial action.

5. Liquefaction Potential: Liquefaction potential is reviewed by a study of the results of geotechnical investigations including boring logs, laboratory classification test data and soil profiles to determine if any of the site soils or the tailings embankment material could be susceptible to liquefaction. The results of in situ tests such as the standard penetration tests along with the density and strength tests on undisturbed samples obtained in exploration borings are examined. Ground water conditions are reviewed. The analysis of the expected maximum ground acceleration and the potential for soil amplification are also reviewed.

   If it is determined that there may be liquefaction-susceptible soils beneath the site or in the tailings embankment, the site exploration methods, laboratory test program, and analyses are reviewed for adequacy and reasonableness. The liquefaction potential analysis submitted is reviewed in detail and compared to an independent study performed by the staff, if necessary.

6. Soil Cover Engineering Properties: The review of the earth cover includes: evaluating the suitability of the proposed borrow materials for radon barrier earth cover; determining that adequate quantity of the specified borrow material is available at the borrow source; ascertaining that placement density, moisture content, permeability and other engineering properties used in the radon cover design are determined by suitable laboratory testing; reviewing the methodology and calculations

for determining the long-term residual moisture content of the cover material under as-constructed conditions; verifying that the particle size gradation of the earth cover, gravel bedding and the rock layer are compatible to assure their stability against particle migration during the design life. Review of the radon cover design is addressed in the SRP for Radon Attenuation.

7. Construction Considerations: The geotechnical aspects of the engineering design and earthwork plans are reviewed to identify related construction considerations. The review will ascertain that all the tailings and uranium contaminated materials at the site can be placed within the configuration of the proposed stabilized pile. The construction sequence is reviewed to verify the feasibility of achieving the intended final configuration of the tailings embankment, particularly when tailings are to be placed at selected zones within the embankment. Construction procedures intended to achieve the desired moisture content (drying, if needed) and placement density are reviewed. If mixing of the fine tailings (slime) with sand is proposed, the specifications to control this mixture and determination of engineering properties of this mixture are reviewed. The quality control and quality assurance program are reviewed to determine if adequate provisions have been included to ensure that the actual construction is in accordance with the RAP.

IV. REVIEW CONCLUSIONS

If the evaluation by the staff, based upon complete review of geotechnical engineering aspects of remedial action plan documents, confirms that the standards and regulatory guidelines have been met, documentation of the review will state; 1) that the geologic and seismotectonic investigations adequately and conservatively characterize the site (WMGT input), 2) that the investigations performed at the site are adequate to justify the soil and rock properties characterizing the subsoils, tailings and borrow materials, 3) that the analyses necessary to provide reasonable assurance of long-term geotechnical stability are acceptable and contain adequate margins of safety, and 4) that the general remedial action design represents a feasible plan for assuring long-term stability provision of the EPA standards established by 40 CFR, Part 192, Subpart A. Staff reservations about any portion of the RAP will be stated in sufficient detail to make clear the precise nature of the staff concern.

VI. REFERENCES

1. Code of Federal Regulations, Title 40, Protection of Environment, Part 192, "Health and Environmental Protection Standards for Uranium Mill Tailings, 1983.

2. U.S. NRC Regulatory Guide 1.132, "Site Investigations for Foundations of Nuclear Power Plants."

3. U.S. NRC Regulatory Guide 1.138, "Laboratory Investigations of Soils for Engineering Analysis and Design of Nuclear Power Plants."

4. U.S. NRC Regulatory Guide 3.11, "Design, Construction, and Inspection of Embankment Retention Systems for Uranium Mills."

5. Journal of the Geotechnical Engineering Division, Proceedings of the American Society of Civil Engineers.

6. Book of ASTM Standards and Special Technical Publications, American Society for Testing and Materials.

7. Geotechnique, The Institution of Civil Engineers, London

8. Earthquake Engineering Research Center, University of California, Berkeley.

9. Engineering Manual EM 1110-2-1907, "Soil Sampling," U.S. Army Corps of Engineers, March 1972.

10. Engineering Manual EM 1110-2-1908, "Instrumentation of Earth and Rockfill Dams," U.S. Army Corps of Engineers, August 1971.

11. Engineering Manual EM 1110-2-1906, "Laboratory Soil Testing," U.S. Army Corps of Engineers, November 1970.

12. Corps of Engineers, "Engineering and Design Stability of Earth and Rock-Fill Dams," Manual N. EM 11110-2-1902, Office of the Chief of Engineers, Dept. of the Army (1970).

13. Bureau of Reclamation, "Earth Manual," First Edition, U.S. Dept. of Interior (1968).

14. K. Terzaghi and R. B. Peck, "Soil Mechanics in Engineering Practice," 2nd ed., John Wiley & Sons (1967).

15. Department of the Navy, "Soil Mechanics, Foundations, and Earth Structures," NAVFAC DM-7, March 1971.

16. K. Stagg and O. Zienkiewicz, "Rock Mechanics in Engineering Practice," John Wiley & Sons (1968).

17. Shannon & Wilson, Inc. and Agbabian-Jacobsen Associates, "Soil Behavior Under Earthquake Loading Conditions - State-of-the-Art Evaluation of Characteristics for Seismic Responses Analyses," U.S. Atomic Energy Commission Contract W-7405-eng-26, January 1972.

18. NRC (U.S. Nuclear Regulatory Commission), October 1983 "Design Considerations for Long-Term Stabilization of Uranium Mill Tailings Impoundments," NUREG-3397.

19. NRC (U.S. Nuclear Regulatory Commission), October 1983 "Consolidation of Tailings," NUREG-3204.

20. NRC (U.S. Nuclear Regulatory Commission), October 1983, "Guidance for Disposal of Uranium Mill Tailings: Long-Term Stabilization of Earthen Cover Materials," NUREG-3199.

21. NRC (U.S. Nuclear Regulatory Commission), August 1982, "Rock Riprap Design Methods and Their Applicability to Long-Term Protection of Uranium Mill Tailings Impoundments," NUREG-2684.

22. NRC (U.S. Nuclear Regulatory Commission), June 1983, "Geotechnical Quality Control: Low-Level Radioactive Waste and Uranium Mill Tailings Disposal Facilities," NUREG-3356.