UNITED STATES

NUCLEAR REGULATORY COMMISSION

REGION IV

URANIUM RECOVERY FIELD OFFICE
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Docket No. 40-6659
SUA-551, Amendment No. 29
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MEMORANDUM FOR: Docket File No. 40-6659

FROM: Dawn L. Jacoby
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SUBJECT: AMENDMENT NO. 29 TO SOURCE MATERIAL LICENSE SUA-551 FOR RECLAMATION AND CLOSURE OF PETROTOMICS URANIUM MILL IN SHIRLEY BASIN, WYOMING

BACKGROUND

The Petrotomics Uranium Mill is located in the Shirley Basin area of Wyoming. Milling at Petrotomics commenced in 1962 and continued until 1985. Decommissioning of the mill occurred between June and October of 1985. The mill and associated structural materials were buried onsite or placed in the tailings impoundment. The mill site was graded and 2 feet of clean soil was placed over the entire area. Review of the Decommissioning Report was completed by the NRC on April 10, 1986 (Reference 1).

In accordance with 10 CFR Part 40 and License Condition No. 30 of Source Material License SUA-551 which required submittal of a detailed reclamation plan, the licensee, Petrotomics Company, submitted a proposed plan by letter dated June 27, 1986. The initial plan was reviewed and a request for additional information was sent to Petrotomics on November 10, 1986. Several rounds of questions resulted in additional information being submitted by Petrotomics. These submittals are listed in Enclosure 1.

Petrotomics' reclamation plan consists of stabilizing the tailings in place (Figure 1). All of the tailings solution has been evaporated from the impoundment area. The small amount of water that remains is recovered seepage water which is being removed by evaporation.

DISCUSSION

Review of the reclamation plan has been divided into six sections: structural stability and liquefaction, radon attenuation, earthwork construction specifications, settlement, surface water hydrology, and erosion protection. Each of these sections are discussed below.

Structural Stability and Liquefaction

The existing tailings embankment was reviewed when Petrotomics' license was renewed (Reference 2) and it was determined that the structure was designed and constructed in accordance with Regulatory Guide 3.11, "Design, Construction, and Inspection of Embankment Retention Systems for Uranium Mills," (Reference 3). The structural stability and liquefaction potential of the reclaimed facility is therefore not a concern as the reclaimed configuration significantly flattens all the outslopes and eliminates the impoundment (Figure 2). Future infiltration from rainfall events will be minimized by the cover system. Therefore, the staff concludes that the structural stability of the reclaimed disposal area will meet the criteria set forth in 10 CFR Part 40, Appendix A.

Radon Attenuation

The radon cover system proposed by the licensee can be found in their February 8, 1989 submittal. The cover, which was designed using the RAECOM computer model (Reference 4), consists of 2 feet (62 cm) of clay material covered by 2 feet (61 cm) of overburden material (silty sand) and 0.8 foot (25 cm) of topsoil (Figure 3). Only 0.5 foot (14 cm) of topsoil was considered in the radon attenuation analysis as 0.3 foot (11 cm) will be needed for 1000-year wind and sheet water erosion. The radon barrier is modified under the rock armored slopes by increasing the thickness of the overburden material from 61 cm to 63 cm and eliminating the topsoil (see Figure 3). Parameters used in the licensee's analysis are shown below in Table 1.

Review of Petrotomics' RAECOM model input found the cover system soil parameters to be reasonable. The density of the tailings was based on three in-place tests and represents a conservative value, as does the associated moisture content. The radium activity was measured and analyzed by the NRC and was set at 170 pCi/g in License Amendment No. 12 (Reference 5). Densities and porosities of the clay and overburden materials were selected based on the results of laboratory tests. The emanation coefficient of 0.208 was justified by measurements which were made as part of an NRC sponsored program reported in NUREG/CR-3533 (Reference 4), along with testing of 14 samples in conjunction with the 1986 NRC study of activity (Reference 5).

Table 1

TAILINGS PARAMETERS

	Thickness cm	Density g/cm³	Moisture Content %	Porosity	Emanation Coefficient	Radium Activity pCi/g
Tailings	500	1.6	12	.386	0.208	170

COVER SYSTEM PARAMETERS

	Thickness cm	Density g/cm³	Moisture Content %	Porosity
Clay	62	1.41	12.0	.457
Overburden	61	1.78	8.0	.319
Topsoil	14	1.44	2.0	.447

Long-term moisture contents for the tailings and cover materials were "selected" in the design as being conservative. No further substantiation was given. The review considered empirical estimates of long-term moisture contents based on climatic information and 15-bar moisture correlations along with in-situ moisture contents. Based on these methods, the selected long-term moisture contents are considered conservative. The resulting percent saturation of the material also indicates that the model is conservative.

The results of the licensee's RAECOM model were verified by the RADON program (Reference 6). The layer diffusion coefficients calculated by RADON were equivalent to the values used by the licensee. Results indicate that the exit flux from the overburden material will be 20.0 picocuries per square meter per second (pCi/m²s). This value meets the requirements of Criterion 6, Appendix A to 10 CFR Part 40 which limits releases to the atmosphere of radon-222 from byproduct material to 20 pCi/m²s. Therefore, the radon attenuation design is acceptable.

Earthwork Construction Specifications

Construction specifications can be found in the licensee's March 18, 1987 submittal. The proposed specifications require that the clay material be placed at 95 percent of the maximum dry density and between 6.0 percent dry and 2.0 percent wet of the optimum moisture content. Overburden material is to be placed at 95 percent of the maximum dry density and between 3.0 percent dry and 1.0 percent wet of the optimum moisture content. Lift thickness is limited to six inches after compaction. Field moisture content and density tests are to be performed every 1,000 cubic yards of compacted fill. Representative compaction tests are to be performed for every 20,000 cubic yards of compacted fill. Representative gradations and Atterberg limit determinations are to be performed for each 5,000 cubic yards of compacted fill.

The clay material will be obtained from the clay stockpile. Although not anticipated, the report states that if needed, "additional clay materials which compare closely with the clay pile material are located in the tailings dam embankment and in the eastern portion of the South Dump." As these additional sources of material were not considered in the radon attenuation modeling, their use as the 2-foot thick clay layer will require additional review and approval by NRC. The overburden material will be obtained from the Southwest Drainage Channel excavation. As with the clay material, any deviation from this source will require reevaluation by NRC. The topsoil will be obtained from stockpiles 8, 9, and 10.

Field and laboratory tests will be made by Petrotomics in accordance with ASTM D698, D2922, D3017, and D1556. Petrotomics will maintain documentation to provide assurance that the cover materials meet the specifications.

Although use of nuclear gauges is becoming a standard of the industry, there have been some problems with their use in proximity to contaminated materials. Therefore, NRC will require that the results from the nuclear gauge be compared to results from the sand cone test prior to acceptance of gauge results. The comparison methodology indicated in the "Staff Technical Position on Testing and Inspection Plans during Construction of DOE's Remedial Action at Inactive Uranium Mill Tailings Sites" (Reference 7) will be required. All other applicable aspects of the Staff Technical Position on Testing were addressed.

Petrotomics will attempt to complete radon barrier placement during one construction season. If, however, it is not possible to complete placement in one season, the winter shutdown and spring startup procedures should be established and submitted for NRC review and approval.

The proposed specifications are adequate to support the design for radon attenuation as long as the results from the nuclear gauge can be correlated with sand cone results. If any borrow sources other than the primary sources evaluated for the radon model are used, the design and/or specifications may require modification.

Settlement

Petrotomics has proposed in their April 28, 1989 submittal, to initiate a settlement monitoring plan and construction sequence that will verify that future settlements in the area will not detrimentally affect the performance of the cover system. The compacted clay portion of the radon barrier will be placed as an interim cover for the tailings and will be used to construct the evaporation ponds.

Eleven settlement monitoring stations will be established at the approximate locations shown on Figure 4. Monuments will consist of steel bars welded to steel plates that will be embedded in concrete. These monuments will be monitored as shown in Table 2 until 90 percent consolidation has been reached. When primary settlement is complete at all the monitoring stations as defined in Reference 8, and the enhanced evaporation effort is complete, the clay cover

will be regraded and reworked as necessary to assure that the material meets the specifications for the radon barrier. The remaining overburden portion of the radon barrier and the topsoil will then be placed.

Table 2

SETTLEMENT MONITORING INTERVALS

Time Period	Survey Interval
First Month	One Week
Second Month	Two Weeks
Third-Sixth Months	One Month
After Sixth Month	Three Months

Petrotomics will be required to submit the monitoring results along with a report detailing the covers' performance and possible defects when consolidation is essentially complete. Construction of the remaining cover will not proceed until NRC agrees that consolidation is essentially complete and that the existing clay cover is acceptable.

Surface Water Hydrology

Hydrologic Description

The Petrotomics Uranium Mill is located in the Shirley Basin area of south central Wyoming. There are two perennial streams in the nearby area, the Little Medicine Bow River and Sand Creek. The Little Medicine Bow River flows in a southerly direction about 3 miles east of the mill. The drainage downgradient of the tailings pile is part of the Sand Creek drainage system, with the creek being located about 2 miles from the mill.

As shown in Figure 1, the pile top has been designed with two drainage swales, the North Swale and the South Swale, which will convey runoff from the pile top to two riprapped swale discharge channels. The North Swale Discharge Channel will then convey flow to the North Channel and the South Swale Discharge Channel will convey flow to an area south of the tailings pile. The reclamation plan will also incorporate several diversion channels to intercept and divert runoff away from the tailings pile. Two channels, the West Dump Channel and the East Dump Channel, will divert runoff from an area to the north. South of these two channels, there is a third channel, the North Channel, which will convey runoff from a small intervening area north of the pile and from a portion of the pile top. A fourth channel, the Southwest Channel will drain an area to the south and west of the pile. The North and Southwest Channels will merge in a riprapped structure at the western edge of the reclamation area.

Flood Determinations

To evaluate the effects of flooding and to determine the need for erosion protection, the licensee analyzed the effects of flooding from two sources;

(1) flooding due to Probable Maximum Floods (PMFs) from adjacent drainage areas, and (2) a Probable Maximum Precipitation (PMP) event occurring directly over the reclaimed tailings pile. The PMP/PMF design events meet or exceed the criteria outlined in 10 CFR Part 40, Appendix A, and therefore provide acceptable isolation of the reclaimed tailings.

PMP values were estimated by the licensee in their June 30, 1988 submittal, using Hydrometeorological Report No. 55 (HMR-55) (Reference 9). A 1-hour PMP value of 11.0 inches was used as a basis for estimating appropriate PMFs for the small drainage areas at the site.

Subsequent to HMR-55 being published in March 1984, the authors reexamined the report and determined that several changes had to be made to HMR-55. These changes resulted in lower PMP estimates for small areas and short durations at higher elevations. As a result, a revised report (HMR-55A)(Reference 10) was published in June 1988. This revised report supersedes HMR-55.

Since HMR-55A is the current reference to be used for estimating PMP values, the 1-hour PMP was independently estimated at 9.1 inches. Because the 1-hour PMP used by the licensee (11.0 inches) is greater, it is acceptable.

The time of concentration is the amount of time required for flood runoff to reach the outlet of a drainage basin from the most remote point in that basin. The peak runoff for a given drainage basin is inversely proportional to the time of concentration for that basin. Therefore, if the time of concentration is conservatively computed to be small, the peak discharge will be conservatively large.

Various times of concentration (tc) for the various drainage areas were estimated by the licensee using the Kirpich Method, as discussed in Reference 11. The procedures used for computing tc are considered representative of the small drainage areas at the site.

As discussed above, the 1-hour PMP was estimated by the licensee to be 11.0 inches. For durations of 15, 30 and 45 minutes, the licensee used percentages recommended in Table 12.4 of HMR-55 (Reference 9). These percentages are the same as those recommended in NUREG/CR-4620 (Reference 12). Percentages used to determine PMP amounts for 2.5 and 5-minute durations were those recommended by the NRC. Since the licensee used procedures recommended in a NUREG or by the NRC, the rainfall distribution used by the licensee is acceptable.

Probable Maximum Flood Estimates

Probable Maximum Floods were estimated by the licensee in their June 30, 1988 submittal, using the Corps of Engineers' computer program HEC-1 (Reference 13), which is a standard computational method for estimating peak flood discharges. Review of the licensee's computations indicates that reasonable and conservative methods were used for estimating input parameters such as lag times, infiltration losses and rainfall distributions. Based on this review of

the licensee's calculations and on independent calculations as discussed below, the estimated PMF discharges are acceptable.

Water Surface Profiles and Channel Velocities

Water surface elevations and velocities were estimated by the licensee using Manning's equation. These calculations were provided in the submittal dated June 30, 1988. Water level and velocity computations were independently checked in accordance with standard procedures given in Reference 14. In several cases, water surface profiles and velocities were independently calculated using the Corps of Engineers' HEC-2 computer program (Reference 15). These calculated values of elevations and velocities were then compared with the licensee's. Based on this comparison, the licensee's estimates of water levels and velocities are acceptable.

Erosion Protection

The drainage channels in the reclamation plan were designed for a maximum velocity of 3 feet per second (fps). In outlying areas where velocities will exceed 3 fps, the licensee designed appropriate rock erosion protection or provided analyses to show that any erosion that could occur would not affect the stability of the reclaimed tailings pile. These analyses are presented in the licensee's June 30, 1988 submittal.

Maximum potential erosion and migration of the drainage channels were predicted by considering cumulative channel sediment transport over a 1000-year period plus a PMF event. To predict the maximum cumulative erosion that could occur from 1000 years of ephemeral flows, the licensee assumed that ten 100-year floods would occur in a 1000-year period. Flood events having recurrence intervals of less than 100 years were not considered because the velocities would be low enough to be considered nonerosive.

The Colby method (Reference 16) was employed by the licensee to calculate sediment transport. It was conservatively assumed that all erosion would occur on the channel bank closest to the tailings pile and to account for potential migration of the channels, the extent of erosion was doubled. Other conservatisms used in the analyses included an assumption that peak PMF flows would last for at least 30 minutes and flood waters arriving in each channel section would be clear water so that all sediment transported would originate within the channel.

North Channel

As shown in Figure 1, the North Channel will carry runoff from the North Swale on the tailings pile and from a drainage area of about 200 acres. The total drainage area is about 256 acres. In general, the channel side slopes will be 200H:1V on the left side and 50H:1V on the right side. In addition, the channel will have a 0.5 foot deep low-flow section with a 40-foot bottom width and 5H:1V side slopes. The upstream end of the channel will have a triangular cross section with 50H:1V side slopes. The downstream end will be trapezoidal in cross section with 3.5H:1V side slopes and will be armored with a 1.9-foot

thick layer of riprap. A discussion on the adequacy of this riprap follows below. The channel bottom slope will vary from 0.017 to 0.026.

The licensee in their June 30, 1988 submittal, estimated PMF and 100-year flood discharges at several locations along the North Channel. The PMF varied from 570 cubic feet per second (cfs) to 2794 cfs. The 100-year discharge varied from 70 cfs to 308 cfs.

Using Manning's equation with a roughness coefficient of 0.03 and the above discharges, the licensee estimated flood depths and velocities in the North Channel. The flow velocities varied from 6.2 feet per second (fps) to 6.7 fps for the PMF. The 100-year velocities varied from 3.7 fps to 4.2 fps. Since both of these flood events could potentially result in some erosion, the licensee performed a sediment transport analysis to estimate the amount of erosion that could occur. This analysis indicated that over a 1000-year period, the North Channel could move about 76 feet closer to the tailings pile. Since the channel is at least 450 feet away from the toe of the reclaimed tailings pile, the licensee concluded that the pile will not be affected by any erosion that occurs in the North Channel.

Water surface profiles and flow velocities were independently developed for the North Channel using the Corps of Engineers' HEC-2 computer program for gradually varied flow (Reference 15). The independent estimates of velocities in the channel were slightly higher than the licensee's in some areas and lower in others. The estimated velocities varied from 5 fps to 7.7 fps in the channel and from 3.6 fps to 4.1 fps in the overbanks. A sediment transport analysis using the HEC-2 velocities was also performed. This analysis indicated that erosion of the North Channel would be about 110 feet, somewhat greater than the licensee's estimate of 76 feet. Since, as discussed above, the toe of the reclaimed pile is at least 450 feet away from the North Channel, it was concluded that long-term erosion of the North Channel will not affect the stability of the tailings pile. Therefore, the design of the North Channel is acceptable.

Southwest Channel

The Southwest Channel will drain an area from west and southwest of the tailings pile. The total drainage area is about 64 acres. The channel will have 100H:1V side slopes on the left side and 50H:1V on the right. The channel will also have a 0.5-foot deep low flow section with a 30-foot bottom width and 5H:1V side slopes. The downstream end of the channel will be similar to the North Channel in that it will be armored with a 1.9-foot thick layer of riprap.

The licensee estimated PMF and 100-year flood discharges at several locations along the Southwest Channel. PMF discharges varied from 269 cfs to 1232 cfs. The 100-year discharges varied from 33 cfs to 138 cfs.

Using Manning's equation with a roughness coefficient of 0.03 and the above discharges, the licensee estimated flood depths and velocities in the Southwest Channel. For the PMF, flow velocities varied from 3.4 fps to 12.5 fps, and for the 100-year flood, discharges varied from 2.6 fps to 5.9 fps. A

conservative sediment transport analysis performed by the licensee indicated that for the Southwest Channel, erosion over a period of 1000 years could result in the channel moving about 17 feet closer to the tailings pile. Since the channel is about 330 feet away from the toe of the tailings pile outslope and about 500 feet away from tailings, the licensee concluded that erosion in the Southwest Channel will not affect the stability of the reclaimed pile.

Water surface profiles and flow velocities were independently developed for the Southwest Channel using HEC-2 (Reference 15). These velocity estimates varied from 2.3 fps to 12.9 fps with the higher velocities being in the downstream portion of the channel which will be armored with riprap. These velocities compared closely with the licensee's estimates of 3.4 fps and 12.5 fps discussed above. On the basis of this close comparison of velocities, it was concluded that the design of the Southwest Channel is acceptable.

Confluence of the North and Southwest Channels

As shown in Figure 1, the North and Southwest Channels will converge into one channel west of the tailings pile. This confluence will be protected with a 1.9-foot thick layer of riprap having a median stone diameter (D_{50}) of 1.1 feet. The riprap will be placed over a 6-inch thick filter layer which will be underlain by 6 inches of coarse sand. As shown in Figure C.2-5 of the June 30, 1988 submittal, the riprap will be extended 170 feet upstream from the confluence along the North Channel and about 770 feet along the Southwest Channel. Downstream from the confluence, the riprap will be extended about 390 feet. At the outlet of the channel, the riprap will be extended 6 feet below the channel bottom to prevent excessive scour and potential headcutting. Details of the design of the outlet are presented in Figure C.2-5 of the June 30, 1988 submittal.

An independent analysis was performed using HEC-2 (Reference 15). Based on this analysis, it was concluded that the design velocity of 13 fps used by the licensee to design the riprap is acceptable, since the maximum velocity independently estimated from HEC-2 was also 13 fps. The riprap design was checked using the Corps of Engineers' Shear Stress method (Reference 17). On the basis of the review and independent analyses, it was concluded that the proposed D_{50} of 1.1 feet is acceptable.

The gradation of the riprap was determined by the licensee using Corps of Engineers' criteria (Reference 17). The filter material gradation will conform to criteria proposed by Barfield (Reference 18). Riprap and filter criteria are given in the June 30, 1988 submittal. The proposed gradations were reviewed using procedures described in NUREG/CR-4620 (Reference 12). Based on this review, the filter material and riprap gradations were found to be acceptable.

West Dump Channel

The West Dump Channel will intercept runoff from an area of about 23 acres and convey the runoff toward the west, away from the tailings pile. The channel will have a trapezoidal cross section with a 3H:1V slope on the left side. The

right side slope will reflect the natural ground slope which is much flatter than 3H:1V. The channel bottom slope will be 0.011 and the bottom width will vary from 50 feet at the upstream end to 140 feet at the outlet.

PMF and 100-year flood discharges were estimated by the licensee at several locations along the channel. These varied from 244 cfs to 521 cfs for PMF conditions and from 29 cfs to 57 cfs for the 100-year flood.

Using Manning's equation with a roughness coefficient of 0.03 and the above discharges, the licensee estimated flood depths and velocities in the West Dump Channel. The flow velocities calculated in this manner varied from 4.5 fps to 5.8 fps for PMF flows. The licensee's calculations are presented in their June 30, 1988 submittal. These velocities are higher than what would be preferred to avoid erosion. Thus, the licensee performed a conservative sediment transport analyses using the Colby method (Reference 16), as discussed above. This analysis indicated that over a 1000-year period, there will be some erosion, but the erosion will not be sufficient to cause the PMF to overflow the channel. Therefore, the licensee concluded that the integrity and stability of the reclaimed tailings will not be affected by any erosion that occurs in the West Dump Channel.

An independent sediment transport analysis was not performed for this channel as was done for the North and Southwest Channels. However, based on a review of the design calculations provided for the West Dump Channel, and considering the conservatisms assumed in the erosion calculations and in the selection of a PMF event, it was concluded that the design of the West Dump Channel is acceptable.

East Dump Channel

The East Dump Channel will intercept runoff from an area of approximately 36 acres. The channel will have a trapezoidal cross section with a 3H:1V slope on the right side. The left side slope varies but is no steeper than 3H:1V. The channel bottom slope will be 0.003 and the bottom width will vary from 20 feet at the upstream end to 40 feet at the downstream end.

PMF and 100-year flood discharges were estimated by the licensee at several locations along the East Dump Channel. These varied from 280 cfs to 541 cfs for the PMF and from 34 cfs to 58 cfs for the 100-year flood.

Using the above discharges together with Manning's equation and a roughness coefficient of 0.03, the licensee in their June 30, 1988 submittal estimated flood depths and velocities. The flow velocities calculated varied from 4.0 fps to 4.4 fps for PMF conditions. For the 100-year flood, velocities varied from 2.0 fps to 2.2 fps. The licensee also performed a sediment transport analysis for the East Dump Channel and concluded that there will be some limited erosion in the East Dump Channel. This erosion, however, will not affect either the integrity of the channel nor the tailings pile. Based on an

independent review of the design of the East Dump Channel, and considering the conservative assumptions made in the erosion calculations and in selecting a PMP value, it was concluded that the design of the East Dump Channel is acceptable.

Pile Top

As shown on Figure 1, the pile top will consist of an upper level and a lower level. The slopes of these areas have been designed for no erosion using the Horton equation discussed in the Draft Staff Technical Position (Reference 19). The upper level will be crowned so that runoff will flow radially off the pile. This level will be 16 to 20 feet higher than the lower level. A minor portion of the runoff from the upper level will flow into a closed basin located east of the tailings. The majority of the runoff from the upper level will flow down a 5H:1V slope, then onto the lower level. The 5H:1V slope will be protected with a 5.75-inch thick layer of riprap having a D_{50} of 3.3 inches. This riprap will be placed on a 4-inch thick filter blanket (Figure 3). The riprap at the upper end of the 5H:1V slope will be extended 8 feet onto the upper level. At the toe of the 5H:1V slope, the riprap will also be extended 8 feet onto the flatter lower level to provide an apron for dissipating the energy of the flowing water (Figure 3).

The gradation of the riprap to be used on the 5H:1V slope on the pile top was determined using Corps of Engineers' criteria (Reference 17). The filter gradation conforms to criteria proposed by Barfield (Reference 18). Both riprap and filter specifications for the 5H:1V slope on the pile top are shown in the licensee's April 28, 1989 submittal. The proposed gradations were reviewed using procedures from NUREG/CR-4620 (Reference 12). Based on this review, it was concluded that the proposed riprap and filter gradations are acceptable.

The adequacy of extending the riprap 8 feet at the top and toe of the 5H:1V slope was independently checked. At the top of the slope, the velocity and shear stress during a PMP event would be about 1.9 feet per second (fps) and 0.14 pounds per square foot (psf), respectively. At the toe, the velocity would be about 1.6 fps and shear stress about 0.09 psf. These values are considered to be less than the allowable for the soil being used. Therefore, extending the riprap 8 feet at the top and toe of the 5H:1V slope on the pile top is acceptable.

The licensee's stable slope calculations for the pile top were also checked. Using cross-sections SL-6a and SL-6b shown in Figure G.5-1a of the licensee's April 28, 1989 submittal, stable slopes were independently calculated for the upper and lower levels using the Horton equation (Reference 19). In addition, the riprap D_{50} was calculated using the Stephenson Method (Reference 20). A comparison between the results is shown in Table 3.

Table 3

COMPARISON OF STABLE SLOPES AND ROCK SIZE

Stable Slope	Licensee Analyses	NRC Analyses
(a) upper level	.0071	.008
(b) lower level	.0043	.005
Median Rock Size (D_{50}) for the 5H:1V slope	3.3 inches	3.3 inches

Since the independent calculations were in close agreement with those of the licensee, it was concluded that the design of the pile top is acceptable.

There is an area on the pile top adjacent to the North Swale Discharge Structure where slopes are somewhat steeper than the calculated stable slopes. The licensee in a submittal dated August 15, 1989, agreed to place rock in these steeper areas. The rock armor will have a D_{50} of 2.6 inches. It will be placed to a thickness of 4.5 inches over a 4.0-inch thick filter layer. This design of the riprap was reviewed and its adequacy checked using the Safety Factors Method (Reference 21). On the basis of this review and analysis, the design of the riprap is acceptable for the steeper areas of the pile top adjacent to the North Swale Discharge Structure.

The effects of wind and sheet water erosion on the pile top were also considered. The licensee in their June 27, 1986 submittal performed an analysis of expected wind and sheet water erosion using the Universal Soil Loss Equation and the Wind Erosion Equation, respectively. The licensee estimated that a soil loss of 0.1 foot due to sheet water erosion and 0.2 foot due to wind erosion will occur over a 1000-year period for a total soil loss of 0.3 foot. Based on a review of the licensee's analysis, this estimate is acceptable. Since the cover design has 0.3 foot of soil for potential wind and sheet water erosion, the design is acceptable.

Embankment Swales

Runoff from the pile top will flow into two broad and gently sloping swales (Figure 1). Each of these swales will convey flow from the tailings cover to a riprapped channel. These channels are described as the North Swale Discharge Channel and the South Swale Discharge Channel. The design of these channels is as shown on Figure C.2-3 of the licensee's June 30, 1988 submittal.

The North Swale Discharge Channel will be trapezoidal in cross-section with 5H:1V side slopes. The bottom width will be 75 feet. The slope of the channel will vary from 0.003 to 0.125, as shown on Figure C.2-3 of the June 30, 1988 submittal. At the upstream end of the channel, the riprap will be extended 40 feet onto the pile top to minimize the potential for erosion. At the downstream end, a stilling basin will be provided to contain a hydraulic jump which will occur as the PMF goes through critical depth. Downstream of the

stilling basin, the riprap will be extended 6 feet down into the existing ground in order to prevent excessive scour and potential headcutting.

For the North Swale Discharge Channel, the licensee estimated flood depths and velocities using Manning's equation with a roughness coefficient of 0.04 and a PMF discharge of 1052 cfs. Flow velocities varied from 3.7 fps to 12.8 fps. The riprap to be placed in the channel was sized using the Isbash method and a velocity of 13 fps. This resulted in a D_{50} of 1.1 feet. The licensee also sized the riprap using four other methods but the D_{50} calculated using the Isbash equation (Reference 17) resulted in the largest riprap size. Thus, it was the method accepted for riprap design.

The licensee's design calculations were reviewed and the required D_{50} was independently estimated for the North Swale Discharge Channel using the Safety Factors Method (Reference 21). This analysis indicated that a D_{50} of 1.3 feet is required. However, considering that the licensee used a larger PMP than required to calculate the PMF, it was concluded that a minimum D_{50} of 1.1 feet as proposed by the licensee is acceptable.

The licensee's design of the South Swale Discharge Channel is similar to the North Swale Discharge Channel except that the channel bottom is wider, 90 feet, to accommodate the larger PMF of 1243 cfs. The riprap to be used in the South Swale Discharge Channel also has a minimum D_{50} of 1.1 feet.

The licensee's design calculations were reviewed and it was concluded that the design is acceptable since it is similar to the North Swale Discharge Channel.

Embankment Outslope

Details of the embankment outslope are shown in Figure C.2-2 of the licensee's June 30, 1988 submittal. The tailings pile will be contoured so that flood runoff from the pile top does not contribute to flows on the embankment outslope. As shown on Figure 2, the existing tailings dam outslope will be flattened from its present 2H:1V to a variable slope which will be 5H:1V at the top, gradually decreasing to a maximum of 22H:1V. At the toe of the embankment, the slope will increase to 5H:1V and will be armored with riprap (Figures 2 and 5). The riprap will have a minimum D_{50} of 2.6 inches and will be placed in a layer 4.5 inches thick over a 4-inch filter.

The gradation of the riprap to be used on the 5H:1V slope at the toe of the embankment outslope was determined using Corps of Engineers criteria (Reference 17). The filter gradation conforms to criteria proposed by Barfield (Reference 18). Both riprap and filter specifications are shown in the licensee's June 30, 1988 submittal. The proposed gradations for the riprap and the filter were reviewed using procedures from NUREG/CR-4620 (Reference 12) and it was concluded that they are acceptable.

In order to check the adequacy of the outslope design, the Method for Determining Sacrificial Slope Requirements shown in Appendix B of Reference 19 was used. Using conservative values for shear stress (0.10 psf), angle of repose (30°), rainfall intensity (60 in/hr) and flow concentration factor (3),

it was concluded that the reclaimed pile outslopes may develop a gully as deep as 15 feet. However, this gully will be located about 130 feet from tailings. Using an angle of repose of 30° to project the gully towards the tailings, still indicates that tailings will not be exposed. Based on this analysis, it was concluded that the outslope design of the embankment is acceptable.

The adequacy of the riprap proposed for the 5H:1V slope at the toe of the outslope was also checked. Using the Safety Factors Method (Reference 21), a required D_{50} of 2.7 inches was estimated. Since as discussed above, the licensee has proposed a D_{50} of 2.6 inches, it is acceptable.

Rock Durability

Durability testing of a rock source for riprap has not yet been performed. However, in a submittal dated April 28, 1989, the licensee committed to use the "Procedures for Designing Riprap Erosion Protection" which are discussed in Appendix D of Reference 19. The occasionally saturated criterion will be used for determining rock suitability except for the stilling basins located in the North and South Swale Discharge Channels. In these areas, the frequently saturated criterion will be used.

With this commitment, it is concluded that adequate riprap will be provided. However, once a rock source has been identified, the licensee will be required to review its riprap designs and make any necessary modifications. For example, a rock specific gravity of 2.64 was used to size the riprap. If the specifications allow use of rock with a smaller specific gravity, then the riprap D_{50}'s may have to be increased.

Testing and Inspection of Riprap During Construction

Unless otherwise indicated, testing and inspection of riprap and filter material shall conform to Reference 7.

EVALUATION OF RECLAMATION PLAN AGAINST APPENDIX A CRITERIA

Appendix A to 10 CFR 40 establishes criteria for the technical, financial, ownership and long-term site surveillance criteria relating to the siting, operation, decontamination, decommissioning and reclamation of uranium milling facilities. Each site-specific licensing decision is to be based on the criteria in the appendix, taking into account the public health and safety and the environment. Decisions as to the ability of the design to meet "reasonably achievable" criteria must take into consideration the state of technology as well as evaluating the economic cost to resulting benefit.

The following Appendix A criteria were considered for the proposed licensing decision to amend Source Material License SUA-551 in accordance with the reclamation plan submittals. Criterion 2, 8 and 11 are not applicable for review and approval of a reclamation plan and were therefore not considered.

Criterion 1

Criterion 1 addresses the general goal of siting and designing facilities to provide for the permanent isolation of tailings and associated contaminants by minimizing disturbance and dispersion by natural forces without the need for ongoing maintenance. Items that were considered when evaluating the proposed plan include:

1. Remoteness from populated areas: The site is located in Carbon County, Wyoming, approximately 48 miles south of Casper, Wyoming. The nearest permanent residence is at a ranch located approximately 7 miles northwest of the site. A trailer park (the Shirley Basin Townsite) is located 2 miles south of the mill. This trailer park which was used by people employed at the nearby uranium mines and mills has been almost abandoned and very few residents remain. The nearest towns are Medicine Bow, about 35 miles south, and Alcova, about 35 miles northwest. There is no reason to believe that any population centers will be built or that there will be significant population increases within 35 miles of the site.

2. Hydrologic and other natural conditions as they contribute to continued immobilization and isolation of contaminants from ground-water sources: The reclaimed disposal area will be covered with a minimum 4.8-foot thick cover system. Infiltration through the cover will be minimized by using soil cover material whose permeability is considered low to practically impervious.

   A ground-water review of the site to assure compliance with 10 CFR 40, Appendix A, is currently being done under other licensing actions. Compliance standards were set in December 1988. The licensee is currently implementing the corrective action program to return ground-water quality to established standards.

3. Potential for minimizing erosion, disturbance and dispersion by natural forces over the long-term: The potential for erosion will be minimized by several design features as follows. The surface of the pile will be provided with flat slopes designed to be nonerosive, or erosion protection will be provided in areas having steeper slopes. The existing 2H:1V pile outslopes will be reduced to 5H:1V or less. Also, the dam height will be reduced by about 20 feet. Runoff from the stable pile top will be conveyed down the outslopes by two riprap-lined swale discharge channels. The toes of the swale channels will be keyed into the existing ground to prevent scour and headcutting. At the break in slope between the pile top and the swale discharge channels, a transitional riprap-lined area will be provided.

Criterion 3

Criterion 3 sets below grade disposal as the prime option for tailings disposal. Relocation of the tailings to another site so that all the contaminated material could be placed below grade is technically feasible. However, the benefits over stabilizing the tailings in place would be

negligible. Since the existing facility is essentially sound, the cost of disposing the contaminated materials below grade by relocating the disposal area would be much greater than the benefit realized, making relocation economically impracticable.

If below grade disposal is not practicable, the disposal plan must provide reasonably equivalent isolation of the tailings from natural erosional forces. The licensee utilized PMP/PMF events to design the diversion channels and erosion protection for the facility. Wind and sheet water losses on the pile top were calculated for 1000 years. Therefore, the tailings will be acceptably isolated from natural erosional processes.

Criterion 4

Criterion 4 sets specific technical criteria for disposal of tailings.

Criterion 4(a) requires that upstream rainfall catchment areas be minimized so that the tailings are protected from floods. This criterion will be met by constructing diversion channels to intercept runoff from a PMP/PMF event over the upstream drainage area of over 390 acres. In addition, the pile top will be graded so that the only runoff that flows off the embankment outslopes will be from precipitation that occurs on the outslopes.

Criterion 4(b) states that topographic features should provide good wind protection. At Petrotomics, the prevailing wind direction is west through southwesterly. There are no topographic features to provide protection to the existing pile as the higher elevations are to the north of the pile. Relocation of the pile to another site which would provide good wind protection is technically feasible, but the benefits over stabilizing the pile in place would be negligible. Since the facility is essentially sound, the cost of disposing the contaminated materials in an alternate location that would offer good wind protection would be much greater than the benefit realized.

Criterion 4(c) states that cover slopes must be relatively flat such that final slopes should be as close as possible to those which would be provided if tailings were disposed of below grade. With one small exception, the proposed reclamation plan places all the tailings under a cover with very flat slopes designed to be stable even under extreme runoff conditions. The exception is a small area adjacent to the South Swale Discharge Structure. However, riprap will be provided in this area. Water runoff from the tailings cover will exit the tailings area through two riprap-lined channels. None of the other slopes associated with the plan are underlain by tailings.

Criterion 4(d) requires a full self-sustaining vegetative cover be established or a rock cover employed. The licensee has opted for a combination of rock, extremely flat slopes and vegetation. Although the licensee has had some success in establishing self-sustaining vegetation, no attempt was made to substantiate self-sustaining vegetation over a 1000-year period. Therefore, although vegetative cover will be placed on the final reclaimed tailings pile and mill site area, vegetation is not necessary to assure long-term stability.

Criterion 4(e) requires that the impoundment not be located near a capable fault. The existing tailings embankment was reviewed when Petrotomics' license was renewed. At that time, it was determined that the structure was designed and constructed in accordance with Regulatory Guide 3.11, "Design, Construction, and Inspection of Embankment Retention Systems for Uranium Mills," (Reference 3). The seismic design of the reclaimed facility is therefore not an issue.

On the basis of independent reviews and analyses, it is concluded that all the requirements of Criterion 4 will be met by the licensee's proposed reclamation plan.

Criterion 5, 7 and 13

Criteria 5, 7 and 13 concern ground-water protection standards. As previously discussed, ground water is being addressed under separate licensing action. It is noted, however, that the ground-water protection standards at the site will be in accordance with these criteria.

Criterion 6

Criterion 6 requires that waste disposal areas be closed in accordance with a design which provides reasonable assurance that average releases of radon-222 and radon-220 to the atmosphere will be limited to 20 picocuries per square meter per second (pCi/m^2s). The design is to be effective for 1000 years to the extent reasonably achievable and, in any case, for at least 200 years.

The evaluation of the radon barrier utilized a RADON model and conservative parameters to estimate radon emanation from the tailings. The design is supported by adequate construction specifications, settlement monitoring, and quality control programs. The resulting cover design is acceptable, and the average release of radon-222 and radon-220 will meet the requirement.

The design basis events for erosion protection of the pile top, embankment outslope and diversion channels are the Probable Maximum Precipitation (PMP) and the Probable Maximum Flood (PMF) events. Both of these events are considered to be the most severe that are reasonably possible and thus provide reasonable assurance of not occurring during the 1000-year design life. The pile top slope has been designed so that eroding forces of flowing water are less than the soil resistance. This design should assure that excessive erosion does not occur during the design life. Accordingly, it was concluded that the proposed design meets the requirements of Criterion 6.

Criteria 9 and 10

Criteria 9 and 10 require that a financial surety arrangement be established to assure that sufficient funds are available to carry out the decontamination and decommissioning of the facility and the reclamation of the disposal area. The licensee initiated reclamation work at the site prior to plan approval, and mill decommissioning was completed in 1985. Several residual cost items must be included in an acceptable surety instrument written in favor of the State of

Wyoming or the NRC. These items include the long-term surveillance fee, completion of tailings area reclamation, a 15 percent contingency and 10 percent project management figure, ground-water restoration costs, and site monitoring requirements. The existing surety, written in favor of the NRC for $1,920,545, is based on an earlier approved plan. The licensee will be allowed 3 months from issuance of the reclamation plan approval to provide a detailed update of the cost estimate to be used to assure that the surety arrangements are adequate. This final surety amount will meet the requirements of Criteria 9 and 10.

Criterion 12

Criterion 12 requires that the final disposition of tailings or wastes at milling sites should be such that ongoing active maintenance is not necessary to preserve isolation.

Every reasonable concern has been considered in the design of the facility. The technical criteria in Appendix A have been met to the extent reasonably achievable by considering economics and by utilizing state-of-the-art design methods and conservative design basis events. Therefore, ongoing maintenance is not required to assure that the reclaimed mill tailings pile will remain effective for 1000 years and that radon emanation will be limited to an average of 20 pCi/m^2s. There will be, however, a long-term program of surveillance and maintenance administered through a license as required by Criterion 11. It is expected that routine maintenance will be performed as needed, but it is not required to preserve the facility. Therefore, the requirements of Criterion 12 are met by the proposed design.

CONCLUSIONS

Review and independent analyses of the reclamation plan for the Petrotomics Uranium Mill site have resolved all issues and open items and it is concluded that the proposed design is consistent with 10 CFR Part 40, Appendix A.

Therefore, it is recommended that Source Material License SUA-551 be amended by deleting License Condition No. 30 and adding License Condition No. 49 to read as follows:

49. The licensee shall reclaim the tailings impoundment as stated in their submittals dated June 27, 1986; January 15, March 18 and August 31, 1987; June 30, 1988; and February 8, April 28, August 15 and August 16, 1989; subject to the following:

    A. Should the clay stockpile not contain an adequate amount of clay material for the pile top cover, the licensee shall locate an alternate clay source and provide documentation of its acceptability for NRC review and approval in the form of a license amendment prior to placement. This documentation shall include appropriate laboratory testing and radon attenuation modeling to indicate that the design using the alternate clay material meets the requirements of Criterion 6, Appendix A to 10 CFR Part 40.

B. Should the overburden material obtained from the Southwest Channel excavation not be adequate to provide the required overburden material for the pile top cover, the licensee shall locate an alternate overburden source and provide documentation of its acceptability for NRC review and approval in the form of a license amendment prior to placement. This documentation shall include appropriate laboratory testing and radon attenuation modeling to indicate that the design using the alternate overburden material meets the requirements of Criterion 6, Appendix A to 10 CFR Part 40.

C. Should complete placement of the radon barrier in one construction season not be possible , the licensee shall establish winter shutdown and spring startup procedures and submit these for NRC review and approval prior to initiating winter shutdown.

D. Testing and inspection of the rock and the correlation of the nuclear gauge with sand cone results during construction shall meet or exceed the criteria set forth in the "Staff Technical Position on Testing and Inspection Plans During Construction of DOE's Remedial Action at Inactive Uranium Mill Tailings Sites," January 1989.

E. The rock to be used for riprap shall meet the scoring criteria described in Appendix D of the "Draft Staff Technical Position on Design of Erosion Protection Covers for Stabilization of Uranium Mill Tailings Sites," August 1989. Minimum riprap specifications and durability test results from representative samples must be submitted for NRC review and approval at least 60 days prior to placement of the riprap. Minimum durability tests shall include L. A. Abrasion, absorption, soundness and specific gravity.

F. The licensee shall submit a report for NRC review and approval, detailing the results of the settlement monitoring program and substantiation that any projected settlement will not adversely affect the clay covers' performance over the design life. This report must be approved in the form of a license amendment prior to placement of the overburden and topsoil.

G. The licensee shall submit to NRC a final cost estimate based on this approved plan no later than three (3) months following issuance of this amendment. This estimate shall be used as a basis for the surety arrangement required by License Condition No. 23.

In making the above changes, the Post Office Box number in License Condition No. 2 was found to be in error. Therefore, License Condition No. 2 should be revised as follows:

OCT 23 1989

2. P.O. Box 8509
Shirley Basin, Wyoming 82615

In addition to the amendments described above, this licensing action should be utilized as an opportunity to modify the license expiration date in License Condition No. 4 as follows:

4. Until NRC determines that site reclamation has been completed.

Dawn L. Jacoby
Project Manager

Raymond O. Gonzales
Project Manager

Approved by:
for Ramon E. Hall
Director

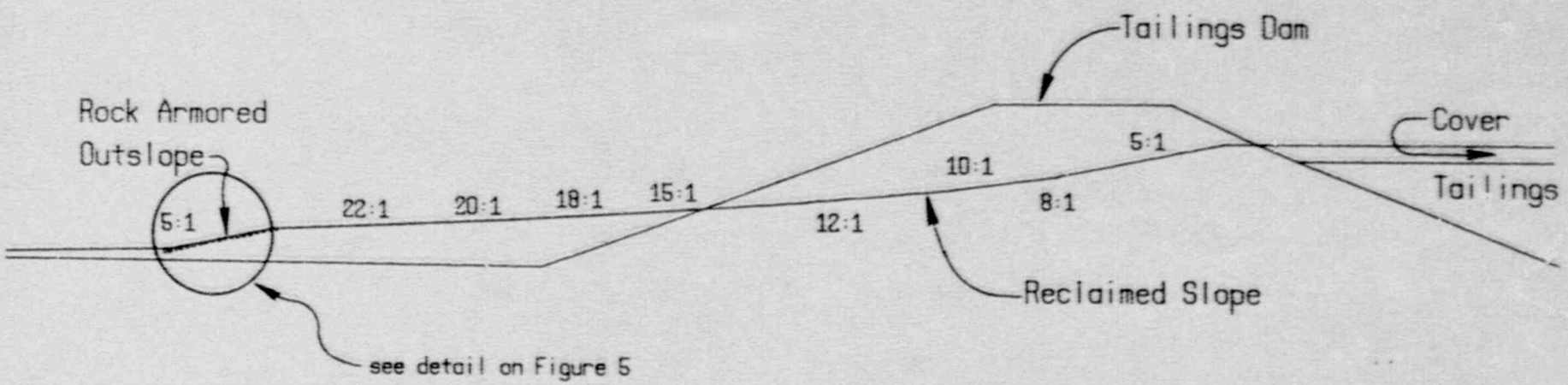
Cases Closed: 04006659450E
04006659451E
04006659452E
04006659453E

PETROTOMICS URANIUM MILL
RECLAMATION PLAN

SURFACE WATER FEATURES

(Modified from Figure C.2, April 28,1989 Submittal)

Figure 1

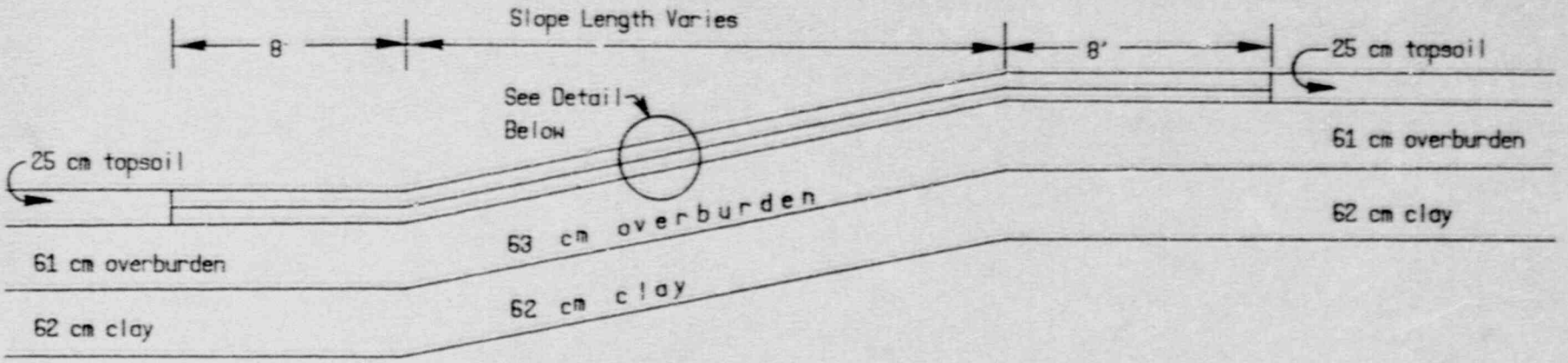


PETROTOMICS URANIUM MILL
RECLAMATION PLAN

RECLAMATION OUTSLOPE
TYPICAL CROSS SECTION

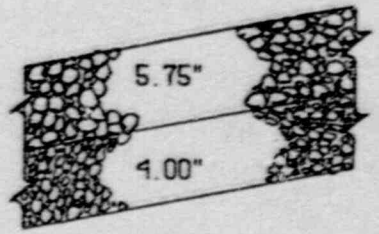
(Modified from Figure 6.2-2, April 28,1980 Submittal)

Figure 2



ROCK ARMORED SLOPE

AND COVER



Rock Armor

Filter Blanket

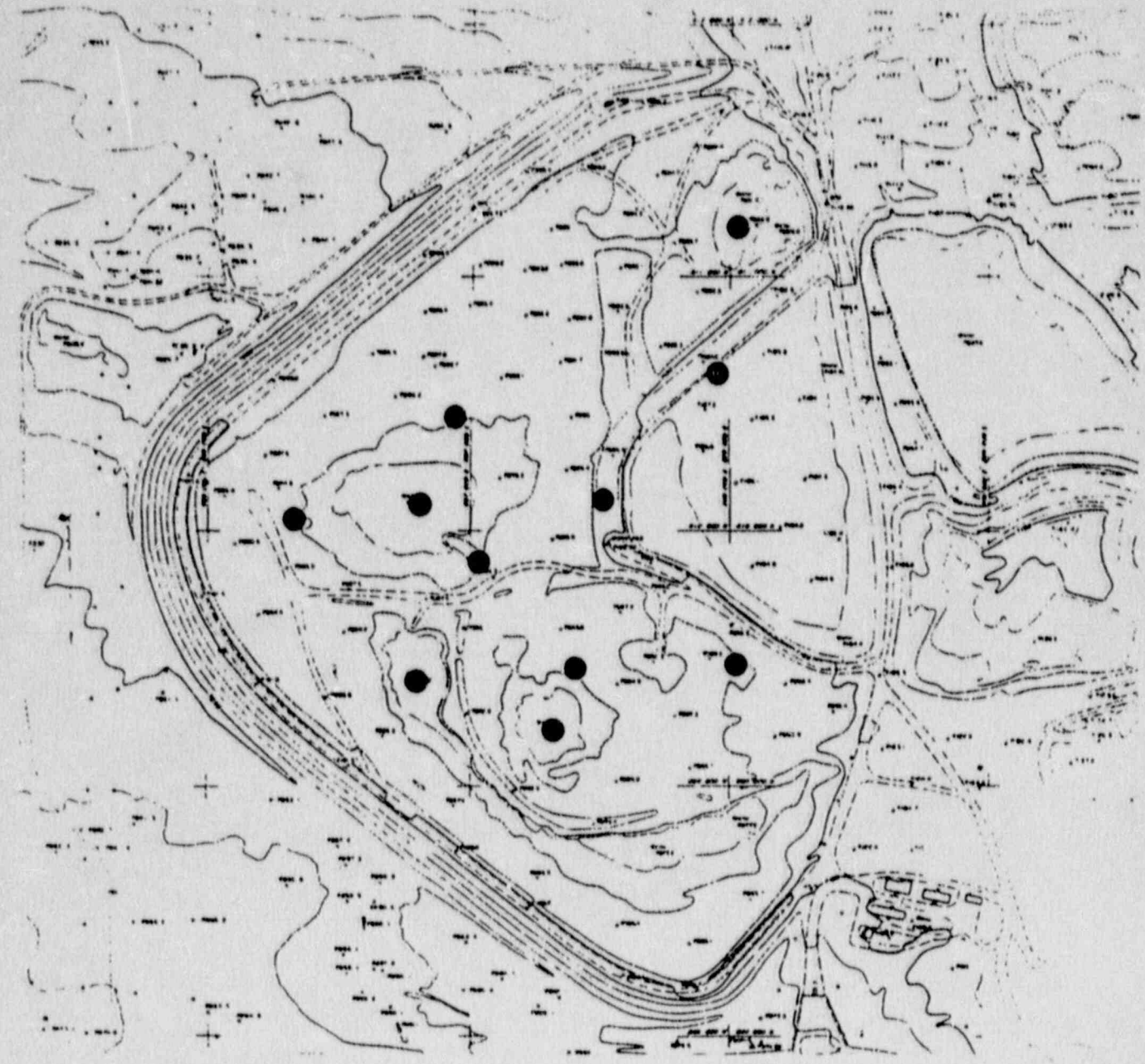
EROSION PROTECTION

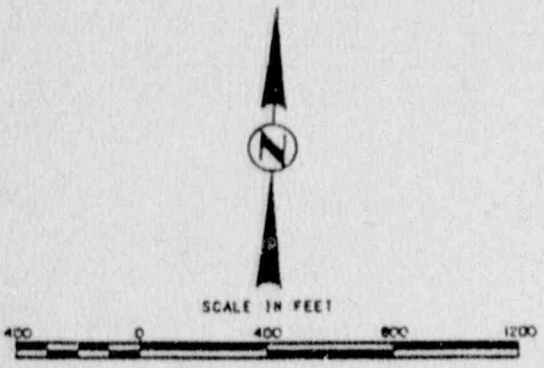
PETROTOMICS URANIUM MILL
RECLAMATION PLAN

DETAILS OF ROCK ARMORED SLOPE
AND RADON BARRIER

(Modified from Figure 6.3-2, April 30, 1989 Submittal)

Figure 3



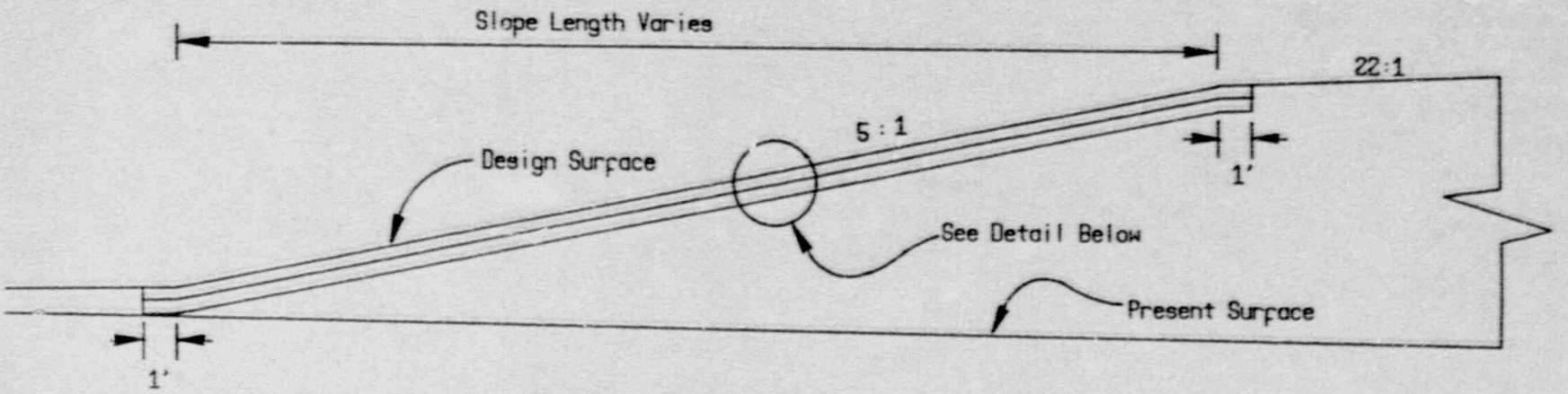


PETROTOMICS URANIUM MILL
RECLAMATION PLAN

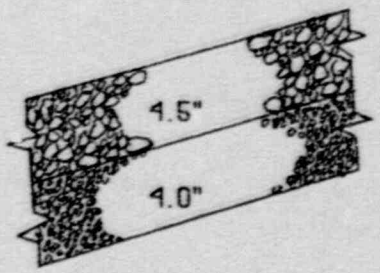
PROPOSED SETTLEMENT
MONUMENT LOCATIONS

(Modified from Figure 5.1, April 28,1989 Submittal)

Figure 4



ROCK ARMORED OUTSLOPE



EROSION PROTECTION

PETROTOMICS URANIUM MILL
RECLAMATION PLAN

DETAILS OF ROCK
ARMORED OUTSLOPE

(Modified from Figure 6.2-2, April 28, 1989 Submittal)

Figure 5

REFERENCES

1. Brich, Randall F., NRC, to Docket File No. 40-6659, Subject: "Review of Petrotomics Mill Decommissioning Summary," April 10, 1986.

2. Konwinski, Gary R., NRC, to Docket File No. 40-6659, Subject: "Safety Evaluation Report for Petrotomics Company, Shirley Basin Uranium Mill," September 28, 1984.

3. Regulatory Guide 3.11, "Design, Construction, and Inspection of Embankment Retention Systems for Uranium Mills," U.S. Nuclear Regulatory Commission, December 1977.

4. NUREG/CR-3533, "Radon Attenuation Handbook for Uranium Mill Tailings Cover Design," Roger, V.C., et al., April 1984.

5. Konwinski, Gary R., NRC, to Docket File No. 40-6659, Subject: "Amendment No. 12 to Source Material License SUA-551," May 1986.

6. Regulatory Guide 3.64, "Calculation of Radon Flux Attenuation by Earthen Uranium Mill Tailings Covers," U.S. Nuclear Regulatory Commission, July 1989.

7. "Staff Technical Position on Testing and Inspection Plans during Construction of DOE's Remedial Action at Inactive Uranium Mill Tailings Sites," Revision 2, U.S. Nuclear Regulatory Commission, January 1989.

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12. NUREG/CR-4620, "Methodologies for Evaluating Long-Term Stabilization Designs of Uranium Mill Tailings Impoundments," Nelson, J. C., et al., June 1986.

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18. Barfield, B.J., Warner, R.C., and Haan, C.T., "Applied Hydrology and Sedimentology of Disturbed Lands," Oklahoma Technical Press, 1981.

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20. Stephenson, D., "Rockfill in Hydraulic Engineering, Developments in Geotechnical Engineering, Volume 27," Elsevier Scientific Publishing Company, 1979.

21. Simons, D.B., and Senturk, F., "Sediment Transport Technology," Water Resources Publications, Fort Collins, Colorado, 1977.

ENCLOSURE 1

LIST OF SUBMITTALS

1. Letter from S. J. Pfaff, Petrotomics Company, to H. J. Pettengill, NRC. Subject: Submittal of Detailed Reclamation Plan; dated June 27, 1986.

2. Letter from S. J. Pfaff, Petrotomics Company, to E. Hawkins, NRC. Subject: Responses to NRC's November 10, 1986 comments on the Reclamation Plan; dated January 15, 1987.

3. Letter from R. A. Juday, Petrotomics Company, to E. F. Hawkins, NRC. Subject: Responses to NRC's February 17, 1987 letter on the Reclamation Plan Radon Barrier; dated March 18, 1987.

4. Letter from S. J. Pfaff, Petrotomics Company, to E. F. Hawkins, NRC. Subject: Responses to NRC's July 10, 1987 comments on Petrotomics' January 15, 1987 submittal; dated August 31, 1987.

5. Letter from S. J. Pfaff, Petrotomics Company, to E. F. Hawkins, NRC. Subject: Responses to NRC's November 27, 1987 comments on Petrotomics' August 31, 1987 submittal; dated June 30, 1988.

6. Letter from S. J. Pfaff, Petrotomics Company, to E. F. Hawkins, NRC. Subject: Reclamation Plan Radon Emanation Factors; dated February 8, 1989.

7. Letter from R. A. Juday, Petrotomics Company, to E. F. Hawkins, NRC. Subject: Responses to NRC's March 15, 1989 comments on Petrotomics' June 30, 1988 submittal; dated April 28, 1989.

8. Letter from R. A. Juday, Petrotomics Company, to E. F. Hawkins, NRC. Subject: Proposal to add rock armor north and south of the North Swale Discharge Channel; dated August 15, 1989.

9. Letter from R. A. Juday, Petrotomics Company, to E. F. Hawkins, NRC. Subject: Revised Figure G.4-77, dated August 16, 1989.

6659/ROG/89/02/28/M

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