UNITED STATES

NUCLEAR REGULATORY COMMISSION

REGION IV

URANIUM RECOVERY FIELD OFFICE
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URFO:ROG
Docket No. 40-8907
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MEMORANDUM FOR: Docket File No. 40-8907

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SUBJECT: AMENDMENT NO. 10 TO SOURCE MATERIAL LICENSE SUA-1475 FOR RECLAMATION AND CLOSURE OF THE UNITED NUCLEAR CORPORATION (UNC) CHURCH ROCK MILL NEAR GALLUP, NEW MEXICO

In accordance with 10 CFR 40, Appendix A, the licensee, UNC Mining and Milling, in a letter dated June 1, 1987, submitted a proposed reclamation and closure plan for the Church Rock Mill. Review of the proposed plan resulted in numerous requests for additional information, reevaluation, and redesign. As a result, additional information was provided by UNC Mining and Milling in submittals dated January 20, May 23, June 29, July 26; and August 31, 1988; February 23, 1989; and September 12, and December 4, 1990. Also reviewed was a copy of a letter from UNC's consultant, Canonie Environmental Services Corporation (Canonie), to UNC dated December 7, 1990, and a letter to NRC from Canonie dated December 28, 1990. A chronology of review activities is listed in Enclosure 1.

The state of New Mexico, as an Agreement State, was responsible for licensing and regulating the Church Rock Mill until June 1986 when the NRC assumed regulatory authority at the request of the Governor of New Mexico. At the time the NRC assumed authority for regulating New Mexico uranium mills, the Church Rock Mill was listed on EPA's National Priority List for response action under the Comprehensive Environmental Response Compensation and Liability Act of 1980, as amended (CERCLA). The NRC and EPA thus had overlapping responsibilities regarding remedial action at the Church Rock Mill. To ensure that remedial actions occurred in a timely manner, the EPA and NRC entered into a Memorandum of Understanding (MOU) on August 26, 1988. Under this MOU, the NRC assumed the lead role for disposal area reclamation and closure activities. EPA was to monitor those activities and provide review comments. The objective

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RGonzales	DJacoby	PMichaud	PGarcia	JGrimm	EHawkins	REHall
01/23/91	01/23/91	01/23/91	01/23/91	01/23/91	01/23/91	01/23/91

of obtaining EPA's comments is to ensure that activities conducted by NRC would permit attainment of appropriate requirements under CERCLA, outside of the byproduct disposal area. EPA indicated that they had no comments on this licensing action.

BACKGROUND

The Church Rock Mill is owned by UNC Mining and Milling which is a division of United Nuclear Corporation. The mill operated from 1977 to July 1979 when a breach in the tailings embankment occurred. Milling operations resumed in the fall of 1979 after the breach was repaired and the spill was cleaned up. In May 1982 the mill was placed in a standby mode due to a depressed uranium market. During its operation from 1977 to 1982, the Church Rock Mill produced approximately 3.8 million tons of tailings. A dam was constructed to form a disposal area to contain those tailings. The disposal area, which occupied approximately 100 acres, was subdivided by cross dikes to form a South Cell, a Central Cell, and a North Cell. Two borrow pits, No. 1 and No. 2, were excavated within the central cell to provide additional tailings storage and construction materials for the tailings retention structure. Figure 1 shows the general locations of the mill facilities.

The tailings solution in the disposal area has been evaporated except for Borrow Pit No. 2, which is currently being used for storage of water extracted from tailings seepage and ground water (Figure 1 shows the location of the pit). A spray system is currently being used to evaporate the water from the borrow pit. Once the borrow pit has been drained, it will be reclaimed by backfilling with mill demolition debris, soil that is unsuitable for radon cover, and other soil as necessary. It is estimated that 500,000 cubic yards of material will be required to fill Borrow Pit No. 2 to final grade.

GENERAL DESCRIPTION OF PROPOSED RECLAMATION PLAN

As shown in Figures 2 and 3, UNC's proposed reclamation plan consists of stabilizing the tailings in place. The tailings will be graded to allow positive drainage off the pile top. A soil cover will then be placed over the tailings to limit radon emanation to acceptable levels. To protect against erosion, a soil/rock layer will be placed over the radon soil cover. The pile top slopes will vary from less than one percent to about four percent. To minimize the potential for erosion of the pile top, wide gently sloping swales will be placed perpendicular to the slopes to limit runoff distances. These swales will be lined with riprap. The embankment outslopes will be flattened to 20 percent (5H:1V) and erosion protection will be provided by a layer of riprap.

As shown on Figure 1, Pipeline Arroyo is an ephemeral channel that flows from northeast to southwest along the western edge of the disposal area. The arroyo has a massive bedrock outcrop adjacent to the tailings pile. This outcrop, which is designated as the "nickpoint" on Figure 2, stabilizes the arroyo by minimizing the potential for headcutting. As a result, the arroyo upgradient of the nickpoint is geomorphically stable, being characterized by a very flat gradient and a channel that is wide and shallow. In contrast, the arroyo downgradient of the nickpoint is fairly unstable, having a much steeper slope and a deep, narrow channel.

Although the bedrock nickpoint in Pipeline Arroyo provides stability to the upstream reach of the arroyo, it is not certain that the bedrock is continuous across the entire valley. Therefore, in order to maintain the stable channel, the licensee has proposed to reinforce the nickpoint by constructing a rock-filled trench across the arroyo valley. For the arroyo reach downstream of the nickpoint, the licensee proposes to leave the channel relatively unaltered and to depend on the massive overbank area to provide erosion protection for the reclaimed tailings pile. Additional erosion protection design features include a protective bench and rock-lined runoff control ditch at the toe of the tailings dam, and a low flow channel along the west side of Pipeline Arroyo. The purpose of these design features is as follows: The rock filled trench (referred to as a buried jetty in Figure 2) will provide additional stability at the nickpoint, the protective bench will provide a buffer between PMF flows in the arroyo and the toe of the tailings embankment, the runoff control ditch will minimize erosion and prevent headcutting into the tailings pile, and the low flow channel will route flows along the west side of Pipeline Arroyo as far away from the pile as possible. Figure 4 shows typical sections of the protective bench, runoff control ditch, the Pipeline Arroyo low flow channel and the buried jetty.

The South Diversion Ditch is an existing ditch that will require no modifications. The existing North Diversion Ditch is also of adequate size. This ditch, however, will be slightly modified by extending the north end of the ditch so that it will empty into Pipeline Arroyo north of the tailings pile. In addition, riprap will be placed in the ditch where required.

TECHNICAL EVALUATION OF THE PROPOSED RECLAMATION PLAN.

Review and technical evaluation of the proposed reclamation plan was divided into seven sections as follows: 1) stability and liquefaction analyses, 2) settlement, 3) radon attenuation, 4) surface water hydrology, 5) erosion protection, 6) construction specifications, and 7) cost estimates. Each of these sections is discussed below.

<u>Stability and Liquefaction Analyses</u>

Structural Stability

To demonstrate the stability of the reclaimed facility, a critical section was selected at Station 48 + 00 (See Figure 2) and analyzed under static and pseudodynamic loading. The section and the parameters used in the modeling are illustrated on Figure 7-11 of the June 1, 1987, submittal. The physical property values assumed for the homogeneous section are considered reasonable for the simplified section. The phreatic surface modeled represents a worst case. An acceleration coefficient of 0.05g was used to simulate earthquake loading. The resulting factor of safety of 5.0 for both loading conditions is greater than required by Regulatory Guide 3.11 (NRC, 1977) for static and pseudodynamic loadings. The site is located on the borderline between a recommended acceleration coefficient of 0.05g and 0.10g on the Seismic Zone Map (COE, 1983). The use of the lower coefficient in the licensee's analysis is acceptable due to the resulting large factor of safety.

Although the licensee's analyses are very limited, a review of available discussions on the stability of the existing facility indicates that the operational structure met the requirements of Regulatory Guide 3.11. The failure of the southern section of the tailings dam in July 1979 resulted in analyses of the facilities' stability by numerous regulatory agencies and by UNC. It was determined that the probable cause of the failure was differential settlement of the foundation, causing the embankment to experience internal erosion under the action of the resulting cracking. The embankment had been constructed on collapsible soil deposits up to 100 feet in depth. Test results indicated that some of the foundation soils could be expected to collapse in excess of 10 percent upon wetting. It was also determined that the embankment soils were dispersive in tests where the pH of the dispersive agent approached 1.2. The estimated pH of the tailings solution at the time of failure was 1.2. As the facility was filled with liquors, the foundation soils and the embankment experienced a wetting front, which collapsed the foundation soils. This was supported by the observation of longitudinal cracks on the upstream face of the embankment prior to failure. Transverse cracks then formed as a result of differential settlement along the axis of the embankment. As this cracking process allowed the tailings solution to enter the embankment, the soils began eroding internally, causing the embankment to breach. After the failure, the embankment was repaired and it has operated without signs of distress since that time. Concerns of similar failures over the design life of the reclaimed facility should therefore be negligible. The reclamation process will enhance the stability of the facility by limiting infiltration into the structure and allowing the area to dewater.

Liquefaction

The licensee determined that the liquefaction potential of the facility was not a design concern as the retention embankment was constructed of compacted earthen borrow material consisting of fine sand, silt, and clay mixtures in an unsaturated state. These materials were described as "insensitive to liquefaction."

As saturation is a requirement for the liquefaction phenomenon, the potential for failure due to liquefaction will become negligible as the facility continues to dewater. Review of the available information indicates that the current embankment is not saturated and the amount of water entering the system is to be minimized by the earthen cover. Therefore, the potential for failure due to liquefaction is minimal.

Conclusion

The licensee's evaluation of the reclaimed disposal area is representative and utilized acceptable methodology to establish the long term structural stability. Therefore the reclamation plan satisfies the applicable portions of the requirements of Criteria 1, 6, and 12 of Appendix A to 10 CFR 40. The plan contains the parameters necessary to ensure the structural stability of the site with regard to the control of radiological hazards over the design life without active maintenance after reclamation is complete.

Settlement

To monitor settlement within the disposal area, the licensee proposes to establish eight settlement monuments located as shown on Figure 1 of the January 20, 1988, submittal. This figure also details the monument which will consist of a horizontal base plate measuring 2 feet by 2 feet by 4 inches thick placed on the existing tailings surface. A 3/4-inch steel rod will be connected to the base plate and will extend a minimum of 12 inches above the final surface of the disposal area. The locations of the monuments were selected on the basis of the thickness of regraded tailings over existing tailings and/or the areas of maximum thicknesses of fine tailings, which are most susceptible to consolidation.

The monuments will be monitored daily during the first week following tailings regrading and placement of each layer (lift) of soil cover. After the first week, monitoring will be done monthly until approximately 90 percent of tailings consolidation has occurred or until sufficient documentation exists to demonstrate that no adverse effects are occurring to the cover due to the observed magnitudes and rates of settlements. The next lift of material will not be placed until the previous lift has met the above criteria.

In the original plan, submitted on June 1, 1987, it was estimated that the initial 12-inch lift would be in place for 5 years prior to placement of the second lift, due to reclamation activity sequencing rather than consolidation criteria. This sequencing of construction was to have minimized the effect of settlement by gradually loading the disposal area and allowing intermediate settlements to be complete prior to placement of the next lift. With the revised cover design described in the December 4, 1990, submittal, this phased construction approach may no longer be possible and the settlement plan should be revisited. The December 4, 1990, submittal does not address settlement.

Conclusion

The licensee's settlement plan is not clearly defined as it has not been revised to reflect recent design revisions. Therefore, the licensee must readdress his settlement plan to ensure that the long-term design requirements relating to the control of radiological hazards without active maintenance are met as required in Criteria 1, 6, and 12 of Appendix A to 10 CFR 40.

Radon Attenuation

Characterization of Materials

The exploration program for the site was performed in 1986. Primary areas of investigation included Pipeline Arroyo, the alluvial plain to the north of the disposal site, and the mill site. Results of previous investigations were also considered. Borings assumed to be in tailings were also selectively used to determine radiological parameters.

The laboratory testing program for the fine and coarse tailings included in-place moisture contents, in-place densities, and specific gravities. A standard Proctor test was performed on coarse tailings as they are to be relocated over the fines. Radiological testing included radon diffusion coefficient, radium content, and radon emanation coefficient determinations. Eleven samples of coarse sands from three borings and nine samples of fine tailings from four borings were selected for testing. Summaries of laboratory test results are provided in Tables 2.5 and 2.6 of the December 4, 1990, submittal.

Due to the modifications that have evolved since the original exploration program was performed, the supporting data for the cover material have been selectively restricted to results from the exploration of Pipeline Arroyo, the stockpile located to the east of the disposal area, and to the material that has been placed on the north and central cell as interim cover. A summary of the data that were considered in selecting representative cover parameters is given in the September 12, and December 4, 1990, submittals. The laboratory testing program for cover material included in-place moistures, classification, compaction, and dispersivity testing. Permeability tests performed on interim cover material resulted in permeabilities ranging from 10^{-6} to 10^{-8} centimeters per second. Crumb tests performed on clay samples indicated no susceptibility to dispersion. Although the laboratory testing program associated with the embankment failure indicated that soils from the area may be dispersive when tailings solutions with low pH are encountered, the possible migration of tailings solution through the cover should not be a design concern. A sample was also selected for capillary-moisture relationship testing. This test determines the moisture content of fine grained soils for tensions between 1 and 15 atmospheres.

Selective test results from the exploration program on Pipeline Arroyo, the existing stockpile, and testing of the interim cover on the north and central cells were used to develop an acceptable gradation envelope for potential cover materials. This material can be expected to be non-dispersive and to exhibit acceptable permeabilities to limit infiltration. Frost heave and cracking should therefore not be a design concern. Material specifications were provided which support this gradation envelope.

Modeling

The modeling of the reclaimed facility was done using the RADON computer code (NRC, 1989). The latest analyses are documented in Appendix B of the December 4, 1990, submittal. The disposal area was modeled assuming that all fine tailings were overlain by a minimum of 7 feet of coarse sands. The licensee is proposing that 18 inches of soil cover will attenuate the average radon release rate sufficiently to meet 10 CFR 40, Appendix A, Criterion 6.

For modeling purposes, the radiological values assigned in the modeling process represented the outer bound 95 percent confidence limits associated with laboratory test results. For conservatism, the licensee used only the results from a single boring to establish the diffusion coefficient of the tailing sands due to the high moisture contents encountered in the other two borings. The densities of the tailings were assigned the average in-place dry density. The porosities were calculated for each sample tested and the outer bound 95 percent confidence limit value was assigned.

The long-term moisture content of the fine tailings was estimated after considering the in-place moistures and the Rawls and Brakensiek (1982) equation for estimating the volumetric moisture content at 15 atmospheres of tension (-15 bars). The licensee assigned a long-term moisture content based on the outer bound 95 percent confidence limit of the in-place moisture contents, assuming it was the most conservative. The moisture content, however, was improperly based on a volumetric ratio, rather than a ratio based on weight. The moisture content should have been converted to a weight basis for use in determining the radon barrier thickness. Use of a moisture content based on a weight ratio will result in a lower value and, consequently, an increased required radon cover depth.

The long-term moisture content of the sand tailings was selected by considering the in-place moisture content of sand tailings and the in-place moisture contents of near surface, non-tailings sands. The average moisture content of the near surface non-tailings sands was used as input to the radon computer model.

The modeling parameters of the cover material were assigned values based on the data that were obtained during the construction of the interim cover on the north and central cells plus results of testing performed on samples from the proposed borrow areas. A weighted average maximum dry density was determined that was defined as representative of the remaining borrow sources. In accordance with the specifications, 95 percent of this value was used in the model. The remaining physical properties were calculated assuming a specific gravity of 2.6. The long-term moisture content was estimated based on the Rawls and Brakensiek equation for estimating the volumetric moisture content at -15 bars, the laboratory -15 bar moisture content from the capillary-moisture relationship test, published values from literature, and in-place moistures.

The licensee did not convert the Rawls and Brakensiek moisture to a moisture content resulting from a ratio of weights rather than volumes. The diffusion coefficient was calculated by the computer model.

Evaluation

The licensee's analysis of radon attenuation contained several calculation errors associated with the selection of the long-term moisture contents, as noted above. As this particular parameter can significantly affect the required cover thickness, the licensee must reanalyze the radon cover after reconsidering the values assigned to long-term moisture. Also, the licensee must determine an average fines percentage of the sand tailings so that the Rawls and Brakensiek equation can be used when determining the appropriate long-term moisture, or some other acceptable method should be considered. The capillary-moisture test on the proposed cover soil was performed on a sample that contained 67 percent fines. The minimum percentage of fines allowed in the specifications is 40 percent which corresponds roughly to the lower 95 percent confidence limit of soils tested. The upper bound of the 95 percent confidence limits is about 70 percent. The capillary-moisture relationship test was performed on a soil sample having 67 percent fines which is essentially the upper 95 percent confidence limit. Test results from a material that represents the upper limit of the maximum fines percentage cannot be considered a conservative representation of acceptable materials as described by the specification. Therefore, this -15 bar moisture value should be considered an upper limit for long term moisture for the cover soil.

It was also noted that the data that were considered from the borrow sources did not all meet the gradation specification. For example, almost one third of the samples presented for the Pipeline Arroyo borrow did not meet specifications and would be rejected as fill. By excluding this data from the density determination, it appears that a lower average density would be expected for the soil cover. These changes in parameters may increase the required cover depth.

Conclusion

Due to the errors and deficiencies in the selection of modeling parameters, the licensee must reevaluate the model input and recalculate the required cover thickness. It is expected that the required cover thickness will increase over the 18 inches proposed by the licensee. Without adjustment in parameters or further justification for the parameters that were assigned, it cannot be concluded that the proposed plan will limit the average release rate of radon to 20 picocuries per square meter per second as required by Criterion 6 of Appendix A to 10 CFR 40.

Surface Water Hydrology

Hydrologic Description and Conceptual Design

The Church Rock Mill and disposal areas are located at elevations ranging from about 6950 to 7000 feet above mean sea level within the drainage area of Pipeline Arroyo. As sho on Figure 1, Pipeline Arroyo is an ephemeral channel that flows from northeast to southwest along the western edge of the disposal area to a point about 2.5 miles southwest of the mill site where it joins the Rio Puerco. The drainage area of Pipeline Arroyo upstream of the disposal area is about 17 square miles (See Figure 5).

A second drainage area of approximately one square mile is located south and east of the tailings disposal area. Surface water runoff from this area is currently intercepted and diverted away from the disposal area by the north and South Diversion Ditches.

In order to comply with 10 CFR 40, Appendix A, which requires that tailings be stabilized for a 1000-year period to the extent reasonably achievable or in any case for at least 200 years, UNC proposes to stabilize the tailings and contaminated material in place and to protect them from flooding and erosion by various design features as discussed below.

Flood Determinations

The flood to be used for erosion protection design should be one for which there is reasonable assurance that it will not be exceeded during the 1000-year design life. Statistical analyses can be used to estimate the future frequency of flood events. However, these analytical methods are limited in that extrapolation of the frequency curve does not provide defensible estimates of flood probabilities much beyond the length of record, which is usually less than 100 years. Because of this limitation, the design flood event cannot be reasonably estimated using historical records. Instead, it must be based on estimates of probable maximum precipitation (PMP) for the particular geographic area. Techniques for estimating PMP amounts are available in several reports that have been published by the National Weather Service. The report that covers the Church Rock area is Hydrometeorological Report (HMR) No. 49 (U.S. Department of Commerce, 1977).

The PMP values were estimated by the licensee using HMR No. 49. The average rainfall that falls over a particular drainage area during a PMP event varies with the size of the area; the smaller the area, the larger the average rainfall. A 1-hour PMP of 8.33 inches was used as a basis for estimating a Probable Maximum Flood (PMF) for Pipeline Arroyo which has a drainage area of about 17 square miles. For the 1-square mile drainage area that drains into the North and South Diversion Ditches, a 1-hour PMP of 8.42 inches was used. A 1-hour PMP of 8.47 inches was used for both the embankment outslopes and the pile top. For the runoff control ditch, the appropriate PMP was 8.43 inches. Based on a review of the information provided by the licensee it is concluded that the 1-hour PMP values were acceptably derived. PMP amounts for durations of less than 1 hour were estimated by the licensee by multiplying the 1-hour PMP value by appropriate percentages. The percentages were those recommended in NUREG/CR-4620 (Nelson and others, 1986) and are therefore acceptable.

The PMP design events meet or exceed the applicable portions of the requirements outlined in 10 CFR 40, Appendix A, particularly Criteria 4 and 6 and are therefore acceptable for use in designing any required erosion protection.

Probable Maximum Flood (PMF) Estimates

A design flood based on the PMP is called a PMF. PMF's are dependent not only on the magnitude of the PMP but also on the amount of precipitation that is lost mainly by infiltrating into the ground. Other important parameters are the duration and temporal distribution of the PMP and the hydraulic characteristics of the watershed. By considering all of these parameters, a PMF can be estimated.

The PMF's for Pipeline Arroyo, the North and South Diversion Ditches, the Runoff Control Ditch, and the swales on the pile top were estimated by the licensee using a procedure developed by the Soil Conservation Service (U.S. Department of Agriculture, 1972). This procedure accounts for infiltration by considering vegetation type, density of vegetation, and hydrologic soil classification. The PMF for Pipeline Arroyo was estimated to be 26,300 cubic feet per second (cfs). For the North Diversion Ditch, the PMF varied from 1080 cfs at the upstream end of the ditch to 5840 cfs at the downstream end. The PMF for the South Diversion Ditch was estimated to be about 1370 cfs, and for the Runoff Control Ditch the estimate was 52 cfs. (The Pipeline Arroyo estimate was provided in the May 23, 1987, submittal and the Runoff Control Ditch estimate was in the December 4, 1990, submittal. All others were provided in the June 1987, submittal).

For the tailings dam outslopes and the pile top, the licensee used the Rational Formula (Chow, 1959) which is a standard method for estimating flood discharges. In using the Rational Formula, it was conservatively assumed that the entire PMP would result in runoff so that the runoff coefficient would be equal to 1. In addition, when estimating the size of rock required for erosion protection a flow concentration factor of 3 was used.

To evaluate the adequacy of the licensee's calculations, spot checks were made of the Pipeline Arroyo and South Diversion Ditch PMF's. This was done by independently calculating PMFs for the two areas. A comparison between results is show in Table 1.

Table 1

PMF Peak Discharges (cfs)

Drainage Area	Licensee Estimate	NRC Estimate
Pipeline Arroyo	26,300	26,800
North Diversion Channel	1,370	1,440

Based on this close comparison, it is concluded that the licensee's PMF estimates are acceptable.

Water Surface Profiles and Channel Velocities

With the exception of Pipeline Arroyo, water surface elevations and velocities were estimated by the licensee using Manning's equation (Chow, 1959). Water levels and velocities were independently checked using procedures given in Chow, 1959. Based on this independent evaluation, it was concluded that the licensee's flood levels and flow velocity values estimated using Manning's equation are acceptable.

For Pipeline Arroyo, water surface elevations and velocities were estimated by the licensee using the HEC-2 computer program (COE, 1989). This program is a standard computational model that is widely used and accepted for determining water surface profiles. Since it is an acceptable code for this particular application, independent calculations are not required for evaluating the information provided by the licensee. Instead, the information and computer printout sheets provided by the licensee were independently reviewed and it was concluded that estimates of water elevations and velocities were reasonably derived and are therefore acceptable.

Conclusion

The surface water hydrology design of the reclamation plan contributes to meeting the requirements of Criterion 4 of 10 CFR Part 40, Appendix A, which requires in part that embankment and cover slopes be either relatively flat or be covered by self-sustaining vegetation or rock to minimize the potential for erosion. Criterion 4 also requires that upstream drainage areas be minimized.

The North and South Diversion Ditches meet this requirement by diverting flood flows away from the reclaimed pile.

Erosion Protection

Pipeline Arroyo

As discussed above, the Pipeline Arroyo nickpoint will be reinforced by construction of a buried jetty, as shown on Figure 2. The jetty will consist of a stone-filled trench that will extend across the valley from the nickpoint to the top of the protective bench along the toe of the tailings embankment. The purpose of the jetty is to provide vertical control of the Pipeline Arroyo channel bottom. This control will maintain the flat gradient of the arroyo upstream of the nickpoint and thus maintain the long-term geomorphic stability of Pipeline Arroyo. It will also ensure that flows will continue to pass over the nickpoint. In addition, the proposed low flow channel will contain smaller but more frequent flood events up to the 100-year flood and direct these flows over the nickpoint as far away from tailings as possible.

In estimating the required riprap size for the buried jetty, the licensee used the Safety Factors Method (Simons and Senturk, 1977), together with the results of the HEC-2 computer analyses. The licensee's analysis indicated that a median stone diameter (D_{50}) of six inches is required. (Figure 4 presents details of the buried jetty). An independent analysis was performed using the Corps of Engineers' shear stress method (COE 1970). This analysis indicated that a D_{50} of six inches is adequate for the buried jetty and is therefore acceptable.

The PMF water surface elevations in Pipeline Arroyo will be below the top of the proposed protective bench. Thus the bench will protect the toe of the tailings dam embankment and the runoff control ditch will be above the PMF level. (See Figure 4 for a typical section of Pipeline Arroyo showing the PMF water level in relation to the protective bench and runoff control ditch). The average velocities and depths of the PMF along the 5H:1V sideslopes of the protective bench were determined by the licensee using the HEC-2 computer program. The results of this analysis indicated that during a PMF event, a maximum average velocity of 6.4 feet per second would occur at station 57+75. To determine the amount of scour that would take place during the PMF the licensee used methods described by the Bureau of Reclamation (Pemberton and Lara, 1984). This evaluation indicated that the maximum lateral erosion to be expected would be less than five feet. As shown on Figure 4, the runoff control ditch is located 14 feet from the protective bench and the toe of the tailings embankment is 40 feet away. Thus the licensee concluded that the protective bench will provide adequate protection to the tailings pile.

The HEC-2 computer printout sheets and scour calculations provided by the licensee were independently reviewed, and it was concluded that estimates of water levels, velocities and magnitude of scour along the protective bench were reasonably estimated and are therefore acceptable.

Pipeline Arroyo downstream of the nickpoint will be modified only slightly from its present configuration. This will basically consist of filling in depressions and headcuts in the overbank areas between the arroyo and the tailings embankment. Erosion protection will be provided by the vast overbank area between the arroyo and the tailings pile. To demonstrate that the material in the overbank area is adequate to provide the necessary erosion protection, the licensee evaluated the potential for meander grown along Pipeline Arroyo. This evaluation was performed by first characterizing existing meander patterns of Pipeline Arroyo and a nearby similar arroyo that is in its natural state. The characteristics were then applied to the proposed arroyo configuration and potential impacts were identified by estimating the magnitude of potential meandering of the arroyo. On the basis of this study, the licensee concluded that even if all of the meander growth were to occur in the direction of the tailings, there would be no release of tailings.

The potential for headcuts to form at the Pipeline Arroyo channel banks downstream of the nickpoint was also addressed by the licensee and it was concluded that although headcuts may form, the stability of the reclaimed tailings will not be affected.

The information provided by the licensee was independently reviewed and it was concluded that there appears to be no reasonable method to prevent geomorphic changes in the deeply incised arroyo downstream of the nickpoint. Erosion and arroyo widening is likely to continue until the arroyo is sufficiently wide to contain a stable channel. However, based on a review of appropriate literature, it appears that this type of arroyo will attain a stable width when the width to depth ratio is about ten. At present the arroyo is about 30 feet deep. Therefore, a stable channel will be attained when the channel widens to about 300 feet. The toe of the tailings dam is about 400 to 450 feet from the arroyo. Assuming that all arroyo widening occurs toward the tailings, the overbank area is sufficiently wide to protect the tailings (See Memorandum to Docket File No. 40-8907 dated January 22, 1991, which is attached as Enclosure 2).

North Diversion Ditch

As shown on Figure 5, the North Diversion Ditch will intercept flows from a small drainage area east of the tailings pile. The ditch is an existing structure having a relatively uniform channel gradient of approximately 0.0075. Using Manning's equation the licensee estimated that during a PMF, velocities in the North Diversion Ditch will average between 9 and 18 fps. Velocities of this magnitude are considered to be erosive. However, since tailings are located at least 300 feet from the North Diversion Ditch, the licensee concluded that erosion protection is not required. Based on a review of the licensee's calculations and an independent calculation, the staff concluded that the licensee's estimates of velocities in the North Diversion Ditch are conservative. However, it was concluded that erosion protection is required at two locations along the ditch where erosion along the outside banks of curves in the ditch could potentially affect tailings. In response, the licensee proposed to provide riprap at the two locations shown on Figure 2. In estimating the required riprap size, the licensee used the Maynord Method (Maynord, 1987). This analysis indicated that a D_{50} of 4.3 inches is required at one curve and 5.5 inches at the other. Based on this analysis, the licensee proposes to use a D_{50} of six inches at both locations. The thickness of the riprap layer will be nine inches and it will be underlain by a six-inch thick filter layer. Based on an independent review of the licensee's calculations, the riprap design of the North Diversion Ditch is acceptable.

South Diversion Ditch

The South Diversion Ditch also intercepts flood flows from a small drainage area to the east as shown in Figure 5. The ditch is an existing structure, generally trapezoidal in shape with a 15-foot bottom and 2H:1V side slopes. The average gradient is about 0.003. Using Manning's equation the licensee determined that the ditch is capable of conveying the PMF with sufficient freeboard and thus no modification to the ditch is required. The licensee did not provide flow velocity estimates for the South Diversion Ditch so an independent calculation was made. This calculation indicated a maximum average velocity of about 6 fps. This velocity is marginally erosion. However, since the ditch is at least 500 feet from tailings, it is concluded that erosion protection is not required for the South Diversion Ditch.

Pile Top

As shown in Figures 2 and 3, the tailings will be graded to drain toward both the south and the north sides. In estimating the require riprap size for the pile top, the licensee used an equation from NUREG/CR-4651, Volume 2 (Abt and others, 1988) and a flow concentration factor of 3. The licensee's analysis indicated that a D_{50} ranging from less than 1 inch to 1.6 inches is required for the pile top. On the basis of this evaluation, the licensee proposed a D_{50} of 1.5 inches for the pile top.

An independent analysis was performed using the Safety Factors Method (Simons and Senturk, 1977). This analysis indicated that a D_{50} of 1.5 inches is adequate for the pile top.

The licensee proposes to place a minimum 3-inch depth of the required riprap on the pile top. This will be followed by a four- to six-inch layer of soil which will be compacted into the rock. The soil/rock matrix design was reviewed, and it was concluded that it is acceptable. This conclusion is based on the results of research performed by NRC (Abt and others, 1988), in which laboratory research showed that when soil is compacted into a riprap layer, the rock becomes more stable as the stones are tightly wedged together. In addition, the soil fills the void spaces, further stabilizing the rock from movement and providing a growth medium for vegetation.

As shown in Figure 2, slopes as steep as about 7.0 percent will converge onto the tailings surface from the east. To minimize the potential for erosion, the licensee proposes to limit flow distances and thus flow velocities by constructing branch swales perpendicular to the direction of flow. These branch swales, shown in Figures 2 and 3, will convey flows to either the North Cell Drainage Channel or the South Cell Drainage Channel.

The branch swales will be trapezoidal in shape having minimum depths of 2 feet, bottom widths of 10 or 20 feet and 3H:1V side slopes. The gradients of the swales will range from 0.002 to about 0.009. For the swales, the licensee sized the riprap using the Safety Factors Method (Simons and Senturk, 1977). On the basis of this analysis, the licensee proposed a D_{50} of 1.5 inches for Branch Swales A through G and J. For Branch Swales H and I, the licensee proposed a D_{50} of three inches. The licensee did not specify the thickness of the riprap layers. Therefore, the licensee will be required to provide a riprap thickness of at least 1.5 times the minimum D_{50} or the D_{100} size, whichever is larger. In addition, a 6-inch thick bedding layer will be required under the riprap having a D_{50} of three inches.

Runoff will be conveyed off the pile top by the South Cell Drainage Channel (SCDC) and the North Cell Drainage Channel (NCDC). The SCDC will be excavated into bedrock along part of its reach. In estimating the required riprap size for the SCDC the license used the Maynord Method (Maynord, 1972). This analysis indicated that a minimum D_{50} of 24 inches is required. The licensee did not specify the thickness of the riprap. Therefore, a thickness of 1.5 times the minimum D_{50} or the D_{100} size, whichever is greater shall be required by license condition. In addition, a suitable bedding layer shall underlie the riprap. A design for the bedding must be provided by the licensee for review and approval prior to placement.

The licensee has not proposed erosion protection for the NCDC and has not provided sufficient information to show that erosion protection is not needed. Therefore, they will be required to provide a riprap design for review and approval, or provide justification showing why erosion protection is not needed in the NCDC.

Tailings Dam Outslopes and Runoff Control Ditch

The outslopes will be flattened to 20 percent (5H:1V). At the toe of the outslopes, a ditch identified as the Runoff Control Ditch (See Figures 2, 3, and 4) will prevent headcutting and provide stability to the outslopes. In addition, the ditch will minimize the runoff that will contribute to flows in Pipeline Arroyo. The riprap proposed for the outslopes is a 3-inch thick layer having a D_{50} of 1.5 inches. This D_{50} was estimated using an equation described in NUREG/CR-4651, Volume 2 (Abt and others, 1988). The design discharge used in this equation was calculated using the Rational Method (Chow, 1959) with a runoff coefficient of one and a flow concentration factor of three, which is conservative.

For the Runoff Control Ditch, the licensee estimated a D_{50} of 1.5 inches except for the last 630 feet of the ditch where a D_{50} of 3 inches is required. These riprap sizes were estimated using the Safety Factors Method (Simons and Senturk, 1977).

The information and calculations provided by the licensee were reviewed and an independent calculation was performed for the riprap to be placed on the tailings dam outslopes. Based on this review and analysis, it was concluded that the riprap proposed for the tailings dam outslopes and Runoff Control Ditch is acceptable.

Rock Durability and Gradation

In the original reclamation plan provided in a submittal dated June 1, 1987, the results of durability testing were provided for two samples of Todilto limestone. Using the criteria in NUREG/CR-4620 (Nelson and others, 1986), the licensee concluded that the limestone was acceptable for use as riprap. However, minimum durability requirements and gradation specifications were not provided. Subsequently in a submittal dated December 4, 1990, the licensee committed to provide specifications for riprap that will conform with Appendix D of the NRC's staff technical position on "Design of Erosion Protection Covers" dated August 1990.

With this commitment, it is concluded that adequately durable riprap will be provided. However, once a rock source has been identified, the licensee will be required to review its riprap designs and make modifications if necessary and to submit these for review and approval. For example, a specific gravity of 2.6 was used to size the riprap. If the specifications to be provided at a later date allow the use of rock with a lower minimum specific gravity, the riprap sizes may have to be increased.

Riprap and filter material gradation requirements were provided in the December 4, 1990, submittal for each riprap size. The information provided was reviewed and compared to criteria recommended by the Corps of Engineers (See NUREG-4620, Nelson and others 1986). Based on this review, it appears that the proposed gradations do not conform to accepted gradation criteria in that they appear to contain an excessive amount of fine materials. The licensee will therefore be required to provide the basis for the gradation design and justify that it meets accepted gradation criteria.

Conclusion

Justification for various features of the erosion protection design has not been provided. Without such justification, it cannot be concluded that the proposed reclamation plan will provide adequate erosion protection to ensure long-term stability as required by Criterion 4 of Appendix A to 10 CFR 40. Therefore, the licensee must provide additional information regarding the bedding layers and the thickness of riprap to be used in the pile top swales and in the South Cell Drainage Channel. Also, the proposed plan must be modified to provide bedding and riprap in the North Cell Drainage Channel unless the licensee can provide justification that it is not needed. Construction specifications must be provided for compacting soil into the riprap on the pile top and for the durability of the rock to be used as a riprap source. Finally, assurance must be provided that the proposed riprap gradations meet accepted engineering criteria.

Construction Specifications

The specifications for the project were initially submitted as Appendix B to the June 1, 1987, submittal. Requested revisions to the specifications have resulted in specifications being scattered throughout numerous documents. For the purposes of this review, the latest documents are considered to contain the most current information. This may negate information contained in previous submittals. The September 12, 1990, submittal contains additional field construction control specifications. The December 4, 1990, submittal contains revisions to the specifications for materials and some construction control. Revisions to the specification document were made in the January 20, 1988 submittal. The placement specifications are contained in the June 1, 1987, submittal.

Material Specifications

Radon Barrier Materials - The proposed plan requires the radon barrier soil be classified as CL, ML, SM, or SC soils meeting the following gradation requirements:

Sieve Size	Percent Passing
3/4 inch	95 - 100
No. 4	90 - 100
No. 10	85 - 100
No. 40	65 - 100
No. 100	50 - 100
No. 200	40 - 85

This gradation band is based on the results of field and laboratory tests from the proposed borrow sources and the north and central cell interim covers. The licensee did not propose any plasticity requirements for the materials. (December 4, 1990, submittal).

Riprap - In Table 2.3 of the December 4, 1990, submittal, the licensee has stated that the source for material to be used for riprap shall meet the requirements of Appendix D of the NRC Staff Technical Position (STP) on "Design of Erosion Protection Covers," dated August 1990. The suitability of the rock must be assessed by laboratory tests to determine the physical characteristics of the rock. Several durability tests must be performed to classify the rock as to being of poor, fair, or good quality. As a minimum, four test methods must be selected for determining the acceptability of the rock.

The licensee has stated in the December 4, 1990, submittal that the rock will be considered acceptable if it scores a minimum of 50 percent using the STP on erosion protection. The STP states that a score of 50 is acceptable for non-critical areas such as top slopes, side slopes, and well-drained toes and aprons. For critical areas such as channels, control structures and energy dissipation areas, a minimum score of 65 is required.

On the basis of the STP, a score of 50 is acceptable for the pile top outslopes, and runoff control ditch. However, for Pipeline Arroyo and the North and South Diversion Ditches a minimum score of 65 is required unless the licensee can demonstrate that the cost of obtaining this higher quality rock is clearly excessive.

Soil/Rock Matrix - The rock to be used in the soil rock matrix on the pile top shall meet the same material specifications as discussed above for the riprap.

Placement Specifications

Relocated Contaminated Materials - The proposed specifications in the June 1, 1987, submittal require that a minimum of seven feet of coarse sand tailings shall be placed over all fine tailings. The final tailings surface shall be compacted to a minimum of 90 percent of the maximum dry density.

Radon Barrier - The proposed specifications (Section 4.3.3.4 of the June 1, 1987, submittal as revised in the January 20, 1988, submittal) require the interim cover soils to be placed at optimum to plus 2 percent of optimum moisture and to at least 90 percent of the Proctor maximum dry density. After clearing and grubbing the existing interim stabilization cover, the remaining interim cover shall be compacted to a minimum of 95 percent of the maximum dry density at a moisture content of within two percent above the optimum moisture. Subsequent barrier soils shall be placed in loose lifts not to exceed 12 inches, within 2 percent above optimum moisture, and to at least 95 percent of the Proctor maximum dry density (Section 9.3.3.6 of the June 1, 1987, submittal).

Riprap - The specification proposed for placement of riprap in Section 5.3.4 of the June 1, 1987, submittal requires that all riprap be placed to the depth and grades shown on the Drawings. The riprap shall be placed in a manner to ensure that the larger rock fragments are uniformly distributed and the smaller rock fragments serve to fill the spaces between the larger rock fragments so that a densely-placed, uniform layer of riprap of the specified thickness will result. Hand placing will be required only to the extent necessary to secure the results specified above.

Soil/Rock Matrix - A specification for placement of the soil rock matrix has not been provided by the licensee. Therefore, the licensee will be required to provide this specification. The specification should include procedures for testing to ensure that the riprap is at least three inches thick and that the soil will be adequately compacted into the rock.

Construction Control

Classification Testing - The proposed specifications in the December 1, 1990, submittal require gradation and Atterberg testing of the radon barrier once every 1500 cubic yards of soil cover placed. The testing frequency to date has been once every 6500 cubic yards placed. To ensure that the material that has been placed as interim cover on the north and central cells meets the specification, it will be tested at the higher frequency when it is conditioned for final cover placement.

In-Place Testing - The specifications proposed in the September 12, 1990, submittal require that the in-place density and moisture be determined once every 2000 cubic yards of material placed, or a minimum of two tests for each day of fill placement in excess of 150 cubic yards. The December 4, 1990, submittal specifies that the sand cone method of in-place density determination will be used exclusively.

Laboratory Testing - The proposed specifications require that a Proctor test be performed once for every 15 field density tests, or once every 25,000 cubic yards of material placed. One-point Proctors are to be performed once every 5 field density tests, or once every 10,000 cubic yards of material placed (September 12, 1990, submittal).

Rock Quality Testing - In the September 12, 1990, submittal, the proposed specifications require that one series of durability tests (specific gravity, absorption, soundness, and L.A. Abrasion) be performed at 10,000 cubic yards and 20,000 cubic yards of riprap placed. One test series will be performed for every 10,000 cubic yards of riprap placed in excess of 30,000 cubic yards. As written, this specification is deficient in that a durability test will not be performed at 30,000 cy. Therefore, the specification must be revised to include a test for each 10,000 cy including one at 30,000 cy. In addition, the durability tests must be performed for each riprap size.

Conclusion

Except for the lack of a specific material specification for riprap and the soil/rock matrix, a placement specification for the soil/rock matrix and a deficiency in the rock quality testing specification, the proposed construction specifications and revisions are acceptable to ensure that the construction process will support the design. However, the licensee must compile one single document containing all specifications and revisions.

Cost Estimates

A detailed review of the reclamation plan cost estimates was performed. The purpose of this review was to verify that all required reclamation activities were included and funded at an appropriate level. Criteria 9 and 10 of Appendix A to 10 CFR 40 contain the financial requirements which must be met.

The licensee provided a cost estimate in their August 31, 1988, submittal. This estimate was based on completion of each task by a third party, as required. Activities were divided into three phases entitled, "Interim Stabilization," "Seepage Collection," and "Final Reclamation." Within each of these phases, a breakdown of costs for individual tasks was provided. Unit costs were provided for each activity and were extended using estimated quantities of material and times. These costs were compared against industry reference guides to verify their accuracy. Activities within the three phases include costs for mobilization and demobilization, mill decommissioning and demolition, earthwork, radiological monitoring, and ground-water remediation. The August 1988 cost estimate did not include an amount for the state of New Mexico gross receipts tax nor the Criterion 10 long-term surveillance fee.

Revisions to the reclamation plan and their associated costs were submitted to the NRC in letters dated December 4, 7, and 28, 1990. The cost data were not detailed, but provided a sufficient basis for determining a surety amount. In an effort to set a surety amount, the design modifications proposed by the licensee and their associated costs as set forth in the December 4, 1990, submittal were utilized as proposed. As set forth in preceding sections, certain assumptions or design conditions may require further justification or revision. Any such changes may affect the cost estimates and the required surety amount.

In determining an acceptable surety amount, the base costs from the August 1988 cost estimate were escalated to December 1990 dollars using the change in the Consumer Price Index (CPI-U). The licensee's estimated additional cost of $983,000 contained in their December 4, 1990, submittal was then added to the escalated 1988 costs. This amount was then increased by 15 percent to cover contractor overhead and profit. To this total was added a 15 percent contingency amount, an amount for the state of New Mexico gross receipts tax, and the 10 CFR 40, Appendix A, Criterion 10, long-term surveillance fee. This resulted in a total estimated reclamation cost of $16,392,000 as detailed in Table 2.

TABLE 2

UNC ADJUSTED RECLAMATION COSTS

ITEM	COST
Interim Stabilization (1988 Cost)	$ 2,486,417
Seepage Collection (1988 Cost)	$ 2,638,621
Final Reclamation (1988 Cost)	$ 4,239,165
Subtotal of 1988 Costs	$ 9,364,203
Inflation from August 1988 to December 1990 (12.4%)	$ 1,161,161
Subtotal in 1990 Dollars	$10,525,364
Additional Costs for 1990 Revisions	$ 983,000
Subtotal	$11,508,364
Contractor Overhead and Profit (15%)	$ 1,726,255
Subtotal	$13,234,619
Contingency (15%)	$ 1,985,193
State of New Mexico Gross Receipts Tax (5.125%)	$ 678,274
Criterion 10 Long-Term Surveillance Fee	$ 494,000
TOTAL	$16,392,086

Conclusion

The NRC review and independent verification of the licensee's reclamation cost estimates indicates a sufficient basis exists for establishing a surety amount. The required surety amount has been determined to be $16,392,000.

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 a comparison of the economic cost to resulting benefit.

The following Appendix A criteria were considered for the proposed licensing decision to amend Source Material License SUA-1475 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 Church Rock site is located in McKinley County New Mexico, approximately 20 miles northeast of the city of Gallup. The nearest resident to the site is approximately one mile northwest of the site. Gallup is the largest community in the immediate vicinity, having a 1990 census population of 18,802. McKinley County has a 1990 census population of 56,352.

   Population projections for these areas are difficult to make, due to the unpredictable nature of the uranium industry. However, there is no reason to believe that there will be significant population increases within 10 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 capped with a cover system designed to minimize infiltration.

   A ground-water review of the site to assure compliance with 10 CFR 40, Appendix A, is currently being done under other licensing actions. The corrective action program was submitted on March 29, 1989, and approved by

NRC on June 12, 1989. Compliance standards were set in January 1989 and the corrective action program became fully operational prior to April 1, 1990. 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 reclaimed pile top will be covered by a soil/rock matrix which will prevent the formation of rills and gullies. The embankment outslopes will be flattened and protected by riprap.

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 erosion protection for the facility. 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 directing runoff from upstream drainages around the reclaimed facility. The only runoff on the embankment outslopes will be from precipitation that falls directly on the outslopes.

Criterion 4(b) states that topographic features should provide good wind protection. Relocation of the tailings 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. To minimize erosion due to wind, the tailings pile will be covered with a soil/rock matrix, over the radon barrier.

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. In general, slopes should not be steeper than 5H:1V. The proposed reclamation plan places tailings under covers which are protected with riprap designed to be stable even under extreme runoff conditions.

Criterion 4(d) requires a full self-sustaining vegetative cover be established or a rock cover employed. The licensee has opted for a soil/rock cover. Due to the arid nature of the site, the licensee made no attempt to substantiate self-sustaining vegetation over a 1000-year period.

Criterion 4(e) requires that the impoundment not be located near a capable fault. The licensee assessed the literature, evaluated local faults, and determined that no capable faults exist near the site. The staff's independent evaluation concludes that capable faulting probably does not exist to the extent that tailings piles would be adversely affected.

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, as modified by the exceptions noted previously.

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 actions. However, 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 proposed design of the radon barrier was found to be unacceptable. Radon barrier design is therefore considered to be an open item and reevaluation will be required by license condition.

The design basis events for erosion protection of the pile top, embankment outslopes, and diversion ditches are the PMP and the PMF events. Both of these events are considered to be the most severe that are reasonably possible and thus provide reasonable assurance of not being exceeded during the 1000-year design life. This design should assure that excessive erosion does not occur during the design life. Accordingly, it is concluded that the proposed erosion protection design as modified by the exceptions discussed previously, 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's cost estimate includes such amounts for performance of reclamation activities by a third party. All costs and assumptions were independently reviewed and revised or supplemented where appropriate to include acceptable cost estimates for activities to be performed under Source Material license SUA-1475 for decommissioning, decontamination, reclamation, and long-term surveillance of the Church Rock site. The surety amount of $16,392,000 is sufficient to meet the requirements of 10 CFR 40, Appendix A, Criteria 9 and 10. License Condition No. 25 will be amended to reflect the surety requirements. The licensee will be allowed 90 days from the issuance of the amendment revising License Condition No. 25 to submit, for NRC approval, the information and forms required to evidence a surety in an amount no less than $16,392,000.

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.

With modifications to the proposed design, every reasonable concern has been considered in the proposed erosion protection design of the facility. The technical criteria in 10 CFR 40, Appendix A will be 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 disposal area 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 will be met.

CONCLUSION

Review and independent analyses of the reclamation plan for the Church Rock Mill site has identified numerous open items in the design that are not consistent with 10 CFR 40, Appendix A. Therefore, it is recommended that Source Material License SUA-1475 be amended by modifying License Condition No. 25 and by adding License Condition No. 34 to read as follows:

25. Within 90 days of the issuance of this amendment, the licensee shall submit a surety instrument acceptable to the NRC, to cover the estimated costs, if accomplished by a third party, for decommissioning and decontamination of the mill and mill site, reclamation of any tailings or

waste disposal areas, ground-water restoration as warranted, and the long-term surveillance fee. The amount of the surety shall be no less than $16,392,000. Upon resolution of the exceptions identified in License Condition No. 34, the licensee shall submit for NRC review and approval, a proposed revision to the financial surety arrangement if the estimated costs for resolving these exceptions exceed $16,392,000. The surety shall be written in favor of the NRC for the purpose of complying with 10 CFR 40, Appendix A, Criteria 9 and 10, and shall be continuously maintained until a replacement is authorized by the NRC.

Annual updates to the surety amount, required by 10 CFR 40, Appendix A, Criteria 9 and 10, shall be submitted to the NRC at least three months prior to the anniversary of the effective date of the approved surety instrument. Along with each proposed revision or annual update, the licensee shall submit supporting documentation showing a breakdown costs and the basis for the cost estimates with adjustments for inflation, changes in engineering plans, activities performed, maintenance of a 15 percent contingency fee, and any other conditions affecting the estimated costs for decommissioning and decontamination of the mill and mill site, reclamation of the tailings and waste disposal areas, soil and water sample analysis to confirm decontamination, long-term surveillance, and ground water restoration as warranted. If the NRC has not approved a proposed revision to the surety 30 days prior to the expiration date of the existing surety arrangement, the licensee shall extend the existing surety arrangement for one year.

34. The reclamation plan as described by the licensee's submittals dated June 1, 1987; January 20, May 23, June 29, July 26, and August 31, 1988; February 23, 1989; and September 12, and December 4, 1990, is approved. The licensee shall provide by September 1, 1991, a single comprehensive document describing the approved reclamation plan, including specifications, after acceptable resolution of the following exceptions to the approval.

    A. The proposed radon barrier shall be redesigned and submitted for NRC approval based upon modification of the following modeling parameters:

        1. The proposed long-term moisture contents of the fine tailings and cover material shall be converted from the computed volumetric moisture contents to weight ratio moisture contents, and shall also be substantiated as being representative of long-term conditions.

        2. The long-term moisture content of the coarse tailings shall be determined based on NRC acceptable methodology, as described in Regulatory Guide 3.64 or equivalent.

3. The expected cover material density shall be determined based on considering only test results from material that meets the specification.

B. The licensee shall submit a settlement plan for NRC approval that will provide a basis to demonstrate that the radon barrier will not be compromised by subsequent settlement.

C. A 6-inch bedding layer shall be constructed underneath the riprap in the South Cell Drainage Channel and in the Branch Swales or substantiate an alternative design. The submittal shall include the median size (D_{50}) and the gradation limits.

D. The licensee shall construct a riprap thickness of 1.5 times the median stone size (D_{50}) or D_{100}, whichever is greater, for the South Cell Drainage Channel and the Branch Swales.

E. A riprap design for the North Cell Drainage Channel shall be submitted for NRC approval based on procedures discussed in the August 1990 Staff Technical Position, "Design of Erosion Protection Covers for Stabilization of Uranium Mill Tailings Sites," or equivalent.

F. Minimum durability specifications for the rock to be used for erosion protection shall be submitted for NRC approval. The specifications shall comply with Appendix D of the August 1990 Staff Technical Position, "Design of Erosion Protection Covers for Stabilization of Uranium Mill Tailings Sites," or equivalent.

G. The basis for the riprap gradation designs shall be submitted for NRC approval and demonstrated that they meet acceptable criteria.

H. The licensee shall provide material and placement specifications for the riprap and soil/rock matrix. The specification shall include procedures for testing to ensure that the riprap is at least three inches thick and that the soil will be adequately compacted into the riprap.

I. The rock source for the riprap to be placed in critical areas shall have a score of at least 65 as described in Appendix D of the August 1990 Staff Technical Position, "Design of Erosion Protection Covers for Stabilization of Uranium Mill Tailings Sites." Alternatively, a lower score of at least 50 may be acceptable if it can be demonstrated that the cost of obtaining adequate rock is excessive. The results of the durability testing used to determine the scores discussed above shall be submitted for review and approval by NRC.

Raymond O. Gonzales
Project Manager

Dawn L. Jacoby
Project Manager

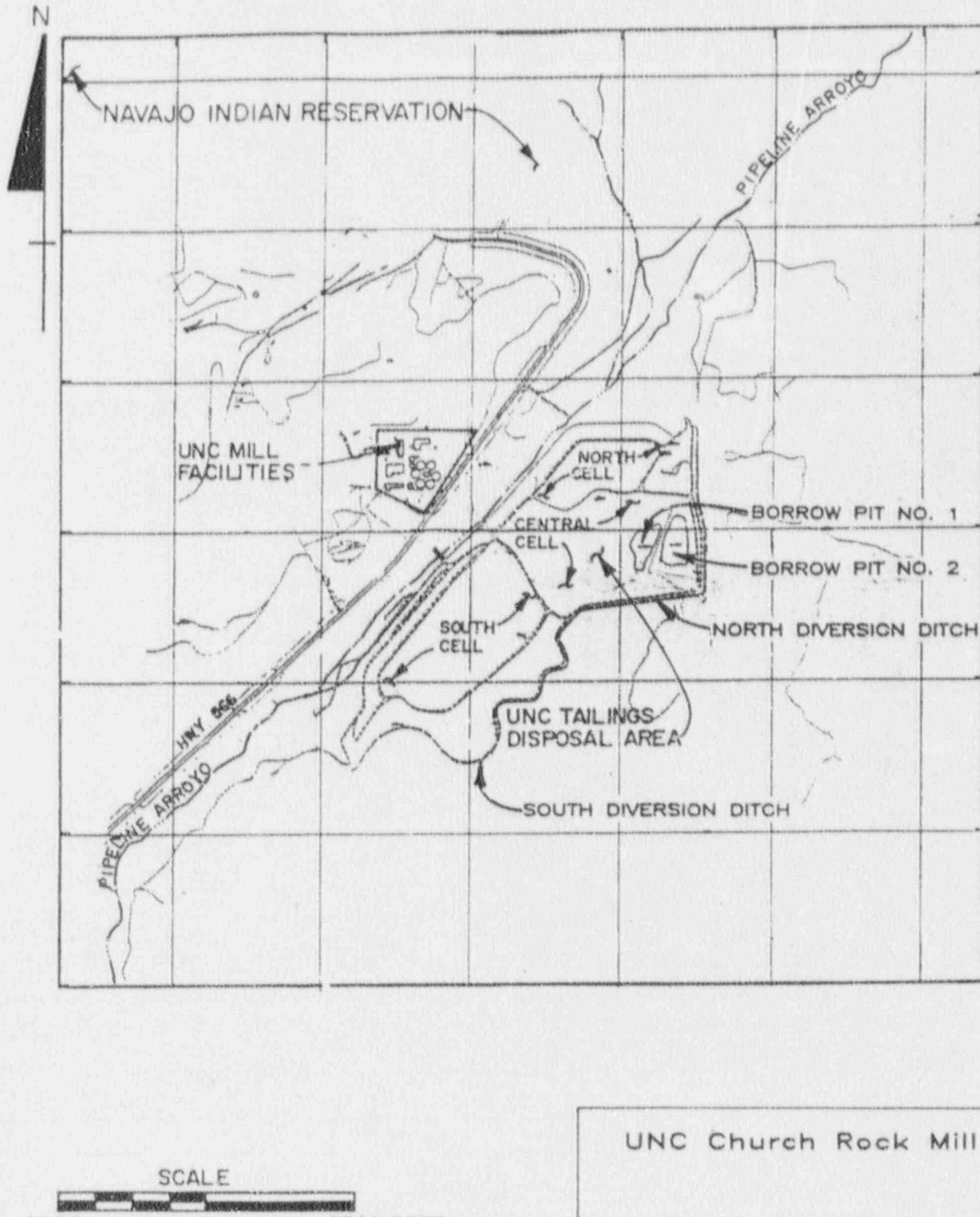
for Paul W. Michaud
Project Manager

Enclosures:
1. Church Rock Mill Reclamation Chronology
2. Memorandum to Docket No. 40-8907

Cases Closed:
~~04008907170E~~
04008907171E
04008907172E
04008907174E

bcc:
*Docket File No. 40-8907
*LFMB
*PDR/DCS
*URFO r/f
*ABBe h, RIV
*LLO Branch, LLWM
*ROGonzales
DLJacoby
PWMichaud
*JPGrimm
*PJGarcia
*BGarcia, RCPD, NM
*EMontoya, NM
8907/ROG/UNC-TER/91/01/M

*Without enclosure 2.

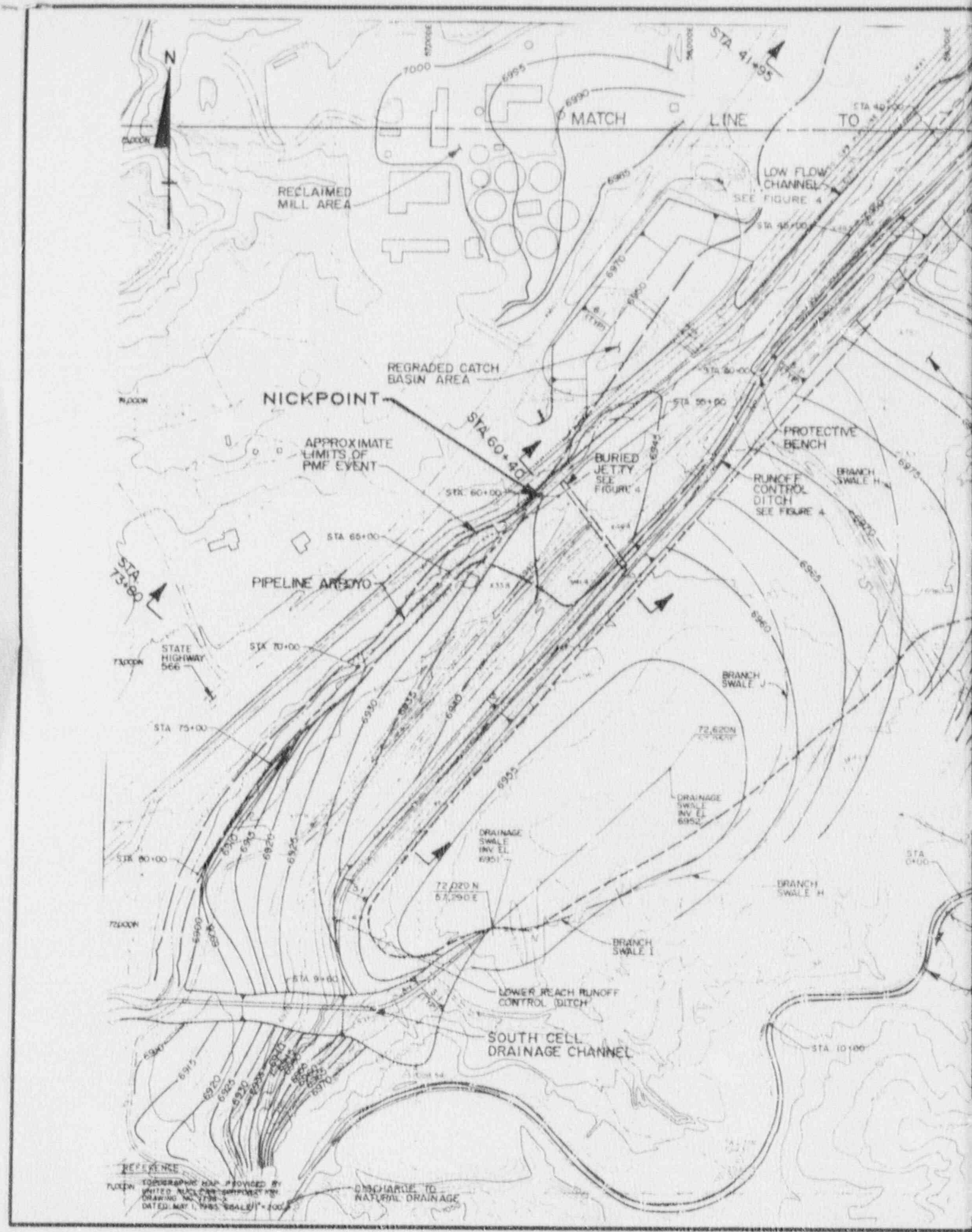


UNC Church Rock Mill

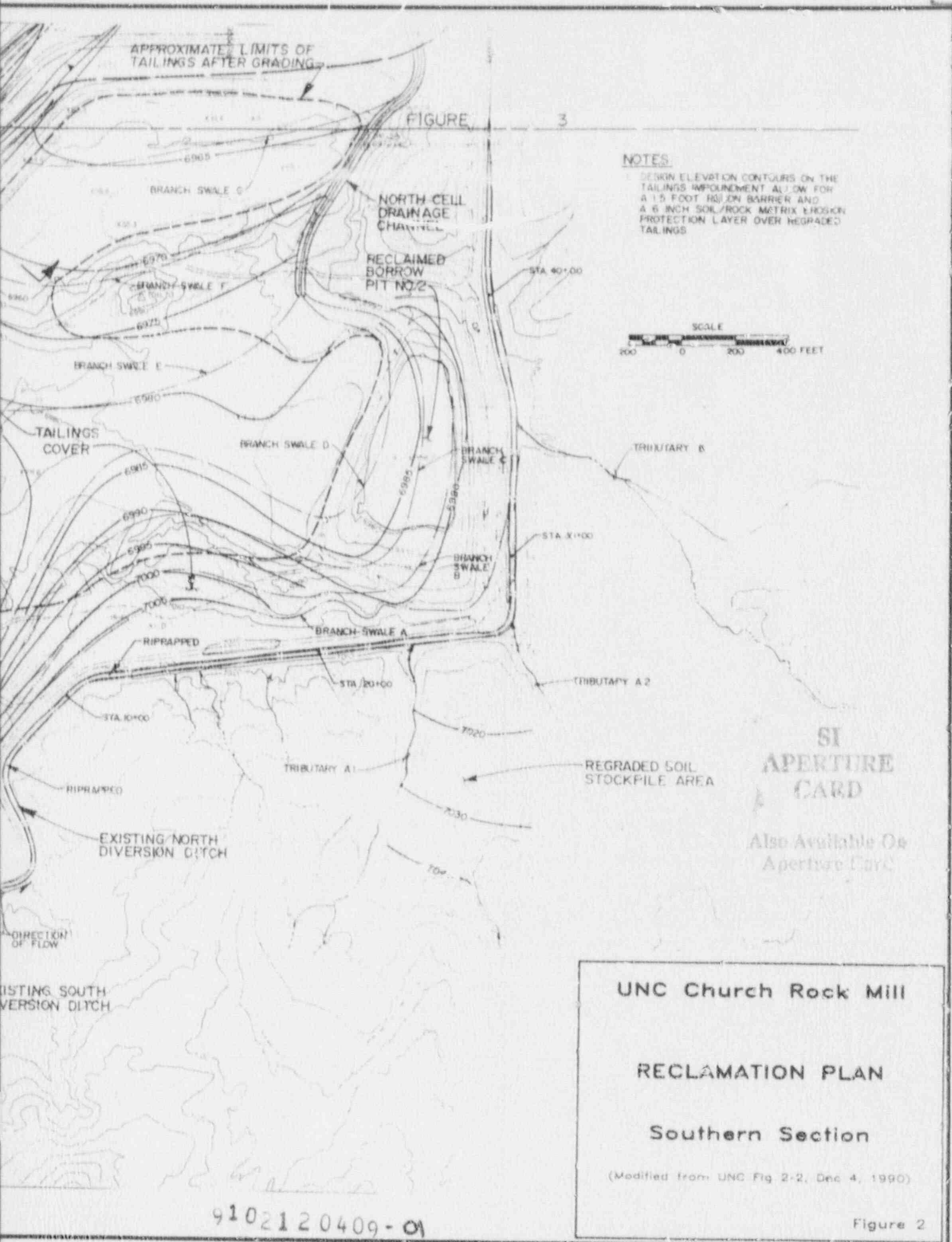
LOCATION MAP
Mill Facilities and
Disposal Area

(Modified from UNC Fig 1-2, June 1, 1987)

Figure 1



N
MATCH LINE TO
STA 41+95
RECLAIMED MILL AREA
LOW FLOW CHANNEL
SEE FIGURE 4
REGRADED CATCH BASIN AREA
NICKPOINT
STA 60+40
APPROXIMATE LIMITS OF PMF EVENT
BURIED JETTY SEE FIGURE 4
PROTECTIVE BENCH
RUNOFF CONTROL DITCH SEE FIGURE 4
BRANCH SWALE H
STA 73+80
PIPELINE ARROYO
STATE HIGHWAY 566
BRANCH SWALE J
72,620N
DRAINAGE SWALE INV EL 6952
DRAINAGE SWALE INV EL 6951
72,020 N
57,290 E
BRANCH SWALE I
LOWER REACH RUNOFF CONTROL DITCH
SOUTH CELL DRAINAGE CHANNEL
DISCHARGE TO NATURAL DRAINAGE
REFERENCE
TOPOGRAPHIC MAP PROVIDED BY UNITED NUCLEAR CORPORATION
DATED MAY 1, 1985



SI APERTURE CARD

Also Available On Aperture Card

UNC Church Rock Mill

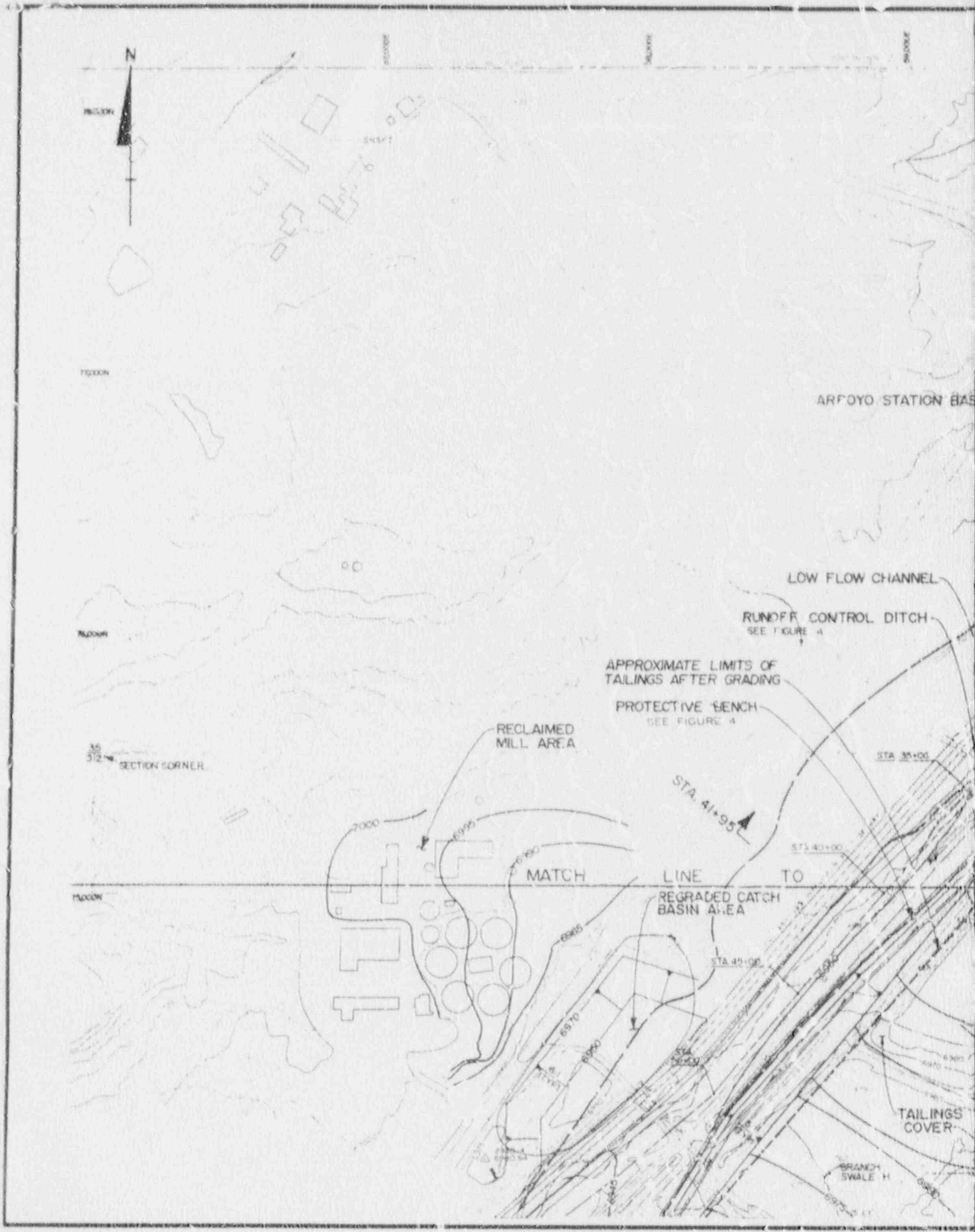
RECLAMATION PLAN

Southern Section

(Modified from UNC Fig 2-2, Dec 4, 1990)

Figure 2

9102120409-01


N
ARROYO STATION BAS
LOW FLOW CHANNEL
RUNOFF CONTROL DITCH
SEE FIGURE 4
APPROXIMATE LIMITS OF
TAILINGS AFTER GRADING
PROTECTIVE BENCH
SEE FIGURE 4
RECLAIMED
MILL AREA
SECTION CORNER
STA. 41+95
MATCH LINE TO
REGRADED CATCH
BASIN AREA
STA 45+00
TAILINGS
COVER
BRANCH
SWALE H
7000
6995
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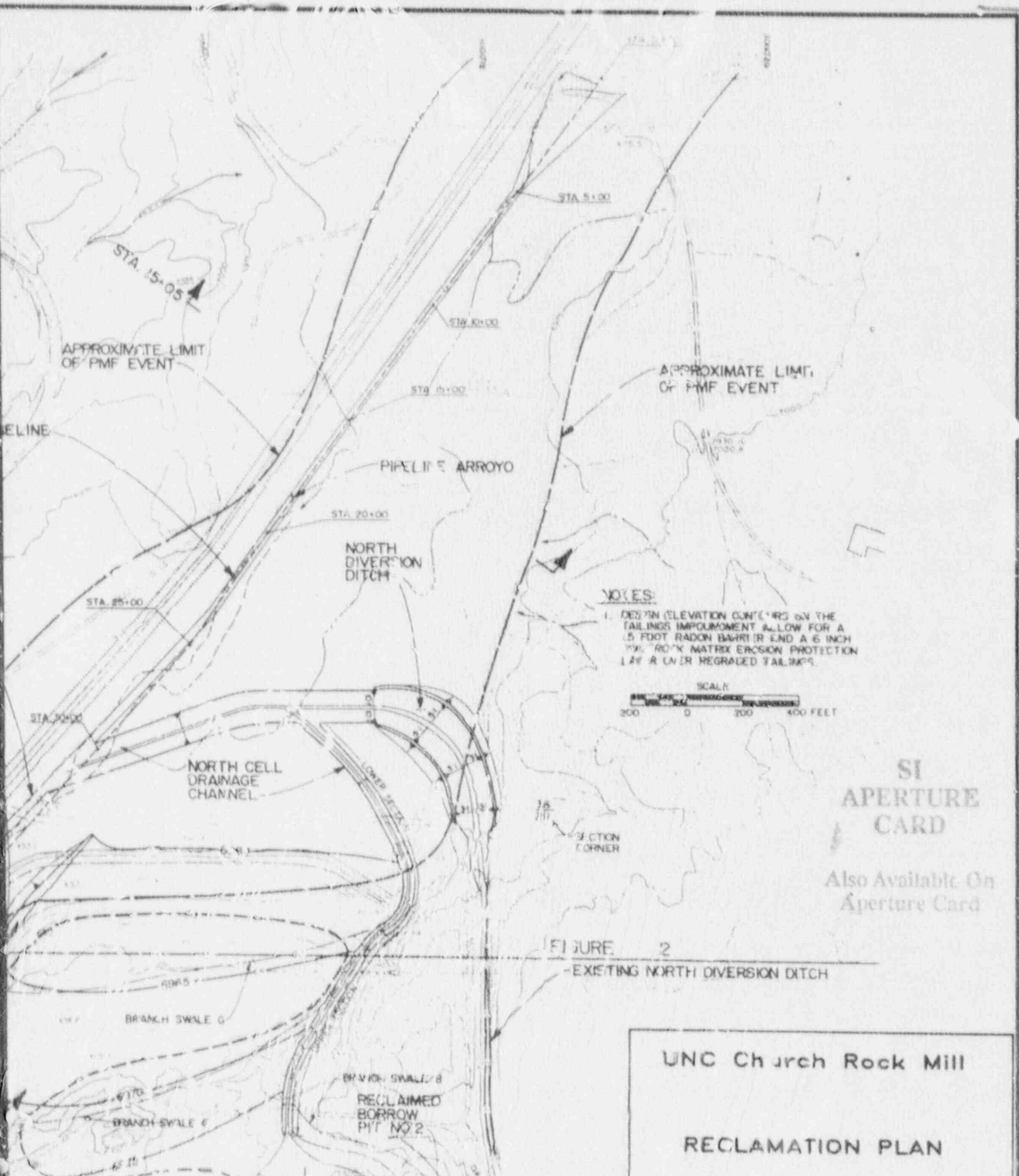


UNC Church Rock Mill

RECLAMATION PLAN

Northern Section

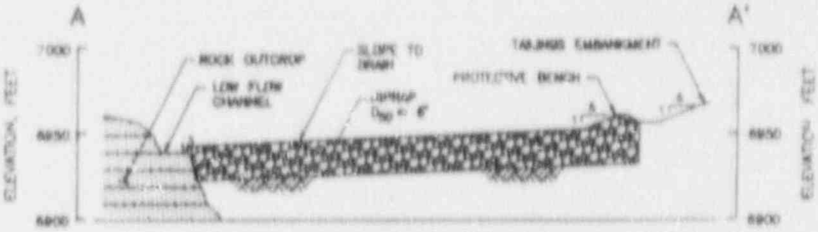
(Modified from UNC Fig 2-3, Dec 4, 1990)

Figure 3

SI APERTURE CARD

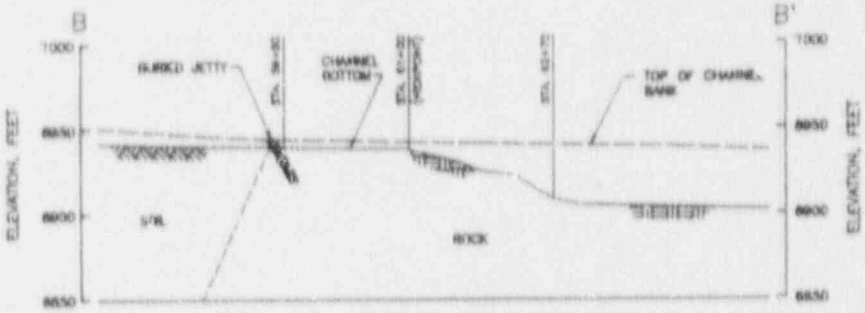
Also Available On Aperture Card

9102120409-02



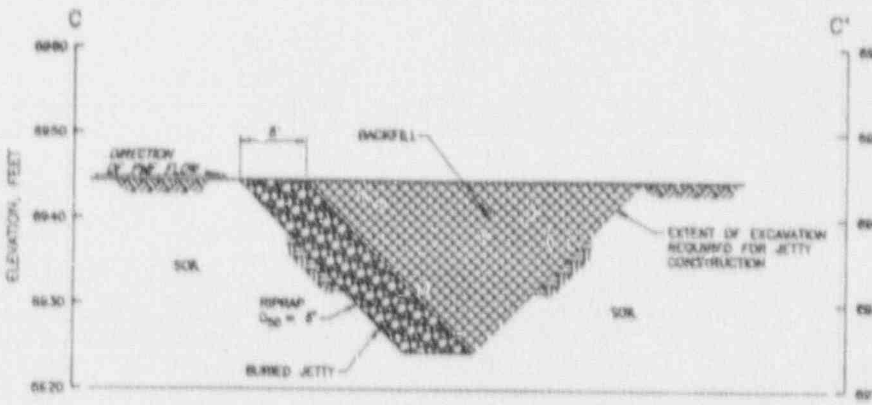
SECTION A-A'

VERTICAL SCALE 50 0 50 FEET
HORIZONTAL SCALE 100 0 100 FEET



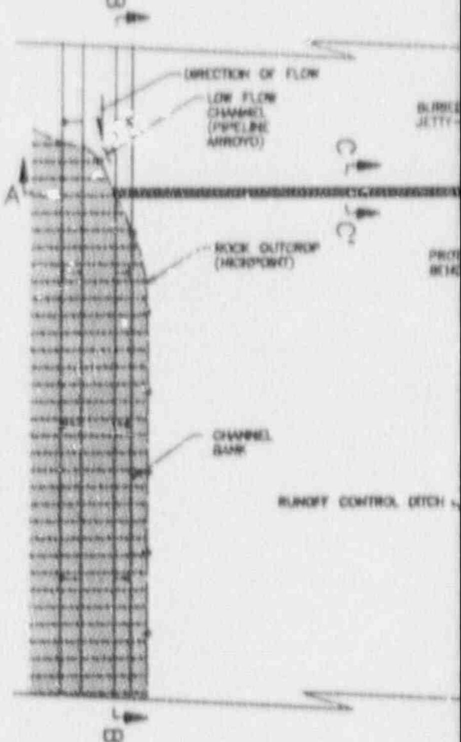
SECTION B-B'
NICKPOINT REINFORCEMENT

VERTICAL SCALE 50 0 50 FEET
HORIZONTAL SCALE 100 0 100 FEET
VERTICAL EXAGGERATION = 2X



SECTION C-C'

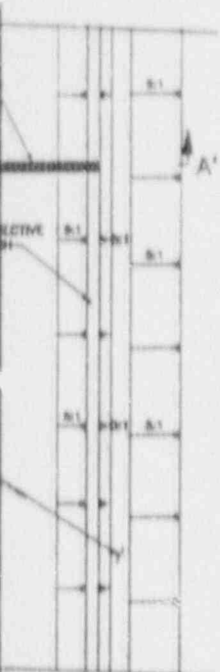
SCALE 10 0 10 FEET

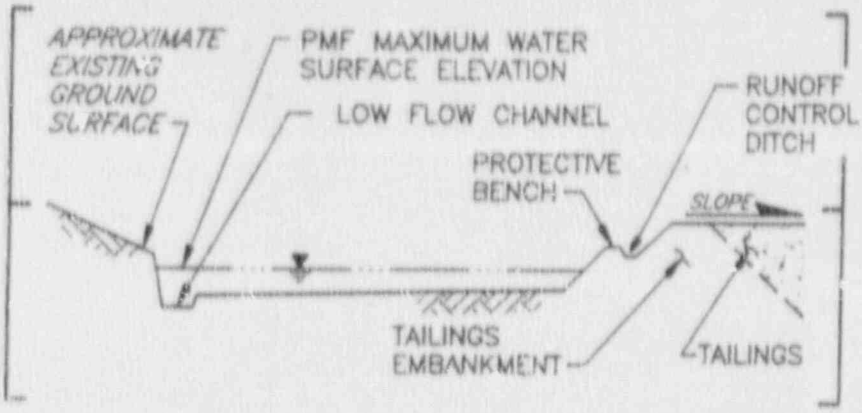


PLAN

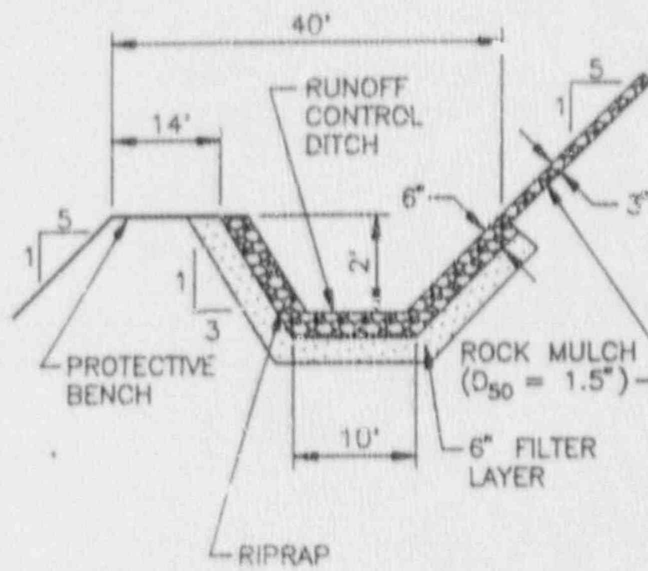
SCALE 100 0 100 FEET

Buried Jetty





Pipeline Arroyo Cross Section



Details

Runoff Control Ditch

UNC Church Rock Mill

DESIGN FEATURES DETAILS
AND
TYPICAL CROSS SECTIONS

(Modified from UNC Figures, Dec 4, 1990)

Figure 4

UNC Church Rock Mill

DRAINAGE AREAS
Pipeline Arroyo
and Diversion Ditches

(Modified from UNC Fig 7-3, June 1, 1987)

Figure 5

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ENCLOSURE 1

UNC CHURCH ROCK RECLAMATION PLAN CHRONOLOGY
40-8907

June 1, 1987	UNC submits reclamation plan.
Nov. 23, 1987	NRC requests additional information on geotechnical portion of reclamation plan by January 8, 1988.
Dec. 2, 1987	UNC requests extension to Jan. 15, 1988, for submittal of geotechnical information.
Jan. 20, 1988	UNC provides partial response to Geotechnical Information request (5 days late). Complete response has not been provided to date.
Jan. 21, 1988	Meeting with UNC to discuss reclamation plan and Q's that have been sent to UNC.
Mar. 22, 1988	NRC requests information on surface water hydrology and reclamation costs by April 22, 1988.
Apr. 1, 1988	UNC notifies NRC that they cannot meet April 22, 1988, deadline for hydrology and cost information, but will submit information by May 22, 1988, unless NRC "has a problem."
Apr. 22, 1988	NRC provides response to April 1, 1988, request for extension which agrees to proposed date of May 23, 1988, for hydrology information and establishes new deadlines of April 29, 1988, for submittal of cost information. Additional comments on the reclamation plan are included in this letter.
May 23, 1988	UNC provides response to March 22, 1988, and April 22, 1988, NRC questions on reclamation plan. UNC does not provide cost information.
May 31, 1988	Meeting with UNC to discuss remaining geotechnical questions (from January 21, 1988, meeting); NRC staff discusses initial review of UNC's May 23, 1988, submittal. NRC and UNC discuss upgrade of license.
June 1, 1988	NRC sends geotechnical questions as follow-up to the January 21, 1988, and May 31, 1988, meetings; NRC requires responses by July 1, 1988.

June 29, 1988	UNC responds to NRC's June 1, 1988, geotechnical questions.
July 26, 1988	UNC submits addendum to reclamation plan which includes surface water hydrology, active ground-water program, windblown cleanup, mill decommissioning, and reclamation schedule. Cost estimate is not provided. Meeting is held to discuss addendum.
July 29, 1988	NRC sends additional erosion protection questions on reclamation plan and requires UNC response by September 2, 1988.
Aug. 31, 1988	UNC provides responses to NRC questions on the reclamation plan dated July 29, 1988.
Aug. 31, 1988	UNC provides detailed cost estimate for its tailings reclamation plan.
Jan. 19, 1989	Meeting to discuss UNC's August 31, 1988, hydrology responses.
Feb. 3, 1989	NRC requests additional hydrology information as a result of UNC's August 31, 1988, submittal and the meeting held on January 19, 1989.
Feb. 23, 1989	UNC responds to NRC's February 3, 1989, questions.
Mar. 20-21, 1990	NRC inspection and site visit of the Church Rock Mill site.
June 29, 1990	NRC sends UNC 13 additional questions on the reclamation plan. These include geotechnical, geomorphologic, and surface water/erosion protection concerns. NRC requires responses by August 17, 1990.
July 27, 1990	Meeting with UNC to discuss NRC's questions of June 29, 1990.
Aug. 1, 1990	Meeting; further discussions were held on NRC's questions of June 29, 1990.
Aug. 16, 1990	NRC sends UNC questions on the reclamation plan. These questions clarify questions 9, 10, and 11 in NRC's June 29, 1990, submittal. Questions 1-8 and 12-13 in the June 29, 1990, submittal remain unchanged.
Aug. 20, 1990	Telephone call, UNC to NRC. UNC requested more time to respond to NRC's questions of June 29, 1990, and August 16, 1990. UNC will meet with consultant on August 23, 1990, and get back to NRC within a week.

Sept. 12, 1990	UNC provides responses to questions 1-6 and 11-13 of NRC's June 29, 1990, letter and question 9A of NRC's August 16, 1990, letter. Responses to questions 7 and 8 of the June 29, 1990, letter and questions 9B and 9C of the August 16, 1990, submittal were not provided.
Oct. 12, 1990	Meeting with UNC to discuss responses to comments provided by UNC on September 17, 1990, and to obtain a commitment from UNC for responding to the remaining comments in NRC's June 29, and August 16, 1990, letters. The need for having an adequate surety in place by the end of 1990 was discussed.
Nov. 01, 1990	Meeting with UNC consultant, Canonie Environmental, to discuss studies done by consultant to date in preparing report for submittal to NRC.
Dec. 04, 1990	UNC provides responses to questions 7 and 8 of NRC's June 29, 1990, letter and questions 9B and 9C of the August 16, 1990, letter.
Dec. 07, 1990	Canonie Environmental (consultant to UNC) provides additional information to justify the project costs that were provided in the December 4, 1990, submittal.
Dec. 28, 1990	Canonie Environmental (consultant to UNC) provides letter to UNC further justifying the project costs in the December 4, 1990, submittal. Copy of the letter was provided to NRC for information.

UNITED STATES

NUCLEAR REGULATORY COMMISSION

REGION IV

URANIUM RECOVERY FIELD OFFICE
BOX 25325
DENVER, COLORADO 80225

JAN 22 1991

URFO:JPG
Docket No. 40-8907

MEMORANDUM FOR: Docket File 40-8907

FROM: Joel P. Grimm, Project Manager

SUBJECT: REVIEW OF GEOLOGIC AND GEOMORPHIC ASPECTS OF THE UNC-CHURCH ROCK RECLAMATION PLAN

BACKGROUND

10 CFR 40, Appendix A, requires uranium mill operators to provide a disposal site and tailings stabilization design to prevent the release of tailings for 1000 years, to the extent reasonably achievable, and, in any case, for at least 200 years. This correspondence provides partial results of reviews of the reclamation plan submitted by United Nuclear Corporation (UNC) for the uranium mill and tailings pile at Church Rock, New Mexico. Included in the plan were design features to protect the tailings pile from erosive processes in the neighboring Pipeline Arroyo. The purpose of this report is to provide a review of geologic aspects of the site and form a basis for amending the license approving the reclamation plan.

Traditionally, the design basis used to meet the long-term stability requirement in 10 CFR Part 40 is protection of a tailings pile from extreme events known as Probable Maximum Precipitation (PMP) and the Probable Maximum Flood (PMF). Accordingly, UNC submitted a design including artificial excavation of Pipeline Arroyo to dimensions capable of containing and passing a PMF event without flood flows along the tailings embankment.

Geomorphic Setting of the Site

Pipeline Arroyo and UNC's site occur in an area underlain by Cretaceous sandstones and shales. The rocks dip north-northeast about 3 degrees, forming elongated sandstone cuestas and intervening valleys underlain by intervening mudstones. The Pipeline Arroyo drainage basin is elongated parallel to the cuestas and valleys, converging on and cutting through a narrow bedrock constriction (fig. 1), draining south two miles to the Rio Puerco. In the tailings area, the valley includes a flat valley floor 380 to 500 meters wide. The drainage channel is found at the far western side of the valley. The tailings occupy the greater part of the valley's floor to the eastern hillslopes.

PM:URFO	PM:URFO	PM:URFO	DD:URFO	D:URFO:RIV
JPGrimm/db	PJGarcia	ROGonzales	EFHawkins	REHall
1/22/91	1/22/91	01/22/91	1/22/91	1/22/91

9102120321

11pp

Pipeline Arroyo is a channel incised in excess of 10 meters adjacent to the pile (fig. 2). The arroyo's vertical banks are subject to mass wasting and erosion, as revealed by aerial photographs and field observations. The channel gradient in the deeply incised area is approximately 0.018. The arroyo has headcut upstream from the Rio Puerco. Approximately one-third of the way northward along the tailings pile, Pipeline Arroyo encounters resistant sandstone bedrock in its channel. The channel rises steeply in a short distance, resulting in a nickpoint that comes to nearly the same elevation as the valley floor. The arroyo no longer occurs upstream, and the channel is unincised on a wide valley floor (fig. 2). The unincised area is a sediment storage area, maintaining a very low channel gradient of only 0.002 (Table 1).

Originally Proposed Design

The applicant's goal is stabilization of the pile for the required 1000 years, using a PMF as the design basis. The applicant originally proposed to excavate through the nickpoint, creating one continuous, straight, and deep channel from the northern property boundary (fig. 2) to beyond the southern end of the tailings pile. The design included lowering the channel in excess of 8 meters at the nickpoint, creating 2:1 sideslopes in the bedrock reach, knocking down the vertical gully walls in alluvial reaches to 3:1 sidelopes, and steepening the channel gradient upstream to about 0.008, and downstream up to 0.025. The goal of this design was to contain the PMF within the excavated channel, preventing high-velocity flow along the tailings embankment. The entire reach of Pipeline Arroyo along the tailings and up-valley would be channelized, and would mostly occur in alluvium. Most importantly, the tailings embankment is adjacent to the channel for a distance exceeding 400 meters, with no intervening buffer area.

DISCUSSION

Current Geomorphic Processes in Pipeline Arroyo

The conditions and processes observed in Pipeline Arroyo are known as rejuvenation, and occur in response to base-level lowering. For several decades, geological and engineering field studies and laboratory simulations have been employed to determine the processes of basin rejuvenation. Base-level lowering creates a nickpoint where the tributary meets the main channel, and the nickpoint begins to migrate up the tributary channel, creating a gully. Once a nickpoint is formed, headcutting in the arroyo is quite rapid, proceeding through a basin in time scales measured in years or decades (Schumm and Hadley, 1957). Typically, the same depth of channel degradation occurs throughout the channel length, with the main impact felt early near the mouth (Begin and others, 1980). The rate of gully growth at any station is initially high, then slowly decreases.

Channels experiencing gullying display unstable conditions downstream of the migrating nickpoint, evidenced by bank failures and high sediment loads (Schumm and others, 1984; Meyer, 1989). Sediment is typically transported downstream as bed load. The applicant has demonstrated that alluvium in this valley is mostly sand sized. In arroyos with sandy bank material, bed load occurs as braided bars and the active channel occupies the entire arroyo floor (Meyer, 1989). Both arroyo walls are nearly vertical, and the arroyo experiences large amounts of widening by bank failure and erosion (fig. 3). These findings resemble existing conditions in Pipeline Arroyo Unstable conditions continue for extended periods of time, and stability is not achieved until large volumes of sediment are removed, and sediment production upstream abates (Meyer, 1989).

Effects of Channelization

Channelization causes artificial straightening and shortening of a channel, thus steepening its gradient. The steeper and concentrated flow results in increased stream power, leading to channel incision and bank erosion as the channel readjusts to the steeper gradient (Emerson, 1971).

Meyer (1989) summarizes numerous studies of the effect of channelization:

> Channelized or straightened stream channels commonly respond like gullies. Vertical incision results from concentration of flow that formerly spread over the valley floor. After or accompanying downcutting, channel side walls erode, usually by lateral channel erosion and mass wasting of vertical banks. In channelized streams, ten-fold increases in channel area are common, which are attributed to both downcutting and bank-top widening (Meyer, 1989; p. 3-4).

The result of channelization, therefore, is the same as arroyo formation by nickpoint migration. All channel reaches downstream of the uppermost channel modifications are likely to display unstable conditions leading to channel incision, arroyo widening by bank failures, and associated high sediment loads in the channels.

Review of the Originally Proposed Design

All the typical unstable conditions associated with basin rejuvenation are observed in Pipeline Arroyo, and are due to base-level lowering in Rio Puerco. This area is probably in an early stage of basin rejuvenation which became widespread beginning in the late nineteenth century (Cooke and Reeves, 1976). Migration of Pipeline Arroyo's nickpoint, however, has halted on account of encountering resistant bedrock in the channel.

Considering the site characteristics and geomorphic concepts discussed above, it is concluded that geomorphic conditions downstream of the nickpoint are unstable, and the southern one-third of the tailings pile is in jeopardy of becoming involved in arroyo widening. In addition, removal of the nickpoint and channelization of the northern area will result in destabilization of that area, including the area where no buffer area occurs between the embankment and channel. Specifically, the unincised area's valley gradient is probably as steep as is stable. If a gradient steeper than 0.002 were stable, excess sediment would have be deposited upstream to raise valley slope. Thus, the northern part of the site will become susceptible to basin rejuvenation if altered. Without considerable engineered enhancements to this design, it is concluded that the proposal is not likely to provide stabilization of the tailings pile for the time period required in 10 CFR Part 40. These findings were summarized in NRC correspondence dated June 29 and August 16, 1990.

Latest Design Modifications

UNC's submittal of December 4, 1990, provided significant design modifications in consideration of the geomorphic concepts described above. The changes consist of:

1) Changing the proposal to excavate the northern channel. Instead, the existing channel will be altered only to provide a low-flow channel 30 feet wide from the northern property line to the nickpoint. Erosion of the tailings embankment during extreme events will be minimized by construction of an erosion resistant berm along the embankment interceptor ditch at the calculated level of the PMF.

2) Abandoning the proposal to remove the nickpoint by excavation. Instead, the nickpoint will be reinforced with a buried riprap jetty from the exposed bedrock, through the subsurface, to the tailings embankment. This proposal will provide stable base level for the drainage basin north of the nickpoint.

3) Leaving the arroyo south of the nickpoint relatively unaltered. The area known as the sacrificial slope will be regraded to promote sheet flow of direct runoff. In addition, the base of the tailings embankment will be ringed by an interceptor ditch, and runoff from the embankment will be diverted to a controlled structure.

Relying on the long-term stability of the nickpoint and its reinforcement by the buried jetty, it is concluded that geomorphic stability north of the nickpoint is reasonably assured for the required performance period of the remedial action. This assurance is contingent upon the suitability of the erosion resistant berm at the base of the embankment, and the buried rock jetty in the channel.

Stability of the area downstream of the nickpoint is more difficult to assure. Based on the concepts discussed above, it is concluded that the incised arroyo is geomorphically unstable. Erosion and arroyo widening there seems likely to continue, perhaps for decades or centuries, until the arroyo is sufficiently wide to contain a stable channel (Meyer, 1989). Even formidable engineered enhancements to the channel are likely to be undercut or sidecut by continued arroyo growth. The rate of arroyo growth is unpredictable. The tailings embankment now lies 130 to 150 meters from the arroyo. In larger drainage basins, arroyos commonly display width-depth ratios up to 100 (Meyer, personal communication). Experimental evidence suggests smaller basins may stabilize when the ratio is 10. Assuming all arroyo widening occurs eastward, the sacrificial slope is perhaps suitably wide to protect the tailings embankment. The design, however, does not allow for a deeper arroyo, nor for a shift in the arroyo's position in the valley.

In order to add assurance that the sacrificial slope will remain sufficient throughout the performance period, the applicant proposes the following enhancements:

1) The slope of the sacrificial area will be decreased to nearly zero percent near the embankment. Therefore eroded gullies forming on the slope will be unable to headcut to the embankment.

2) The area will be graded to promote sheet flow. Even though the slope is relatively steep (2 to 9 percent), drainage area is small and gully erosion will be limited.

3) Runoff from the embankment will be diverted at a basal interceptor ditch. This runoff will not contribute to erosion of the sacrificial slope.

CONCLUSIONS

Pipeline Arroyo is an example of an unstable drainage basin undergoing rejuvenation. While landscape stability and protection of the tailings is difficult to assure, base level provided by a resistant nickpoint in the arroyo helps assure stability along the northern two-thirds of the tailings embankment. The applicant's design to augment the nickpoint from the channel to the embankment provides reasonable assurance that the northern part of the tailings cell will not be affected by channel processes upstream of the nickpoint.

Meanwhile, there appears to be no reasonable method to prevent geomorphic changes in the deeply incised arroyo downstream of the nickpoint. Given enough time, erosive processes associated with base-level lowering in the Rio Puerco will run their course and remove much of the sediment currently stored in the valley which contains Pipeline Arroyo. The rate and extent of erosion is difficult to predict. The applicant, however, has provided information to conclude that the arroyo will not experience widening exceeding the sacrificial area.

It is concluded that the proposed design and modifications will prevent tailings instability to the extent reasonably achievable.

Joel P. Grimm

Joel P. Grimm
Project Manager

Attachment:
As stated

bcc:

Docket File No. 40-8907
LFMB
PDR/DCS
URFO r/f
ABBeach, RIV
LLO Branch, LLWM
OB:IMNS:NMSS
JPGrimm
ROGonzales
PJGarcia
BGarcia, RCPD, NM
EMontoya, NM
8907/172E/JPG/91/01/17/M

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Schumm, S.A. and Hadley, R.F., 1957, Arroyos and the semi-arid cycle of erosion: American Journal of Science, v.255, p. 161-174.

Schumm, S.A., Harvey, M.D., and Watson, C.C., 1984, Incised channels: morphology, dynamics, and control: Littleton, Colorado, Water Resource Publications, 200 p.

Table 1: Comparison of Physical Characteristics of Pipeline Arroyo and its Channel Upstream and Downstream of the Nickpoint Position

	Upstream	Downstream
Gradient	0.002	0.018
Bank Height	approximately 1 meter	up to 10 meters
Channel Form	braided-sinuous	braided

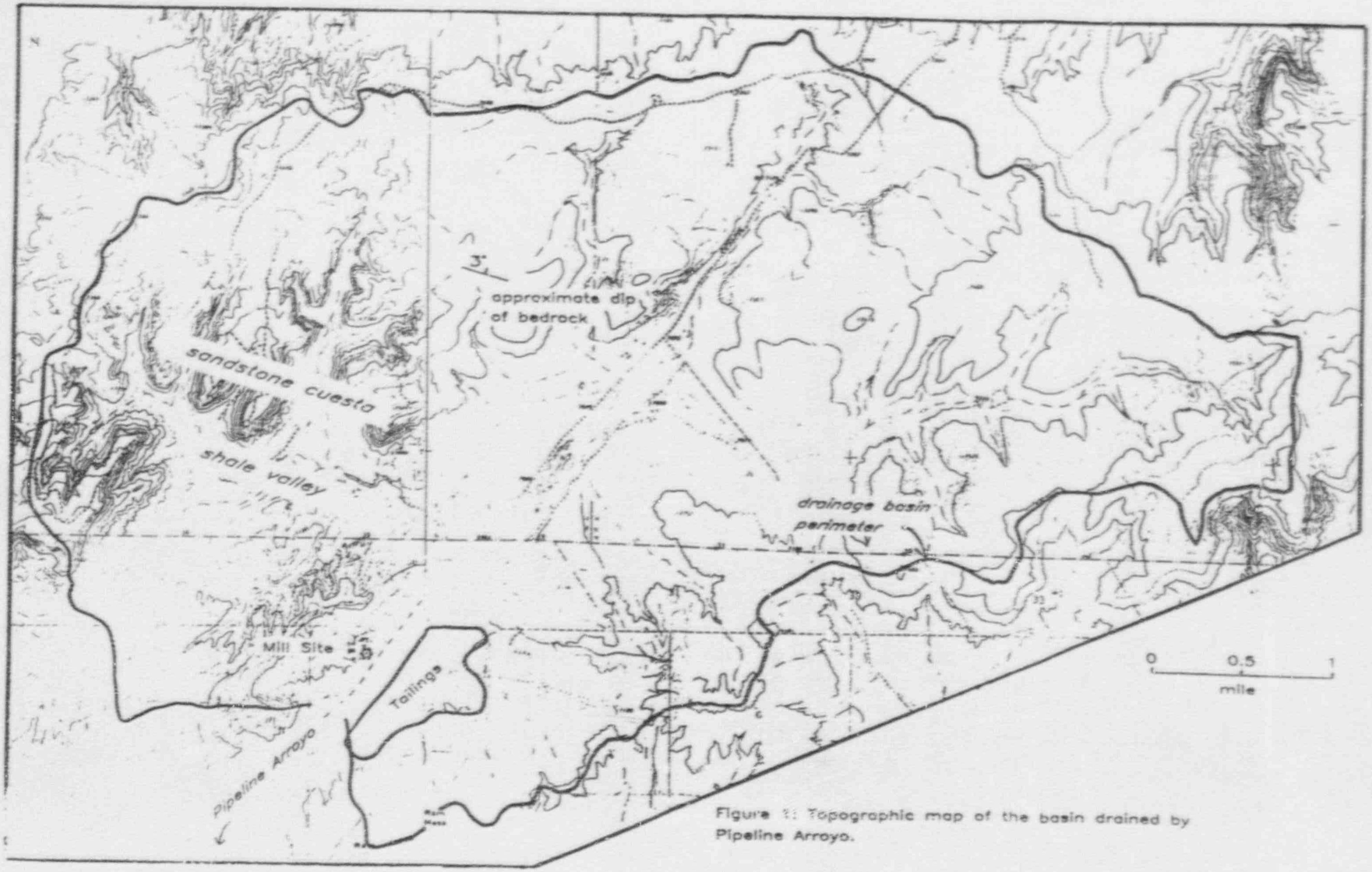

Figure 1: Topographic map of the basin drained by Pipeline Arroyo.

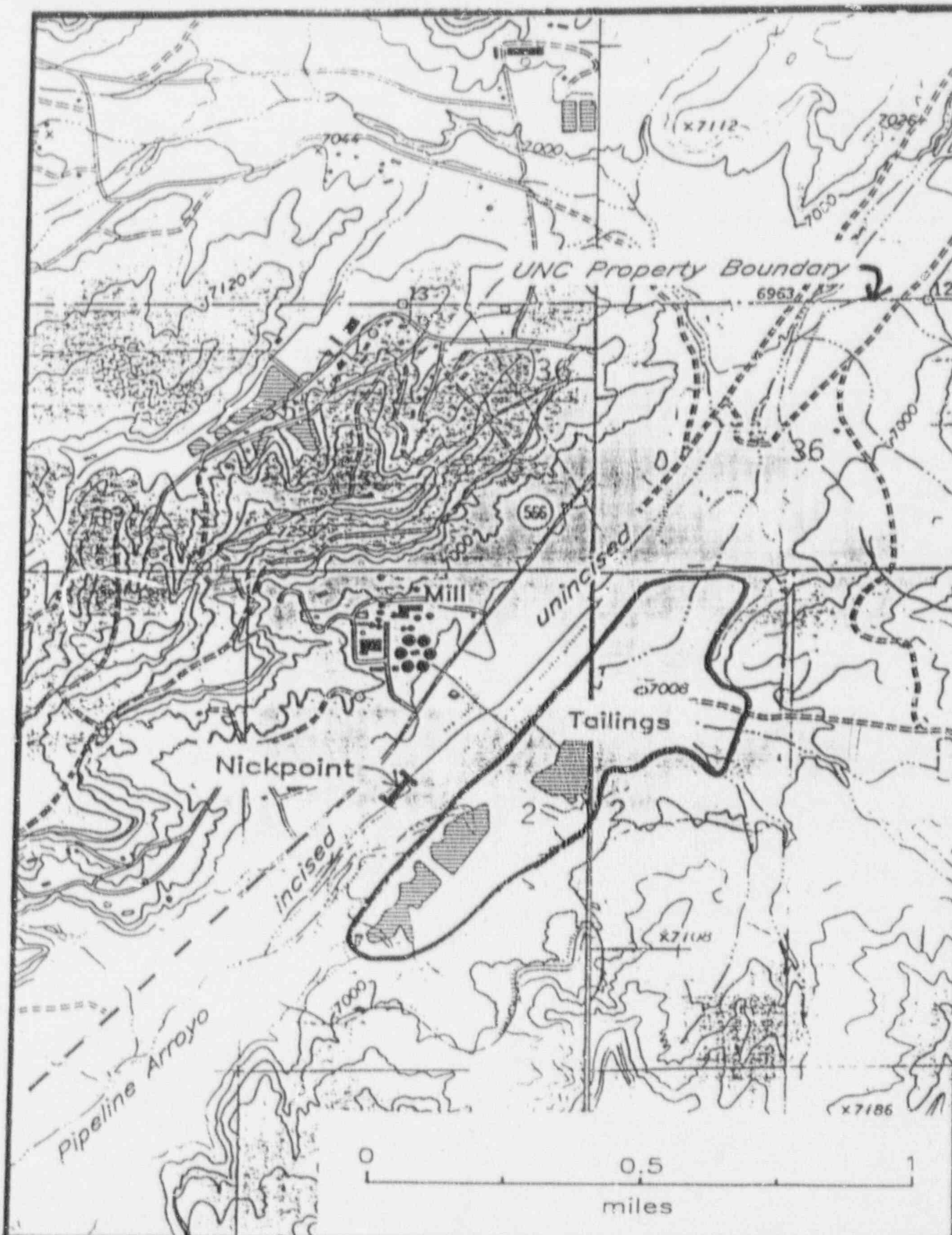

Figure 2: Detailed topographic map of the approximate tailings disposal area and its relationship to Pipeline Arroyo.

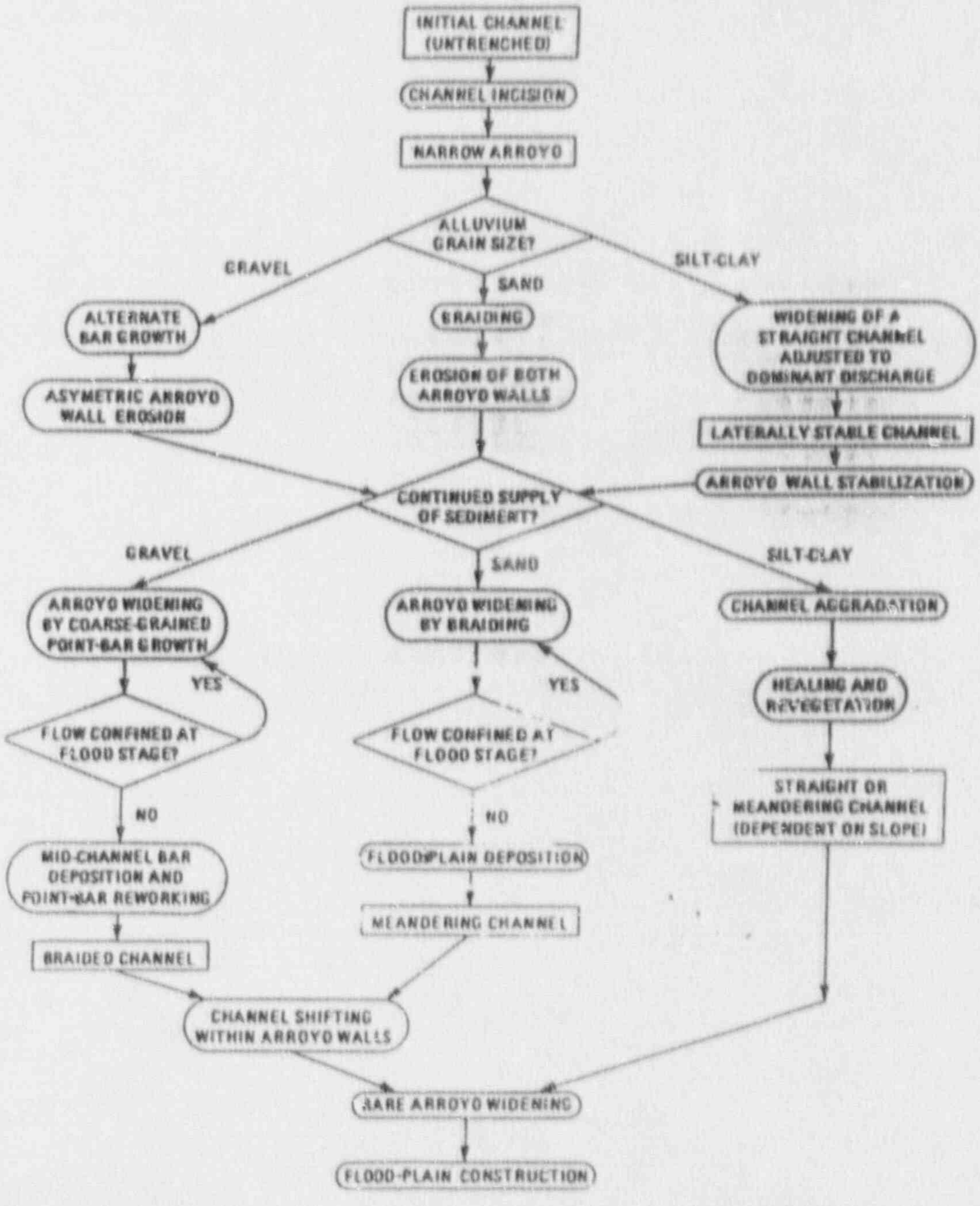

Figure 3: Model of arroyo development in different sediment, based on field studies and laboratory simulations. Pipeline Arroyo conditions are similar to those in the central column (from Meyer, 1989; Figure 37).