Based on the observed and predicted stability of the Dilco Coal member exposed in the North Diversion channel excavation from stations 41+00 to 50+00, the cut slopes will remain stable throughout the 1,000-year design life of the reclaimed site. No modifications to stabilize the channel cut slopes are necessary or required.

5.6 Pipeline Arroyo and Embankment Stability

In addition to the tailings cover, the long-term stability of the tailings embankment is necessary to prevent the release of tailings. The primary surface water drainage on the United Nuclear property is the Pipeline Arroyo, an ephemeral channel that flows to the southwest parallel to the west tailings embankment. Consistent with the objective (10 CFR 40, Appendix A) of maximizing reclamation design longevity to 1,000 years (to the extent reasonably possible) the Pipeline Arroyo channel and the tailings embankment were investigated, and hydrologic analyses and designs were developed to minimize channel erosion and meandering, and to ensure protection of the reclaimed tailings disposal area. This section of the reclamation plan describes the channel and embankment evaluations, provides results of hydrologic analyses, and presents planned channel modifications and embankment protection measures to satisfy these objectives.

5.6.1 Existing Pipeline Arroyo Channel Description

The United Nuclear mill site and tailings disposal area are adjacent to Pipeline Arroyo, an ephemeral channel draining approximately 18.2 square miles of upland areas. These upland areas consist of relatively flat mesas with steep side slopes, as shown on Figure 5-5. The channel slopes of the arroyo vary considerably (0.0018 to 0.053 ft/ft) from its headwaters to its confluence with the North Fork Rio Puerco ephemeral drainage. These channel slopes depend on local bedrock control, such as the nickpoint located near United Nuclear's facilities, shown on the channel profile (Figure 5-8. The nickpoint is a steep head-cut into Zones 1, 2, and 3 of the Upper Gallup Sandstone.

The channel above the nickpoint is relatively wide and has a braided stream pattern due to the nickpoint, which provides a channel base-control section. The channel slope above the nickpoint is as low as 0.0018 ft/ft. The sediment capacity of the channel immediately upstream of the nickpoint is less than that of locations farther upstream. When sediment-laden runoff reaches the area above the nickpoint, the sediment is deposited in bars, and the braided pattern forms.

Below the nickpoint, the channel slope steepens to as high as 0.053 ft/ft. The channel cross section in this area is narrow and deeply incised into the previously deposited alluvial sediment. Incision occurs because the flow increases its sediment capacity when it enters the steeper channel slopes downstream of the nickpoint. The flow gains this additional sediment capacity by causing channel and bank erosion. The channel maintains the meandering pattern established before the nickpoint provided local control.

The channel bottom near the United Nuclear facilities lies above the expected base level of the channel because of the local base control provided by the nickpoint. Figure 5-8 illustrates the actual channel base and its expected base, if the controlling nickpoint did not exist. The expected base level is the level to which the channel will attempt to reach over a long period of time, if the nickpoint were not providing base control.

If the channel moved off the nickpoint, the channel will downcut into the alluvium. Head-cuts would form and migrate upstream. The increased sediment load induced by this action would cause aggradation (deposition of sediment) at the location of the decrease in channel slope near its exit from the United Nuclear property as shown on Figure 5-8. This aggradation might raise the actual base level in this area as the channel reaches its new state of dynamic equilibrium. However, the location of the expected base level shown on Figure 5-8 provides a more conservative level for reclamation design purposes. Thus, one of the final reclamation design objectives was to fix the nickpoint as a more stable control point and to maintain the base level of the channel as described later.

Information gathered during geotechnical and geological field investigations include subsurface information in the area adjacent to and upstream of the nickpoint. Section 3.0 and Appendix A summarize the field investigation results. The alluvial soils in this area of the channel consist primarily of silts intermixed with varying quantities of sand and clay. Grain-size analyses of the soil samples indicated an average gradation of 40 percent sand and 60 percent fine-grained material (i.e., silts and clays). The average D_{50} size is 0.07 millimeters (mm). These particles have been lightly cemented by calcium carbonate throughout the alluvial zone.

The depth of the alluvium ranges from 0 feet at the edges of the valley and at the nickpoint outcrop to more than 150 feet at near the southwest corner of Section 36 (Figure 5-2). The alluvium at the greater depth indicates the filling of a paleochannel (Canonie, 1987a).

Several auger holes in alluvium were extended into the underlying rock formations with a coring bit. The channel cross section (Figure 5-9) illustrates subsurface conditions extending across the channel 100 feet northeast of the nickpoint, using auger hole and rock coring data. This cross section shows that the nickpoint is formed by an outcrop of Zone 3 of the Upper Gallup Sandstone. This outcrop was not continuous across the arroyo, but ends abruptly under the alluvium near the present channel.

The surface of the rock underlying the alluvium is moderately-to-highly weathered. Beneath the weathered zone, the sandstone varies from soft to hard. Within the nickpoint, the sandstone of Zone 3 appears massive with few fractures.

The shales of Zone 2 (beneath Zone 3) are softer and less competent than the Zone 3 sandstone. The fissile nature of the Zone 2 shales make this material less competent and more erodible than the sandstones above (Zone 3) and below (Zone 1). Zone 2 is exposed only as a thin layer (less than 5 vertical feet) within the nickpoint.

The sandstone of Zone 1 is similar in appearance to that of Zone 3 sandstone. It is exposed only at the bottom of the nickpoint for about 10 vertical feet, and forms a relatively stable base.

The channel cross section on Figure 5-9 shows that the existing channel walls within the nickpoint are higher on the west side than on the east side. The maximum height of the west rock wall is approximately 10 feet, while on the east side it is approximately 4 feet high.

5.6.2 Historical Analysis of Pipeline Arroyo Channel Morphology

The channel characteristics of sinuosity, meander wave length, amplitude, and channel width/depth ratio were determined for the channel reaches above and below the nickpoint on Pipeline Arroyo and below the confluence between Pipeline Arroyo and the North Fork Rio Puerco drainage. These characteristics were identified from aerial photographs taken over a 33-year period in 1952, 1983, and 1985, and are summarized in Table 5.10.

Although a 33-year time span is minimal on the geologic scale, several changes occurred in the channel's morphology. The nickpoint adjacent to the mill is evident in the 1952 aerial photograph, although its effect on channel morphology is not as pronounced as in the later photographs. The morphological effects of the nickpoint were probably enhanced by the large mine water drainage discharges from both the Quivira and United Nuclear mines beginning in 1968. These discharges were relatively free of sediment and, thus, had large sediment capacities to fulfill. The mine water discharges were continuous from 1968 to 1986. Accordingly, their slow but continual ability to downcut the channel became apparent after several years of operation.

The width/depth ratio of Pipeline Arroyo below the nickpoint decreased between 1952 and 1983. This decrease was caused by the downcutting of the channel, primarily due to increased flow velocities at and below the nickpoint, which increased the flow's sediment capacity. This capacity resulted in further channel erosion. The moderate cementation of the silty alluvial soils resulted in steep channel banks.

The channel reach above the nickpoint evolved from a meandering pattern to a braided pattern and its width/depth ratio increased, by the sediment deposition above the nickpoint. The changes from a meandering pattern to a braided pattern reflect the stream's attempt to carry as much sediment as possible.

The North Fork Rio Puerco drainage below the confluence with Pipeline Arroyo showed an increase in the width/depth ratio from aggradation in this reach. The aggradation was caused by a decrease of the channel gradient, an increased sediment load from Pipeline Arroyo and the subsequent sediment deposition. The zone showing aggradation is relatively short and does not extend far downstream. The sinuosity of the channel in this reach decreased from 1952 to 1985 as several meanders were cut off and a straighter channel developed.

5.6.3 Pipeline Arroyo Drainage Basin Description

The Pipeline Canyon drainage basin has been thoroughly described in previous license applications, renewal applications and reports (United Nuclear Corporation, 1981; Faith Engineering, 1981). The drainage basin shown on Figure 5-5 was delineated as the appropriate contributing basin for calculating flood events. The outlet of this basin is adjacent to the north end of the tailings disposal area. The drainage areas to the east of the tailings disposal area are intercepted by diversion ditches that either route the flows to the arroyo channel below the United Nuclear facilities, or pass the peak flows from these areas before the flood peak on the main channel arrives at their confluence.

The Pipeline Arroyo basin consists of an area of 18.2 square miles, has a total relief of 819 feet, and has a longest drainage path of 6.2 miles (Table 5.11). The basin is elliptical in shape and has a circularity ratio of 0.74. These data were determined from 7.5-minute USGS maps as illustrated on Figure 5-5. A Soil Conservation Service (SCS) curve number of 79 was selected for use based on the hydrologic characteristics of the soil and vegetation conditions of this basin (Faith Engineering, 1981). This number was confirmed by Canonie in 1987.

5.6.4 Pipeline Arroyo Design Flood Calculations

The PMF was used as the design flood event for evaluating the long-term hydraulic stability of the Pipeline Arroyo. To minimize erosion and prevent the release of tailings, the potential impacts of large flood events (e.g., the PMF) must be evaluated and protection against erosion provided. Use of the PMF is consistent with the guidelines set forth by the Nuclear Regulatory Commission NUREG/CR-3397 (NRC, 1983b). However, during review of the proposed plan, NRC expressed additional concern that, over time, the arroyo meandering would result in channel migration significant enough to impact the tailings impoundment. Consequently, the geomorphology of Pipeline Arroyo and the potential for channel meandering to adversely affect the tailings impoundment was evaluated as described in Section 5.6.6.7 below.

The peak-flow rate of the PMF originating from the Pipeline Arroyo drainage basin was estimated by the SCS Synthetic Triangular Unit Hydrograph Method (Bureau of Reclamation, 1977). The one-hour PMP from a thunderstorm event was determined using Hydrometeorological Report 49 (NOAA, 1984). Appendix E provides the work sheet for the calculation of the PMP. The resulting PMP amount for the drainage area of 18.2 square miles, and a mean basin elevation of 7,275 feet was 6.2 inches.

Appendix E also provides the PMF hydrograph generation by the SCS method. This method uses basin geometry such as the maximum relief and the longest drainage path to calculate a synthetic triangular unit hydrograph. The PMP rainfall is divided into quarter-hour segments, which amounts are reordered to simulate an actual thunderstorm. The amount of runoff produced by these rainfall amounts is determined by applying the appropriate curve number. The runoff amounts are applied to the unit hydrograph to produce intermediate hydrographs for each quarter-hour segments. These intermediate hydrographs are then combined to produce the composite hydrograph for channel-design purposes.

The peak-flow rate of the composite PMF hydrograph was calculated to be 26,300 cubic feet per second (cfs). This peak occurs approximately 1.7 hours from the beginning of the PMP.

5.6.5 PMF Routing - Existing Pipeline Arroyo Channel

Hydrologic modeling of existing channel conditions was conducted to determine if modifications of Pipeline Arroyo would be necessary as part of reclamation. The PMF of 26,300 cfs was routed through the existing Pipeline Arroyo channel and valley adjacent to the United Nuclear facilities by using the COE's HEC-2 water surface profiles model (Corps of Engineers, 1977). Eight channel cross sections were developed from 1985 topographic mapping and four additional channel cross sections were field surveyed. The HEC-2 program was used to separately develop the water surface profiles of the subcritical flow expected above the nickpoint, and the supercritical flow expected below the nickpoint.

For the existing unmodified channel, the flood waters of the PMF would contact the full extent of the main earth embankment of the North and Central Cells, but would not overtop the crest of the embankment in any location. The average flow velocities above the channel and against the embankment (i.e., HEC-2 right overbank area) in the sections where the flood waters would contact the embankment range from 2.7 to 7.9 feet per second (fps), and would generally increase in the downstream direction. These velocities would be sufficient to cause minor erosion of the main embankment and indicate that some modifications to the channel and embankment protection are required as part of final reclamation.

For the existing unmodified channel downstream of the nickpoint, the flood waters would be contained primarily in the existing, deeply-incised channel. The PMF flow velocities within the channel would be extremely high and range from 27.2 to 37.3 fps. These velocities would cause a large amount of bank and channel erosion, and local scour. However, the channel in this location would not be expected to migrate to the tailings disposal area during a PMF flood event, based on volumetric determinations of scour compared to the amount of available material between the channel and tailings disposal area.

The channel and overbank flow velocities in the nickpoint area would be high enough (12.5 to 17.2 fps) to also cause bank erosion and local scour of both the alluvial channel and the overbank area. Avulsion (large movement) of the existing channel off the nickpoint and into the alluvium southeast of the nickpoint would be likely. Such channel movement would allow rapid downcutting or further channel migration during the PMF or subsequent flood events. Thus, without protection of the alluvium east of the nickpoint to reduce the potential channel movement, the channel might migrate over a long period of time as far as the tailings disposal area embankment.

Previous studies of the flood stability of Pipeline Arroyo have also indicated the probability of existing channel migration, large-scale scouring and avulsion of the existing channel during large-scale flooding events (Simons, Li & Associates, 1980; Faith Engineering, 1982). Based on this hydrologic modeling of existing conditions, the plan proposed in 1987 called for the Pipeline Arroyo channel and embankments to be excavated, reconfigured and protected to stabilize the channel and provide protection of the tailings disposal area for a 1,000-year period, to the extent practicable.

The design approach to provide arroyo stability was changed in response to NRC comments. The new approach approved by NRC in this plan involves artificially extending the nickpoint across the alluvial plain to the tailings embankment by construction of a buried rock "jetty." The design approved by NRC will allow the arroyo channel to meander naturally in a low-flow channel upgradient from the nickpoint, as described below.

5.6.6 Arroyo Channel and Tailings Embankment Modifications

The design objectives for the channel and embankment modifications were as follows:

1. Pass the PMF in the modified channel without encroachment on the tailings cover,

2. Prevent lateral migration of the channel into the tailings disposal area,

3. Provide a geomorphologically stable channel configuration, and

4. Prevent gully formation on the tailings soil cover.

Alternatives considered in the preliminary evaluations included widening and/or deepening the channel, increasing the channel slope, incising the channel into the nickpoint, relocating the channel, and/or providing an artificial base-control section. The ability of each of these design alternatives to fulfill the design objectives was qualitatively evaluated. The combination of alternatives best fulfilling the objectives was then selected for quantitative analyses. The June 1987 proposed plan submitted to NRC contained a design that depended significantly on channel excavation and reconfiguration. Based on NRC review comments, the design was subsequently modified to focus on controlling the nickpoint and protecting the tailings embankment without extensive channel excavation.

Figures 5-1 and 5-2 show a plan view of the Pipeline Arroyo and tailings embankment at final reclamation. The channel itself will be modified only slightly from its present configuration to enhance its flow capacity, while maintaining its present shallow channel bottom slopes. The modifications to the present channel and embankment configuration will include the following:

1. Constructing a protective bench at the toe of the tailings embankment that will contain the runoff control ditch, which will collect surface drainage off the embankment face. The bench will also protect the tailings embankment toe from the PMF within Pipeline Arroyo.

2. Constructing a buried jetty from the nickpoint outcrop east across the Pipeline Arroyo floodplain to the runoff control ditch. This jetty will augment the geomorphic control provided by nickpoint.

3. Enhancing the low-flow capabilities of the present channel by constructing a 30-foot-wide, low-flow channel within the reach upstream of the nickpoint from station 0+00 to station 61+40.

4. Filling in the depressions and headcuts that presently exist in the area between Pipeline Arroyo and the tailings embankment.

Figure 5-10 provides profiles of the channel bottom, PMF water surface elevation (WSEL), protective bench toe, protective bench top, and tailings embankment top from station 0+00 to station 82+90. The profile shows the shallow slopes of the Pipeline Arroyo channel bottom upstream of the nickpoint, and the spatial relationship of these features.

5.6.6.1 Tailings Embankment

The tailings embankment will be modified to protect the embankment from erosion. These modifications include the use of a protective rock mulch, as well as construction of a protective bench and riprapped runoff control ditch. The tailings embankment slope design incorporates rock mulch armor for erosion protection of the upper portion of the embankment, installation of a runoff control ditch to channel runoff from the slope, and the construction of a protective bench at the toe of the tailings embankment to provide a buffer between PMF flows in Pipeline Arroyo and the toe of the tailings embankment.

The long-term stability of the tailings embankment depends on the rock mulch on the embankment side slope and the runoff control ditch. The following discussion describes the design considerations used to develop and provide long-term stability of these features. Appendix E provides the detailed calculations for the long-term stability evaluations of the tailings embankment.

Figures 5-1 and 5-2 show the configuration of the tailings embankment at final reclamation. The side slopes will remain at 5H:1V as provided in the original design and will terminate at the runoff control ditch, located at the top of the protective bench to collect runoff from the embankment. The embankment side slopes will be protected from erosion by a 3-inch-thick rock mulch layer, which extends from the top of the tailings embankment to the runoff control ditch. The rock mulch for protecting the embankment side slopes from the erosional forces of runoff generated by the PMP was designed using the CSU method (NUREG 4651, 1989). The resulting D_{50} of 1.5 inches and thickness of 3.0 inches for this rock mulch is similar to that of the rock mulch used in the soil/rock matrix in the tailings-cover design, so that the same rock material could be used for both areas. Table 5.6 provides the gradation for this rock mulch.

A theoretical slope stability analysis was also conducted to confirm the structural stability of the regraded tailings retention embankment. A critical section, illustrated on Figure 5-11, was selected for the analyses. Analyses were performed for both static and earthquake (pseudostatic) loadings to determine the factor of safety against a slope failure that could cause the release of tailings. The factor of safety against slope failure for static conditions was 2.7, and for earthquake conditions was 1.6, representative of a highly stable configuration. The slope stability calculation is provided in Appendix E.

5.6.6.2 Protective Bench

A protective bench, adjacent to the runoff control ditch at the base of the tailings embankment, will be located between the embankment toe and the Pipeline Arroyo channel. The protective bench will be 40-feet wide and up to 20-feet higher than the Pipeline Arroyo channel bank. Figure 5-10 shows the profiles of the bench toe, bench top and embankment top. Figures 5-12 and 5-13 show several cross sections illustrating the spatial relationship among these features, as well as the Pipeline Arroyo channel. Figure 5-13 provides a detail of the protective bench and the runoff control ditch.

5.6.6.3 Runoff Control Ditch

The runoff control ditch, shown on Figures 5-1 and 5-2, will intercept runoff from the western side slope of the tailings cover, located between the protective bench and the embankment toe (Figures 5-1 and 5-13). Interception of runoff will preclude the formation of gullies at the Pipeline Arroyo channel, which could otherwise eventually intrude upon the tailings disposal area. The runoff control ditch will transport the collected runoff to a downdrain, to the south cell drainage channel, then to the Pipeline Arroyo (Figure 5-4).

Calculation of the PMP amount and the PMF hydrograph were conducted using the methods described in Section 5.5.4. Appendix E includes the work sheets for these calculations. The cross sections and channel slopes were determined from Figures 5-1 and 5-2. Maynard's method was used to calculate the normal flow depth and the riprap sizes.

The runoff control ditch was designed as a trapezoidal channel with a 10-foot bottom width (Figure 5-13). The side slope on the bank of the protective bench, which makes up the outer bank of the runoff control ditch, will be 3H:1V. The side slope of the protective bench will be the same as the tailings embankment slope (5H:1V) on the east bank. The minimum depth will be 2 feet. The channel slope will vary from 0.003 to 0.019 ft/ft. Figure 5-13 shows a typical channel section.

The PMF for the runoff control ditch has a peak discharge of 52 cfs. This peak discharge produces a peak flow depth of 1.26 feet in the channel sections, sufficiently lower than the 3-foot depth of the ditch, allowing the PMF flow to pass.

The riprap that will be used to protect the ditch during a PMF event was sized using the Safety Factors method. This resulted in a D_{50} size of 1.5 inches in the upper reach and a D_{50} size of 3 inches in the lower reach of the runoff control ditch. The riprap layer will be 6 inches. A 6-inch-thick filter layer will underlie the riprap in the lower reach of the runoff control ditch only (Figure 5-13). Due to the low flow velocity in the upper reach, the smaller riprap (D_{50} of 1.5 inches) does not require a bedding layer. Tables 5.6 and 5.7 show gradation sizing of the riprap and bedding material (for the lower reach), respectively. Section 5.6 describes requirements for the rock riprap.

5.6.6.4 Buried Jetty

The nickpoint must be stabilized to maintain the geomorphic stability of Pipeline Arroyo, which will be accomplished by constructing a buried jetty, a stone-filled trench, that will extend across the valley approximately 150 feet north of the nickpoint outcrop. The jetty will extend from the Gallup Sandstone subcrop in the arroyo's west bank to the top of the protective bench along the tailings embankment toe at station 59+50. The jetty will ensure flows continue to pass over the nickpoint, and will provide vertical control of the Pipeline Arroyo channel bottom. Vertical control will maintain the shallow slopes for the channel reach upstream from the nickpoint and thus, will maintain the long-term geomorphic stability of Pipeline Arroyo. The jetty has been designed to withstand the effects of the PMF passing over it. In addition, the low-flow channel will contain smaller, but more frequent, flood events and direct these flows over the nickpoint.

Figure 5-1 shows the location of the jetty, while Figure 5-9 provides the jetty details. The jetty will be keyed into the nickpoint at its furthest extent to maximize the flow capacity within the nickpoint. The exact configuration of the eastern edge of the nickpoint will be determined in the field during construction. The low-flow channel is designed to be 30 feet wide and located at the jetty's west terminus. The low-flow channel width constructed at the nickpoint may change, depending on the nickpoint configuration determined in the field.

The sizing of the jetty stone (riprap) was calculated using the Safety Factors method. The maximum depth of the PMF at this station (8.0 feet), as determined by the HEC-2 simulation and the actual channel-bottom slope, was used in these calculations. Appendix E provides the detailed calculations. The resulting D_{50} rock size of the jetty is 6 inches.

5.6.6.5 Flood Routing - Modified Pipeline Arroyo Channel

The PMF was routed through the Pipeline Arroyo channel as configured in this plan to evaluate the effectiveness of the planned channel and embankment modifications. The COE's program HEC-2 was used to simulate the passage of the PMF of 26,300 cfs through the modified arroyo channel. Appendix E includes the simulations. The simulation for reaches 1 and 2 (station 0+00 to station 61+40) was conducted for the subcritical flow conditions that will occur in these reaches, while the simulation for reach 3 (station 61+40 to station 82+90) was performed to model the supercritical flow conditions occurring in this reach.

Figures 5-1 and 5-2 show the extent of the PMF floodplain, while Figure 5-10 shows the profile of the PMF maximum WSEL. The PMF fills most of the wide valley north of the tailings impoundment. The WSEL of the PMF stays below the top of the protective bench from station 35+00 to station 80+10 (Figure 5-10). Thus, the bench will protect the embankment toe, and will keep the runoff control ditch above the PMF level. The average velocities and depths of the PMF within Pipeline Arroyo along the 5H:1V side slopes of the protective bench were determined by the HEC-2 program and are summarized below:

Station No.	Average Velocity (fps)	Depth (feet)
82+90	0	0
80+10	0	0
73+80	0	0
63+80	0	0
62+30	0	0
61+40	2.79	1.0
60+40	5.92	3.5
57+75	6.40	4.6
50+00	3.82	4.0
41+95	3.91	3.0
35+00	0.97	0.5

Downstream of station 63+90, the PMF is contained within the Pipeline Arroyo channel and does not reach the overbank area or the protective bench.

While some portions of the side slope of the protective bench will be contacted by water produced during the PMF passage, the low-flow velocities along the side slopes indicate that little scouring will occur during this one-time event. Evaluation of the scour amount was completed using the methods described in the Bureau of Reclamation's Technical Guideline for Computing Degradation and Local Scour (Pemberton and Lara, 1984). Appendix E provides the detailed scour calculations.

The evaluation indicated the maximum expected lateral bank scour during the PMF passage was 4.9 feet. As shown on Figures 5-12 and 5-13, the runoff control ditch will be located 14 feet from the protective bench edge, and the tailings embankment toe is 40 feet from the protective bench. Thus, the PMF will not contact either the runoff control ditch or the tailings embankment toe.

The flow capacity was evaluated for the portion of the low-flow channel protected from erosion by the nickpoint rock to determine what flow rate would be required to exceed the low-flow channel. At Station 59+50, the low-flow channel bottom and west bank will be protected by the nickpoint rock, while the east bank will be protected by the buried jetty. The low-flow channel in this area will have a bottom width of 30 feet, 3H:1V side slopes, and a depth of 4.0 feet. HEC-2 simulations were used to determine that 2,250 cfs will be contained within this low-flow channel. This flow is slightly greater than the peak discharge of the 100-year flood of 2,100 cfs for Pipeline Arroyo. Thus, the low-flow channel is capable of containing all low flows up to, and including, the 100-year flood.

5.6.6.6 Stability of the Jetty and Pipeline Arroyo Below Jetty

Some potential exists for headcuts to form at the Pipeline Arroyo channel banks downstream of the buried jetty, when flows are greater than those that could be contained in the low-flow channel, i.e., flows greater than 2,250 cfs. These flows would pass across areas not protected by riprap and into the channel below the nickpoint. The increasing depth from the channel bank to the channel bottom, within the nickpoint, will capture these flows and allow potential headcut formation that could migrate towards the jetty. The location of the headcuts will depend upon the water-surface elevation of the flows.

Flows greater than 2,250 cfs have a recurrence interval greater than approximately 110 years. Therefore, in a 1,000-year period, flood events with peak discharges greater than 2,250 cfs should occur, on the average, only nine times. Consequently, in a given year, the probability of occurrence of a flood event greater than 2,250 cfs is less than 1 percent and flows will remain within the low-flow channel more than 99 percent of the years.

As shown on Section B-B' of Figure 5-9, any potential headcuts will have to start at least 150 feet downstream from the jetty, at the beginning of Reach 3. The low-flow channel remains stable for this distance at a constant small slope on the nickpoint rock. Thus, the propensity for creating headcuts will not exist in the first 150 feet below the jetty because any flows in the overbank area will be traveling parallel to the channel banks.

The channel slope begins to increase 150 feet from the jetty. At this point, the channel will be able to carry more flow and will capture any overbank flow. As this overbank flow enters the channel, it could induce headcut formation beginning at this location. Any headcuts formed at this point will be shallow headcuts because the channel depth is shallow.

Headcuts that could affect the toe of the jetty will have to start at least 308 feet downstream from the buried jetty. As shown on Section C-C' of Figure 5-9, the toe of the jetty will extend downward to an elevation of 6,923 feet at Station 59+70. Assuming a headcut channel slope of 0.01 ft/ft, a potential headcut will have to form at or below Station 62+78, where the Pipeline Arroyo channel bottom is at elevation 6,920 feet, to be below elevation 6,923 feet at the toe of the jetty. This potential headcut could migrate only about 308 feet from Station 62+78 to Station 59+70.

Only the large, more infrequent flood events will be able to remain in the overbank area 308 feet downstream from the jetty. Thus, the likelihood of a large flood event is extremely small. For example, the PMF is fully contained within the Arroyo 420 feet downstream of the jetty.

Given the unlikely scenario that a potential headcut migrated from below Station 62+78 to the jetty by the occurrence of nine or less flood events, additional flood events with recurrence intervals greater than 110 years will be required to breach the jetty and migrate upstream from the jetty, further reducing the likelihood of a potential headcut breaching the jetty within a 1,000 year period.

Finally, even in the unlikely event of a potential headcut breaching the jetty, the headcut would then migrate directly upstream parallel to Pipeline Arroyo, and thus parallel to the protective bench at the toe of the tailings embankment. Therefore, a potential headcut will not intercept the tailings embankment. In addition, the runoff control ditch on the protective bench will intercept runoff from the tailings embankment, ensuring that potential tributary headcuts do not form on or towards the embankment.

Therefore, considering the many reasons provided above, headcut formation is extremely unlikely to breach the jetty and create conditions that could cause the release of tailings in a 1,000-year period. It follows logically that such an occurrence in a 200-year period is infinitely smaller.

5.6.6.7 Geomorphic Effects - Modified Pipeline Arroyo Channel

The long-term stability of the Pipeline Arroyo channel was evaluated in terms of the potential channel bank erosion, the potential for meander formation, the effects of the nickpoint and jetty reinforcement of the nickpoint by the buried jetty, on channel geomorphology.

Channel Erosion - The design of the reconfigured Pipeline Arroyo creates little change to the existing erosional and geomorphic conditions within the valley. The channel slopes will remain extremely flat (0.003 ft/ft) in reaches 1 and 2 (Station 0+00 to Station 61+90). Thus, the erosional capacity of all flows in these reaches will be minimized. The steeply sloped area within the nickpoint will be protected from erosion by the nickpoint rock. The jetty will also ensure that flows remain on the nickpoint at a location as far as possible from the tailings embankment. Some erosion is expected in reach

3, below the nickpoint, but the channel slopes in this reach will remain at their existing values (0.0118 to 0.0220 ft/ft) to minimize this erosion. In addition, the vast volume of material in the area between the Pipeline Arroyo and the tailings embankment effectively prevents the release of tailings due to channel erosion, within a 1,000-year period.

The North Diversion Ditch and South Cell Drainage Channel enter the Pipeline Arroyo with the same channel-bottom elevation as the arroyo in the respective locations (Figures 5-1 and 5-2). Also, both the North Diversion Ditch and the South Cell Drainage Channel are separated from the tailings by a reach cut through rock. Erosion in the reaches downstream from the rock cuts will not be able to affect the reaches upstream from the rock cuts. Thus, the rock cuts provide long-term stability for these channels.

Meander Growth - An evaluation of potential meander growth along Pipeline Arroyo was conducted to assess the likelihood of the release of tailings due to this geomorphic phenomenon. The evaluation first characterized existing meander patterns of the Pipeline Arroyo and a nearby similar arroyo. These characteristics were then applied to the modified-channel configuration and location, and the potential impact was identified.

Figure 5-14 shows the channel reaches and watersheds, characterized in the watershed known as Hard Ground Canyon, which is about 5 miles northwest of Pipeline Arroyo. The two watersheds are similar in size, soil and vegetation characteristics. The channels draining these watersheds are also similar, in that their lower reaches are deeply incised, probably by headcutting that has migrated from downstream areas. The headcuts have been terminated by sandstone outcrops (nickpoints), resulting in the formation of large alluvial-fill valleys upgradient of the nickpoint. The channels upgradient of the nickpoints have shallow slopes.

Table 5.12 provides the meander characteristics for the two channels. As can be seen, a wide range in channel slopes exists. However, the range of meander amplitudes (lateral distance from meander trough to meander peak) is quite small. Thus, channel slope does not have a strong influence on meander amplitude for these channels. The average meander amplitude for the two channels is 155 feet with a maximum amplitude of 570 feet within Pipeline Arroyo and 350 feet in Hard Ground Canyon. These maximum values may have been influenced by rock outcrops or variations in soil characteristics.

Comparison of the distances between the Pipeline Arroyo channel and the tailings with the 155-foot average meander amplitude indicates meander growth will not cause the release of tailings. As shown on Figures 5-1 and 5-2, the distance between the channel and the tailings ranges from 335 feet at station 36+50 to 680 feet at station 76+00. Figures 5-12 and 5-13 illustrate this relationship at stations 41+95, 60+40 and 73+80. These distances are all greater than the 155-foot average meander amplitude and approach the maximum amplitudes noted for the two channels. Thus, even if all the meander growth were in the direction of the tailings impoundment, the meander will still be greater than 180 feet from the tailings embankment and will not result in the release of tailings.

5.7 Rock Riprap and Bedding Material

Rock riprap and bedding material layers have been designed for many surface water control swales, channels and ditches to provide long-term stability for the tailings impoundment and radon attenuation soil cover. Tables 5.5, 5.6 and 5.7 summarize the gradation requirements for the riprap and bedding materials. Appendix E includes the calculations for these designs.

5.7.1 Bedding Material Requirements

Rock riprap is designed to provide erosion protection for the PMF events in each channel. As shown in Table 5.7, a filter-blanket, bedding layer is planned under many of the riprap layers. A filter layer prevents the migration of underlying finer-grained soil into the riprap layer to maintain riprap stability during large, high-velocity flow events. Loss of fine-grained soil from the foundation layer, due to migration, can create voids in the foundation material, and lead to riprap failure from loss of support. Accordingly, filter layers have been designed to prevent the migration of fine-grained soil and the riprap failure. In some areas, the riprap is sufficiently fine that filter layer is not required.

Filter layers have been designed, based on criteria presented in NUREG/CR-4480. Two filter layers are required in all locations where bedding material is used. The primary filter will consist of a well-graded mixture with a D_{50} of 0.02 inches (Table 5.7), which will prevent upward migration of the fine-grained soils (silts and clays) in the foundation material. The secondary filter/bedding layer will prevent migration of the fine fraction from the primary bedding layer. The secondary filter/bedding layer will consist of a well-graded material with a D_{50} of 0.35 inches (Table 5.7). Table 5.7 presents more complete gradation requirements.

The primary and secondary filters/bedding layers will have a minimum thickness of 3 inches. Filter material will consist of hard durable material meeting the same durability requirements as the riprap. Filter material used on-site will be tested for the same parameters, and at the same frequency as riprap material.

5.7.2 Rock Riprap Selection

The rock riprap at the United Nuclear site will be subjected to "occasionally" to "seldom" saturated conditions (NRC, 1986). Therefore, freeze-thaw resistance, abrasion and chemical weathering are less important. The intermediate and poor ratings of the limestone samples (Section 3.0) for absorption and abrasion criteria are also less critical than they might be for frequently saturated areas.

NRC guidelines identified in Appendix D, August 1990 Staff Technical Position (STP), "Design of Erosion Protection Covers for Stabilization of Uranium Mill Tailings Sites" suggest that, to be suitable for use as riprap in occasionally-to-seldom saturated areas, rock should have quality scores from 50 to 65. A minimum score of 65 is necessary for rock riprap placed in critical areas. 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.

Testing the limestone rock source considered for use as riprap in critical areas produces a range of rock quality ratings from 57 using all worst-case test results to 67 using all best-case test results. Table 3.4 provides the test results and rating calculations. Thus, the rock-quality rating of this rock may at times be less than 65. In License Condition 34, the NRC requested the rock source for riprap to be placed in critical areas have a quality score of at least 65. Alternatively, a lower score of at least 50 is acceptable, if it can be demonstrated that the cost of obtaining adequate rock meeting the criterion is excessive, compared to the benefit of using better rock. The cost of obtaining, transporting and placing limestone rock is estimated at $54 per cubic yard for rock larger than 12 inches in diameter and $25 per cubic yard for rock less than 12 inches in diameter.

The commercial source of basalt rock investigated, from the Grants, New Mexico area--approximately 80 miles from the site, has rock up to 30 inches in diameter with a rock quality rating of 93. Table 3.5 provides the test results and rock quality rating calculation for this rock. The cost for obtaining and placing this rock is generally the same as for the limestone. However, transportation of the rock will add approximately

TABLE 2

SCORING CRITERIA FOR DETERMINING ROCK QUALITY

Laboratory Test	Weighting Factor			Score										
	Limestone	Sandstone	Igneous	10	9	8	7	6	5	4	3	2	1	0
					Good			Fair			Poor			
Sp. Gravity	12	6	9	2.75	2.70	2.65	2.60	2.55	2.50	2.45	2.40	2.35	2.40	2.25
Absorption, %	13	5	2	.1	.3	.5	.67	.83	1.0	1.5	2.0	2.5	3.0	3.5
Sodium Sulfate, %	4	3	11	1.0	3.0	5.0	6.7	8.3	10.0	12.5	15.0	20.0	25.0	30.0
L/A Abrasion (100 revs), %	1	8	1	1.0	3.0	5.0	6.7	8.3	10.0	12.5	15.0	20.0	25.0	30.0
Schmidt Hammer	11	13	3	70.0	65.0	60.0	54.0	47.0	40.0	32.0	24.0	16.0	8.0	0.0
Tensile Strength, psi	6	4	10	1400	1200	1000	833	666	500	400	300	200	100	0

LIMESTONE ROCK QUALITY RATINGS

Lab Test	Result	Score	Weight	Score x Weight	Maximum Score
Specific Gravity	2.61	7	6	42	60
Absorption, %	1.22	4	5	20	50
Sodium Sulfate, %	6.90	6	3	18	30
L/A Abrasion, %	8.70	5	8	40	80
Schmidt Hammer	51	6	13	78	130
Tensile Strength, psi	670	6	4	24	40
Totals				222	390

Rating: 222/390x100% = 57

TABLE 1

SAND, ROCK, RIPRAP GRADATION REQUIREMENTS

Percent Passing by Weight

D_{50} (inches) / Sieve Size:	20 inch	15 inch	12 inch	10 inch	6 inch	5 inch	4 inch	3 inch	1 inch	3/4 inch	No. 4	No. 10	No. 40	No. 200
.02								100		85-100	65-100	47-94	23-70	15-30
.35								65-100		43-80	22-60	15-38	5-12	0-10
1.5								100	8-37		0-8			
3.0					100		45-67		0-22					
6.0				100	28-51		13-36		0-9					
9.0		100		45-58		10-33		0-23						
15.0	100		28-40		8-21		2-14	0-10						

$17 per cubic yard to the emplaced cost. This represents a 61 percent increase in the cost of the smaller rock and a 31 percent increase in the cost of the larger rock.

The total volume of rock needed in the critical areas for both riprap and bedding material is estimated at 33,500 cy. Thus, the additional cost of transporting the rock from the Grants source is approximately $569,500. United Nuclear deems this amount excessive.

All other sources of rock identified to-date are either more distant than the basalt source, or consist of rock with a minimum rating of less than 65. As a result of NRC review comments, United Nuclear has agreed to provide riprap with a minimum rating of 65 for all critical areas (i.e., Buried Jetty, Runoff Control Ditch, North and South Cell Drainage Channels, and existing North Diversion Ditch). United Nuclear also agreed to further investigate and test other rock sources to identify rock meeting this criterion. Based on the test results, United Nuclear will either propose procedures for meeting this criterion, or propose and justify the use of the best quality rock available near the Church Rock facility. United Nuclear will also investigate alternative testing techniques to identify acceptable test techniques more applicable to limestone materials than testing performed to-date.

5.7.3 Rock Riprap Requirements

The exact rock sources to be used for erosion protection in final reclamation have not been identified. However, based on the rock selection considerations in the previous section, the following requirements have been developed for rock material quality used as riprap.

Rock used as riprap will be tested to determine rock durability for the following criteria: specific gravity, absorption, soundness and the L.A. abrasion test. The rock will be sampled and the tests performed consistent with the NRC's August 1990 STP. The source for material used for riprap and rock mulch shall be dense limestone and shall meet the following minimum criteria:

1.	Specific Gravity	2.6 or greater
2.	Absorption	1.8 percent or less
3.	Sodium Sulfate Loss	10 percent or less

Alternatively, the rock source shall have a minimum score of 50 using the scoring criteria shown on Table D1 of the August 1990 STP and will be oversized, if needed, in accordance with the procedures in Appendix D of the August 1990 STP.

5.8 Revegetating Disturbed Areas and Securing Reclaimed Areas

At the completion of final reclamation, disturbed areas will be revegetated, and the reclaimed areas secured to prevent unauthorized access.

5.8.1 Revegetation Considerations

The areas revegetated in final reclamation will consist of areas disturbed by reclamation construction activity, but not covered with the soil/rock matrix. Revegetation requirements have been developed based on species currently on-site, discussion with local SCS representatives, and adaptability of species to the site. Sod and bunchgrass species have been selected to provide soil stability and to minimize erosion. The native-seed mixture for permanent revegetation, presented in Table 4.2, will be planted between mid-June and mid-September to allow for favorable moisture and temperature conditions.

During final reclamation, the following areas will be revegetated with the permanent seed mixture shown in Table 4.2. Approximately 40 acres will require revegetation, including Catch Basins Nos. 1 and 2, and the regraded area between the embankment and the Pipeline Arroyo. These recontoured areas are shown on Figures 5-1 and 5-2.

The areas to be revegetated will be prepared in the following manner:

1. The area will be recontoured using construction equipment and prepared for seeding by disking or harrowing along the contours.

2. Soil samples will be taken from the areas prepared for seeding to determine soil fertility. Analyses will assess the amount of nitrate-nitrogen, phosphorus, organic matter, and potassium contained in the areas to be revegetated.

3. The permanent seed mixture (Table 4.2) will be planted using one of two seeding methods, including drill or broadcast seeding. The primary seeding method will be drill seeding. Drill seeding offers uniform placement of seeds, requires fewer seeds per acres planted, and can be drilled directly into a preparatory crop stubble, providing a uniform stand of seeded plants. Broadcast seeding is not considered as effective as drill seeding due to uneven seed distribution and, if seeds are not properly covered with soil, seed desiccation can occur. If broadcast seeding methods are used, the application rate in Table 4.2 will be doubled.

4. Mulch will be applied to all seeded areas planted with the permanent seed mixture to conserve soil moisture and to protect the bare soil from water- and wind-induced erosion. Mulch will be applied immediately after seeding and fertilization. If a stubble stand has been developed through the use of a preparatory crop, mulching may not be required. This point will be decided

at the time of seeding. No slopes will be greater than 5H:1V. Accordingly, no special mulch, such as jute netting, cellulose fiber, exclusion mat, etc., will be required.

5.8.2 Maintenance and Revegetation

The success of the revegetation will be evaluated yearly with respect to desired germination levels. If the desired results have not been achieved, the area(s) requiring reseeding will be seeded with permanent seed mixture.

5.8.3 Secure Fencing

Existing barbed-wire fencing will be used to control access into the majority of the reclaimed areas. The fencing will prevent livestock grazing and will remain in place as long as United Nuclear is responsible for maintaining the areas. Permanent fencing will be installed at the time of license termination to separate areas to be deeded to the U.S. Department of Energy.

5.9 Materials Balance

To understand the material balance during final reclamation, this section summarizes where various materials will be obtained and placed. Excavation and grading operations during final reclamation are planned, as shown on Figures 5-1 and 5-2, to provide materials handling flexibility and an approximate balance between cut and fill quantities. Estimated areas and volumes for each major materials handling activity are presented in Table 5.13 and discussed briefly below.

Borrow Pit No. 2 - Borrow Pit No. 2 will have been backfilled with mill demolition debris and excavated ore-pad materials during interim stabilization. During final reclamation, approximately 155,000 cy of material, including catch-basin materials, unsuitable soil-cover materials, and other soil as necessary, will be required to bring the surface of the borrow pit to the final grades shown on Figures 5-1 and 5-2.

Pipeline Arroyo - The Pipeline Arroyo, will be modified to have a consistent 30-foot-wide low-flow channel, and the protective bench between the arroyo and the runoff control ditch. This modification will occur during final reclamation over about 27 acres, and will require the excavation of approximately 36,000 cy and placement of approximately 103,000 cy of soil. This results in a net fill requirement of 67,000 cy. The extra soil required for the fill sections will be taken from the South Cell Drainage Channel excavation.

South Cell Drainage Channel - The South Cell Drainage Channel will be extended to the Pipeline Arroyo (Figure 5-1) to allow PMF passage. This channel excavation will provide approximately 84,000 cy of soil, expected to be used in fill sections near the Pipeline Arroyo.

Soil Stockpile - The existing soil stockpile will be used as a source for cover materials, evaporation pond backfill and Borrow Pit No. 2 backfill as needed. It is estimated the existing stockpile contains approximately 325,000 cy of material. An additional 135,000 cy is available from excavating existing soils beneath the pile if necessary. An anticipated 352,600 cy of material from the stockpile will be used in the radon attenuation layer of the soil cover, the soil/rock matrix, and for backfill in the evaporation ponds and the borrow pit.