2

2.0 SITE RADIOLOGICAL SURVEY

A radiological survey of the Church Rock facility was conducted for the purpose of assessing the radiological characteristics of the site and to form a basis for reclamation planning, in accordance with NRC regulations (Appendix A of 10 CFR 40). These standards stipulate that remediation is generally required when the Radium-226 (Ra-226) concentration, averaged over areas of 100 square meters, exceeds the background level by 5 picoCuries per gram (pCi/g) in the first 15 centimeters (cm) of soil or 15 pCi/g in any 15 cm layer of soil below the first 15 cm.

The survey primarily consisted of 1) determination of soil radium concentrations and gamma ray exposure rate background values, 2) a gamma ray exposure rate survey of the mill and tailings disposal area, 3) borehole logging for subsurface characterization of Ra-226 levels, and 4) soil sample collection and analysis to determine the soil Ra-226 activity concentration.

Radiological surveying was performed by Western Radiation Consultants, Inc. (Fort Collins, Colorado) under subcontract to Canonie Environmental Services Corp. (Canonie) for Canonie's use in determining the type and extent of reclamation required on the site. Details of the radiological survey are described in the following sections.

The survey was conducted using the following systematic steps:

1. Determine natural (i.e., background) Ra-226 concentrations in site soils through sampling and laboratory analyses of soils taken from areas unaffected by uranium processing activities.

2. Determine background gamma ray exposure rates in areas unaffected by uranium processing activities.

3. Conduct a systematic gamma ray exposure survey of the site.

4. Collect soil samples for laboratory determination of Ra-226 concentrations where gamma ray exposure rates were observed to exceed 4 microroentgens per hour (μR/hr) above background, as described in NUREG-2954 (NRC, 1983a), and in other areas of concern.

5. Correlate laboratory-determined concentrations of Ra-226 with gamma ray exposure readings.

6. Drill boreholes in areas where surface gamma ray exposure readings were greater than 4 μR/hr above background, and in other areas of concern, to estimate Ra-226 concentrations in layers of soil below the first 15 cm.

7. Delineate areas to which Appendix A of 10 CFR 40 criteria may apply by comparison of observed or estimated by-product Ra-226 concentrations at the site to the background Ra-226 concentration.

The areas surveyed in accordance with this approach as part of this program are shown on Figures 2-1 through 2-5 and include:

1. Three background areas to determine natural concentrations of Ra-226 at the site and background gamma ray exposure rates.

2. A radial grid centered on and extending from the approximate center of the tailings disposal area.

3. Areas proximate to the tailings disposal site to identify areas affected by tailings.

4. The mill site and facilities area, excluding actual structures.

2.1 Survey Methods and Procedures

Consistent with regulatory guidance, a practical methodology using correlations between gamma ray exposure rates and Ra-226 concentrations was employed to identify areas of high Ra-226 levels, and is described in NUREG/CR-2954 (NRC, 1983a). These relationships indicate that Ra-226 concentrations greater than 5 pCi/g above background due to residual radioactivity are almost never present in soils at locations having gamma ray exposure rates of less than 4 μR/hr above background levels.

The areas surveyed include three background areas to estimate preoperational radiological characteristics of the site, the mill site itself (in the northeast quadrant of Section 2), the area surrounding the tailings impoundment (Section 2), and areas of potential wind-blown tailings activity (Sections 2 and 36). All areas are shown on Figure 2-1.

Ra-226 concentrations in soils were estimated by 1) a gamma ray exposure survey for near surface soils, 2) a borehole logging survey for subsurface characterization of soils, and 3) soil sample collection and laboratory analyses to determine Ra-226 concentrations. All three types of surveys were conducted in the background areas to determine baseline comparison values.

Delineation of areas planned for remediation, as shown on Figure 2-4, was accomplished by visual interpolation of gamma ray activity data points. Identification of these areas does not necessarily indicate the existence of areas exceeding the by-product action level criteria because the technique of averaging Ra-226 concentrations over a 100-square-meter area was not used.

2.1.1 Gamma Ray Exposure Survey

The gamma ray exposure surveys were performed using a Precision 111B scintillometer calibrated against a Pressurized Ion Chamber (PIC). All measurements were made at approximately one meter above the surface. For areas where the unshielded instrument recorded a value greater than 4 μR/hr above background, a measurement was also made with the detector shielded with an annulus of lead approximately 1.5 cm (0.6 inches) thick. Shielded and unshielded Precision 111B measurements were correlated with measured surface soil Ra-226 concentrations.

2.1.2 Borehole Measurements

Boreholes were drilled in areas selected on the basis of surface gamma ray exposure survey readings greater than 23 μR/hr to obtain gamma ray exposure readings below the ground surface. This gamma ray action level was developed using the correlation between Ra-226 and gamma ray exposure rates as discussed in NUREG/CR-2954 (NRC, 1983a). In areas accessible to a truck-mounted auger, holes were drilled to a depth of approximately three meters (10.0 feet). In other areas, where possible, holes were dug using a hand-operated gas-powered auger or a simple hand auger. The locations of the boreholes were dictated by accessibility and soil conditions.

The borehole logger used was a Victoreen Thyac III Model 490 survey meter and a Model 489-55 NaI probe with a 3.5-meter (11.5-foot) cable. The barrel of the probe was encased in a layer of thinsulite foam [approximately 1.0 cm (0.4 inch)] and a plastic bag to protect it from shock, sudden temperature changes and moisture. All cable connections were wrapped with electrical tape to reduce stress on the connections when the probe was suspended.

The borehole logger cable was marked at 15-cm (0.5-foot) intervals. Readings were generally made in the boreholes drilled at the surface and in the center of each subsequent 15-cm (0.5-foot) interval to a depth of two to three meters (6.5 to 10 feet). In some cases, where exposure rates were changing rapidly with depth, 5.0-cm (0.2-foot) intervals were used. However, graphs of exposure rate versus depth were nearly identical for both interval readings.

2.1.3 Soil Sample Collection and Analyses

Cuttings were collected from boreholes at 15-cm (0.5-foot), 30-cm (1.0-foot), 1.0 meter (3.3 feet), 2.0 meters (6.6 feet), and 3.0 meters (10.0 feet) depths for radiological analyses in the laboratory. The samples were placed in one-gallon plastic bags and labeled with borehole identification and depth.

Samples were also collected from drill holes at 0 to 15 cm (0 to 0.5 feet), 15 to 30 cm (0.5 to 1.0 feet), and in some cases, 30 to 45 cm (1 to 1.5 feet). All soil samples were placed in one-gallon plastic bags, marked with the location, depth, and date of collection. Samples were stored in an on-site storage room. Selected soil samples were sent to Colorado State University (CSU) for analysis.

Soil samples were dried, pulverized, and packed into one-quart (946 milliliter) steel cans. The can lid was fitted securely and sealed with silicone sealant. A Ra-226 in-growth period of at least 20 days was allowed before counting.

The sample cans were counted by a shielded Ge(Li) high resolution gamma ray spectrometry system. Ra-226 activity concentrations was calculated from the net spectral area under either the 0.60932 megaelectron volts (MeV) peak or the 1.7645 MeV peak, due to the gamma rays of Bi-214. Uranium-238 (U-238) concentration was calculated from the net spectral area under the gamma rays of Pa-234 at 0.0947 MeV and 0.984 MeV. Secular equilibrium with the parent U-238 was assumed.

A representative fraction of the soil samples obtained in areas around the tailings disposal area was analyzed by the CSU gamma ray spectroscopy laboratory for Ra-226 and U-238. These analyses were performed to obtain actual Ra-226 activity concentrations and to establish the equilibrium relationship between the two radionuclides.

2.2 Background Determination

Three background areas, illustrated on Figure 2-1, were surveyed to estimate pre-operational radiological conditions at the mill and tailings disposal areas as a basis for ascertaining the radiological impact of site operations. The background areas were selected on the basis of distance and direction from the tailings and their locations opposing the predominant wind direction. Plot No. 1 is located in the southeast corner of Section 3 on both the east and west sides of Highway 566. Plot No. 2 is located in the southwest area of Section 35, west of the water towers. Plot No. 3 is located in the southeast corner of Section 2.

2.2.1 Radium in Background Soils

Table 2.1 presents results of laboratory analyses for Ra-226 concentrations in composite soil samples obtained from the three background test plots illustrated on Figure 2-1. The weighted overall mean of the measurements was 0.78 pCi/g Ra-226 with a standard deviation of $\pm$0.53 pCi/g. The value of 1 pCi/g Ra-226 was selected as the background concentration for the site, based on the upper 95 percent confidence interval of the mean as shown in Table 2.1. On this basis, the remediation criteria identified in Appendix A of 10 CFR 40 indicate that 6 pCi/g Ra-226 (5 pCi/g plus background) is the target acceptable limit for surface Ra-226 activity and 16 pCi/g Ra-226 activity is the target acceptable limit for depths greater than 15 cm.

2.2.2 Gamma Survey

Fifty gamma ray exposure rate measurements were made at each background area. Table 2.2 summarizes results of unshielded gamma ray exposure readings measured on the background plots. These readings were obtained as a baseline for comparison to areas affected by tailings. As indicated in Table 2.2, the mean (corrected) background external gamma ray exposure rate is 15 μR/hr with a standard deviation of 12 percent. Statistically, the probability of observing a background gamma ray exposure rate of between 11.5 and 18.5 μR/hr is 95 percent. The probability of observing a gamma ray exposure rate greater than 18.5 μR/hr, which is due only to background, is 2.5 percent.

The mean background gamma ray exposure rate (15 μR/hr) was first used as the basis for identifying areas around the tailings disposal area and mill facilities area that required more extensive evaluation. Areas showing gamma ray exposure rates of 4 μR/hr or greater above background (i.e., $\geq$19 μR/hr) were subjected to further assessment (shielded readings, borehole logging, and/or soil sampling/analyses).

Table 2.3 presents the correlations between Ra-226 soil activity concentrations versus measured gamma exposure rates as determined using simple linear regression analysis. The 6 pCi/g Ra-226 correlates to a gamma ray exposure rate of 23 μR/hr. This value was used as the action level for determining Ra-226 at the surface in lieu of soils laboratory analyses.

2.2.3 Borehole Logging

Gamma spectroscopy measurements were made and drillholes advanced with a gas auger at 10 to 13 locations in each plot. The drillholes were logged with the downhole gamma ray logger, and soil samples were collected for determination of radium concentrations, as previously described. Borehole logger readings were obtained in these two background plots to assist in calibrating the borehole logger for correlation of readings to Ra-226 concentrations below the first 15 cm soil thickness. Table 2.4 presents results of those readings for background Plots No. 1 and No. 3. Due to the shallow bedrock surface and rocky nature of background Plot No. 2, no drillholes could be advanced in that area. All drill hole measurements are reported as dimensionless values since actual meter readings are meaningless, except as indirect relative measurements between borehole Ra-226 concentrations. As shown in Table 2.4, the mean background borehole logger (BHL) reading was 1.7.

Correlations between Ra-226 activity concentrations and borehole logger readings were developed for holes drilled by truck-mounted rig (boreholes) and drilled by hand auger methods (drillholes) to develop action levels for subsurface soils.

These correlations were also developed using simple linear regression analysis. The derived values differ for truck-mounted auger boreholes and hand auger drillholes because of the difference in diameters between the boreholes and drillholes. The derived correlations for the boreholes and drillholes are presented in Tables 2.5 and 2.6, respectively.

The estimated mean borehole logger reading for a Ra-226 activity concentration of 6 pCi/g is 5.6 (dimensionless) for truck-mounted auger boreholes. A Ra-226 activity concentration of 16 pCi/g for truck-mounted auger boreholes corresponds to an estimated mean borehole logger reading of 12.8 (dimensionless).

Similarly, the estimated mean borehole logger reading for a Ra-226 activity concentration of 6 pCi/g is 3.9 (dimensionless) for hand auger drillholes. A Ra-226 activity concentration of 16 pCi/g for hand auger drillholes corresponds to an estimated mean borehole logger reading of 10.1 (dimensionless).

These values were used as action levels in assisting in a determination of areas that may require reclamation.

2.3 Site Survey Results

2.3.1 Areas Adjacent to the Tailings Disposal Area

Areas adjacent to the tailings disposal area were surveyed by all three methods described previously, including gamma ray exposure rate measurements, BHL, and soil sampling with laboratory analysis for Ra-226.

Gamma Ray Exposure Rate Survey

The gamma ray exposure rate survey of the tailings disposal area was conducted along a radial grid as illustrated on Figure 2-1. The center point of the grid was chosen as the approximate center of the entire tailings disposal area. Eighteen radial lines were set with stakes at 50-meter intervals, and readings were taken at each point. The starting point for each radial line was the outside edge of the tailings embankment. The radials in the direction of the prevailing wind were set at angles of separation of 11.5 degrees. In other directions, the radials were set at 30-degree angles of separation. Radials were not set to the east because of inaccessibility to the area.

At locations where an unshielded measurement was greater than 4 μR/hr above background, indicating the possibility of elevated Ra-226 concentrations, a measurement was also made with a 1.5-cm lead annulus shielding the detector. The results of the gamma radiation survey in the tailings disposal area vicinity and Pipeline Arroyo area are shown on Figures 2-1 through 2-3.

More extensive gamma ray exposure rate measurements were made and boreholes were drilled in areas that had unshielded gamma exposure rates greater than 4 μR/hr above background, based on the radial survey. Four such areas were identified: the area between Highway 566 and the tailings disposal areas, the area to the northeast of the tailings in the predominant wind direction, the topographically elevated area directly west of the east boundary line for Section 2, and an area along Radial "N." The results of these measurements are shown on Figures 2-1 through 2-3 and indicate the extent of wind-blown tailings is limited primarily to the northeast corner and a short distance northeast from the corner of the tailings disposal area, as shown on Figure 2-4.

Borehole Logging

Boreholes were drilled in areas accessible to the truck-mounted auger at the locations identified on Figures 2-1 through 2-3. Measurements were made in these holes using the downhole logger as described in Section 2.1. Drillholes were advanced with either a gas-powered auger or a hand auger in locations inaccessible to the truck-mounted auger. The locations of these drillholes are also shown on Figures 2-1 through 2-3.

A representative number of soil samples was selected for Ra-226 analysis to confirm the borehole logging results. The results are shown in Tables 2.7A through 2.7E. The borehole logging results indicate two limited deposits of tailings outside of the tailings embankment. One is located along radial "N" southwest of the South Cell as shown on Figure 2-1. The other area is located in the south half of the west side of the embankment. These two areas were apparently created when a two-foot thick blanket of coarse tailings sands was placed as a drain for future expansion of the south half of the tailings embankment. The blanket was covered to varying depths with compacted soil, which formed the base of the expanded embankment. The bottom of this drain blanket was encountered at depths ranging from 1.0 meter (3.3 feet) to over 2.3 meters (7.5 feet). Table 2.8 summarizes the depths at which the 16 pCi/g level for Ra-226 activity concentration was observed during borehole logging at the locations shown on Figure 2-1. Table 2.9F presents the analysis results for soil samples collected in the vicinity of the sand blanket material along radial "N."

Tables 2.9A through 2.9G identify Ra-226 concentrations in soil samples obtained at various locations shown on Figures 2-1 through 2-5. These tables also present U-238/Ra-226 ratios of the samples as a relative indication of whether the soil has been affected by ore or by-product materials. A ratio greater than one has a higher probability of being ore-related rather than tailings (i.e, by-product) material waste.

2.3.2 Mill Site

The mill area was similarly surveyed by gamma ray exposure rate measurement, borehole logging, and soil sampling and laboratory analyses for Ra-226. No survey of structures was conducted as part of this work since it is planned that the majority of building debris and equipment will be disposed of in the tailings disposal area as part of final reclamation.

Gamma Ray Exposure Rate Survey

A gamma ray exposure rate survey of the mill site was conducted on an approximate 10-meter (33-foot) grid, as shown on Figure 2-5. The grid spacing was plotted on a site plan and paced off in the field using landmarks from the site plan. The results of the survey are also shown on Figure 2-5.

A portion of the mill area was paved with asphalt after mill startup. Surface presence of by-products, which occurred after the placement of asphalt pavement, was revealed by the gamma ray exposure rate survey. However, determining if these radiological elements were present before paving is not possible with this method.

Elevated gamma ray exposure rates were noted in the vicinity of the ore storage pad, mill building, clariflocculator (CCD) tank, and sewage treatment plant. The overall gamma ray exposure rates on the site were slightly elevated above background, probably due to the proximity to the ore storage pad.

Borehole Logging

Boreholes were drilled on the mill site by the truck-mounted auger wherever possible in areas of elevated gamma ray exposure rates. The borehole locations are shown on Figure 2-5. The choice of borehole locations was limited by the presence of utility lines and other obstructions on the site.

The borehole logging results are shown in Table 2.10, and the Ra-226 analyses of soil samples are shown in Table 2.11. Some of the boreholes in the vicinity of the ore storage pad and the mill building showed elevated readings immediately beneath the asphalt.

Boreholes in the ore storage area were logged using the borehole logger. The depth to 16 pCi/g for most holes was less than 50 cm (1.6 feet), but ranged as high as 120 cm (4 feet). The results of the borehole logging on the ore storage pad are shown in Table 2.12.

Surface soil samples were taken in two areas near the northeast corner of the mill area (Figure 2-5). Elevated gamma ray exposure readings in the area are likely due to the ore storage pad. The samples had Ra-226 activity concentrations of 24 pCi/g and 89 pCi/g with U-238/Ra-226 ratios of 1.7 and 0.92. The ratio of 1.7 clearly indicates the presence of ore; however, the ratio of 0.92 is inconclusive.

Based on the radiological survey, Ra-226 concentrations due to the presence of by-product materials in the mill area appear limited and, where detected, are located near the ground surface.

2.3.3 Catch Basins and Drainage Areas

The area west of the Pipeline Arroyo contains two catch basins as shown on Figure 2-4 that received drainage from the mill site. Catch Basin No. 1 received drainage from the paved area of the mill site, while Catch Basin No. 2 received drainage from the ore storage area. The catch basins were also designed to act as secondary containment in the event of failures in the tailings discharge pipeline where it crosses Pipeline Arroyo. The survey indicated the presence of elevated radiological readings in these catch basins. The results of the gamma ray surveys are shown on Figures 2-2 and 2-3. The results of the borehole logging are presented in Table 2.7D.

The depth of elevated activity in Catch Basin No. 1 is approximately 0.9 meters (3 feet) based on borehole logging results and about 1.5 meters (4.9 feet) in Catch Basin No. 2. Based on the U-238/Ra-226 ratios from gamma ray spectroscopy, Ra-226 concentration activity within Catch Basin No. 2 appears to be from ore. The results of analyses for radium in the soils for Catch Basin No. 2 are presented in Table 2.9G.

2.3.4 Wind-blown Tailings Disposal Areas

The predominant wind direction is from the southwest to the northeast as shown on Figure 2-4. The radiological survey results were evaluated to identify areas that may require cleanup due to wind-blown tailings migration. Limited areas northeast of the tailings exhibited evidence of elevated radioactivity from wind-blown tailings, as illustrated on Figure 2-4. Affected areas were evaluated on the basis of acceptable levels of Ra-226 concentrations compared to background levels, which were determined by the gamma ray exposure rate measurements, borehole logging results, and soils analyses, discussed in previous sections of this plan.

Analyses of samples from within the defined wind-blown area revealed below-background activity levels at shallow depths. Soils below 15 cm were typically found to have Ra-226 concentrations below both the 16 pCi/g limit and the 6 pCi/g surface soil limit.

Tables 2.9A through 2.9E contain the soils analyses for data points in the wind-blown tailings disposal area as shown on Figure 2-4. Wind-blown tailings also affected an area immediately north of the North Cell embankment, as indicated by soil analyses presented in Table 2.8 for Boreholes R-12 through R-17.

Figure 2-4 has been revised since the proposed plan was submitted in 1987 to include an area in Section 1 where wind-blown tailings had impacted the soil. When the plan was proposed in 1987, United Nuclear did not have permission to access Section 1 to radiologically survey the area. Accordingly, this area was not included in the discussion. When the Navajo tribe allowed access to the land, United Nuclear conducted the necessary radiological surveys. Figure 2-4 was revised to show approximately six acres in Section 1, which exhibited evidence of contamination by wind-blown tailings. As described in Section 4.0 below, United Nuclear cleaned the area impacted by wind-blown tailings from Sections 2 and 36 in 1989 and Section 1 in 1990. The results of this cleanup program are contained in reports submitted to the NRC (United Nuclear, 1989 and 1990).

2.3.5 Diversion Ditch

A gamma ray exposure rate survey of the south drainage diversion ditch, located along the east edge of the tailings disposal area (Figures 1-3 and 2-1), indicated no significant elevated readings beyond approximately 350 meters south of the northeast corner of Section 2 as illustrated on Figure 2-1. These areas within the ditch exhibiting gamma ray activity greater than 23 μR/hr (representative of a Ra-226 concentration of 6 pCi/g) were located in the northeast corner of the site and had probably been affected by wind-blown tailings.

3

3.0 GEOTECHNICAL INVESTIGATION

Geotechnical investigations have been performed to obtain data required for reclamation plan preparation (e.g., channel and cover designs), and to supplement extensive engineering investigations conducted previously at the site. The reclamation plan investigation was conducted before the proposed reclamation plan submittal in June 1987. Additional data were generated from sampling conducted during the interim stabilization activities in the North and Central Cells. These data were used to develop responses to NRC reclamation plan review comments. The investigations consisted of drilling test borings, excavating test pits, and conducting geotechnical laboratory tests to characterize the site soils. Soil samples obtained during the investigations were also selectively used to obtain radiological design parameters for the final reclamation soil cover, described in Section 5.0.

3.1 Field Exploration

Canonie performed geotechnical field explorations at the Church Rock facility as part of the reclamation plan investigation completed prior to the June 1987 submittal. Primary objectives of the investigation included:

1. Determining potential sources for soil cover borrow areas,

2. Characterizing bedrock conditions in the Pipeline Arroyo for surface water control evaluations,

3. Characterizing the mill site area for regrading design purposes, and

4. Evaluating potential rock riprap sources.

Borings were also selectively used for radiological field survey purposes as previously described in Section 2.0.

In response to NRC review comments, the data provided from previous investigations at the site and from the reclamation plan investigation were reevaluated. This review resulted in a decision to use only soil data for samples likely to be included in actual borrow areas to develop the radon attenuation soil cover. In addition, data, collected from testing the soil cover placed during interim stabilization of the North and Central Cells, and soil from the soil stockpile were also used to refine the design of the radon attenuation soil cover. The locations of samples for which data was used in the radon attenuation soil cover design are shown on Figure 3-1. Testing during interim stabilization of the North and Central Cells consisted of both in-place moisture-density tests and laboratory tests including moisture-density relationship, gradation characteristics, and Atterberg limits. The methods of data evaluation were refined in responses to NRC comments in September 1990, and the final radon attenuation soil cover evaluation, as approved by the NRC, was presented in the March 1991 response to NRC comments. These requirements for soil cover material are included in the Construction/Technical Specifications provided in Appendix B.

3.1.1 Borings

Geotechnical test borings were drilled to depths of up to 80 feet below the existing ground surface to define subsurface materials and conditions around the tailings disposal and mill tailings areas. The locations of the test borings for which data was used in the radon attenuation soil cover evaluation are illustrated on Figure 3-1. Logs of these borings drilled as part of the reclamation plan exploration program are provided in Appendix A. Drilling was conducted using a Central Mining Equipment (CME) 55 drill rig with hollow stem auger, split spoon and tube sampling, and rock coring (rotary water) methods.

As indicated in the boring logs in Appendix A, the alluvial materials are predominantly silts intermixed with varying quantities of sands and clays, ranging in depth to over 80 feet in the boreholes drilled as part of this program. Sandstones present in the vicinity of the Pipeline Arroyo nickpoint are lightly to moderately cemented. Because sufficient deposits of alluvial soils and sediments exist in the soil stockpile, the areas around the tailings, and the Pipeline Arroyo can be used as soil borrow for a tailings cover.

3.1.2 Test Pits

Test pits were excavated to refusal or depths of approximately 12 feet at the locations shown on Figure 3-1. Logs of the test pits are presented in Appendix A. The test pits were excavated using a Case 580C backhoe. The purpose of the test pits was to obtain bulk soil samples for laboratory testing of representative materials.

The soils in the north alluvial plain were excavated with relative ease and generally consisted of either a brown, clean to silty sand, or a dark brown silt with clay fractions varying from zero to 50 percent and little sand. These two types of soils are distributed in shallow zones that could be easily excavated and placed during reclamation operations to produce a homogeneous soil cover. The results of testing on the actual soil cover placed during interim stabilization of the North and Central Cells confirm the homogeneity and adequacy of the soil cover.

3.2 Laboratory Testing Program

Laboratory testing was performed on samples obtained in the field to identify the characteristics of soils and rock. Soil tests provided data necessary for the evaluation of soil erodibility, natural moisture content, specific gravity, grain size distribution, compaction, and other physical characteristics for design of the cover thickness necessary to attenuate radon flux. Rock test results allowed the evaluation of the suitability of rock material as riprap and provided an indication of the degree of difficulty that would be encountered during rock excavation. These test results were used, along with data from previous geotechnical investigations (Sergent, Hauskins, and Beckwith, 1979), to select and check parameters for reclamation soil cover design as well as data collected during placement of the interim stabilization soil cover (i.e., North and Central Cells).

3.2.1 Soils/Testing

Soil samples obtained from the borings and test pits were subjected to the following geotechnical testing:

1. Natural moisture contents
2. Specific gravity
3. Grain size distribution
4. Compaction (moisture-density relationship)

A summary of the relevant geotechnical test results for acceptable soil cover materials based on the NRC's Staff Technical Position (STP), used in developing the radon attenuation soil cover design, is provided in Tables 3.1 to 3.3. Particle size gradation curves as determined by sieve analyses for samples tested are provided in Appendix A. These data sheets also provide the soil sample description and moisture content. Moisture-density relationships as determined by the Standard Proctor method of compaction (ASTM D 698) are provided in Appendix A.

3.2.1.1 Natural Moisture Content

The natural moisture content of the soil samples was evaluated using laboratory-derived long-term moisture contents and in-situ moisture contents. Laboratory testing (Method

ASTM-D3152) of a representative soil sample to determine the long-term moisture content of the soil cover produced a value of 13.6 percent by weight. Laboratory test data are contained in Appendix C. The sample tested had a fines fraction of 65 percent. A more detailed discussion of the moisture contents used in developing the radon attenuation soil cover is presented in Section 5.0.

Evaluation of in-situ moisture content measurements from 119 representative borrow soil samples identified a long-term moisture content of 13.4 percent by weight. This value is the average moisture content of the samples tested as provided in Appendix D. Samples were obtained from available borrow soils within Pipeline Arroyo, the tailings embankment, and the soil stockpile located east of the tailings impoundment.

NRC review questioned the representativeness of these soils and indicated only samples meeting the acceptable soil cover grain-size envelope and obtained from a depth of between 120 centimeters (cm) and 500 cm should be employed in evaluating long-term moisture, based on observed moisture contents. Therefore, refined evaluation of in-situ moisture content measurements was conducted to include only the data meeting those criteria. Forty-seven soil samples were identified as meeting the gradation and depth requirements and are located in potential borrow areas. The average in-situ moisture content of these samples was determined to be 12.9 percent. This calculation is presented in Appendix D. This value of 12.9 percent was used in design of the radon barrier as described in detail in Section 5.0.

3.2.1.2 Specific Gravity

The specific gravity results indicated a range of values between 2.57 and 2.63, typical of these types of soil materials (Appendix D). A value of 2.6 was used for the specific gravity of the soil in the design of the radon attenuation soil cover as described in Section 5.0.

3.2.1.3 Particle Size Analyses

Particle size analyses were performed for soil classification purposes and to obtain data for establishing a representative site soil gradation for cover design purposes. Particle size distribution curves are provided in Appendix A. Tables 3.1 through 3.3 contain results for over 50 grain size distribution and Atterberg limits analyses for soils from the proposed borrow sources.

The data in Tables 3.1 to 3.3 were used to develop a range of soil material types with characteristics acceptable to meet the design criteria for radon attenuation. The actual soil cover material placed in the field during reclamation will be a blend of various soil types, the result of excavation and placement of the soil during construction. To address NRC review comments regarding soil uniformity, a range of allowable soil types for the soil cover was developed. The graphic envelope, shown on Figure 3-2, provides an expedient method to evaluate gradation results for soil-cover soils. Use of this envelope will ensure consistency with the soil types modeled in the soil-cover design. The radiological soil cover modeling is described in Section 5.0.

The results of grain size analyses indicate, in general, that the proposed borrow soils to be used in construction of the radon attenuation soil cover can be characterized as clay with varying fractions of silt and sand. Figure 3-2 illustrates the average soil gradation of the materials to be used in the soil cover.

The envelope of allowable soil mixtures for the soil cover (Figure 3-2), accounting for blending of all soil types as a result of excavation and placement during construction, will produce a soil cover consistent with that modeled in the design. That design and the allowable grain size distribution envelope include all blended soil types (Unified Soil Classification System) that are expected to be encountered during construction of the soil cover. The gradation curves of soil used to construct the soil cover will fall within the envelope and will classify as silty clay (CL), clayey sand (SC), silt (ML), or silty sand (SM). No individual soil type, particularly sand (SP), is represented to be suitable alone for use as the soil cover. Only those soils falling within the soil cover gradation limits shown on Figure 3-2 will be used for soil cover construction.

The data compiled for the borrow sources is adequate for the soil cover design described in Section 5.0. However, in addition to the borrow sources data described above, data have also been collected for the soil cover material placed during interim stabilization activities in the North and Central Cells. This actual field data was used in the radon attenuation soil cover design as described in Section 5.0 and provides soil data representing a significant portion of the soil cover.

Compaction

In the proposed plan submitted in June 1987, moisture-density relationships of soils within the north alluvial plain and within the arroyo were determined using the Standard Proctor method of compaction (ASTM D 698). The clayey soils most prevalent as borrow material exhibited a representative maximum dry density of about 104 pounds per cubic feet (pcf). The sands exhibited a maximum dry density of about 111 pcf. Moisture-density relationships of soil samples compacted as part of this program are illustrated in Appendix A.

The data used to determine the moisture-density relationship of soil for the radon attenuation soil cover were refined to address NRC concerns about using soil sample data from areas that may not actually be used as borrow sources for the soil cover. Only soil materials that satisfy the requirements in the specifications were used. Figure 3-2 shows the acceptable gradation envelope for soil cover material as approved by NRC. Additionally, the bulk dry density used in determining the required thickness of the final soil cover was determined using soil samples obtained from the interim stabilization cover placed in the North and Central Cells. Maximum bulk dry densities for the soil samples ranged from 109.0 pcf to 121.0 pcf (Appendix A). As presented in the soil cover evaluation in Appendix C, average values were determined for different soil types within the acceptable gradation envelope and a weighted-average value of 113.7 pcf for maximum bulk dry density of soil material was determined using the proportion of borrow soil anticipated for these soil types. A density of 108.0 pcf corresponding to a compaction of 95 percent of maximum dry density was used in the radon attenuation soil cover design.

3.2.2 Testing of Potential Riprap Sources

As part of the reclamation investigation, in preparation for submittal of the 1987 proposed reclamation plan, borings were drilled into four outcrops on or near United Nuclear's property at locations considered to be both representative and reasonably accessible for development of a quarry for riprap. The purpose of the investigation was to determine the availability of on-site sources of rock for riprap. These borings include:

1. Boring No. RR-1 drilled in the southwest quarter of Section 2 just south of the main tailings embankment,

2. Boring No. RR-2 drilled in the northwest quarter of Section 36 east of NECR,

3. Boring No. RR-3 drilled in the northeast quarter of Section 8 northeast of OCR, and

4. Boring No. RR-4 drilled in the southeast quarter of Section 34 southwest of NECR.

The logs for these borings are included in Appendix A. The potential riprap borrow sources investigated were each comprised of sandstone. The sandstone units that were cored included the Upper and Lower Dalton, Zone 1 of the Upper Gallup Sandstone, and the Lower Gallup Sandstone. Each unit was easily cored. Visual inspection of the cores indicated that none of the units would be suitable for use as a source of riprap although testing of rock samples was still performed to verify this conclusion.

Rock samples of on-site sandstone units were prepared for slake durability testing to evaluate their suitability for use as a riprap borrow source. However, due to the poor quality of the sandstone units found on-site, none of the core samples remained intact during simple preparation of the samples. Accordingly, none of the on-site rock sources can be considered satisfactory for use as riprap borrow.

In response to NRC review comments regarding adequate rock for riprap material, United Nuclear investigated other off-site sources of rock. Three potential off-site riprap sources were identified. Samples from two limestone quarries and one basalt quarry have been obtained and tested. Laboratory testing of the limestone indicated a range of rock quality characteristics. Consequently, the NRC requested that additional rock sources be investigated to determine the cost-effectiveness of providing higher quality riprap. Testing of the basalt, from a commercial source in Grants, New Mexico, results in higher rock quality ratings compared to the limestone.

Limestone rock samples were obtained from two quarries that mine rock from the Todilto Limestone formation. The Todilto Limestone formation crops out in north-dipping exposures from the Cebolleta Mesa near Grants, New Mexico, to just east of Gallup, New Mexico. This limestone is a laminated to thickly bedded, finely crystalline limestone. A site inspection of the potential limestone borrow revealed that the laminated bedding planes within the limestone have good cohesion. Therefore, it appears that riprap of 30-inch diameter or greater will be available for use during reclamation.

The most commonly selected reference for evaluating the suitability of riprap materials is NUREG/CR-4620, "Methodologies for Evaluating Long-Term Stabilization Designs of Uranium Mill Tailings Impoundments," (NRC, 1986). This document cites the U.S. Bureau of Reclamation (USBR) durability standards as appropriate for use in stabilizing impoundments.

Samples of the limestone, and later the basalt, were tested for four of the five USBR durability properties. The tests samples included the following:

1. Specific gravity analysis
2. Absorption
3. Sodium and magnesium sulfate soundness
4. L.A. Abrasion

Test results and rock quality rating calculations for the limestone (best and worst cases) and basalt are provided in Tables 3.4 and 3.5, respectively. The rock quality ratings for limestone samples ranged from 57.3 using worst-case results for each individual test to 67.0 using best-case results for each test. The rock quality rating for the basalt sample was 93.2.

A petrographic evaluation of the limestone was also conducted (NRC, 1986). The limestone samples may be classified as a Group 3 rock (carbonate), fresh to slightly weathered, with no clays.

4

4.0 INTERIM STABILIZATION

As originally proposed in the 1987 Reclamation Plan, and initiated in 1989 in conformance with NRC license requirements, interim stabilization focuses on minimizing the potential for pathway releases while placing the first one foot of the radon attenuation soil cover. The interim stabilization concept has provided an opportunity for monitoring success of the program before initiating final reclamation. It has also provided, and will continue to provide, the opportunity to generate data that are useful in confirming or modifying final design parameters.

Activities associated with interim stabilization were selected and designed to mitigate releases in the near term that may affect health and the environment. Interim actions ameliorate current effects while assisting in preparing the site for final stabilization. Accordingly, a number of specific actions were and continue to be undertaken to address potential exposure pathways including emissions to the air via wind-blown tailings and radon gas, and tailings seepage.

Interim reclamation addresses existing and potential sources that may contribute to release pathways, and serves to prepare the site for final reclamation. Wind-blown tailings were minimized or eliminated by protecting the tailings from transport mechanisms using covers or otherwise preventing tailings from dispersal by erosion forces, i.e., wind and water erosion.

Regarding the seepage pathway, sources have been eliminated and future contributions will be prevented. United Nuclear has conducted extensive hydrologic investigation programs in response to NRC and EPA regulatory programs to determine the appropriate means for eliminating sources and mitigating the seepage pathways. These investigations have resulted in a number of significant findings that form the underlying basis for the seepage collection remedial action measures implemented as part of the interim stabilization and final reclamation plans.

Fundamental components needed for mitigating seepage pathways include:

1. Removing sources of continuing seepage,

2. Minimizing precipitation recharge,

3. Eliminating potential pathways of seepage migration through wells constructed before the plan, and

4. Providing active remediation of seepage.

The following actions have been accomplished during the first three years of implementation of interim stabilization, each of which is discussed in more detail in this section or Section 6.0:

1. Dewatered Borrow Pit No. 2 by spraying neutralized water on tailings to assist in controlling wind-blown tailings, using a spray mister system constructed over the tailings.

2. Collected wind-blown tailings north and east of the tailings disposal area in Sections 1 and 2, Township 16N, Range 16W, and Section 36, Township 17N, Range 16W property immediately adjacent to the tailings disposal area (Figure 1-4), and placed those affected soils in the tailings disposal area.

3. Regraded and recontoured the tailings materials in the North and Central Cells of the tailings disposal area to shed precipitation, reduce recharge, and

eliminate ponding. Recontouring was designed to place coarse tailings and other fill materials over fine tailings to reduce radon flux from the tailings disposal area.

4. Placed a 1-foot-thick radon attenuation soil cover over the regraded North and Central Cells of the tailings disposal area to stabilize the site during the interim period, reduce erosion, and further minimize radon releases. The South Cell will be regraded and covered in 1991.

5. Plugged selected wells to prevent them from becoming conduits for seepage migrations.

6. Initiated the Corrective Action Program (CAP) approved by the NRC and the Remedial Design (RD) approved by the EPA, which includes installation of extraction wells, and construction of evaporation ponds and an enhanced evaporation system to dispose of collected seepage.

7. Initiated mill decommissioning.

4.1 Dewatering of Borrow Pit No. 2

Borrow Pit No. 2 was dewatered to eliminate it as a potential source of continuing seepage. Dewatering the borrow pit removed the driving head that caused water recharge into Zone 1 of the Upper Gallup Sandstone (Canonie, 1987a). Borrow Pit No. 2 contained approximately 10 million gallons of neutralized water originating from the pumping well systems, which had been in operation since at least 1983. The water in Borrow Pit No. 2 had been treated to a neutral to basic pH of about 7.5 to 8.5 as part of on-going operations to eliminate acidity and to remove heavy metals and radionuclides. United Nuclear pumped water from the borrow pit and directed it through a spray system onto the tailings sands. This eliminated the pit water by enhanced evaporation and assisted in the suppression of dust during dry periods of the year. It also mitigated radon gas emanation by keeping the surface of the tailings moist.

The spray system was operated under NRC License approval to evaporate the maximum amount of water possible during the dry season while minimizing potential infiltration, which could result if the system was operated at excessive rates of spray during periods when conditions were not conducive to evaporation. The spray nozzles utilized by the system were selected to produce finely atomized droplets, enhancing the evaporation rate. The spacing of the nozzles was selected to provide maximum evaporative area without overlapping.

United Nuclear originally estimated that it would take a minimum of two evaporation seasons to complete dewatering of the borrow pit. United Nuclear successfully dewatered Borrow Pit No. 2 in 1989. It was necessary to temporarily store some water in the borrow pit during the winter of 1990-1991. Details on the progress of dewatering were included in annual progress reports to the NRC and EPA. The borrow pit was dewatered for the final time in early 1991, and is currently being backfilled with debris from the mill decommissioning.

4.2 Regrading and Recontouring Tailings

The interim stabilization plan involving regrading and recontouring of the tailings disposal area is shown in Figures 4-1 and 4-2 with a base map showing conditions prior to the reclamation activities. The North and Central Cells of the tailings disposal area have been regraded and recontoured in conformance with NRC License requirements as part of initial interim stabilization activities in 1989 and 1990, as shown on Figures 4-3 and 4-4, to prevent ponding of precipitation and provide positive drainage. The South Cell is currently being regraded and covered and will be completed by year-end 1991.

The resultant reconfiguration of tailings will provide a minimum seven-foot thickness of coarse tailings sands and/or clean fill material over fine-grained tailings and, once covered with soils, establish relatively flat slopes to prevent erosion.

Regrading and contouring the site produces several beneficial results. Radon gas emanation is reduced as a result of placement of coarse tailings sands, which have a lower radium content, over fine-grained tailings, which have a relatively higher radium content. Placement will reduce the radiological source term significantly. In addition, a more stable working surface is provided over the soft, fine-grained tailings. Most importantly, positive drainage of precipitation off of the North and Central Cells eliminates ponded water and minimize infiltration. As a result of NRC review comments on the proposed plan, the South Cell will be graded, covered, and will remain in the impounded configuration until final reclamation. In the proposed plan, the South Cell was to be graded to allow drainage of surface water. In deference to the NRC's desire and in conformance with NRC License requirements, the South Cell will remain impounded to provide secondary containment for the evaporation ponds.

The total area of tailings to be regraded is approximately 100 acres. Approximately 490,000 cubic yards (cy) of tailings will have been moved during this reconfiguration. Estimated earthwork quantities for interim stabilization activities are listed in Table 4.1.

Details of the tailings regrading program are provided in the Construction/Technical Specifications in Appendix B. Placement of coarse tailings sands over wet fine-grained tailings areas is accomplished by pushing the coarse material over the fine-grained tailings using a low-ground pressure bulldozer until a sufficient thickness of sands is established. The top one-foot-thick layer of the sands is compacted to 90 percent of the maximum dry density as determined using the Standard Proctor method (ASTM D 698) to provide a firm surface for placement of the interim soil cover. In areas where the surface of the fine-grained tailings is especially soft, it may be necessary to place geotextile fabric over the fine-grained tailings before placing the initial layer of coarse sands. The geotextile is used only to provide sufficient support for the tailings sands to allow the movement of construction equipment when moving tailings sand over the slimes. The geotextile fabric allows pore water to transfer from the moist slimes into the drier sands as it is loaded over the slimes, while keeping the materials segregated. This process results in partial dewatering and associated consolidation of the slimes over a relatively short time, while the geotextile is still competent. In the long term, when the geotextile begins to degrade, the pore water pressures in the slime materials will have equilibrated with the pore water pressure in the overlying sands. Because of this equilibration, no long-term detriment to the cover's stability will result.

Actual experience during interim stabilization of the North Cell indicated that only a very small area required the use of geotextile fabric. In the Central Cell, geotextile fabric was not required, and it is not anticipated that any will be required in the South Cell.

The recontoured configuration creates slopes in the tailings ranging from approximately 10:1 (horizontal:vertical) to as little as 120:1, or about 10 percent to 1 percent slopes, as shown on Figures 4-3 and 4-4. The reclamation plan calls for the earth embankment along the west and south sides of the tailings disposal area to be regraded from an exterior slope of about 3:1 to a flatter configuration of 5:1 or less. Drainage of precipitation across these slopes will be slow and controlled, minimizing infiltration and erosion. Excess soil generated by this earthwork is used as part of the interim stabilization soil cover. The exposed tailings surface is covered with an interim soil cover as soon as practicable to further limit erosion, reduce radon emanation, and reduce recharge.

Regrading operations also included the construction of evaporation ponds as illustrated on Figure 4-3 and described in more detail in Amendment I to the proposed plan on July 26, 1988 and subsequently approved by the NRC (See Section 6.0). As discussed above, the drainage channel for the South Cell will not be constructed until the evaporation ponds are no longer needed and are closed. When the channel is constructed, part of the channel will be excavated into the bedrock to maximize its stability and longevity.

The soil regrading during interim stabilization includes construction of haul roads and access to the tailings disposal area as shown on Figures 4-1 and 4-2. During regrading, the external slopes of the existing compacted soil embankment on the west and south sides of the tailings disposal area are graded to a slope of five horizontal to one vertical (5H:1V) or less. For example, at the north end of the tailings disposal area, one section of the embankment has been regraded to a slope of ten horizontal to one vertical (10H:1V) (Figure 4-3).

4.3 Removal of Soils Affected by Wind-blown Tailings

The prevailing wind direction and direction of highest wind intensity is from the southwest to the northeast. Limited amounts of tailings were transported to the northeast of the tailings disposal area, as identified by the radiological investigation described in Section 2.0 of this report. The area influenced by the wind-blown tailings is outlined on Figures 4-1 and 4-2. Soil within this area was stripped and placed in the North Cell and Borrow Pit No. 2.

United Nuclear completed and submitted Wind-blown Tailings Cleanup Verification Reports in December 1989 and November 1990, pursuant to NRC License Condition 33. As described in the verification reports, United Nuclear conducted additional radiological surveys, soil sampling and analyses in 1988 and 1989 to refine the areas potentially impacted by wind-blown tailings. The boundaries of the areas to be cleaned were staked by survey. Trees and large shrubs within these areas were removed and burned. Subsequently, at least six inches of soil was removed from the areas in

Sections 2 and 36 and placed in the North Cell as fill material during regrading. Soil, from the areas requiring additional excavation from Sections 2 and 36 as a result of verification surveys, and soil removed from Section 1 in 1990 was placed into the southwest corner of Borrow Pit No. 2 and sprayed with a polymer binding agent to prevent wind dispersal. Placement of soil into the borrow pit was required because the North Cell had been filled to design grade at the time the additional soil was excavated. Verification surveys were conducted after excavation of soil in the delineated areas to confirm removal of soil potentially impacted by wind-blown tailings. Wind-blown Tailings Cleanup Verification Reports were submitted to the NRC on December 21, 1989 and November 21, 1990 (United Nuclear, 1989 and 1990, respectively). After completing the verification survey, the excavated areas were fertilized with nitrogen and phosphate and revegetated with the native seed mixture provided in Table 4.2. The areas, from where soil potentially impacted by wind-blown tailings was removed, are outlined on Figures 4-1 and 4-2. The stippled areas shown on Figures 4-1 and 4-2, representing areas impacted by wind-blown tailings, are larger than the areas identified in the wind-blown cleanup reports. The areas outside those shown in the cleanup reports were excavated as part of regrading the tailings.

4.4 Placement of Interim Stabilization Soil Cover

During interim stabilization, a soil cover with a minimum thickness of 12 inches was to be placed over the reconfigured tailings disposal area. This cover prevents wind-blown migration of tailings, reduces erosion of tailings, lowers radon gas emanation, and reduces infiltration due to precipitation. It also represents the first 1.0 foot of radon attenuation soil cover to be placed over tailings. During interim stabilization of the North and Central Cells, a soil cover more than 12-inches thick was placed in many areas in order to reach the grades shown on Figures 4-1 and 4-2. Consequently, the final soil cover may be also thicker than required.

The soil cover to be is constructed of soil obtained in part from regrading of areas adjacent to the arroyo as shown on Figures 4-1 and 4-2. Other areas where soil cover material is to be obtained, include the excavation of surface water control channels and the soil stockpile. A detail of the interim soil cover design is shown on Figure 4-5. The total volume of soil needed for this cover is estimated to be approximately 161,000 cubic yards. The interim soil cover placed in 1989 and 1990 represents approximately 125,000 cy or 43 percent of the total soil cover. The remainder of the interim soil cover to be placed over the South Cell in 1991 will contribute approximately 36,000 cy or 12 percent of the total soil cover.

The soil cover is to be placed at or near its optimum moisture content and compacted with mechanical rollers. Details on the placement of soil cover materials are discussed further in Section 5.0.

4.4.1 North and Central Cell Interim Cover Soils

As previously discussed, interim soil cover was placed over the North and Central Cells in 1989 and 1990, respectively. During construction of the interim cover over the North Cell, several small volume borrow sources were utilized, including the northernmost portion of the west embankment of the tailings retention dam and the North Cross Dike, which separated the North Cell from the Central Cell. Both of these structures were made of soils that meet the soil cover envelope criteria previously discussed and depicted on Figure 3-2. A portion of the North Diversion Ditch extension was also excavated to provide additional soil material. The Central Cell soil-cover borrow was also obtained from the west embankment, as well as from the stockpile south of Borrow Pit No. 2. Excavation in these areas provided the 125,000 cy of material needed for interim cover construction in these cells. Figures 4-1 and 4-2 show the construction of the North and Central Cell interim soil covers.

Numerous geotechnical tests were performed on the actual interim soil cover materials to verify their suitability for soil cover material. Test results are summarized in Table 3.3. The location of the tests are shown on Figure 3-1. These data are representative of as-built soil cover conditions. The results of this testing indicate that the majority of the material placed to date classifies as silt or clay material, well suited, as anticipated, for use as a soil cover.

As shown on Figure 3-2, the average gradation of the North and Central Cell interim soil cover material falls well within the limits of the specified "allowable" soil cover gradation envelope. This graphic presentation of allowable soil-cover soil types provides a reliable method to evaluate gradation results before soil is placed in the soil cover. This method ensures the soil placed in the soil cover is consistent with the soil types modeled in the soil-cover design. The gradation envelope was developed in response to NRC review comments.

Atterberg limits and gradation analyses indicate that clays are the most common soil type used in the interim cover constructed to date. As shown on Figure 3-2 and summarized in Table 3.3, the average percent passing the No. 200 sieve is 56 percent, indicating the soils' fine-grained characteristics and suitability for the soil cover. Table 3.3 summarizes the results of the sampling and testing of the interim cover material. Appendix A contains the geotechnical laboratory reports. Thus, laboratory testing performed to date substantiates the suitability of these materials for soil cover. Additionally, these data were used to adjust the final soil cover design presented in Section 5.0.

Interim stabilization has provided the opportunity to develop data regarding the applicability of the reclamation design in the following areas:

1. Constructibility and the successful use of planned construction techniques,

2. Tailings consolidation and the attainment of 90 percent consolidation, and

3. Soil characteristics and the refinement of radon attenuation soil cover design.

The interim stabilization activities conducted in the North and Central Cells have essentially been a large field-scale test of the design. The experience gained in constructing the North and Central Cells, and the data collected during interim stabilization have met or exceeded the conditions anticipated in the design. The refined soil characteristics were used to refine the soil-cover design and gain approval of the design by the NRC.

4.4.2 Interim Stabilization Revegetation

After placement of the interim soil cover, the soil cover and disturbed areas proximate to the North and Central Cells were revegetated. A total area of up to approximately 75 acres was revegetated as part of interim stabilization activities. Approximately 28 acres in the North Cell and areas where wind-blown tailings were removed were revegetated with the seed mixture of native plant species, as identified in Table 4.2. Approximately 45 acres of the interim stabilization cover in the Central Cell was revegetated with the relatively temporary mixture of rye grasses presented in Table 4.3.

Areas that have been heavily compacted by equipment operation were first scarified and/or disked as necessary to provide a suitable planting medium. Areas where wind-blown tailings were removed were ripped with a bulldozer or equivalent equipment with ripper shanks to create parallel cuts along the contours. The area was disked to provide a suitable surface for drill or broadcast seeding.

Drill seeding and broadcast seeding methods were both employed during revegetation. When the drill seeding process was used, the seeding was conducted along the contour or at a right angle to the prevailing wind. When broadcast seeding was used, seeding was accomplished using a cyclone-type broadcaster. After seeding, the area was conditioned by raking and harrowing to ensure proper coverage of the seed with soil. Revegetation of the interim stabilization cover in the South Cell is not planned. Since the cover surface will be sloped only very slightly, no drainage from the South Cell will occur until final reclamation.

4.5 Well Plugging

Recontouring and regrading has occurred over areas where several monitoring and pumping wells were located. These wells were sealed or plugged prior to performance of the earthwork. Some wells along the North Cross Dike and within soil stripping areas required plugging. In addition, United Nuclear plugged selected unneeded wells. All wells were plugged in conformance with approvals received from NRC. Plugging procedures were conducted in compliance with New Mexico State Engineers Office (NMSEO) regulations.

4.6 Seepage Remediation

During the initial interim stabilization activities, United Nuclear initiated the CAP approved by the NRC and the RD approved by the EPA. The actions included the installation of additional extraction wells and construction of evaporation ponds and an enhanced evaporation system to dispose of collected seepage as shown on Figure 1-4. The seepage cleanup activities are described in detail in Section 6.0.

4.7 Mill Decommissioning

In the proposed reclamation plan of 1987, the mill was scheduled to be decommissioned by the end of 1997. Subsequently, the NRC required that decommissioning of the mill be complete by the end of 1992 in License Condition 26. United Nuclear submitted a Mill Decommissioning Plan in December 1988 and subsequently received approval from the NRC, pursuant to License Condition 26, to decommission the mill (United Nuclear, 1988). This plan was initiated in 1991 and will be completed during the interim stabilization period, in accordance with the schedule in NRC License Condition 33.

The mill area at United Nuclear's Church Rock facility will be decommissioned by demolishing the facilities (with the exception of the administration building, warehouse, lube storage area, tire storage shed, and guard/change house building), disposing of the debris in Borrow Pit No. 2, and regrading and revegetating the mill area. The Mill Decommissioning Plan is described in detail in Section 7.0.

4.8 Interim Stabilization Monitoring

As part of interim stabilization, monitoring will be conducted to evaluate the benefits derived from the tailings regrading and soil cover placement. In addition, United Nuclear will continue its current monitoring programs as required by its source materials license. These programs are expected to provide further data to supplement the interim stabilization monitoring program described here.

Settlement of the tailings, and thus the overlying soil cover, can occur by three different methods, which can each apply added weight to the tailings and cause them to consolidate. They are:

1. Natural draining of the hydraulically placed tailings,

2. Placement of additional tailings and other fill materials during regrading operations, and

3. Placement of the interim and final soil covers.

Since tailings disposal was terminated in 1982, much of the settlement from natural draining of the hydraulically placed tailings has already occurred and will continue to occur at an ever-decreasing rate. Placement of coarse tailings and other fill materials over slimes during regrading will be accomplished before final soil-cover placement. Accordingly, the majority of settlement which may influence the integrity of the final soil cover will be due to the weight of the soil cover itself.

Two procedures will be implemented to ensure that future anticipated settlements will not adversely affect the performance of the radon barrier. These procedures relate to the soil placement techniques to be used and concurrent settlement monitoring.

Construction of the first 12-inch-thick lift (interim cover) has commenced in stages across the site commencing from north to south as required by the NRC in License Condition 16. This phased construction will aid the settlement process by slow application of loading on the underlying tailings. United Nuclear has already placed the interim soil cover over the North and Central Cells of the tailings impoundment. United Nuclear will place an interim soil cover layer over a regraded South Cell in 1991. Settlement monitoring will be performed to verify that 90 percent of primary consolidation has occurred before placement of the remaining radon barrier and erosion protection layers during final reclamation.

Figure 4-6 shows the type of survey monument used to monitor settlement. The monuments are used to monitor actual settlement occurring due to regrading of the tailings materials and placement of the interim soil cover. In addition, the monument allows settlement monitoring for a period of time after placement of the interim cover, depending on the observed rate of settlement. The locations for the settlement monuments were originally identified in the proposed plan in 1987 and were revised on June 29, 1988 in response to NRC comments. The approximate locations of the settlement monuments are shown on Figures 4-1 and 4-2. The monuments are placed at locations of expected maximum settlement and at locations that can monitor the areal extent of settlement. They were installed before tailings regrading. Settlement monuments SM-3 and SM-4 will be installed when the evaporation ponds are regraded and closed.

Monitoring settlement monuments has been, and will be, performed daily during the first week following tailings regrading. Monitoring frequency will change after the first week to a minimum monthly schedule, until approximately 90 percent of the tailings consolidation has occurred, as determined using semilogarithmic plots of settlement versus time, or until sufficient documentation exists to demonstrate that no adverse effects are occurring to the cover from settlement. In the event that settlement does occur, additional soil-cover material will be placed and compacted in low areas to maintain the grades shown on Figures 4-1 and 4-2. This process will be repeated until 90 percent consolidation has occurred and low areas of the interim soil-cover surface have been filled to the design grades.

These procedures have been followed in placing the interim cover over the North and Central Cells. NRC staff has inspected the monitoring data generated to-date during their site inspections. At present, the monitoring data indicate that 90 percent consolidations have occurred in the North and Central Cells. Data generated in the future will also be made available.