SEQUOYAH FUELS
A GENERAL ATOMICS COMPANY

RE: 0604-N

January 31, 2006

FedEx

U.S. Nuclear Regulatory Commission
ATTN: Mr. Myron Fliegel, Senior Project Manager
Fuel Cycle Facilities Branch
Division of Fuel Cycle Safety
And Safeguards, NMSS
Two White Flint North
11545 Rockville Pike
Rockville, MD 20852-2738

Subject: Sequoyah Fuels Corporation, Docket – 40-8027
Response to Draft Safety Evaluation Report – Reclamation Plan
(TAC L52511)

Dear Mike,

Your letter dated September 19, 2005 identified open issues (OI) and confirmatory items (CI) on the Reclamation Plan that resulted from developing your draft Safety Evaluation Report (SER). Please find enclosed with this letter SFC responses to the OIs and CIs identified in your letter. Also enclosed are the resulting change pages for the Reclamation Plan and associated documents. Please update your Reclamation Plan with the revised pages.

Once your staff has had time to review these responses, SFC is prepared to meet with you to resolve any outstanding issues that may impede development of your final SER.

If you have any questions, don't hesitate to call me at (918) 489-5511, ext. 13.

Sincerely,

John H. Ellis

John H. Ellis
President

Enclosure

XC: Alvin Gutterman, MLB
Rita Ware, EPA
Toby Wright, MFG
Jeanine Hale, CN
Trevor Hammons, OAG
Saba Tahmassebi, ODEQ

SEQUOYAH FUELS
A GENERAL ATOMICS COMPANY

Reclamation Plan
Sequoyah Facility
January, 2003

Reclamation Plan

Attachment A
Attachment B
Attachment C
Attachment D
Attachment E
Attachment F

Appendix A

ENCLOSURE 1

Reclamation Plan

Draft Safety Evaluation Report

Response to Open Issues and Confirmatory Items

Enclosure 1

Sequoyah Fuels Corporation
Draft Safety Evaluation Report
Open Issues and Confirmatory Items

Open Issues

OI.01 The licensee needs to provide an analysis regarding the potential for Stream 005 to encroach upon the foot or apron of the proposed cell. (SER Section 2.4.2)

Response:
The catchment basin draining to Stream 005 was reduced during operation of the SFC facility, and will be significantly reduced after construction of the disposal cell. In addition, outcrops of Pennsylvanian Period Atoka Formation sandstone and shale along the bed of Stream 005 indicate limited scour of the stream. Therefore, it is unlikely that headward erosion of the stream would impact the disposal cell.

However, in accordance with OI.18, a rock apron has been included in the disposal cell design to protect against headward erosion from Stream 005, and sized according to procedures specified in NUREG 1623. The rock apron will be constructed at the point where runoff from the west slope of the disposal cell discharges into the east end of Stream 005. This apron is shown in the Drawings (Reclamation Plan Attachment A). The design calculations are presented in Appendix D of the Disposal Cell Construction Plan (Reclamation Plan Attachment E) and summarized below.

Scour depth was estimated using the procedures presented in the U.S. Department of Transportation, Hydrologic Engineering Circular 14 (US DOT, 1975). For this calculation, runoff from the west slope of the disposal cell and overland flow from approximately 1.5 acres to the west of the disposal cell discharge at the head of Stream 005. The maximum scour depth is estimated to be approximately 5.4 feet deep. Drill holes near the head of Stream 005 (BH-42 and BH-47) show shale bedrock at a depth of less than 7 feet.

A rock apron (located directly downstream of the perimeter apron in this area) was designed to protect the disposal cell from headward erosion of Stream 005. The rock apron will be keyed into underlying shale and constructed with the perimeter apron rock.

OI.02 The licensee needs to provide information characterizing the shear strength of the colluvium if such information is needed to resolve the open issue regarding the stability of the natural slopes identified in Section 3.3. (SER Section 3.2.1.1)

Response:
The natural slopes in the area are less than 10 percent and covered by a relatively thin veneer of terrace deposits (described in the Reclamation Plan as alluvial and colluvial deposits). As shown in Figures 7-2 through 7-8 of the Hydrogeological and Geochemical Site Characterization Report (SMI, 2001), the slopes have less than 10 feet of alluvial terrace deposits. Because of the relatively thin mantle of alluvial soils and excavation of most of these soils for site cleanup, disposal cell construction would have a limited impact on the stability of the natural slopes.

Weathered soils and terrace deposits in the site area have been sampled and tested for evaluation of embankment construction material. Borrow material investigation reports on these soils include HC (1980), PSI (1990) and GGH (1997). Laboratory testing data indicate the plasticity index varies from approximately 10 to 30 percent. Correlations between plasticity index and shear strength of normally consolidated clays indicates the average shear strength is between 28 and 32 degrees, and values within one standard deviation are between 25 and 38 degrees (Bowles, 1988, and Lambe and Whitman, 1969).

OI.03 The licensee needs to provide an evaluation of the stability of the natural slopes under seismic and long-term static conditions. (SER Section 3.3.1)

Response:
Stability analyses of the natural slopes have been evaluated, with the results summarized in Appendix F of the Disposal Cell Construction Plan (Reclamation Plan Attachment E). Using a conservatively low shear strength for the natural soils of 25 degrees (as discussed in the Response to OI.02 above), the minimum calculated factor of safety for static conditions is 2.48 and for pseudostatic conditions is 1.33, well above factor of safety design criteria of 1.5 and 1.1, respectively.

OI.04 The licensee needs to provide technical specifications for the synthetic liner at the base of the cover system consistent with information used in the licensee stability analysis. (SER Section 3.3.2)

Response:
The SER refers to Section 4.2.4 of the Technical Specifications (2005 Reclamation Plan Attachment A), and the synthetic liner placed at the base of disposal cell, forming of the base liner system. This liner is intended to be smooth, 60-mil nominal thickness HDPE. Section 7.2.2 refers to the synthetic liner used in the cover system. This section specifies textured, 60-mil nominal thickness HDPE for the cover system, as discussed in SER Section 3.3.2, in order to increase the stability of cover system that will be constructed at 5:1 (horizontal:vertical) slopes.

OI.05 The licensee needs to provide particle size specifications for the synthetic liner bedding and cover materials consistent with information used in the licensee=s stability analysis. (SER Section 3.3.2)

Response:
Section 4.2.3 and 4.2.5 and 7.2.3 of the Technical Specifications will be modified to specify the following particle-size distribution for synthetic liner bedding and cover materials:

Sieve Size	Percent Passing
1 inch	100
No. 4	65-100
No. 16	25-85
No. 40	5-45
No. 200	0-10

The above gradation is consistent with the gradation of the granular material used in the direct shear test of the synthetic liner/granular material (Enclosure 1 of SFC, 2004).

OI.06 The licensee needs to provide its proposed approach to addressing the compaction specification for the disposal-cell subgrade. (SER Section 3.4.1)

Response:
The materials to be used for subgrade fill will either be soils excavated from on-site locations or granular material from off-site commercial sources. The Technical Specifications (Reclamation Plan Attachment A) reflects these two potential sources.

For primarily fine-grained soils comprising the subgrade fill, these materials will be compacted in limited lift thickness to a minimum of 90 percent of Standard Proctor density and within three percent of optimum moisture content for the material. For granular materials comprising the subgrade fill (materials with less than 10 percent passing the No. 200 sieve), these materials will be compacted to a minimum relative density of 75 percent for the material. A test section will be established at the site to correlate the number of passes with vibratory equipment to the relative density of the granular material.

OI.07 The licensee needs to provide its proposed approach to addressing placement and compaction specifications for layer-C material and soils placed around such structural materials. (SER Section 3.4.2)

Response:
The compaction specifications for materials within the disposal cell (Reclamation Plan Attachment A) have been modified for the phased approach for cell construction. The materials placed in the disposal cell are outlined the Technical Specifications as material types A, B, C, and D. However, these materials will not be placed in the disposal cell as distinct layers. The material placement strategy (reflected in the Technical Specifications) is to minimize void spaces around the incompressible materials in the cell (using soils) and to minimize void spaces within the compressible materials in the cell. The revised material placement strategy has been analyzed for radon emanation from the disposal cell cover (Appendix C of the Disposal Cell Construction Plan, Reclamation Plan Attachment E), and shows acceptable emanation levels (less than 20 pCi/m^2-sec).

OI.08 The licensee needs to provide its proposed approach to addressing placement specifications for any crushed structural materials, such as piping or tanks. (SER Section 3.4.2)

Response:
<u>Placement Specifications For Any Crushed Structural Materials</u>

Structural materials will be placed in the disposal cell using methods depending on material size and compressibility. Structural materials will be broken or cut to manageable size using typical equipment for demotion work (hydraulic excavators with specialized attachments for shearing and grasping). These materials will be hauled with trucks to the disposal cell for placement.

Compressible material (such as thin-walled piping and tanks) will be flattened or crushed at the disposal cell with hydraulic excavator attachments or with a dozer. Non-compressible material (such as steel beams or concrete) will be laid out in the disposal cell a manner that minimizes void spaces. Both compressible and non-compressible material will be laid flat or placed in a manner to facilitate covering with soil.

Contaminated soils (material type D) will be spread in over a layer of structural material to fill in voids around the structural material. Contaminated soils will be placed in lifts (two feet maximum thickness) sufficient to cover the structural material but thin enough to allow compaction of the soil and underlying material. Each lift of soil will be compacted with at least six passes with vibratory tamping-foot compaction equipment. These procedures are outlined in the Technical Specifications (Reclamation Plan Attachment A).

Compaction Specification For Soil Placed Around Disposed Structural Material

Material type D consists of soils and weathered sedimentary rock from contaminated soil cleanup that is placed with and on top of structural materials (material type C). The soils will be used to minimize void spaces around the structural material and provide bedding for subsequent lift of structural material. Checking soil compaction with standard field density testing methods (such as with a nuclear density gauge) is not recommended because of interference with structural debris.

As a result, a method specification for compaction of this material is outlined in the Technical Specifications (Reclamation Plan Attachment A). The method would be a minimum of six passes over a two-foot maximum thickness lift of soil with a vibratory tamping-foot compactor. The number of passes would be confirmed on a field test section of soils to establish a correlation between the compaction method and 95 percent of the maximum dry density for the material, as determined by the Standard Proctor test.

Changes To Regarding Placement Specifications For Layer-C Materials

The proposed changes in the Clarification of Responses to Request for Additional Information dated June 22, 2004 (SFC, 2004), in addition to changes proposed in this response, are incorporated in the Technical Specifications (Reclamation Plan Attachment A).

OI.09 The licensee needs to provide an evaluation of potential disposal-cell settlement. (SER Section 3.4.3)

Response:
An evaluation of disposal cell settlement and effect on cover performance was provided in a previous RAI response (SFC, 2004a). This evaluation is included as Appendix G of the Disposal Cell Construction Plan (Reclamation Plan Attachment E). Related experience with settlement of disposed materials and cover performance is in three general areas: (1) uranium tailings impoundment reclamation, (2) uranium mill demolition and disposal, and (3) municipal landfill performance.

For this evaluation, several publications were cited estimating the typical amount of settlement at municipal landfills. Values ranged from 5 to 25 percent of the waste thickness. Because the disposal cell will not include biodegradable materials, the amount of settlement in the disposal cell was estimated to be 5 to 10 percent of waste material height (consistent with the amount of short-term landfill settlement). Experience at uranium tailings impoundments has shown typical values of 10 percent of tailings thickness. Limited experience with disposed uranium mill debris has shown negligible settlement.

Because the disposal cell will not have biodegradable materials (like a landfill) or low-density materials (like slurried mill tailings), the settlement would be from compression of

void spaces around structural debris. The placement strategy and techniques described above are planned to minimize these void spaces. The estimated settlement of waste materials in the cell was conservatively based approximately 5 to 10 percent of the waste material height. The maximum estimated settlement at the base of the cover was approximately 1 to 2 feet (Appendix G of the Disposal Cell Construction Plan, Reclamation Plan Attachment E).

OI.10 The licensee needs to provide an evaluation of potential cracking damage to the cover system owing to differential settlement of the cell. (SER Section 3.4.3)

Response:
Based on a conservatively high total settlement of 5 to 10 percent of waste material height, and differential settlement occurring over a distance of 35 feet (representing the internal berm slopes in the disposal cell), differential settlement values were calculated (as outlined in Appendix G of the Disposal Cell Construction Plan, Reclamation Plan Attachment E). These values were converted to estimated tensile strain values, and were compared with allowable tensile strain values developed for covers over uranium mill tailings. The estimated tensile strain values were less than allowable values, indicating that the estimated differential settlement would not adversely affect cover performance.

The differential settlement at the base of the disposal cell cover is likely to be the greatest where vertical profiles of placed material have the largest difference in compressibility. Therefore, the differential settlement analyses (discussed above) were made by calculating the settlement for vertical profiles estimated to represent the least and the most compressible profiles. The closest lateral distance these profiles would occur is represented by the lateral distance of the internal berm slopes (35 feet). NRC stated that 35 feet could underestimate the strain across a stiff inclusion from a beam in material type C, or the concrete slab in the foundation. Stiff inclusions such as beams within a compacted soil matrix are not likely to have significant effects on the top surface of the disposal cell. If such materials were close to the surface, such stiff inclusions could impact settlement at the surface such that cracking may be of concern. The concrete slab will be covered by a minimum of ten feet of material prior to placement of the cover, as will be non-compressible structural materials. Therefore, the effects of any locally high strains across stiff inclusions will be reduced by the overlying compacted materials.

OI.11 The licensee needs to provide its proposed approach to controlling potential settlement of the disposal cell through settlement monitoring. (SER Section 3.4.3)

Response:
Settlement monitoring points are planned for the top of the cover (shown on the Drawings, Reclamation Plan Attachment A). Settlement monitoring is not planned for intermediate surfaces as the disposal cell is constructed and filled. In order to minimize the volume of meteoric water requiring collection, handling, and treatment, the period of time that the disposal cell is open to precipitation is planned to be as short as possible.

OI.12 The licensee needs to provide an analysis of potential instability of the disposal cell from liquefaction of the cell foundation. (SER Section 3.5.1)

Response:
The potential of instability of the disposal cell from liquefaction of the cell foundation was evaluated using procedures presented by Youd et al. (2001). The methods and results are

presented in Appendix F of the Disposal Cell Construction Plan (Reclamation Plan Attachment E). The calculated factor of safety against liquefaction is acceptable (greater than 2.1), even considering conservative conditions within the foundation. Therefore the potential for liquefaction of the cell foundation is negligible, and would not affect the stability of the disposal cell.

OI.13 The licensee needs to provide material and placement specifications for the liner bedding and cover layers to ensure the completed liner bedding and cover will protect the liner from cutting or tearing and provide for free drainage of seepage water along (SER Section 3.6.1)

Response:
This open issue appears to be related to the 2004 version of the Technical Specifications. The current Technical Specifications (Reclamation Plan Attachment A) specify a grain size distribution for the synthetic liner bedding and cover material. This specification has been modified as discussed in the response to OI.05 above. This gradation of material is designed to meet minimum thickness, permeability, and shear strength requirements, and meets filter criteria of both the overlying disposed material and the perforations in the leak detection pipe. Placement specifications to protect the synthetic liner and ensure proper compaction are provided in the Technical Specifications.

The liner bedding and cover materials are placed in one lift by dumping material at the edge of the placement area and spreading the material with a small dozer. Spreading would be done in a direction that does not move or damage the leachate collection or leak detection pipe system. For liner bedding material (placed over compacted soils) the lift thickness is six inches. For liner cover material (placed over synthetic liner), the lift thickness is a minimum of 18 inches (for liner protection). The top surface of the lifts of liner bedding and liner cover materials will be rolled with a smooth-drum roller to compact the lift and prepare the surface for the next material.

OI.14 The licensee needs to provide specifications for the dewatering of calcium fluoride sludge and sediments from the emergency basin, north ditch, and sanitary lagoon; and the placement of such materials in the disposal cell. (SER Section 3.6.1)

Response:
SFC has conducted a study on site to determine the best method of treating the calcium fluoride sludge prior to placement into the disposal cell. The results of this study indicate that solidification with fluidized bed ash (flyash) is effective in transforming Calcium Fluoride Sludge into a soil-like material with strengths acceptable for placement in disposal cell. Testing activities used to simulate the excavation, movement, placement and compaction of solidified materials showed that sludge solidified with flyash could be moved several months after solidification and still obtain substantial load bearing strengths well in excess of what would be necessary to support cell overburden and cap. Therefore, SFC will treat the Calcium Fluoride Sludge with flyash, remove the material to the disposal cell, and place it as outlined in section 6 of the Technical Specifications (Reclamation Plan Attachment A).

The sediments removed from the North Ditch, Emergency Basin, and Sanitary Lagoon may be disposed of at an off-site location if it is economically feasible to do so. In the event that an affordable location cannot be found, these materials will be dewatered and packaged

similar to the raffinate sludge, then placed into the disposal cell as outlined in section 6 of the Technical Specifications (Reclamation Plan Attachment A).

OI.15 The licensee needs to revise the technical specifications to include restrictions to protect the liner and cover during construction. (SER Section 3.7.1)

Response:
The proposed liner installation requirements as discussed in SFC, 2004b, Attachment 1, have been added to the Technical Specifications. The Technical Specifications also include the provisions discussed in the response to OI.13 above to protect the liner and cover during construction.

OI.16 The issue of representing flow in fissures and desiccation cracks in the infiltration model is yet to be resolved. (SER Section 3.8.2)

Response:
The infiltration modeling reviewed by NRC was presented in the Preliminary Design Report (Reclamation Plan Appendix C), and was based on a thick subsoil zone in the cover and no clay layer. The current cover design is a multilayered system of compacted materials. The revised infiltration modeling for the current cover design is presented in Appendix E of the Disposal Cell Construction Plan (Reclamation Plan Attachment E).

The subsoil zone in the current cover design is not a heterogeneous zone, but rather a homogeneous, compacted material. Beneath the subsoil zone is a two-foot thick layer of compacted clay of low permeability. Although prolonged drought conditions can cause desiccation cracks, in clay covers, SFC's cover is designed with the clay layer eight to ten feet below the cover surface. Desiccation cracking of the clay layer at that depth in the climate of eastern Oklahoma is unlikely. In addition, SFC personnel indicate that desiccation cracking is not observed in natural soils at the site.

The reference sited in the original GW5 RAI (Albright, W.H., C.H. Benson, G.W. Gee, A. C. Roesler, T. Abichou, P. Apiwantragoon, B.F. Lyles, and S. A Rock; 2004) looked at desiccation of relatively thin compacted clay covers, which are more heavily influenced by desiccation cracking than a clay layer at the base of a thick cover. Therefore, increased infiltration due to cracking is not expected.

OI.17 The licensee needs to provide analysis of rock size for the riprap apron. (SER Section 4.5.1.2)

Response:
Rock size for the perimeter apron along the toe of the disposal cell was calculated using methods specified in NUREG 1623, Appendix D. These calculations are presented in Appendix D of the Disposal Cell Construction Plan (Reclamation Plan Attachment E).

The median rock size for the perimeter apron is larger than the median rock size for the rock mulch layer on the disposal cell slopes to accommodate energy dissipation. The rock sizing procedure in Abt et al. (1998) was used, resulting in a median rock size of 5.7 to 8.0 inches (depending on rock angularity) for the twenty-foot width of perimeter apron at the toe of the slopes on the north, south, and west sides of the slope, where flow is transitioned to natural ground. The east side of the disposal cell is addressed in the response to OI.19 below.

OI.18 The licensee needs to provide a design of the rock apron to protect against gullies caused by overland flow. (SER Section 4.5.1.2.1)

Response:
As discussed in OI.17, runoff from the north, west, and south slopes of the disposal cell is directed over the perimeter apron to natural ground. The maximum unit flow at the toe of the slope is 0.39 cubic feet per second (per foot width), as calculated in Appendix D of the Cell Construction Plan. Using this maximum flow, and a toe apron slope of one percent, the maximum scour depth was calculated using procedures outlined in NUREG 1623. Scour depth was estimated using the procedures presented in US DOT (1975). The maximum estimated scour depth from runoff at the toe of the disposal cell is 0.46 feet. The perimeter apron is designed to have a median rock size of 5.7 to 8.0 inches, and a minimum thickness of 24 inches. Therefore, protection against scour is adequate.

OI.19 The licensee needs to provide a design of the rock apron on the east side of the cell to accommodate high flows. (SER Section 4.5.1.2.2)

Response:
On the north, west, and south sides of the disposal cell, runoff at the toe of the slopes is directed over the perimeter apron to natural ground. As shown on the reclaimed disposal cell layout (Reclamation Plan Attachment A), approximately 5.4 acres of land between the cell and the east facility boundary line will drain towards the east side of the cell. This flow will be intercepted by the diversion channel on the east side of the cell that will direct flow to the north and south of the cell (Reclamation Plan, Attachment A). The perimeter apron on the east side of the cell is extended to a 40-foot width and will be shaped as a trapezoidal channel, with a channel depth of one foot to accommodate this flow. The rock channel will have the same rock size as the perimeter apron (a median size of 5.7 to 8.0 inches), and will be placed a minimum 24-inch thick layer.

OI.20 The licensee needs to provide a design for rock armor protection of stream 005. (SER Section 4.5.1.3)

Response:
This is provided in response to OI.1

OI.21 The licensee needs to provide specifications for riprap rock gradation. (SER Section 4.5.2)

Response:
The gradation of the rock mulch layer on the side slopes of the disposal cell have been modified to have a median size of 3.4 to 4.7 inches (depending on particle angularity). The rock gradation recommendations, as given in NUREG 4620, Section 4.2.2, pertain to clean riprap. The slope protection planned for the disposal cell is a rock mulch, with the voids filled with smaller particles. As discussed in the Final Staff Technical Position Design of Erosion Protection Covers for Stabilization of Uranium Mill Tailings Sites, Appendix D, rock mulches provide a practical solution for stabilization of slopes and channels. Studies by Abt et al. (1988) indicate that a rock mulch has similar or possibly better stability characteristics as the riprap layer alone.

Placement procedures will be implemented to avoid segregation. The Technical Specifications (Reclamation Plan Attachment A) have been modified to include placement

procedures and have the following gradation requirements (for material from a nearby limestone quarry):

Sieve Size	Percent Passing
9-in	100
4 in	35 - 65
1.5 in	20 - 50
No. 4	0 - 25

OI.22 The licensee needs to provide information necessary to show that rock of acceptable durability will be used for flood protection. (SER Section 4.5.3)

Response:
Two rock sources have been evaluated by SFC: (1) a limestone quarry (Souter Quarry) near the site, and (2) several gravel pits in the site area. Rock from the Souter Quarry has been previously evaluated for durability by SFC, with preliminary results documented in the Disposal Cell Construction Plan (Reclamation Plan Attachment E). The gravel pits in the site area contain rounded particles of chert and other durable materials, but are limited to particles of up to 6 to 8-inch size. No durability testing of the gravel pits has been conducted.

The rock size requirements for the rock mulch and perimeter apron are near the upper limit of what can be produced at from the gravel pits in the site area. In addition, the larger-sized rounded rock is in demand in the area for decorative rock. Therefore the limestone quarry is the preferred source for erosion protection materials. From the tests results presented in the Disposal Cell Construction Plan, the rock quality designation for the limestone is 69, indicating acceptable durability with an oversizing factor of 11 percent. In the rock size specifications in the Technical Specifications (Reclamation Plan Attachment A), a conservative oversizing factor of 20 percent has been used

OI.23 The licensee needs to provide information regarding the licensee's erosion protection testing, inspection, and quality control program. (SER Section 4.5.4)

Response:
Information regarding rock mulch testing, inspection, and quality control per guidance given in NUREG-1623, Appendix F, has been added to the Technical Specifications (Reclamation Plan Attachment A.

OI.24 The licensee needs to provide information regarding the licensee's rock durability testing program. (SER Section 4.5.4.1)

Response:
This is provided in the Technical Specifications (Reclamation Plan Attachment A).

OI.25 The licensee needs to provide information regarding the licensee's riprap placement procedures. (SER Section 4.5.4.3)

Response:
The Technical Specifications (Reclamation Plan Attachment A) have been modified to specify rock mulch placement procedures for the rock mulch and perimeter apron

materials. Rock mulch placement will be facilitated by mixing with fine-grained materials, placing, spreading, and compacting as a single lift, rather than placing rock first and then compacting soil second, as implied in SER Section 4.5.4.3. Recommendations from NUREG-1623 are incorporated into the specifications where appropriate.

OI.26 The licensee needs to provide information regarding the licensee's rock layer thickness testing. (SER Section 4.5.4.4)

Response:
The placed thickness of rock mulch and perimeter apron material will be measured by elevations before and after placement. Elevations at specific points will be measured before and after material placement, or stakes with marked fill depths will be used where possible. These recommendations are included in the Technical Specifications (Reclamation Plan Attachment A).

OI.27 The licensee needs to provide information regarding the adequacy of the soil cover to resist wind erosion. (SER Section 4.5.5)

Response:
Procedures specified in NUREG 4620 were followed to estimate the potential for wind erosion. Soil loss is estimated by the equation A=R*K*LS*VM. R, the rainfall factor, was estimated as 100. K, the soil erodibility factor was estimated from the nomograph, for top soil having approximately 25% sand, 30% very fine sand and silt, 2 percent organic content, fine granular soil structure, and moderate permeability, to have a value of 0.12. LS was calculated for a slope length of 500 feet at a 1 percent slope to be 0.16. The VM factor was conservatively set at 0.4 to represent drought conditions with sparse grasses. The calculated loss due to wind erosion is estimated to be 0.8 tons/acre/year, or approximately 0.004 inches/year. Over the design life of the disposal cell, the 1.5 feet of topsoil placed on the top slope of the cell is adequate for wind erosion protection.

The vegetation on the top surface of the cover may allow wind-borne deposition of materials. In addition, the rock mulch that extends over the top of the slopes onto the top surface provides supplemental wind erosion protection for the areas most susceptible to wind erosion.

OI.28 The licensee needs to resolve conflicts in the reclamation plan regarding hydraulic connection between the terrace and shallow ground-water systems. (SER Section 5.2.2.2)

Response:
As stated in numerous groundwater submittals, the upper terrace/shale 1 groundwater unit is separated from the lower shale aquifers by interbedded sandstone aquicludes that are continuous under the cell footprint. There is a minimal amount of communication between the upper and lower aquifers in some areas that is caused by the presence of old geotechnical borings advanced in 1968 that were not properly plugged. A review of the historic files indicates that there are five borings in the cell footprint that could possibly conduct water from the upper terrace/shale 1 aquifer to lower shale aquifers. The location of these borings is shown on Figure 1 attached to these responses.

Any communication between the upper and lower aquifers should be minimal and insignificant because of the limited number and size of the borings. The total footprint of the cell over which contaminated materials will be placed is approximately 12.3 acres

(535,000 square feet). Assuming each of the borings has a diameter of 12 inches, the total area of the five boring is approximately 4 square feet. If none of the borings could be found and plugged, the total area covered by the borings would be 0.0007% of the total area. Additionally, it is probable that the high clay content soils in the areas where these borings are located have at least partially plugged the upper part of the borings, further reducing any flow potential. It is therefore likely that any impact due to the presences of open borings would be insignificant.

Every reasonable effort will be made to find and plug hydraulic conduits between the upper and lower aquifers during the course of site reclamation and cell construction. Using the known coordinates of the old boreholes, efforts will be made to locate the old borings during soil and/or cell excavation. When excavations are completed to bedrock for soil clean up or cell construction in the areas where the boreholes were advanced, the bedrock surface will be cleaned of residual soils and loose excavation material and, using such methods as spray washing or sweeping, visual inspections will be performed to identify the borehole in the undisturbed shale or sandstone. Methods such as re-drilling or air jetting may be employed to evacuate materials from the old boreholes and the holes will be plugged in accordance with procedures outlined in the Ground Water Monitoring Plan (GWMP), and a bentonite seal will be placed over the stratigraphic interval of the uppermost sandstone unit. This will preclude future vertical migration down the old boring.

OI.29 The licensee needs to provide information to show that the liner cover material will comply with standard filter design criteria to prevent piping and promote drainage. (SER Section 5.3.2)

Response:
Filter criteria between the liner cover material and the overlying fine-grained soil were compared using criteria given in National Engineering Handbook, Gradation Design of Sand and Gravel Filters. The minimum requirements of the liner material have been met, with analyses presented in Appendix D of the Disposal Cell Construction Plan (Reclamation Plan Attachment E).

OI.30 Detection monitoring along the west side of the disposal cell must be addressed. (SER Section 5.4.1)

Response:
Detection monitoring wells were proposed to the north west and south west of the cell as this is the general direction for most of the historic groundwater movement in the area. However, it is recognized that cleanup activity could alter future groundwater directions in the immediate vicinity of the disposal cell. For this reason an additional well has been incorporated into the monitoring system along the west side of the cell as shown on Figure 24 enclosed with this response, and incorporated on Drawing 13 of the Technical Specifications.

OI.31 The licensee must specify and justify the saturated zones that will be monitored by the detection monitoring system. (SER Section 5.4.2)

Response:
Detection monitoring is proposed for the upper aquifer which consists of the terrace and shale 1 materials. If there was leakage from the cell, the upper terrace/shale 1 aquifer would be the aquifer where leakage would be first identifiable and, therefore, would be the

most appropriate for locating detection monitoring wells. As stated above in response to OI.28, very little if any communication between the upper aquifer and any lower aquifers is anticipated. Therefore, in the unlikely event of cell leakage the deeper aquifers would not receive a significant contribution of constituents of concern. The deeper aquifers are monitored as part of the site wide groundwater monitoring program. The site wide program monitor changes in groundwater quality which was impacted by historic operations and is described in the GWMP. The GWMP has been incorporated into the Reclamation Plan by reference in Section 7.4 of the Disposal Cell Construction Plan, Attachment E.

OI.32 The licensee must provide information to show that the proposed detection monitoring system will be capable of detecting leaks in the disposal cell, as required by Criterion 7A of Appendix A. (SER Section 5.4.4)

Response:
The following discussion shows that the proposed design of the new cell and the associated ground water monitoring system meet the requirements of Criterion 7A. In addition, it shows that even if the NRC does not agree that the design meets the letter of Criterion 7A, it should nevertheless approve the design as an acceptable alternative approach that will contain and stabilize the site and be protective of public health, safety and the environment in an equivalent manner to the requirements promulgated in 10 CFR Part 40, Appendix A. Based on this information, SFC requests approval of the proposed cell design.

The proposed design meets the requirements of Criterion 7A because it will provide leak detection capability that accomplishes the purposes of Criterion 7A. Criterion 7A states:

> A detection monitoring program has two purposes. The initial purpose of the program is to detect leakage of hazardous constituents from the disposal area so that the need to set ground-water protection standards is monitored. If leakage is detected, the second purpose of the program is to generate data and information needed for the Commission to establish the standards under Criterion 5B. The data and information must provide a sufficient basis to identify those hazardous constituents which require concentration limit standards and to enable the Commission to set the limits for those constituents and the compliance period. They may also need to provide the basis for adjustments to the point of compliance.

The detection monitoring system consists of two components; (1) a sand blanket and collection pipe system between the synthetic liner at the base of the cell and the underlying compacted clay liner, and (2) a series of monitoring wells beneath the compacted clay liner. Furthermore, a leachate collection system has been designed to collect leachate above the synthetic liner to minimize the zone of saturation (and therefore the driving head for leakage) above the synthetic liner. The leachate collection system and leak detection systems will have outlet pipe systems that drain by gravity to sumps outside of the cell for ease of monitoring and collection. These systems are shown in the Drawings (Reclamation Plan Attachment A) Both components will be used in concert to determine if leakage from the cell is occurring. This system will accomplish both of the purposes stated in Criterion 7A.

The first level of leak detection will be the leak detection system below the synthetic liner of the disposal cell. The presence of fluid in this leak detection system will give a reliable early indication of synthetic liner leakage and the consequent increased potential for

leakage through the compacted clay liner system beneath. In addition, if leakage is found in the liner leak detection system, the fluid will be collected in the leak detection system sumps, and removed and treated if necessary. Thus, this system not only provides reliable early detection of the potential for leakage, but also affords the first step in corrective action, which is collecting the contaminated leakage before it enters the ground water.

The second level of leak detection will be the ground water monitoring wells at the margins of the cell (POC wells) that will be completed in the terrace/shale 1 layer. These wells will be used to monitor the ground-water concentration of hazardous constituents associated with the wastes in the cell. Analysis of this data will permit the NRC and SFC to determine if significant cell leakage is occurring and will provide sufficient information to accomplish the purposes of Criterion 7A.

Constituents of concern that are reasonably expected to be present in the materials disposed in the cell were determined for the Facility as part of the GWMP, and have been evaluated here for presence or absence in the groundwater at the proposed cell location. This evaluation that the existing levels of groundwater contamination in the cell footprint will not prevent the identification of cell leakage. Figures 2 through 19 (enclosed with this response) illustrate that the hazardous constituents antimony (Sb), beryllium (Be), cadmium (Cd), chromium (Cr), lead (Pb), mercury (Hg), molybdenum (Mo), selenium (Se), silver (Ag), and thallium (Tl) are currently well below their respective MCLs in all wells in the area of the cell foot print. The hazardous constituents barium (Ba), fluoride (F) and nickel (Ni) currently exceed their respective MCL in only one well in the area of the cell foot print, and are less than their respective MCL in the other wells in the area. Only three of the 18 identified hazardous constituents, arsenic (As), nitrate (NO3), thorium (Th-230), and uranium (U), are present under the cell footprint at concentrations above the appropriate MCL in more than one well. There is a high likelihood that all constituents will be reduced to levels below their MCL during site reclamation and remediation efforts. It should be noted that the MCL used for thorium 230 is actually the background value since no MCL was specified in Appendix A to part 40.

The POC wells will allow detection of leakage from the cell even in the unlikely event that site remediation does not immediately reduce these few remaining hazardous constituents to background conditions. The POC wells will be used to determine the concentrations of these hazardous constituents immediately following the site reclamation and remediation efforts and to monitor subsequent changes. If an increase in the concentrations is detected in the POC network, a combination of efforts will be undertaken including review of the synthetic liner leak detection system data, review of the ground water POC baseline data, and geochemical characterization of the ground water in the cell area. This review will provide sufficient data and information for the NRC to determine if the increase is due to cell leakage. This system also will provide sufficient data for the NRC Staff to identify those hazardous constituents which require concentration limit standards and to enable the Staff to set the limits for those constituents and the compliance period. Thus, taken together, the two components of the DMS meet the requirements of Criterion 7A. Consequently, the NRC should find that the proposed design of the new cell and the associated DMS meet the requirements of Criterion 7A.

In addition, the DMS combined with the GWMP and the CAP affords comprehensive protection of public health safety and the environment. Due to the existing ground water contamination, the NRC already has sufficient information to determine that there is a need to set ground water protection standards in the vicinity of the proposed cell. SFC conducts

a comprehensive site ground water monitoring program that monitors existing impacted ground water, gathers information useful for developing interim corrective measures and evaluating the effectiveness of ground water cleanup and control activities, and monitors compliance with ground water cleanup standards. The Groundwater Monitoring Plan (GWMP) was approved by the NRC in August of 2005. In addition, NRC is currently reviewing a Ground Water Corrective Action Plan (CAP) submitted by SFC that is actively intercepting ground water contamination up-gradient from potential exposure points to restore ground water concentrations to levels below the cleanup standards. In effect, NRC has already approved ground water protection standards due to the existing contamination, and the only remaining purpose to be achieved by the DMS is to identify increases in the contaminant levels sufficient to trigger additional corrective actions to be implemented, and to establish a compliance period as required by Criterion 7A. The proposed DMS will easily achieve this purpose. For these reasons, the proposed cell design and DMS provide a means of protecting the public health and safety and the environment that is equivalent to Criterion 7A. Consequently, the NRC should approve this design as an acceptable alternative to compliance with Criterion 7A.

OI.33 The licensee must describe the manner in which it will identify potential hydraulic conduits below the disposal cell and how it will address the risk of further contamination to the shallow ground-water system. (SER Section 5.4.4)

Response:
As stated in response to OI 28, every effort will be made to find and plug hydraulic conduits between the upper and lower aquifers. However, even if all of the conduits cannot be found, any impact to the lower aquifers would be minor because of the very small percentage of the area of the cell over which the borings occur. Additionally, if any contamination were to occur in the deeper aquifers, the existing site wide groundwater monitoring program would identify the contamination. This would allow for an evaluation of appropriate actions that might need to be taken to address any contamination in deeper aquifers.

OI.34 The licensee must provide a sampling plan to provide data to justify the source term values used for the upper 15 feet of contaminated material in the radon flux calculations. (SER Section 6.2.2.1)

Response:
SFC provided in previous correspondence radiological characterization of the various layers of material to be placed in the disposal cell for radon assessment. The Th-230 and Ra-226 concentrations in several locations were described as "estimated" values since laboratory analyses were not available. A description is provided here of the means for acquiring specific characterization data for each location.

<u>Layer A</u>

Estimated values for sediments in the Emergency Basin, North Ditch and Sanitary Lagoon will be provided from archived samples as follows:

- Emergency Basin Sediment
    - Five archived site characterization samples will be submitted for determination of Th-230 and Ra-226 concentration.

- North Ditch Sediment

  - Five archived site characterization samples will be submitted for determination of Th-230 and Ra-226 concentration.

- Sanitary Lagoon Sediment

  - Three archived site characterization samples will be submitted for determination of Th-230 and Ra-226 concentration.

<u>Layer B</u>

The Calcium Fluoride Basin Liner, Emergency Basin Soils, North Ditch Soils, and the Sanitary Lagoon Liner will be characterized during remediation activities following removal of the overlying sediments. The Calcium Fluoride Basin Liner and the Sanitary Lagoon Liner, based on site characterization activities and process knowledge, are not expected to have Th-230 or Ra-226 concentrations significantly different from background.

<u>Layer C</u>

Calcium Fluoride sludge will be provided from archived samples as follows:

- Fluoride Holding Basin #1

  - Two archived site characterization samples will be submitted for determination of Th-230 and Ra-226 concentration.

- Fluoride Holding Basin #2

  - Two archived site characterization samples will be submitted for determination of Th-230 and Ra-226 concentration.

- Fluoride Settling Basins & Clarifier

  - Eight archived site characterization samples will be submitted for determination of Th-230 and Ra-226 concentration.

- Buried Fluoride Holding Basin 1

  - One archived site characterization samples will be submitted for determination of Th-230 and Ra-226 concentration.

The Interim Storage Cell contains sand and clay from the bottom of Pond 4, soil excavated from around the Solvent Extraction Building, and various small quantities of soil or soil-like material from previous cleanups. These materials will be characterized as follows:

- Sand and clay removed from Pond 4 during remediation activities was sampled and characterized as follows:

  - average Th-230 concentration = 14 pCi/g (n=36)
  - average Ra-226 concentration = 1.2 pCi/g (n=6)

- The volume of soil to which these concentrations apply is described in the table of Section 4.4.35 of the Site Characterization Report: 13, 932 cubic feet.

- Soil excavated from around the Solvent Extraction Building in 1990:
  - Five archived site characterization samples submitted for determination of Th-230 and Ra-226 concentration
  - The volume of soil to which these concentrations apply is described in the table of Section 4.4.35 of the Site Characterization Report: 44,500 cubic feet.

- The remainder of the materials in the Interim Soil Storage Cell, based on site characterization activities and process knowledge, are not expected to have Th-230 or Ra-226 concentrations significantly different from background.

The Solid Waste Burials (No. 1 and No. 2) will be characterized when exhumed during remediation activities. Based on site characterization information and process knowledge, these burials are not expected to have significant Th-230 or Ra-226 concentrations.

OI.35 The licensee must either provide the borrow material radiological data, or commit to testing the placed upper two feet of cover, and compare the results to established site background radionuclide levels. (SER Section 6.2.3)

Response:
SFC has identified the following borrow areas for sources of soil to be used for construction of the disposal cell cover and liner system[1]:

1. The soil borrow area south of the fertilizer ponds
2. The tornado berm
3. The cut area east of the DUF4 building
4. Uncontaminated portions of the settling pond (Pond 2) berms
5. Fertilizer pond berms

In addition, the Agland Area has been selected as the borrow area where topsoil will be obtained for finishing the cell cover.

The upper two feet of the cell cover, which consists of clay and topsoil layers, will be comprised of soils from the area south of the fertilizer ponds (South Borrow Area) and Agland Area. The clay will be obtained from the South Borrow Area and the topsoil from the Agland Area. These borrow areas were selected to provide soils that are of similar radiological characteristics to native soils in the site area and where sufficient quantities are expected to be available.

Sample analyses have been compiled for soil samples collected from background locations, South Borrow Area and Agland Area. Table 1 presents the analyses of background soil samples. Basic statistical information (number of analyses, minimum, maximum, average and standard deviation) is included. Tables 2 and 3 contain similar information for the Agland Area and South Borrow Area, respectively. The locations of the soil samples collected from the Agland and South Borrow areas are shown on Figure 20

[1] Reclamation Plan, Attachment A, Revision 3, Page 10, March 2005.

(included with this response). Background soil sample locations are shown on Figure No. 21 in Appendix D, Volume II, of the Reclamation Plan dated January 30, 2003.

The mean and standard deviation of each data set has been used to prepare a theoretical distribution of the data for graphical comparison. These distributions are plotted for uranium, thorium-230 and radium-226 as Figures 21, 22 and 23, respectively. In each case the distributions for the South Borrow Area and Agland Area are similar to the background areas. The cleanup level is also indicated on each graph with the label "CL" along the x-axis. In all cases the radiological concentrations are well below the cleanup levels.

The data included here is the basis for SFC's statement in the Reclamation Plan, Section 5.1.3 that the borrow area soil to be used for the top two feet of the cover are of similar radiological characteristics to native soils in the site area.

OI.36 The licensee must provide the gamma-radium correlation graph and indicate the gamma guideline value and its use. The licensee must also provide the Ra-226 to Th-230 correlation if it plans to use it. (SER Section 6.3.4)

Response:
The use of a gamma radium correlation for the Sequoyah Facility was discussed in a letter dated March 30, 2005 (ML050970438) responding to RP3 D. Attachment B, Final Status Survey, of the Reclamation Plan has been revised to reflect the response to RP3 D. Specifically, Section 2.5.1 has been revised to include additional description of the application of a gamma guideline value.

As described in the response to RP3, SFC will apply the gamma survey results in different ways depending upon the source of contamination. For areas that are not contaminated with by-product materials (characterized by lack of thorium/radium), the gamma survey is intended to find areas of elevated activity not detected by soil sampling on a systematic pattern, or to provide a qualitative level of confidence that no areas of elevated activity were missed by sampling on a random pattern. For these areas, the gamma guideline value will not be based upon a quantitative correlation but rather based upon either a detection sensitivity from MARSSIM Table 6.7 or a qualitative assessment by comparison to background.

This quantitative relationship between gamma measurements and radium concentration has not been established to date because a soil sampling/gamma measurement data set cannot be developed in accordance with NUREG-1620 until reclamation begins. Due to the limited areal extent of thorium/radium contamination, the primary areas from which the data could be gathered are currently inaccessible (footprints of active ponds). Gamma measurements will be used in the thorium/radium areas in lieu of soil sample results if a quantitative relationship can be established.

OI.37 The licensee must describe the gamma survey procedure for soil verification indicating the speed and spacing of the readings or scan path, and discuss how management oversight of field personnel will be adequate to provide reliable survey data. (SER Section 6.3.5)

Response:
The gamma survey procedure for soil verification was described in a letter dated March 30, 2005 (ML050970438) responding to RP3 D. Attachment B, Final Status Survey, of the

Reclamation Plan has been revised to reflect the response to RP3 D. Specifically, Section 2.5.1 has been revised to include a description of the gamma survey procedure. The description includes survey speed, spacing and resulting data density.

Management oversight of the field personnel will be conducted in the context of SFC's quality assurance (QA) program described in Attachment C of the Reclamation Plan. Oversight and QA for the gamma survey will also be described in the quality assurance project procedure developed specifically for the final status survey.

OI.38 The Data Management Plan and QAPP procedure must be summarized in some detail in the reclamation plan and be available for NRC staff review during decommissioning. (SER Section 6.3.6)

Response:
A conceptual description of the QAPP for the final status survey is provided in Section 4.2 of Attachment B, Final Status Survey, of the Reclamation Plan. The QAPP will be composed of standardized, recognizable elements covering the entire project from planning, through implementation, to assessment as described in the conceptual description. All aspects of the Data Management Plan will be included in the QAPP. The development, review, approval, and implementation of the QAPP will occur within SFC's existing system for management of the operating procedures and will be a part of SFC's quality system.

OI.39 The licensee must demonstrate that a single sample result is representative of the entire grid (i.e., radionuclide concentration is fairly homogeneous for the area). (SER Section 6.3.7)

Response:
SFC uses a five plug composite sampling procedure for soil sampling of land areas with thorium/radium contamination present. Our procedure was described in a letter dated March 30, 2005 (ML050970438) responding to RP3 D. Attachment B, Final Status Survey, of the Reclamation Plan has been revised to reflect the response to RP3 D. Specifically, Section 2.5.3, Soil Sampling, includes a description of the 5-plug composite sample employed by SFC for these areas.

OI.40 The licensee must identify the location where the records of information important to decommissioning are kept, as required by '40.36(f). (SER Section 6.3.8)

Response:
Information important to the decommissioning, as required by 10 CFR 40.36(f), including documentation of spills, cleanup of contamination, drawings or descriptions of modification of structures in the restricted area, and locations of possible inaccessible contamination, is maintained in the Administration Building at the Sequoyah Facility. This statement has been added to Section 1.4 of the Reclamation Plan. The records are retained within the normal file structure employed at the Facility and have been identified as Decommissioning Records at each storage location.

OI.41 The licensee must address the non-radiological hazardous constituents of the byproduct material to comply with Criterion 6(7). (SER Section 6.3.9)

Response:
SFC addressed the potential non-radiological hazards with wastes in the Draft Corrective Measures Study Report (CMS) dated October 27, 1997. Section 2.5 of this document describes the characterization of potential "sources" of RCRA constituents. The following paragraph taken from page 2-9 of the CMS summarizes the findings and is reproduced here for informational purposes.

> "Source sampling results are described in the Final RFI Report. A summary table which includes the results of the 12 RCRA metals (40 CFR 261, Appendix VIII) is included with this report as Table [4]. The Cell Room dip Tank sludge and the South Yellowcake Sump sediments have been dispositioned since the RFI sampling was performed. The Cell Room Dip Tank sludge was shipped to a hazardous waste landfill in 1996. The South Yellowcake Sump sediments were removed and placed into Clarifier A in 1996. In 1994, a treatability study was conducted on the raffinate sludge and sludge from the fluoride holding basins. The treatability studies included conducting Toxicity Characteristic Leaching Procedure (TCLP) extraction of the sludges. The metals analyses, subsequent to TCLP extraction, indicate that, prior to any treatment, the raffinate and calcium fluoride are not characteristically hazardous."

OI.42 The licensee needs to provide documentation from EPA and the State of Oklahoma that they do not have regulatory authority over the non-11e.(2) byproduct material. (SER Section 7.3)

Response:
In section A.V.3 of the settlement agreement among the State, the Cherokee Nation and SFC, a copy of which is available in ADAMS as an attachment to document number ML043450408, the State agreed that if the Calcium Fluoride sludge is shown by testing not to constitute hazardous waste, then no State permit is required for disposal of SFC's non-11e.(2) byproduct material in the onsite disposal cell.

SFC provided the State with the results of analyses of Calcium Fluoride sludge samples, and provided additional information in response to the State's follow-up questions. After reviewing this information, the State provided the attached letter indicating that the analyses and other information satisfied the requirements of section A.V.3.a of the settlement agreement. Consequently, no State permit is required for disposal of SFC's non-11e.(2) byproduct material in the onsite disposal cell. See attached letter dated May 9, September 20, and October 18, 2005.

In accordance with the Resource Conservation and Recovery Act (RCRA), the Environmental Protection Agency (EPA) has authorized the State of Oklahoma to operate its hazardous waste management program in lieu of the Federal program. *See* 40 CFR § 272.1851 (2005). Consequently, the State's letter shows that no EPA permit is required.

<u>Confirmatory Items</u>

CI.01 The licensee needs to revise figures to show that the terrace ground-water system consists of both the terrace deposits and Unit 1 Shale. (SER Section 5.2.2)

Response:
The site hydrogeologic conceptual model and the associated nomenclature has changed slightly since the Site Characterization Report (SCR) was submitted in 1998. As described in the Site Hydrogeological and Geochemical Characterization Report (HGSCR; SFC, 2002) the terrace aquifer in the center of the site consists of the terrace alluvium and Shale unit 1 which are in intimate contact without a significant aquiclude between them. The Terrace alluvium and Shale unit 1 are considered a single hydrologic unit within the site conceptual model and the characterization of the extent of this unit has been illustrated as the extent of the Shale unit 1 (see Corrective Action Plan Figure 2-14). Table 5 enclosed here is provided to describe the hydrogeologic units, the groundwater system designations, and the groundwater monitoring units used in the site hydrogeologic conceptual model. SFC did not revise the figures in the SCR since the HGSCR is the updated work provided in the Reclamation Plan.

CI.02 The licensee needs to include arsenic background water quality data in the reclamation plan. (SER Section 5.2.4)

Response:
SFC provided arsenic background water quality data to NRC as part of a response to a RAI dated October 29, 2004 for the GWMP amendment request which has been approved on August 22, 2005. Appendix B of the GWMP contains the background water quality evaluation which was presented in the response. The GWMP has been incorporated into the Reclamation Plan by reference in Section 7.4 of the Disposal Cell Construction Plan, Attachment E.

CI.03 The licensee needs to remove references to transplanting seedlings in the reclamation plan. (SER Section 5.3.1)

Response:
The revegetation plan based on grass and forb species is outlined in the Technical Specifications (Reclamation Plan Attachment A). References to transplanting seedlings have been removed.

CI.04 The licensee needs to include the grain size distribution for the liner cover material in the reclamation plan. (SER Section 5.3.2)

Response:
This grain size distribution has been included in the response to OI.05 above and in the Technical Specifications (Reclamation Plan Attachment A).

CI.05 Monitoring well construction details must be added to the Technical Specifications or incorporated into the reclamation plan by reference. (SER Section 5.4.2)

Response:
The monitoring well construction details are provided in the Drawings (Reclamation Plan Attachment A), and is also described in the GWMP which has been incorporated into the Reclamation Plan by reference.

CI.06 The licensee must revise the reclamation plan to incorporate its commitment regarding radioactivity levels in the upper part of the cover. (SER Section 6.2.3)

Response:
Section 5.1.3 has been revised consistent with the changes submitted in response to RP1 E by letter dated January 24, 2005 (ML05042003). See also the response to OI.35.

CI.07 The licensee must revise Appendix G as it indicated in Sequoyah Fuels Corporation, 2005a. (SER Section 6.3.3)

Response:
The Reclamation Plan Appendix G has been revised to reflect the responses included in SFC's letter dated January 24, 2005 (ML05042003). Specifically, the text of Appendix G has been revised to state that the exposure rate from the disposal cell will be reduced to background levels by placement of waste and design of cell cover. Also, the basis for the dose model input of basic radiation dose limit has been changed to the model's default. Finally, a new attachment has been added to Appendix G describing how the proposed soil cleanup levels are ALARA.

In addition, Appendix G has been revised to reflect the responses included in SFC's letter dated March 30, 2005 (ML050970438). Specifically, a new attachment has been added to Appendix G describing justification for use of the resident farmer scenario, and the text of parameter justifications has been revised to provide reference to the data for site-specific hydrogeological values used in the dose model.

Finally, Appendix G has been revised to update or complete references provided in footnotes and text, to reflect the changes in scenario and inputs associated with SFC's letter of March 30, 2005 (ML050970438), and to make editorial revisions necessitated by changes and revisions described here.

The Reclamation Plan Section 3.2.2 "Cleanup Levels" has also been revised to reflect the response to Confirmatory Item 7.

CI.08 The licensee must include soil sampling procedures and analytical methods in the reclamation plan. (SER Section 6.3.5)

Response:
In a letter dated January 24, 2005 (ML05042003) responding to RP1 G and RP3 C, SFC described the soil sampling procedures and the analytical methods that will be used for the final status survey. The operating procedures were referenced in the response as well. Attachment B, Section 2.5.3, Soil Sampling, has been revised to incorporate the description of the soil sampling procedures and the analytical methods provided in that response.

CI.09 The licensee must revise the final status survey plan as it indicated in Sequoyah Fuels Corporation, 2005a. (SER Section 6.3.7)

Response:
Section 2.5.2 and 3.4.1 of the final status survey plan have been revised to incorporate additional description of surface activity measurements and activity limits for structures found in the letter dated January 24, 2005 (ML05042003).

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STEVEN A. THOMPSON
Executive Director

OKLAHOMA DEPARTMENT OF ENVIRONMENTAL QUALITY

BRAD HENRY
Governor

May 9, 2005

James V. Barwick, Esq.
Environmental Protection Unit
4545 N. Lincoln Blvd., Suite 260
Oklahoma City, OK 73105-3498

RE: Characterization Report - Calcium Fluoride Burials
(Settlement Agreement Action Item V.A.3.a.)
Sequoyah Fuels Corporation
Gore, Oklahoma

Dear Mr. Barwick:

The Oklahoma Department of Environmental Quality (Department) has reviewed the above captioned document submitted by Sequoyah Fuels Corporation (SFC) to Alvin H. Gutterman of Morgan, Lewis and Bockius, LLP on April 12, 2005.

The report was submitted in response to Settlement Agreement Provision V.A.3.a. under which SFC agreed "to take representative samples of the Calcium Fluoride Sludge and conduct a Toxicity Characteristic Leachate Procedure Test (TCLP) and total metals analyses on the samples."

It appears that results of the Toxicity Characteristic Leaching Procedure indicate the sludge from the Calcium Fluoride Sludge disposal units is below 5.0mg/L, and therefore may be non-hazardous. However, the Department will require clarification on certain sampling protocol issues before recommending that Provision A.V.3.a. of the Settlement Agreement has been satisfied and that the sampling has been adequate to accurately characterize the material within these disposal units.

Section 4.0 of the report states that samples were collected from three locations at burial units 15A, 15B and 15C, each of which unit is approximately one-fifth to one-quarter acre in size. However, according to Figure 3 of the report, only two samples were collected from disposal unit 15B and only two from the far eastern portion of disposal unit 15C. In addition, three locations (15AW-S, 15B-W, and Misc 15G) were not included in the data provided in Table 2.

The Department recommends that SFC provide clarification of the sampling locations, an explanation for excluding data from soil boring locations 15AW-S, 15B-W, and Misc 15G, and the name of the laboratory which performed the analyses. The Department cannot recommend approval of this document until the information requested is provided.

If you have questions regarding our review of this document, please contact Mr. Robert Replogle at 405.702.5131 or robert.replogle@deq.state.ok.us.

Sincerely,

Saba Tahmassebi, Ph.D., P.E.
Chief Engineer
Land Protection Division

xc: Mr. Myron Fliegel, NRC
Mr. Jim Ellis, SFC
Ms. Rita Ware, EPA

OKLAHOMA DEPARTMENT OF ENVIRONMENTAL QUALITY

STEVEN A. THOMPSON
Executive Director

BRAD HENRY
Governor

September 20, 2005

Trevor Hammons, Esq.
Environmental Protection Unit
4545 N. Lincoln Blvd., Suite 260
Oklahoma City, OK 73105-3498

RE: August 22, 2005 Response to Comments
Characterization Report - Calcium Fluoride Burials
(Settlement Agreement Action Item V.A.3.a.)
Sequoyah Fuels Corporation
Gore, Oklahoma

Dear Mr. Hammons:

The Oklahoma Department of Environmental Quality (Department) has reviewed the above captioned document submitted by Sequoyah Fuels Corporation (SFC) in response to Departmental comments made in a letter to you dated May 9, 2005 in reference to Settlement Agreement Provision V.A.3.a.

The information presented in SFC's response has clarified the issues the Department raised. Therefore, the Department believes Provision A.V.3.a. of the Settlement Agreement has been satisfied and that the sampling has been adequate to accurately characterize the material within these calcium fluoride disposal units.

If you have questions regarding our review of this document, please contact Mr. Robert Replogle at 405.702.5131 or robert.replogle@deq.state.ok.us.

Sincerely,

Saba Tahmassebi, Ph.D., P.E.
Chief Engineer
Land Protection Division

xc: Mr. Myron Fliegel, NRC
Mr. Jim Ellis, SFC
Ms. Rita Ware, EPA

Sequoyah Fuels Corporation\Settlement Agreement Action Item V.A.3.a Response to Comments.APV.050920

O K L A H O M A
DEPARTMENT OF ENVIRONMENTAL QUALITY

STEVEN A. THOMPSON
Executive Director

OKLAHOMA DEPARTMENT OF ENVIRONMENTAL QUALITY

BRAD HENRY
Governor

October 18, 2005

Trevor Hammons, Esq.
Environmental Protection Unit
4545 N. Lincoln Blvd., Suite 260
Oklahoma City, OK 73105-3498

RE: U.S. Nuclear Regulatory Commission
Draft Safety Evaluation Report for Proposed Reclamation Plan
Sequoyah Fuels Corporation (SFC)
Gore, Oklahoma

Dear Mr. Hammons:

The Oklahoma Department of Environmental Quality (Department) has completed its review of the above captioned document prepared by the U.S. Nuclear Regulatory Commission. The document was submitted on September 26, 2005 as an obligatory copy to the original addressed to Sequoyah Fuels Corporation.

The Department concurs with the content of the draft document and has no additional comments at this time. Therefore, the Department recommends the approval of the Safety Evaluation Report.

If you have questions regarding our review of this or other documents, please contact Mr. Robert Replogle at 405.702.5118 or robert.replogle@deq.state.ok.us.

Sincerely,

Saba Tahmassebi, Ph.D., P.E.
Chief Engineer
Land Protection Division

xc: Mr. Myron Fliegel, NRC
Ms. Rita Ware, EPA Region 6

Sequoyah Fuels CorporationReclamation Plan.DraftSafetyEvaluationReport.Concurrence 051018

Table 1

General Engineering Laboratories, Inc.
Background Soil Sample Analyses

Location	Depth, ft		U-Tot	Ra-226	Th-230
	Top	Bottom	µg/g	pCi/g	pCi/g
HA288	0	0.5	3.87 ± 0.0869	1.39 ± 0.403	1.13 ± 0.358
HA289	0	0.5	3.73 ± 0.0688	0.92 ± 0.361	0.915 ± 0.319
HA290	0	0.5	2.73 ± 0.0483	0.693 ± 0.289	0.593 ± 0.277
HA291	0	0.5	3.93 ± 0.0556	0.867 ± 0.345	0.597 ± 0.271
HA292	0	0.5	3.07 ± 0.0525	0.733 ± 0.324	0.55 ± 0.265
HA292 DUP	0	0.5	2.62 ± 0.0451	1.11 ± 0.361	0.629 ± 0.264
HA293	0	0.5	3.24 ± 0.0678	1.44 ± 0.476	0.98 ± 0.375
HA294	0	0.5	3.27 ± 0.0627	0.968 ± 0.353	0.753 ± 0.289
HA295	0	0.5	3.38 ± 0.059	0.937 ± 0.36	1.02 ± 0.352
HA296	0	0.5	3.14 ± 0.0609	1.09 ± 0.39	0.434 ± 0.223
HA297	0	0.5	3.34 ± 0.0669	1 ± 0.317	0.469 ± 0.239
HA298	0	0.5	3.76 ± 0.0776	1.7 ± 0.46	0.942 ± 0.384
HA299	0	0.5	3.08 ± 0.0621	0.735 ± 0.341	0.968 ± 0.416
HA300	0	0.5	1.20 ± 0.0191	0.65 ± 0.32	0.39 ± 0.191
HA224	1	2	4.32 ± 0.0797	1.03 ± 0.374	0.904 ± 0.333
HA224	2	2.6	2.91 ± 0.0453	1.09 ± 0.381	1.1 ± 0.384
HA307	0	0.5	3.27 ± 0.0608	0.985 ± 0.402	0.826 ± 0.312
HA308	0	0.5	3.11 ± 0.0542	1.25 ± 0.443	0.709 ± 0.351

	U-Tot	Ra-226	Th-230
Number of Analyses	18	18	18
Minimum	1.2	0.653	0.388
Maximum	4.32	1.7	1.13
Average	3.22	1.03	0.77
Standard Deviation	0.67	0.28	0.24

Table 2

Agland Top Soil Sample Analyses

Location	Depth, ft Bottom	Depth, ft Top	Sample Date	Uranium µg/g	Radium-226 pCi/g	Thorium-230 pCi/g
AGLAND	0.0	0.5	4/23/1992	2.00	0.900 ± 0.500	0.700 ± 0.400
AGLAND	0.0	0.5	8/17/1998	1.60	0.540 ± 0.190	0.800 ± 0.500
AGLAND	0.0	0.5	8/17/1998	1.20	0.810 ± 0.260	1.30 ± 0.500
AGLAND	0.0	0.5	7/15/2002	1.87		
AGLAND	0.0	0.5	7/15/2002	1.63		
AGLAND	0.0	0.5	3/12/2003	1.60	0.711 ± 0.102	0 ± 0.114
AGLAND	0.0	0.5	3/8/2004	1.52		
AGLAND	0.0	0.5	3/8/2004	1.18		
AGLAND	0.0	0.5	9/9/2004	1.80	0.615 ± 0.143	1.37 ± 0.177
AGLAND	0.0	0.5	9/9/2004	1.32	0.219 ± 0.097	1.25 ± 0.156
AGLAND	0.0	0.5	12/3/2004	2.25	0.464 ± 0.079	0.907 ± 0.183
AGLAND	0.0	0.5	12/3/2004	1.88	0.393 ± 0.079	1.73 ± 0.247
AGLAND	0.5	1.0	4/23/1992	2.10	1.80 ± 0.700	0.600 ± 0.400
AGLAND	0.5	1.0	8/17/1998	1.30	0.680 ± 0.250	0.500 ± 0.400
AGLAND	0.5	1.0	7/15/2002	1.38		
AGLAND	0.5	1.0	3/8/2004	1.77		
AGLAND	0.5	1.0	9/9/2004	2.03	3.17 ± 0.396	1.04 ± 0.172
AGLAND	0.5	1.0	12/3/2004	1.93	0.548 ± 0.114	2.19 ± 0.239
AGLAND	1.0	1.5	8/17/1998	1.20	0.740 ± 0.280	1.50 ± 0.600
AGLAND	1.0	1.5	7/15/2002	1.61		
AGLAND	1.0	1.5	3/12/2003	1.90	0.786 ± 0.103	0 ± 0.164
AGLAND	1.0	1.5	3/8/2004	1.46		
AGLAND	1.0	1.5	9/9/2004	1.73	0.540 ± 0.106	1.00 ± 0.157
AGLAND	1.0	1.5	12/3/2004	2.09	0.550 ± 0.126	1.71 ± 0.260
AGLAND	1.5	2.0	8/17/1998	1.10	0.860 ± 0.340	0.700 ± 0.300
AGLAND	1.5	2.0	7/15/2002	1.58		
AGLAND	1.5	2.0	3/8/2004	1.60		
AGLAND	1.5	2.0	9/9/2004	1.80	0.103 ± 0.053	0.744 ± 0.142
AGLAND	1.5	2.0	12/3/2004	1.94	0.454 ± 0.083	1.42 ± 0.216
AGLAND	2.0	2.5	8/17/1998	1.40	0.390 ± 0.230	1.70 ± 0.500
AGLAND	2.0	2.5	7/15/2002	1.34		
AGLAND	2.0	2.5	3/8/2004	1.70		
AGLAND	2.0	2.5	9/9/2004	1.91	0.158 ± 0.111	1.43 ± 0.197
AGLAND	2.0	2.5	12/3/2004	1.97	0.564 ± 0.120	1.59 ± 0.241
AGLAND	2.5	3.0	8/17/1998	1.20	0.390 ± 0.190	0.900 ± 0.300
AGLAND	2.5	3.0	7/15/2002	1.86		
AGLAND	2.5	3.0	3/8/2004	1.77		
AGLAND	2.5	3.0	9/9/2004	1.85	0.614 ± 0.136	0.420 ± 0.156
AGLAND	2.5	3.0	12/3/2004	2.13	0.738 ± 0.142	1.93 ± 0.241
AGLAND	3.0	3.5	8/17/1998	1.10	0.590 ± 0.200	0.800 ± 0.700
AGLAND	3.0	3.5	7/15/2002	1.86		
AGLAND	3.0	3.5	3/8/2004	1.34		
AGLAND	3.0	3.5	9/9/2004	1.78	0.781 ± 0.119	1.45 ± 0.172
AGLAND	3.0	3.5	12/3/2004	2.25	0.570 ± 0.113	1.78 ± 0.211

Table 2

Agland Top Soil Sample Analyses

Location	Depth, ft		Sample	Uranium	Radium-226	Thorium-230
	Bottom	Top	Date	µg/g	pCi/g	pCi/g
AGLAND	3.5	4.0	8/17/1998	1.20	0.790 ± 0.200	1.10 ± 0.400
AGLAND	3.5	4.0	7/15/2002	2.05		
AGLAND	3.5	4.0	3/12/2003	1.90	0.759 ± 0.106	0.392 ± 0.161
AGLAND	3.5	4.0	3/8/2004	1.53		
AGLAND	3.5	4.0	9/9/2004	1.70	0.390 ± 0.100	1.26 ± 0.183
AGLAND	3.5	4.0	12/3/2004	2.30	0.750 ± 0.136	1.84 ± 0.202
HA061	0.0	0.5	11/14/1994	< 1.00		
HA061	0.5	1.0	11/14/1994	< 1.00		
HA265	0.0	0.5	9/13/1995	< 1.00		
HA266	0.0	0.5	9/13/1995	1.00		
HA269	0.0	0.5	9/14/1995	1.00		
HA273	0.0	0.5	7/20/1995	< 1.00		
HA274	0.0	0.5	9/14/1995	< 1.00		
HA275	0.0	0.5	9/14/1995	< 1.00		
HA276	0.0	0.5	9/14/1995	< 1.00		
HA543	0.0	0.5	3/4/2003	2.10	1.49 ± 0.189	1.09 ± 0.275
HA545	0.0	0.5	3/4/2003	1.60	0.622 ± 0.152	0.829 ± 0.284
HA546	0.0	0.5	3/4/2003	1.80		
HA732	0.0	0.5	8/4/2005	1.92	0.779 ± 0.142	
HA733	0.0	0.5	8/4/2005	1.99	1.42 ± 0.221	
HA734	0.0	0.5	8/4/2005	1.93	0.730 ± 0.144	
HA735	0.0	0.5	8/4/2005	3.26	1.07 ± 0.202	

	Uranium	Radium-226	Thorium-230
Number of Analyses	66	38	34
Minimum	1.00	0.10	0
Maximum	3.26	3.17	2.19
Average	1.64	0.75	1.12
Standard Deviation	0.43	0.52	0.54

Table 3

South Borrow Area Soil Sample Analyses

Location	Depth, ft Bottom	Depth, ft Top	Sample Date	Uranium µg/g	Radium-226 pCi/g	Thorium -230 pCi/g
HA267	0.0	0.5	9/13/1995	1.00		
HA278	0.0	0.5	9/14/1995	1.10		
HA291	0.0	0.5	11/7/1995	1.40	1.30 ± 0.620	0.800 ± 0.700
HA291	0.0	0.5	11/7/1995	3.93	0.867 ± 0.345	0.597 ± 0.271
HA541	0.0	0.5	3/4/2003	1.80		
HA548	0.0	0.5	3/4/2003	2.30		
HA549	0.0	0.5	3/4/2003	2.40		
HA551	0.0	0.5	2/28/2003	1.90	1.32 ± 0.175	1.19 ± 0.314
HA552	0.0	0.5	3/4/2003	2.20		
HA554	0.0	0.5	3/4/2003	2.20		
HA643	0.0	0.5	11/25/2003	3.24		
HA644	0.0	0.5	11/25/2003	3.65		
HA645	0.0	0.5	11/25/2003	2.55		
HA743	0.0	0.5	8/4/2005	2.12	1.27 ± 0.201	

	Uranium	Radium-226	Thorium-230
Number of Analyses	14	4	3
Minimum	1.00	0.87	0.60
Maximum	3.93	1.32	1.19
Average	2.27	1.19	0.86
Standard Deviation	0.87	0.22	0.30

TABLE 4

Source Sampling Results - RCRA Metals
mg/kg

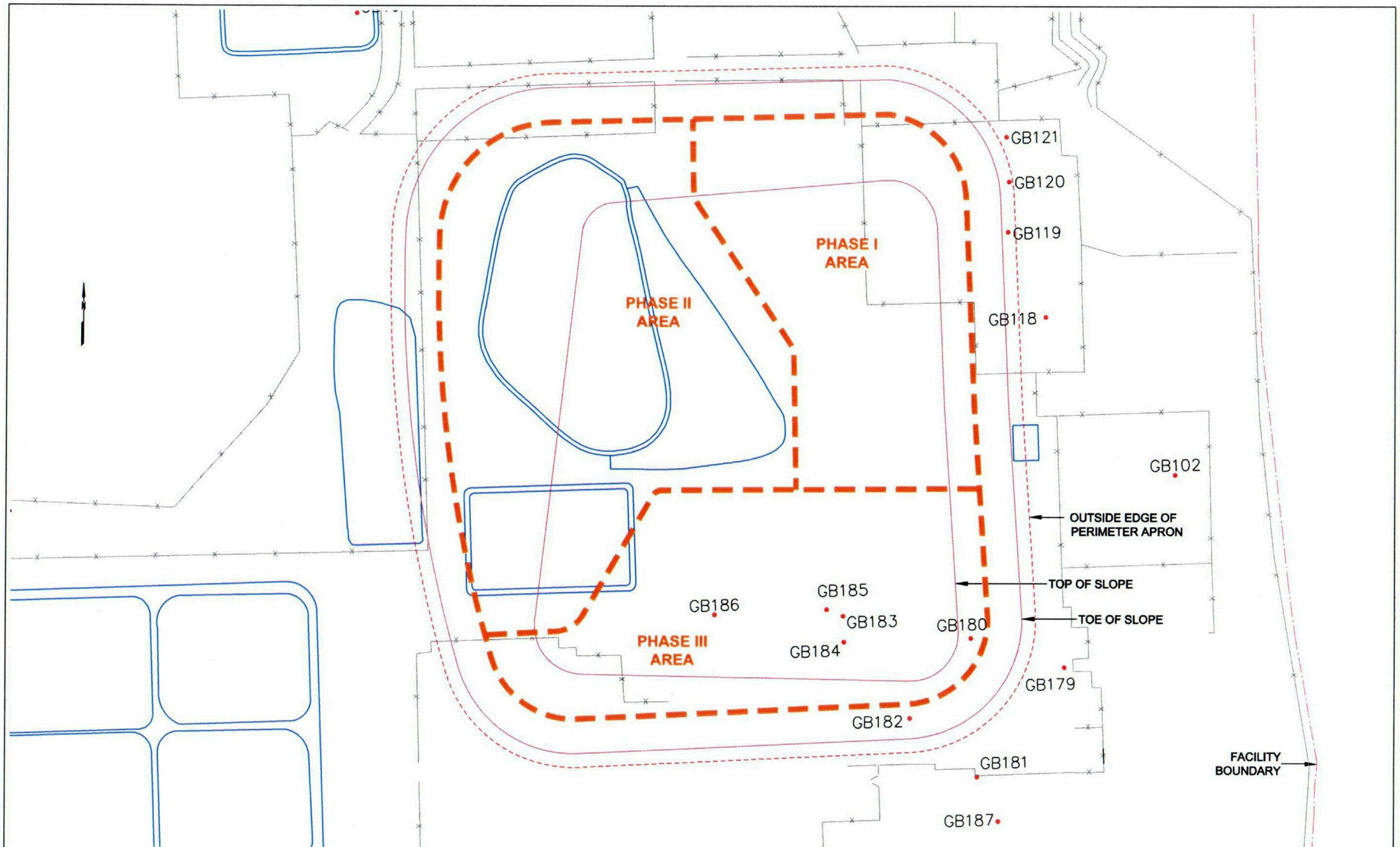
Source Description	Loc ID	Ag	As	Ba	Be	Cd	Cr	Hg	Ni	Pb	Sb	Se	Tl
Fluoride Sludge (S.W. Area)	SD013	< 0.6	133	40.5	< 0.05	< 0.7	30.2	0.05	66	< 10	< 10	< 10	< 10
Fluoride Sludge Basin No. 1 (North)	SD016	< 0.6	17.3	13.9	< 0.05	< 0.7	15.2	0.02	28.1	< 10	< 10	< 10	< 10
Composite from Clarifier 1A	SD014	1.9	1350	2750	4.12	< 0.7	259	0.34	721	515	17.7	87.2	36
North End Pond 1 Spoils Pile	BH131A/B	< 0.6	15.4	157	0.96	3.3	21.1		36.7	23.1	< 10	< 10	20.9
South End Pond 1 Spoils Pile	BH131B	< 0.6	< 10	64.6	0.37	1.1	7.8	0.01	7.4	< 10	< 10	< 10	< 10
MPB - Cell Room Dip Tank	SD012	8.6	128	83	< 0.05	9.7	55.2	1.1	26700	962	19.3	27.7	15.1
South Yellowcake Sump	SD015	< 0.6	15.9	407	0.56	< 0.7	81.6	0.02	342	267	< 10	< 10	< 10
North Ditch	SD017	1	39.3	282	0.42	< 0.7	53	0.13	96	86.1	< 10	< 10	< 10
Emergency Basin	SD018	65.5	97.5	282	0.14	< 0.7	38.2	0.14	43.8	49.5	117	30.4	< 10
Sanitary Lagoon	SD019	185	440	611	2.84	< 0.7	42.2	0.29	423	555	4.4	29.8	< 10
Interim Storage Cell	BH149	< 0.6	< 10	138	0.8	2	32.4	0.03	51.3	32.4	< 10	< 10	< 10

Table 5
Sequoyah Fuels Corporation
Typical Groundwater Monitoring Designations and Hydrogeological Units

System	Unit Designation	Unit Description
Terrace Groundwater	Terrace Deposites (0 to 16.5 feet thick)	Silts, sandy silts, silty clays, sandy gravely clays, silty sandy clays, clays
Terrace Groundwater	Unit 1 Shale (0 to 20 feet thick)	Dark grayish brown fissile, silty and sandy near contacts
Aquitard	Unit 1 Sandstone (0 to 12.5 feet thick)	Highly cemented very fine to medium grained pale brown to dark gray
Shallow Bedrock Groundwater	Unit 2 Shale (2.5 to 10 feet thick)	Dark gray to light brownish gray, fissile sand, silty and continuous with thin discontinuous silty sandstone lenses
Shallow Bedrock Groundwater	Unit 2 Sandstone (3 to 14.5 feet thick)	Dark gray to very dark gray, very fine grained, quartzose and well cemented in upper protion
Shallow Bedrock Groundwater	Unit 3 Shale (1 to 18 feet thick)	Very dark gray, sandy to silty, carbonaceous and contains thin discontinous sandstone layers
Shallow Bedrock Groundwater	Unit 3 Sandstone (1.5 to 3 feet thick)	Highly cemented, very fine grained, very dark gray and very hard
Shallow Bedrock Groundwater	Unit 4 Shale (12 to 18 feet thick)	Dark gray to grayish black, fissile and becoming sandy near the lower contact with the Unit 4 Sandstone
Aquitard	Unit 4 Sandstone (15.5 to 18 feet thick)	Medium gray to dark gray, very fine grain dense quartz sand, silicious and has a very abrupt lower contact with Unit 5 Shale
Deep Bedrock Groundwater	Unit 5 Shale (> 22 feet Thick)	Very dark gray to black, soft to hard, fissile, with sandy to silty lenses

Notes: 1) Unit thicknesses are estimates from hydrogeological investigations conducted at the site.

2) The Terrace Groundwater System consists of the terrace deposites and the shale unit immediately beneath the terrace deposites, if a shale unit is present prior to encountering a sandstone unit.



No.	DESCRIPTION	BY	CHKD.	APPROVED	DATE

REVISIONS

DWG No.	DRAWING TITLE

REFERENCES

ENGINEERING RECORD	BY	DATE

DESIGNERS

PREPARED FOR

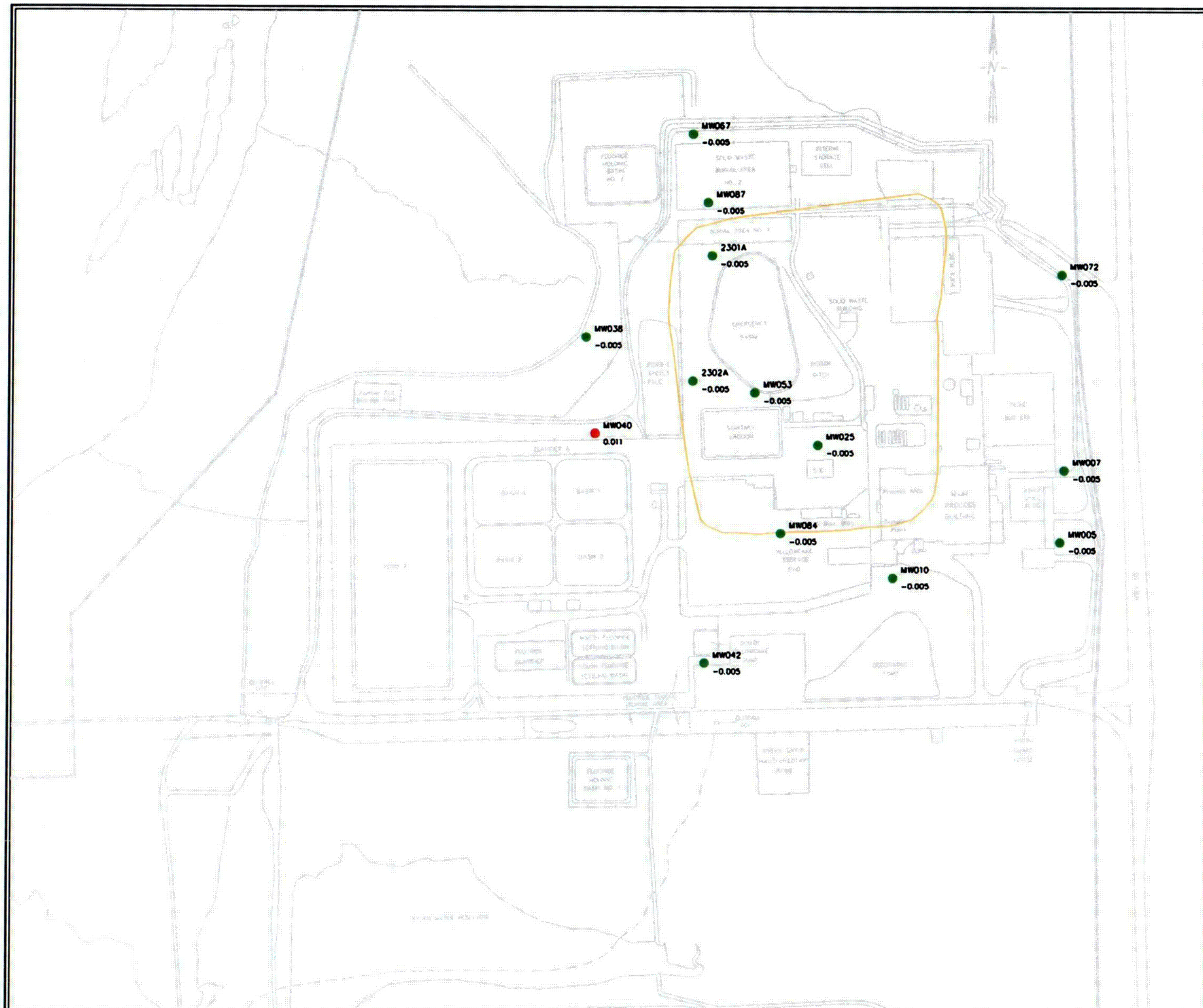
SEQUOYAH FUELS
A GENERAL ATOMICS COMPANY

TITLE

Figure 1
Borehole Locations

PROJECT: 100734	DATE: JANUARY 2006	DRAWING: 5	REVISION: C
SCALE: AS SHOWN	ACAD FILE: GeoBoringLocToCell.dwg		

C01

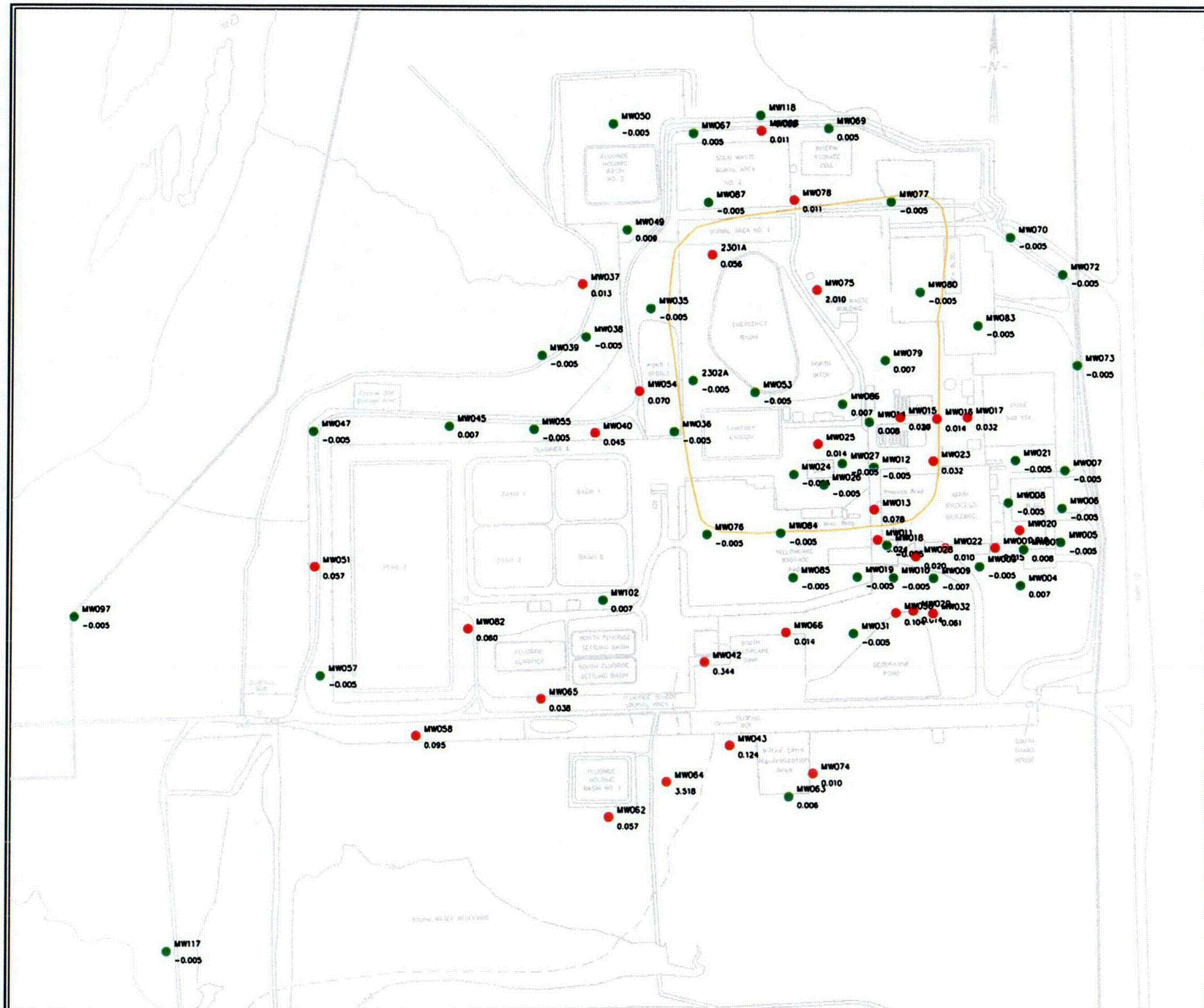


Less Than MCL
Greater Than or Equal to MCL
Disposal Cell Boundary

A minus sign indicates a less than detection value.
All units in mg/l.

SEQUOYAH FUELS CORPORATION	
Title: Terrace Groundwater Monitoring System Antimony (MCL = 0.006 mg/l)	
PREPARED BY: SFC	Filename: GW_Sb.dwg
Reviewed by: CH	Figure No. 2
Date: 12 Jan 2006	

C02



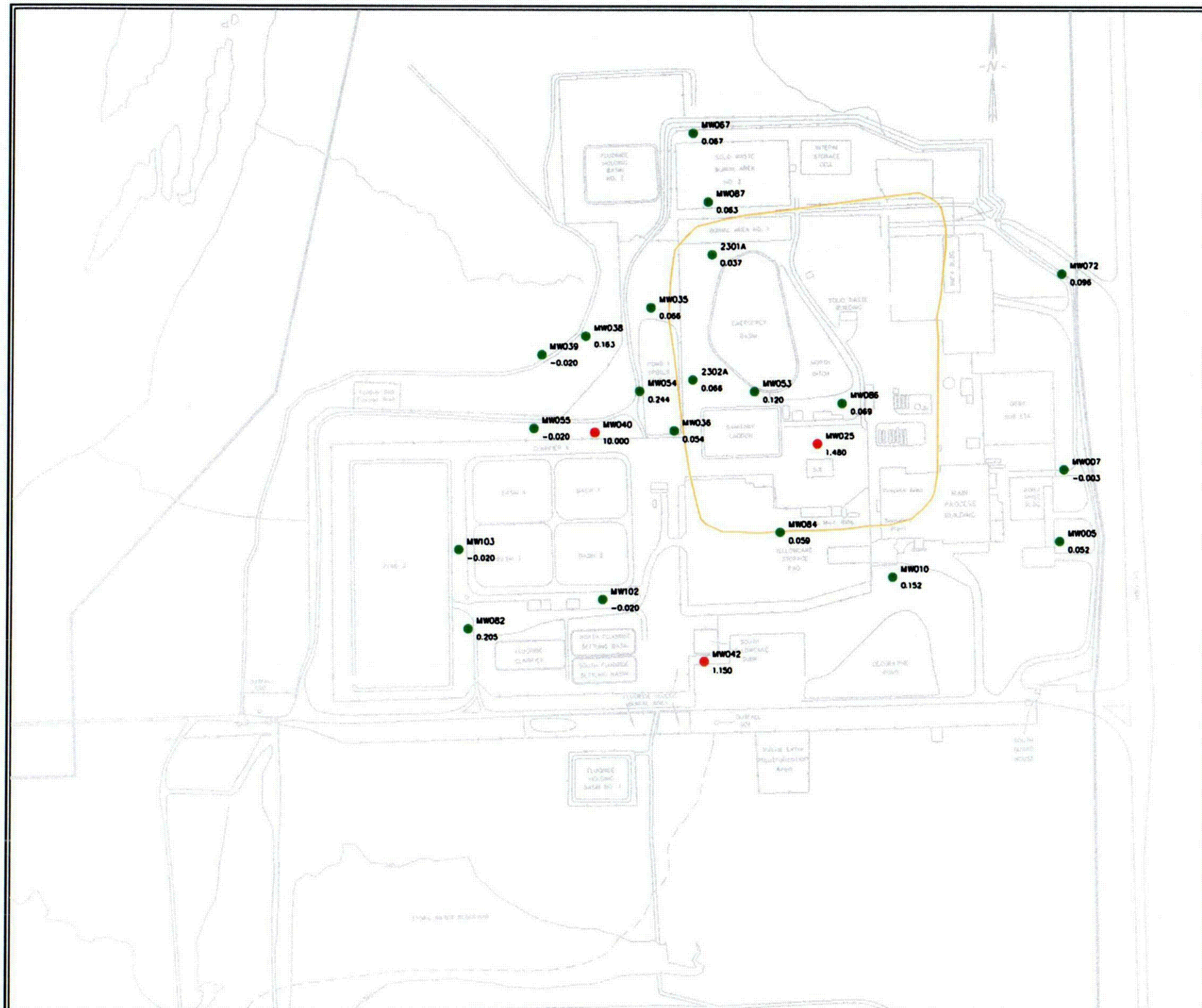
- Less Than MCL
- Greater Than or Equal to MCL
- Disposal Cell Boundary

A minus sign indicates a less than detection value.
All units in mg/l.

SEQUOYAH FUELS CORPORATION

Title: Terrace Groundwater Monitoring System Arsenic (MCL = 0.01 mg/l)	
PREPARED BY: SFC	Filename: GW_As.dwg
Reviewed by: CH	Figure No. 3
Date: 12 Jan 2006	

C03



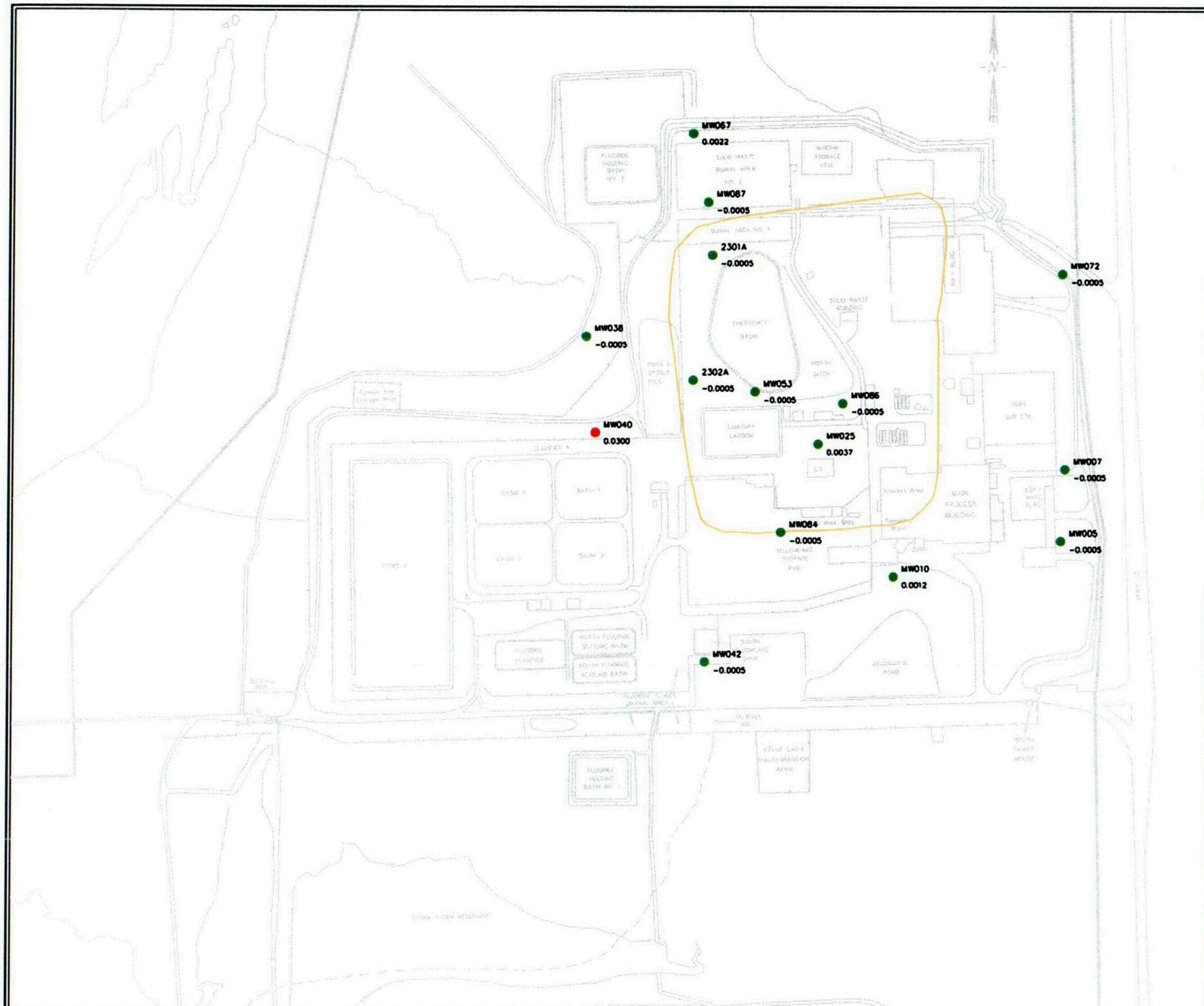
- Less Than MCL
- Greater Than or Equal to MCL
- Disposal Cell Boundary

A minus sign indicates a less than detection value.
All units in mg/l.

SEQUOYAH FUELS CORPORATION

Title: Terrace Groundwater Monitoring System Barium (MCL = 1.0 mg/l)	
PREPARED BY: SFC	Filename: GW_Ba.dwg
Reviewed by: CH	Figure No. 4
Date: 12 Jan 2006	

C04

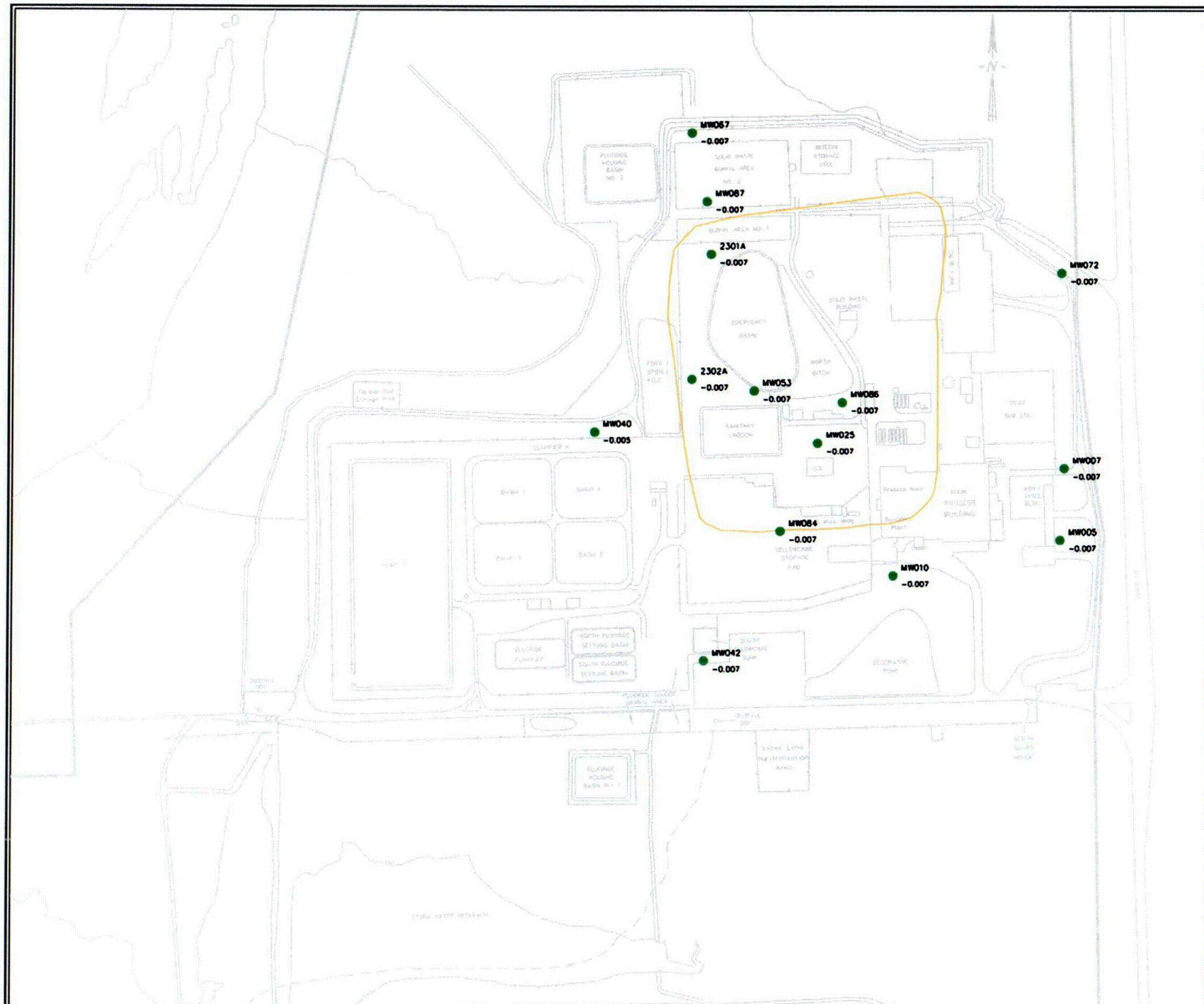


- Less Than MCL
- Greater Than or Equal to MCL
- Disposal Cell Boundary

A minus sign indicates a less than detection value.
All units in mg/l.

SEQUOYAH FUELS CORPORATION	
Title: Terrace Groundwater Monitoring System Beryllium (MCL = 0.004 mg/l)	
PREPARED BY: SFC	Filename: GW_Be.dwg
Reviewed by: CH	Figure No. 5
Date: 12 Jan 2006	

C05



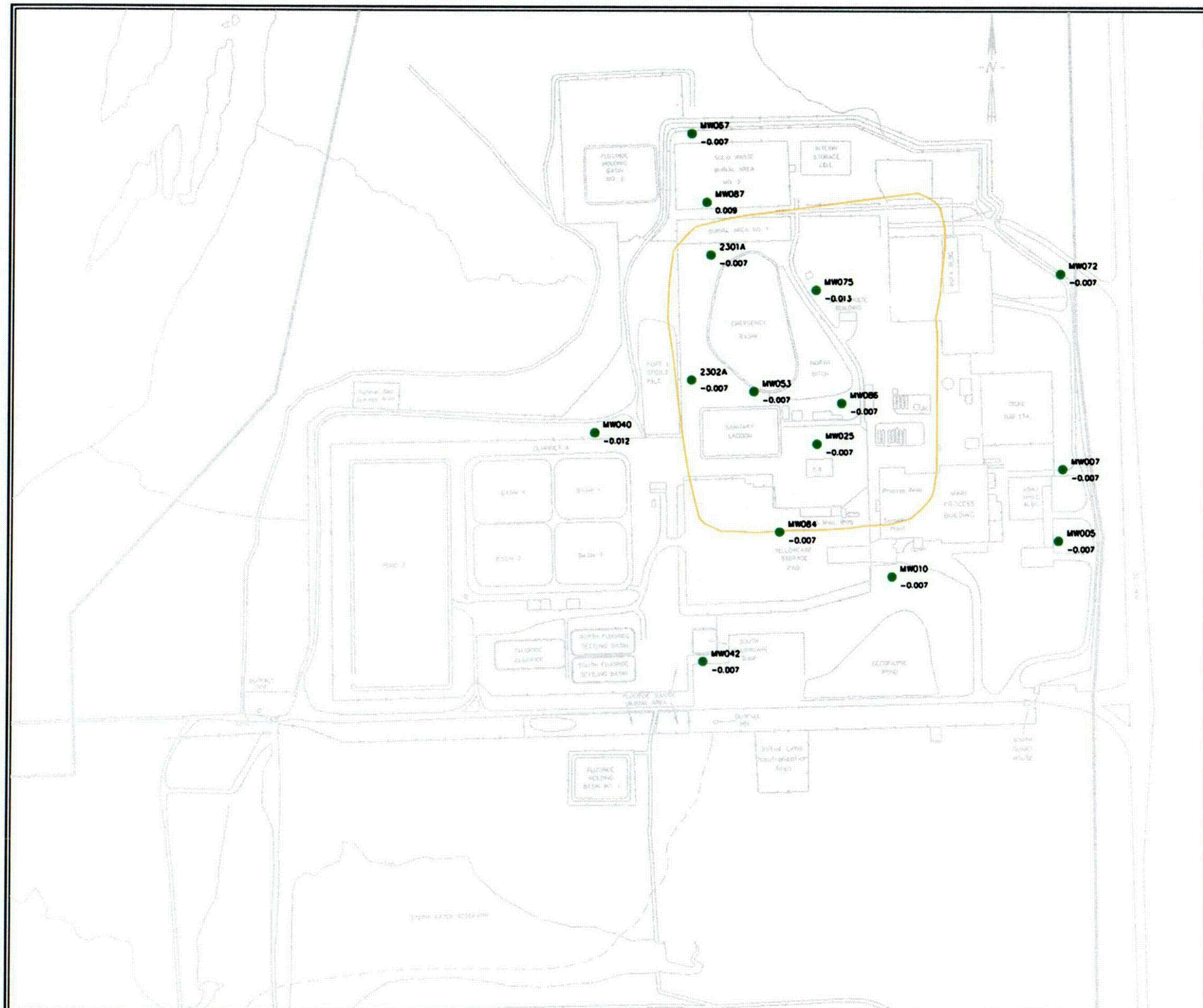
- Less Than MCL
- Greater Than or Equal to MCL
- Disposal Cell Boundary

A minus sign indicates a less than detection value.
All units in mg/l.

SEQUOYAH FUELS CORPORATION

Title: Terrace Groundwater Monitoring System Cadmium (MCL = 0.01 mg/l)	
PREPARED BY: SFC	Filename: GW_Cd.dwg
Reviewed by: CH	Figure No. 6
Date: 12 Jan 2006	

C06



- ● Less Than MCL
- ● Greater Than or Equal to MCL
- — Disposal Cell Boundary

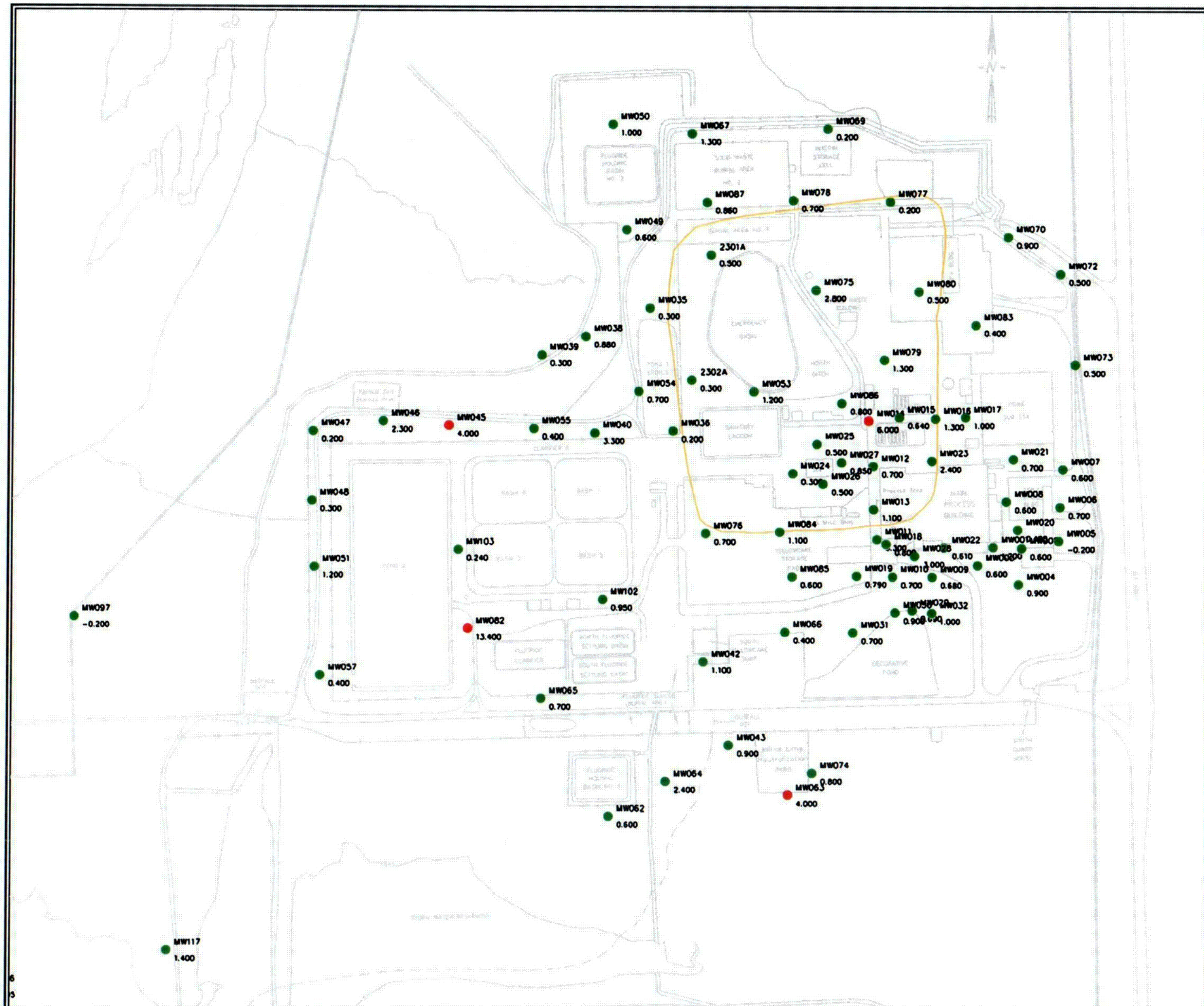
A minus sign indicates a less than detection value.
All units in mg/l.

SEQUOYAH FUELS CORPORATION

Title: Terrace Groundwater Monitoring System
Chromium (MCL = 0.05 mg/l)

PREPARED BY: SFC	Filename: GW_Cr.dwg
Reviewed by: CH	Figure No. 7
Date: 12 Jan 2006	

C07



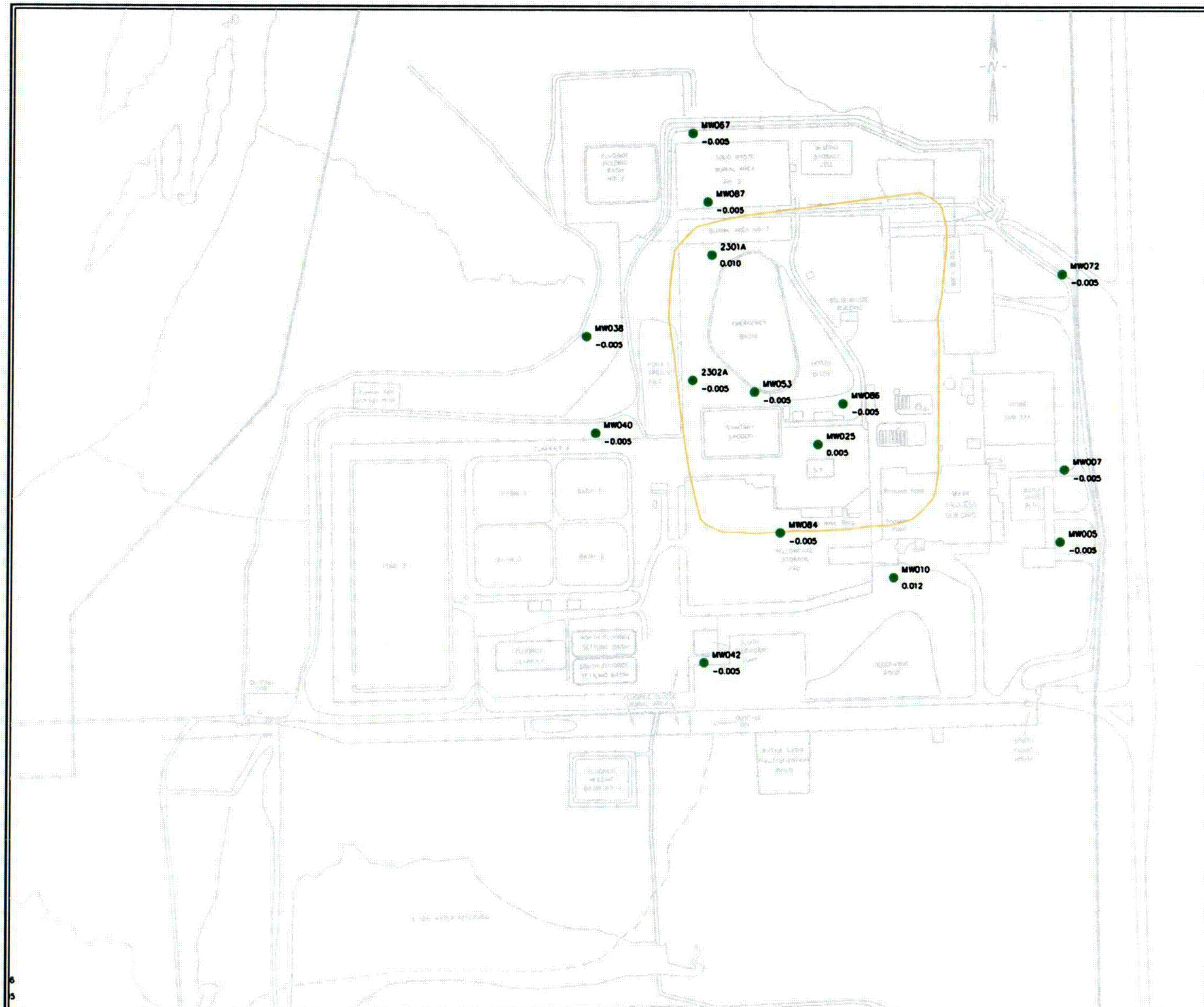
- Less Than MCL
- Greater Than or Equal to MCL
- Disposal Cell Boundary

A minus sign indicates a less than detection value.
All units in mg/l.

SEQUOYAH FUELS CORPORATION

Title: Terrace Groundwater Monitoring System Fluoride (MCL = 4.0 mg/l)	
PREPARED BY: SFC	Filename: GW_F.dwg
Reviewed by: CH	Figure No. 8
Date: 12 Jan 2006	

C08

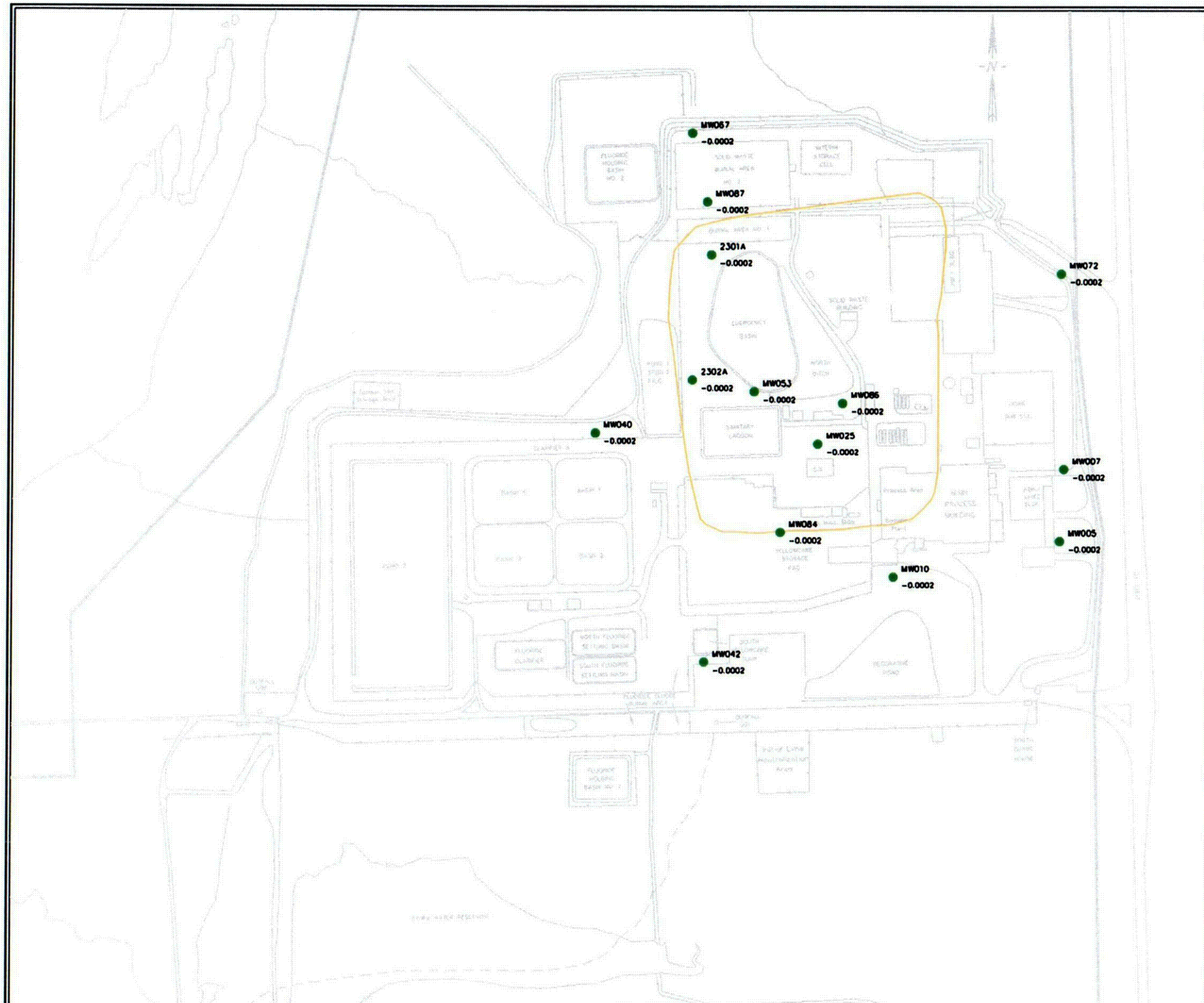


Less Than MCL
Greater Than or Equal to MCL
Disposal Cell Boundary

A minus sign indicates a less than detection value.
All units in mg/l.

SEQUOYAH FUELS CORPORATION	
Title: Terrace Groundwater Monitoring System Lead (MCL = 0.05 mg/l)	
PREPARED BY: SFC	Filename: GW_Pb.dwg
Reviewed by: CH	Figure No. 9
Date: 12 Jan 2006	

C09



- Less Than MCL
- Greater Than or Equal to MCL
- Disposal Cell Boundary

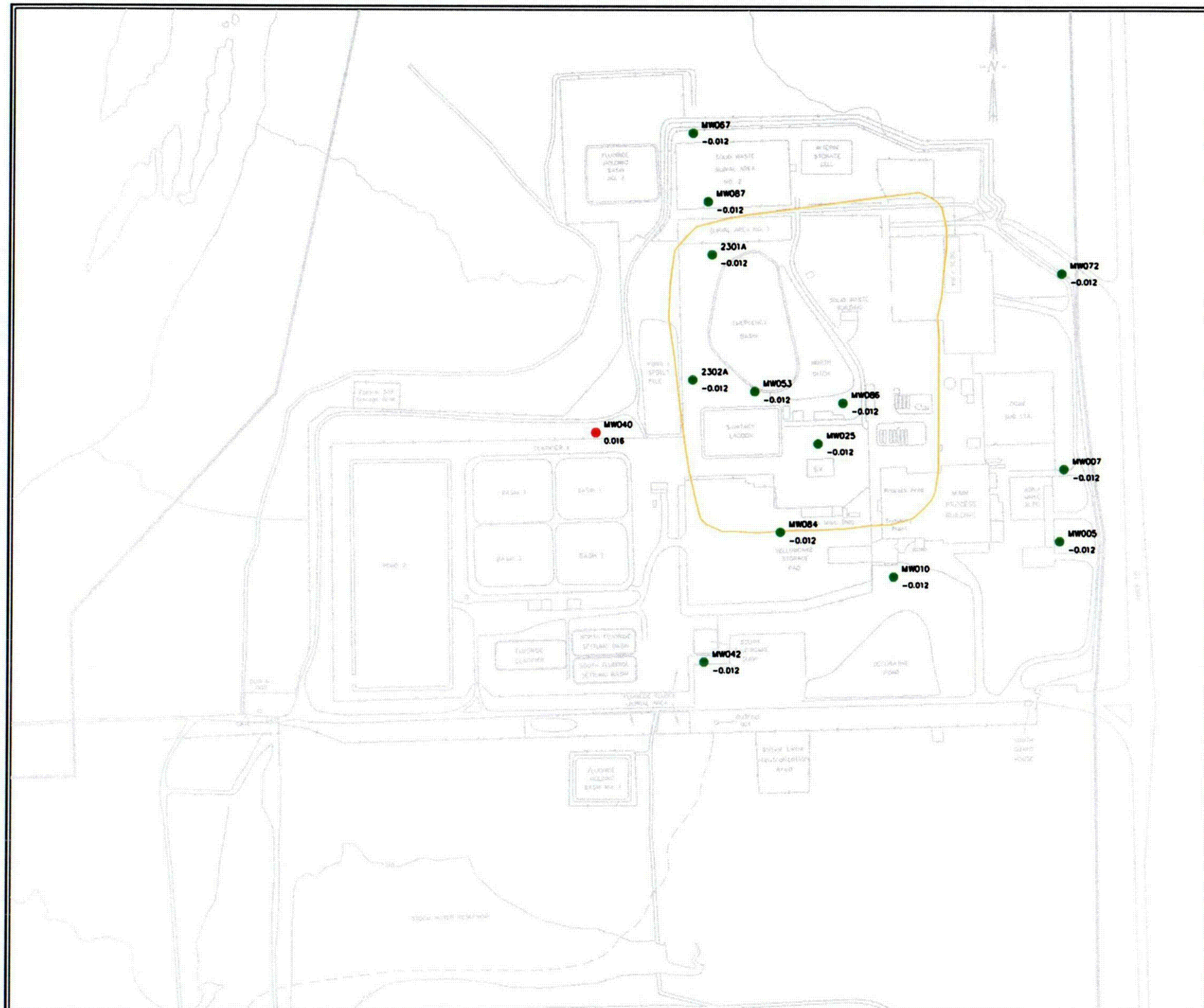
A minus sign indicates a less than detection value.
All units in mg/l.

SEQUOYAH FUELS CORPORATION

Title: Terrace Groundwater Monitoring System
Mercury (MCL = 0.002 mg/l)

PREPARED BY: SFC	Filename: GW_Hg.dwg
Reviewed by: CH	Figure No. 10
Date: 12 Jan 2006	

C10



- Less Than MCL
- Greater Than or Equal to MCL
- Disposal Cell Boundary

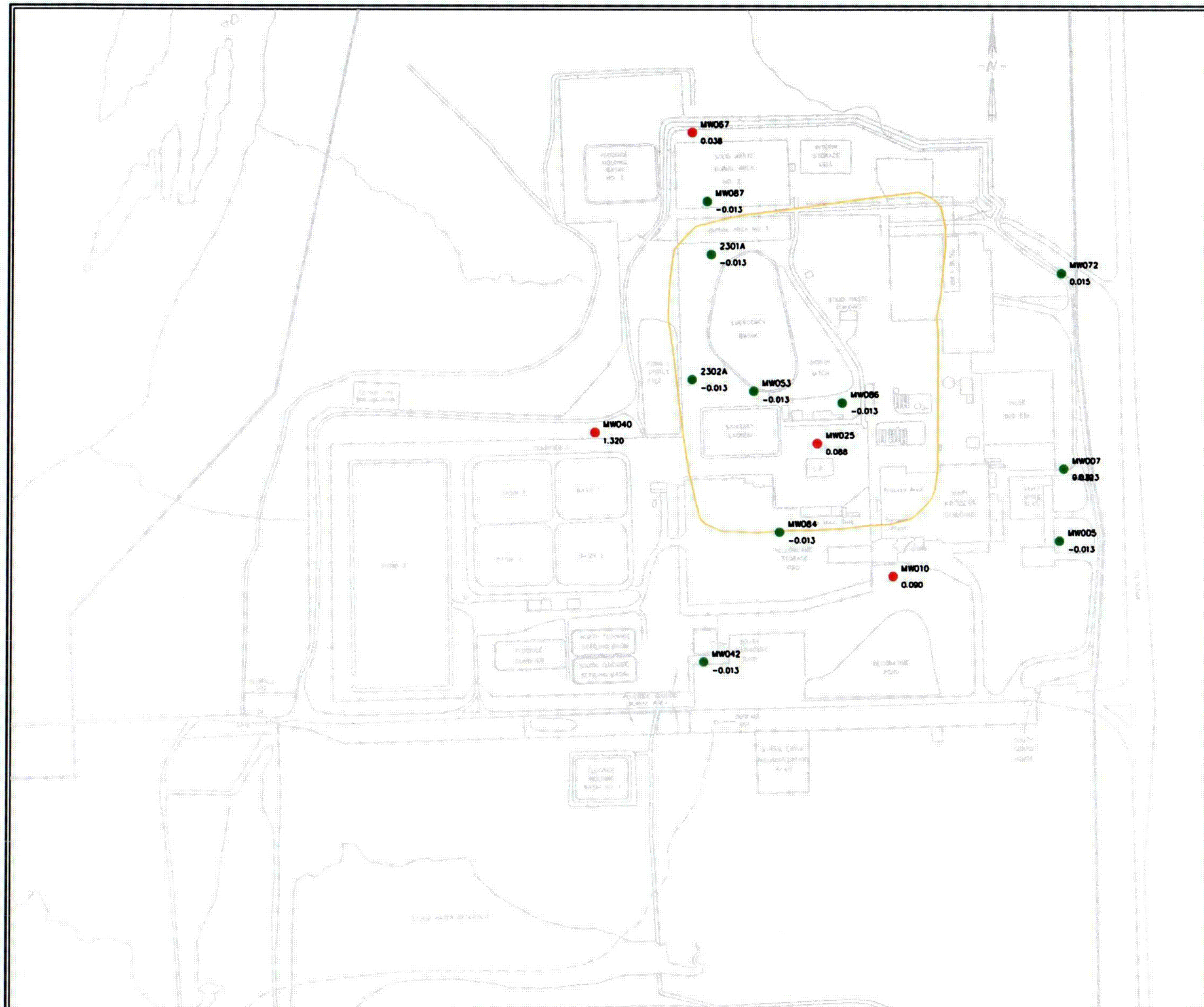
A minus sign indicates a less than detection value.
All units in mg/l.

SEQUOYAH FUELS CORPORATION

Title: Terrace Groundwater Monitoring System
Molybdenum (MCL = 0.012 mg/l)

PREPARED BY: SFC	Filename: GW_Mo.dwg
Reviewed by: CH	Figure No. 11
Date: 12 Jan 2006	

C11

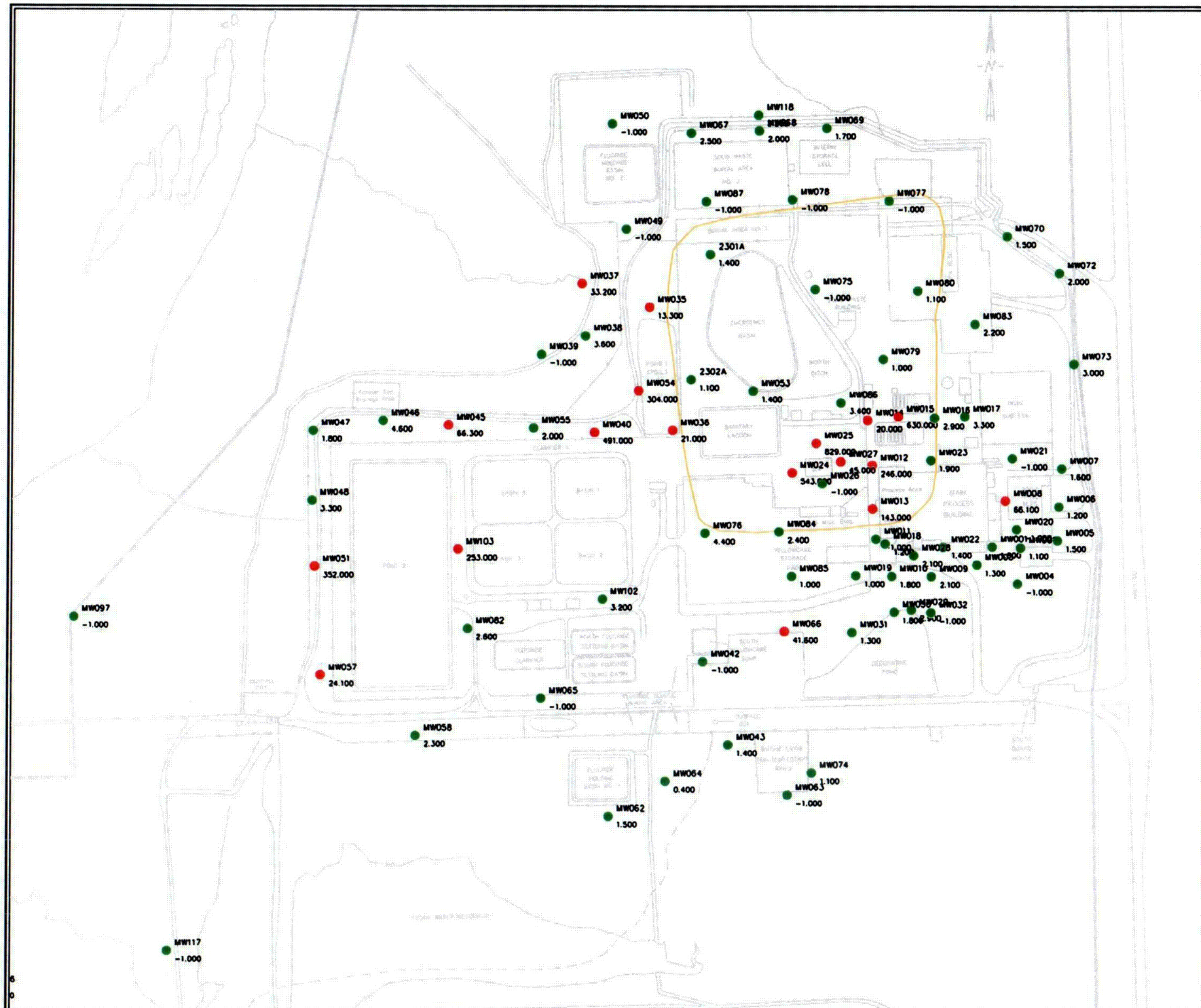


● Less Than MCL
● Greater Than or Equal to MCL
— Disposal Cell Boundary

A minus sign indicates a less than detection value.
All units in mg/l.

SEQUOYAH FUELS CORPORATION	
Title: Terrace Groundwater Monitoring System Nickel (MCL = 0.023 mg/l)	
PREPARED BY: SFC	Filename: GW_Ni.dwg
Reviewed by: CH	Figure No. 12
Date: 12 Jan 2006	

C12



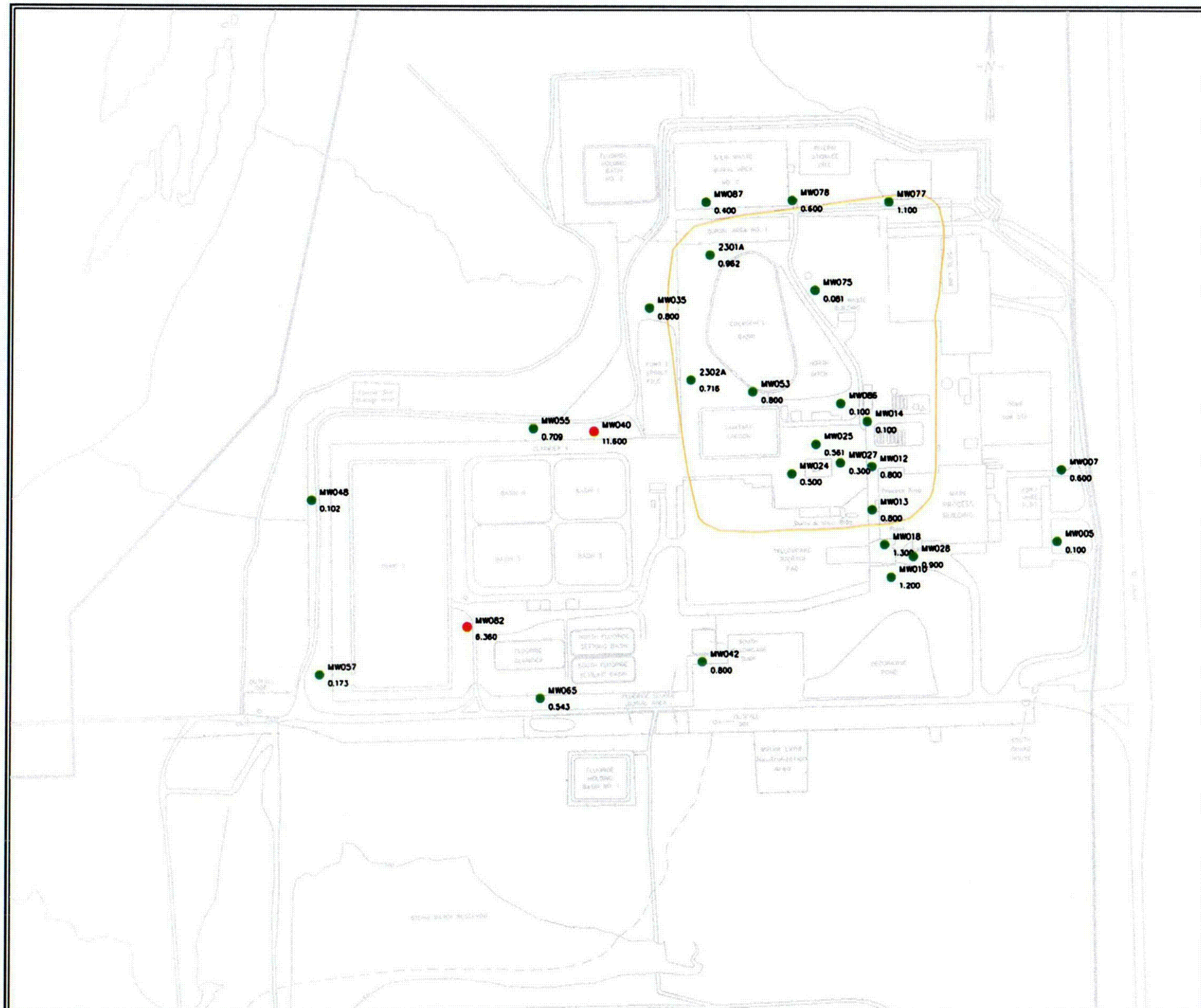
- ● Less Than MCL
- ● Greater Than or Equal to MCL
- — Disposal Cell Boundary

A minus sign indicates a less than detection value.
All units in mg/l.

SEQUOYAH FUELS CORPORATION

Title: Terrace Groundwater Monitoring System Nitrate (MCL = 10 mg/l)	
PREPARED BY: SFC	Filename: GW_NO3.dwg
Reviewed by: CH	Figure No. 13
Date: 12 Jan 2006	

C13



- Less Than MCL
- Greater Than or Equal to MCL
- Disposal Cell Boundary

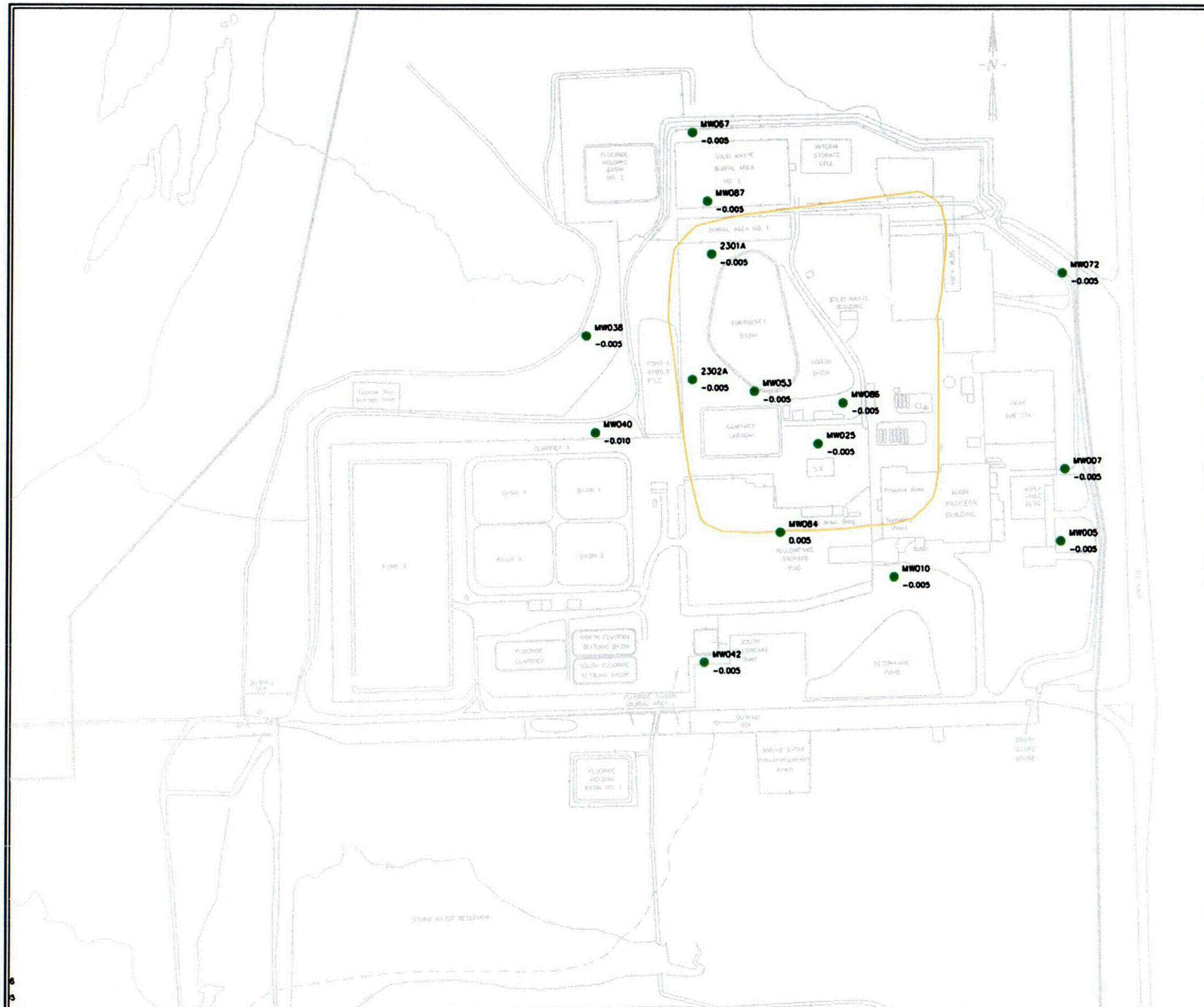
A minus sign indicates a less than detection value.
All units in pCi/l.

SEQUOYAH FUELS CORPORATION

Title: Terrace Groundwater Monitoring System
Radium-226 (MCL = 5.0 pCi/l)

PREPARED BY: SFC	Filename: GW_Ra226.dwg
Reviewed by: CH	Figure No. 14
Date: 12 Jan 2006	

C14



● Less Than MCL

● Greater Than or Equal to MCL

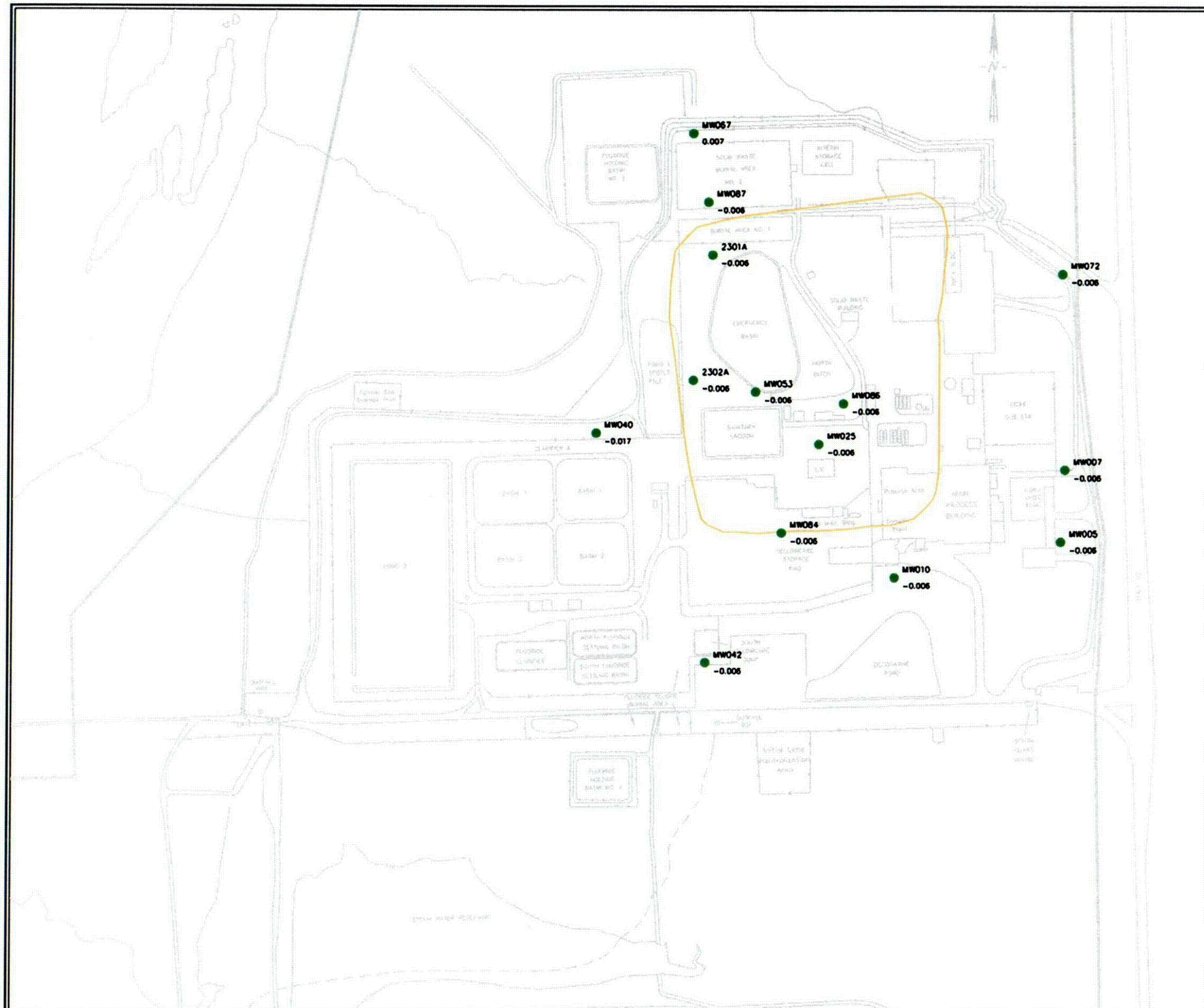
— Disposal Cell Boundary

A minus sign indicates a less than detection value.
All units in mg/l.

SEQUOYAH FUELS CORPORATION

Title: Terrace Groundwater Monitoring System Selenium (MCL = 0.01 mg/l)	
PREPARED BY: SFC	Filename: GW_Se.dwg
Reviewed by: CH	Figure No. 15
Date: 12 Jan 2006	

C15



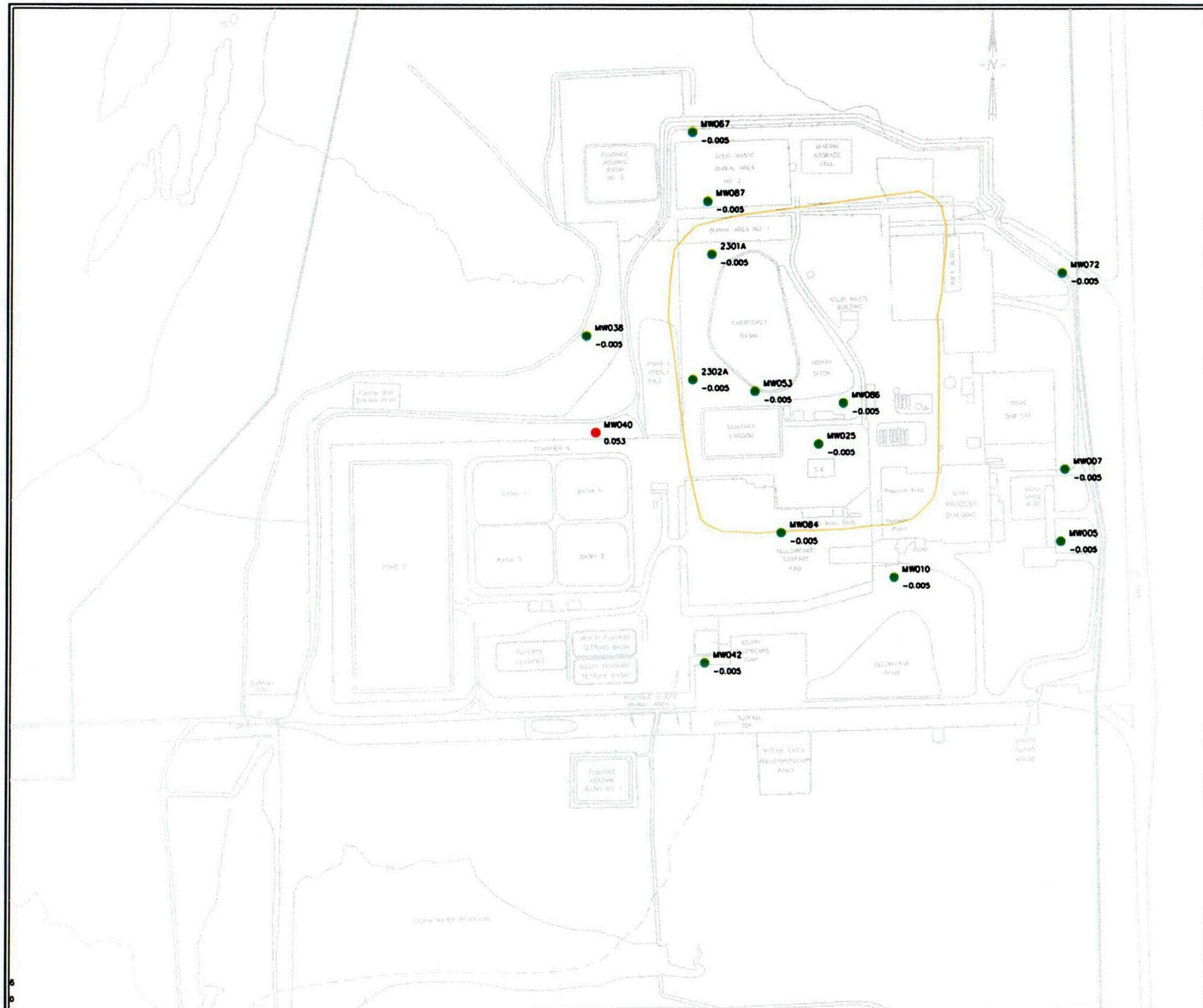
● Less Than MCL
● Greater Than or Equal to MCL
— Disposal Cell Boundary

A minus sign indicates a less than detection value.
All units in mg/l.

SEQUOYAH FUELS CORPORATION

Title: Terrace Groundwater Monitoring System Silver (MCL = 0.05 mg/l)	
PREPARED BY: SFC	Filename: GW_Ag.dwg
Reviewed by: CH	Figure No. 16
Date: 12 Jan 2006	

C16

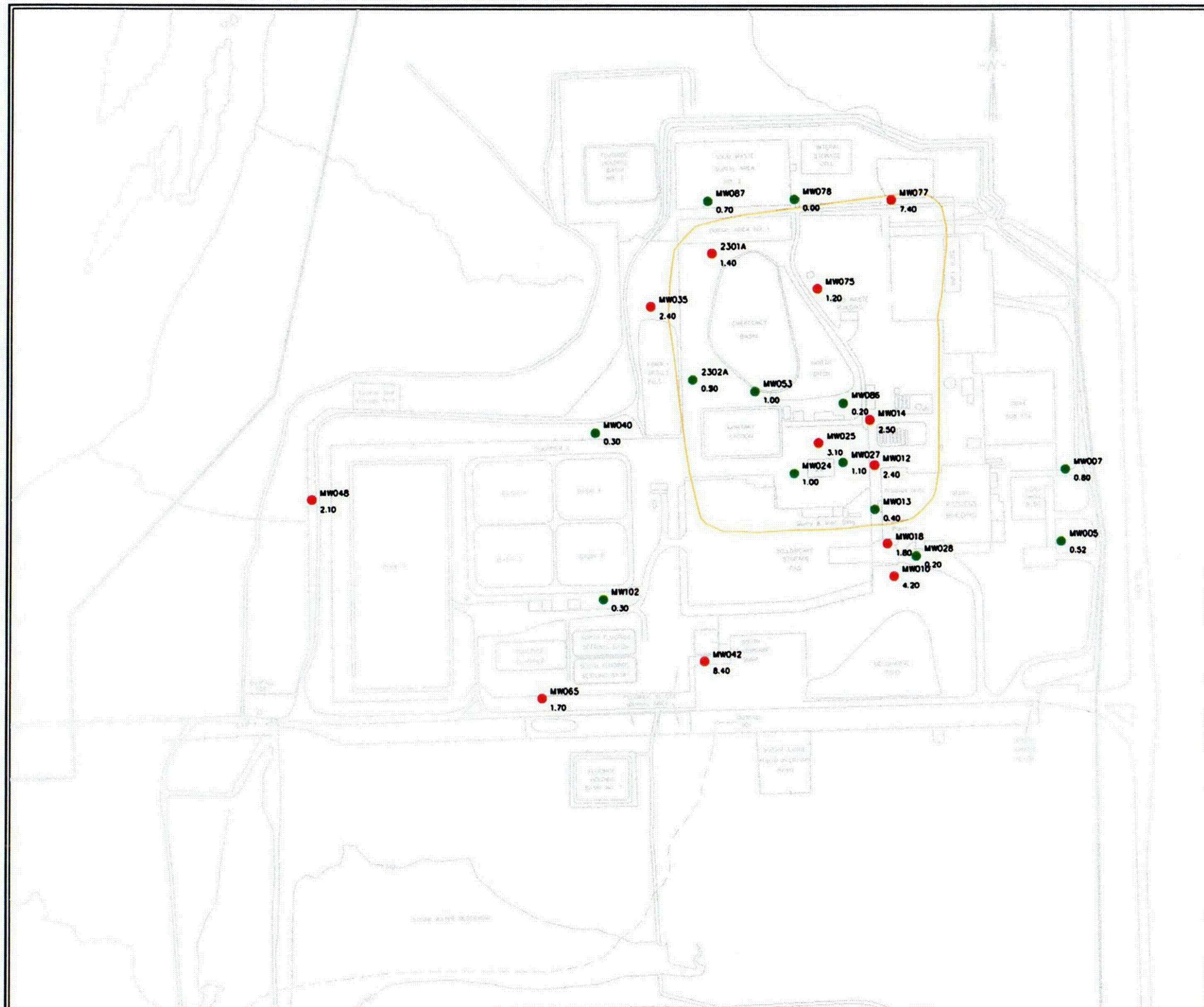


- Less Than MCL
- Greater Than or Equal to MCL
- Disposal Cell Boundary

A minus sign indicates a less than detection value.
All units in mg/l.

SEQUOYAH FUELS CORPORATION	
Title: Terrace Groundwater Monitoring System Thallium (MCL = 0.005 mg/l)	
PREPARED BY: SFC	Filename: GW_Tl.dwg
Reviewed by: CH	Figure No. 17
Date: 12 Jan 2006	

C17

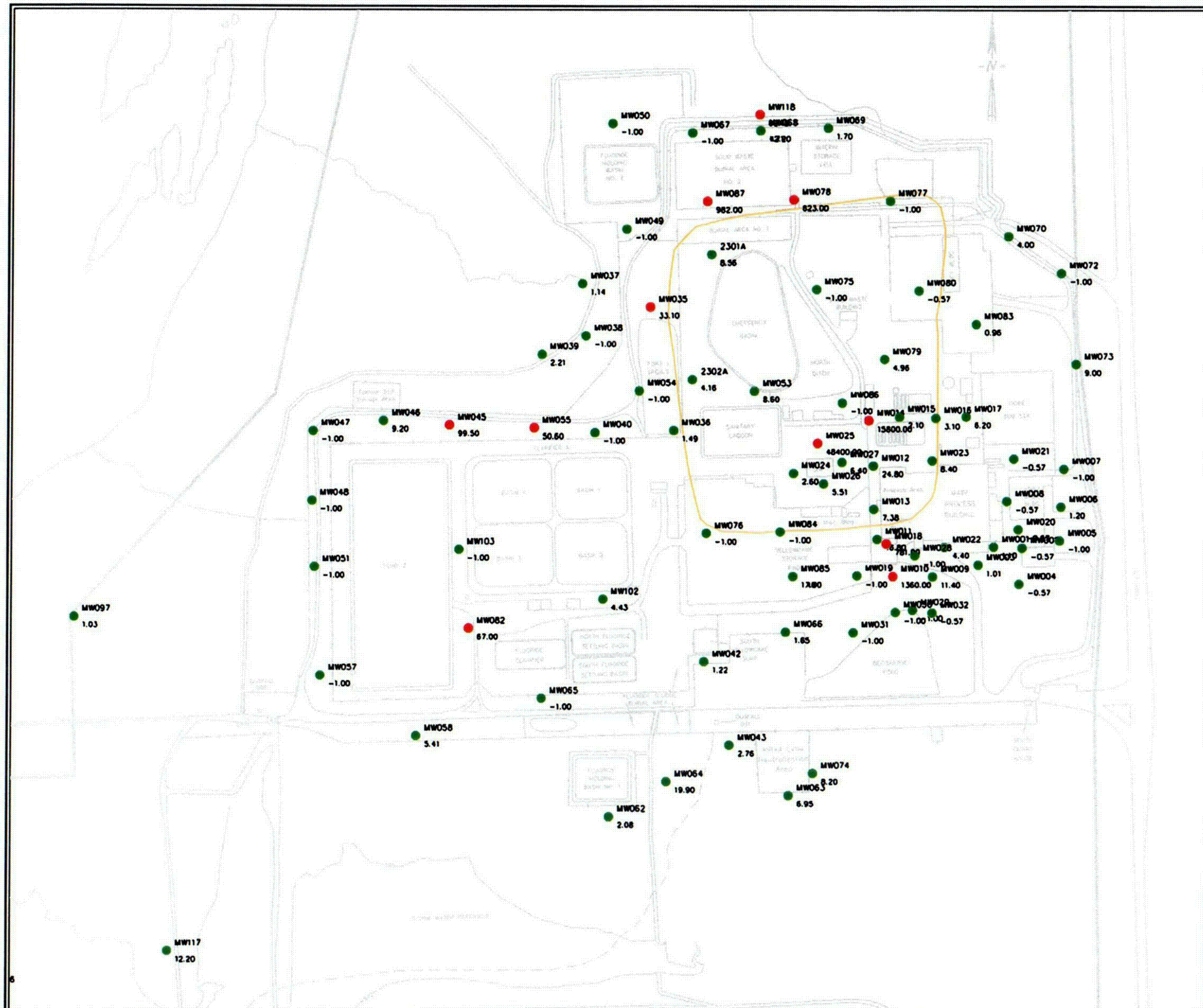


- Less Than MCL
- Greater Than or Equal to MCL
- Disposal Cell Boundary

A minus sign indicates a less than detection value.
All units in pCi/l.

SEQUOYAH FUELS CORPORATION	
Title: Terrace Groundwater Monitoring System Thorium-230 (MCL = 1.2 pCi/l)	
PREPARED BY: SFC	Filename: GW_Th230.dwg
Reviewed by: CH	Figure No. 18
Date: 12 Jan 2006	

C190



Less Than MCL

Greater Than or Equal to MCL

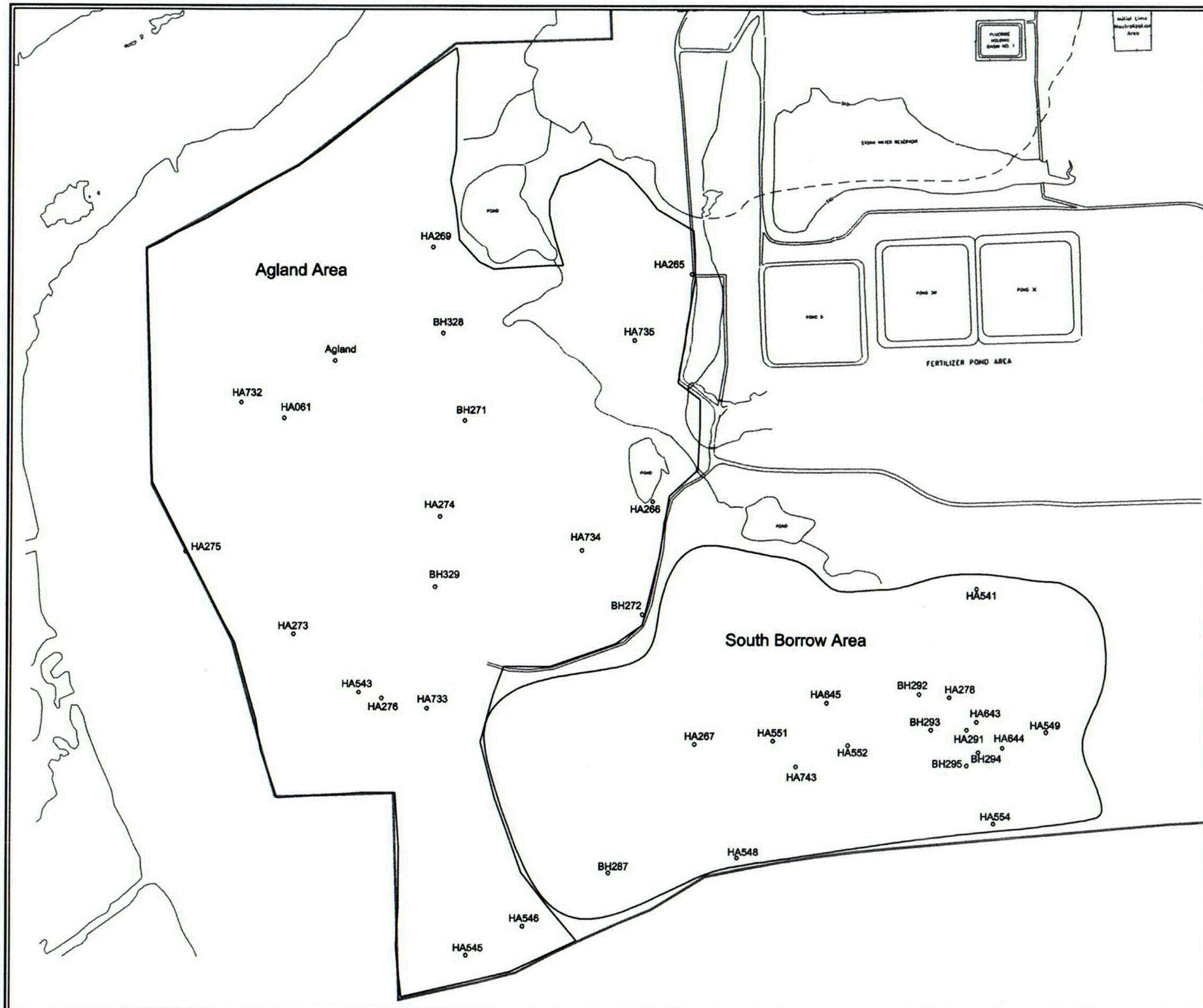
Disposal Cell Boundary

A minus sign indicates a less than detection value.
All units in µg/l.

SEQUOYAH FUELS CORPORATION

Title: Terrace Groundwater Monitoring System Uranium (MCL = 30 µg/l)	
PREPARED BY: SFC	Filename: GW_U.dwg
Reviewed by: CH	Figure No. 19
Date: 12 Jan 2006	

C19

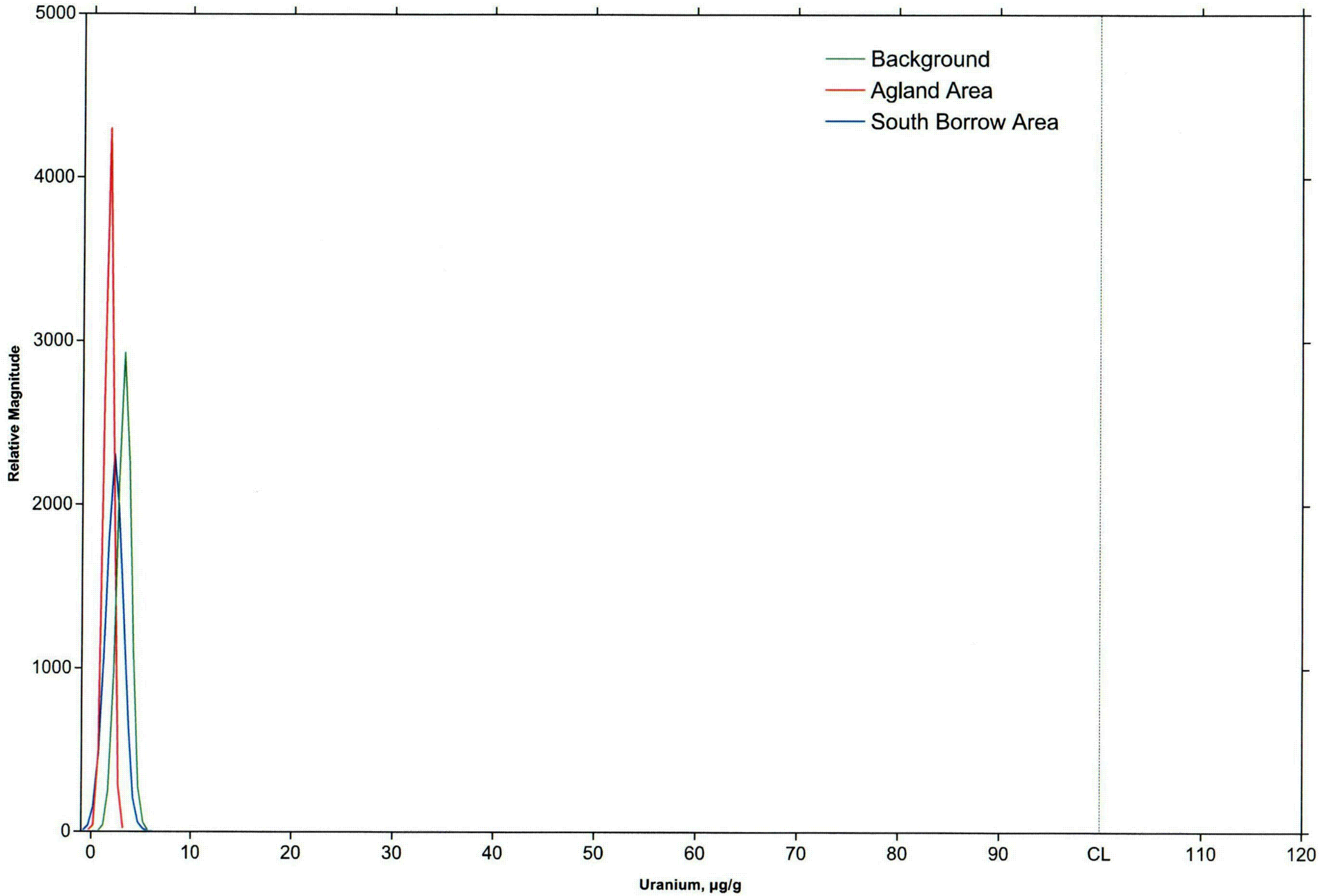


SEQUOYAH FUELS CORPORATION

Title:	Soil Sample Locations Agland and South Borrow Areas
PREPARED BY: SCM	Filename: Figure1RAI_OI35.dwg
Reviewed by: CLH	Figure No. 20
Date: 04Dec2006	

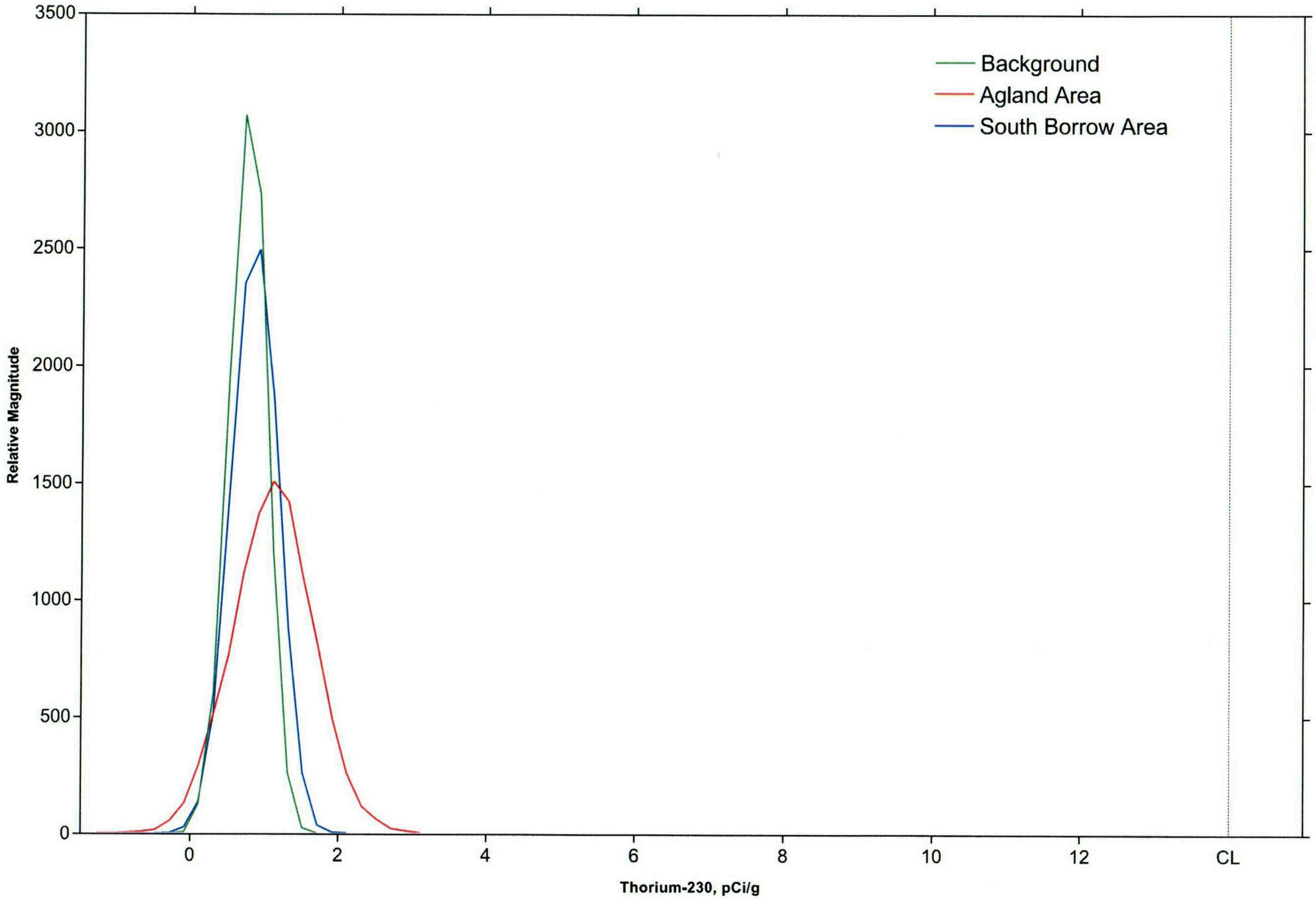
C20

Figure 21
Borrow Material Characterization - Uranium



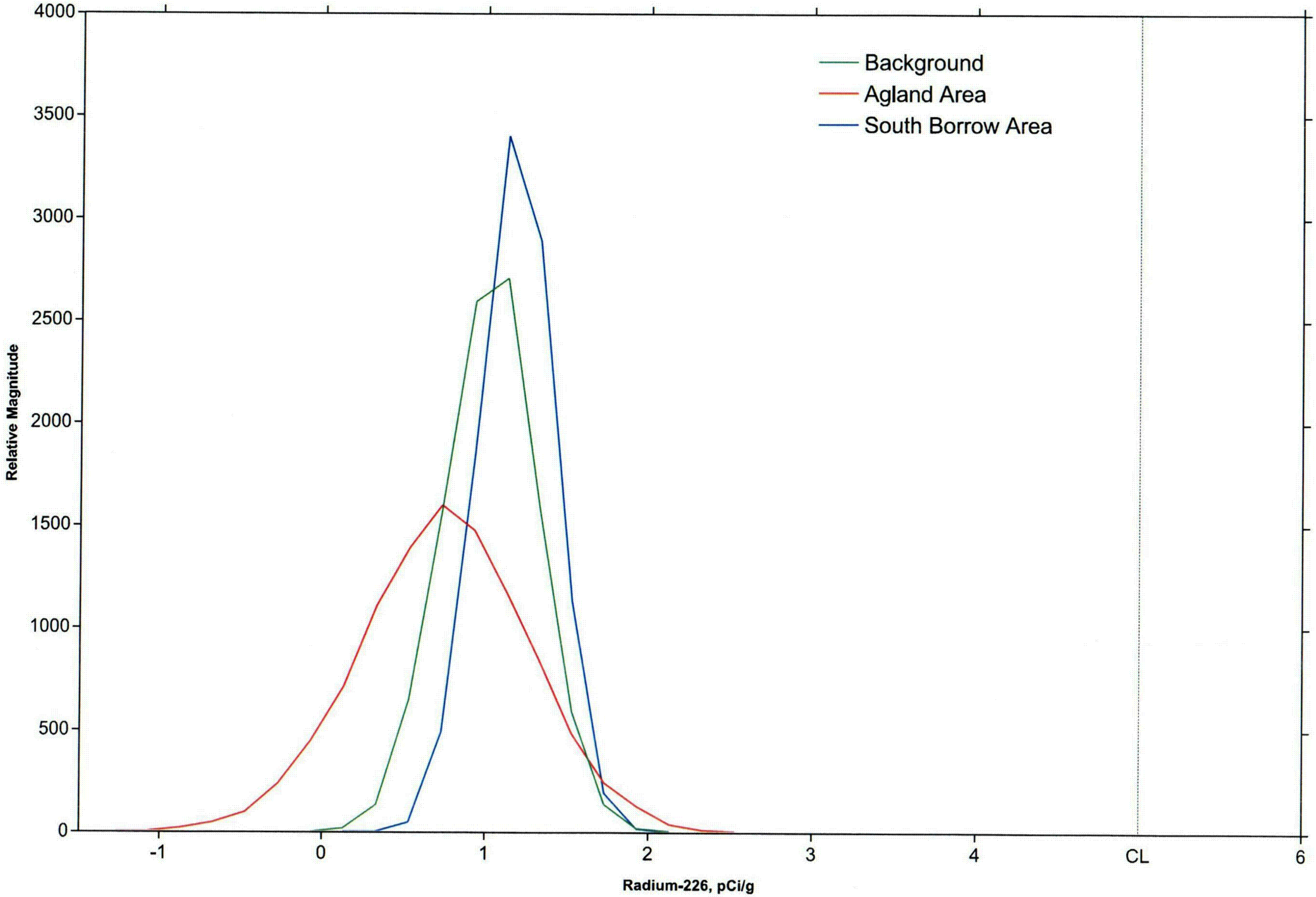
(21)

Figure 22
Borrow Material Characterization - Thorium230

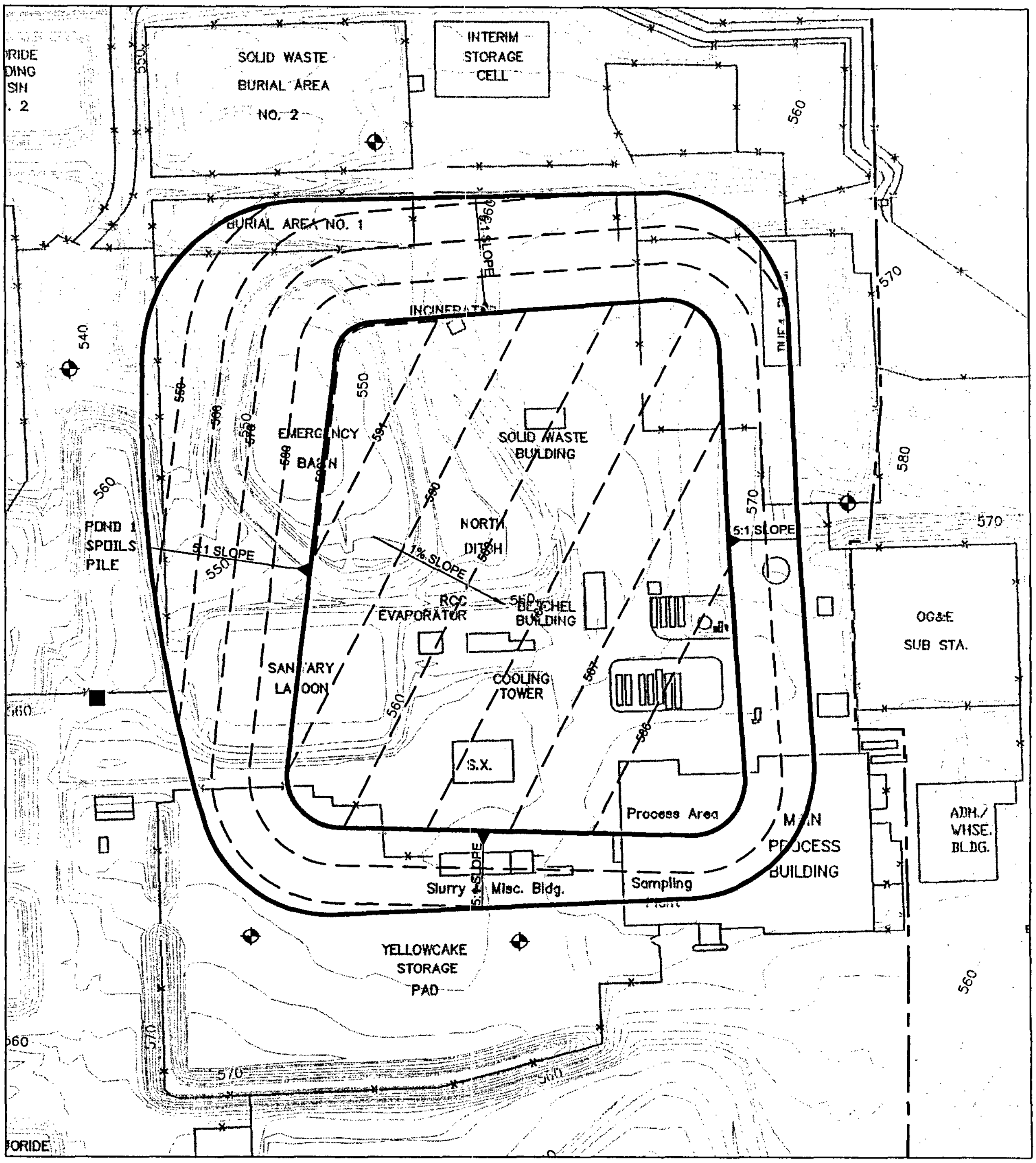


CZZ

Figure 23
Borrow Material Characterization - Radium226



C23



LEGEND

- CELL FOOT PRINT
- CELL ELEVATION CONTOURS
- PLANNED MONITORING WELLS
- PROPOSED ADDITIONAL MONITORING WELL

NORTH

SCALE IN FEET

0 200

MFG, Inc. *consulting scientists and engineers*	FIGURE 24 PROPOSED ADDITIONAL DETECTION MONITORING WELL	Date: JANUARY 2006 Project: 180735 File: WELL-LOC-PR.DWG

ENCLOSURE 2
Reclamation Plan

Update Instructions:

1. Remove text and figures from Reclamation Plan
2. Insert text and figures enclosed here

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1.0 INTRODUCTION

1.1 Background

Sequoyah Fuels Corporation (SFC) operated a nuclear fuel-cycle facility licensed by NRC at U.S. Interstate-40 and Oklahoma State Highway 10, Gore Oklahoma 74435. SFC engaged in different operations in different areas of the Facility, pursuant to NRC Source Material License SUB-1010, including (1) the recovery of uranium by concentration and purification processes, (2) the conversion of concentrated and purified uranium ore into UF_6 between the years of 1970 and 1993, and (3) the reduction of UF_6 into UF_4 from February 1987 until 1993.

SFC ceased production in 1993 and submitted a Preliminary Plan for Completion of Decommissioning (PPCD). The PPCD indicated that decommissioning the facility would include construction of an on-site disposal cell using the performance criteria contained in Appendix A to 10 CFR 40 to isolate the decommissioning waste. SFC conducted site characterization and decommissioning planning activities in order to develop a decommissioning plan for the Sequoyah Facility. In addition, SFC submitted information in support of an Environmental Impact Statement (EIS) initiated by the NRC.

In July 1997, the U.S. Nuclear Regulatory Commission (NRC) adopted new regulations that establish radiological criteria for license termination, including restricted release. Under these criteria, SFC submitted a decommissioning plan proposing an onsite disposal cell meeting the performance criteria in Appendix A of 10 CFR 40 with restricted release of the site once decommissioning activities were completed. During the NRC Staff's review of the plan the NRC Staff expressed concern that SFC had not yet identified a third party that would accept responsibility to enforce the proposed institutional controls. Subsequently, the NRC concluded that the front-end waste at the SFC Facility could be classified as byproduct material as defined in section 11e.(2) of the Atomic Energy Act (11e.(2)), and that such waste may be disposed of in accordance with Appendix A to 10 CFR 40. Appendix A provides for long term custody by assigning the

Department of Energy as custodian of reclaimed sites under a general license in 10 CFR 40.

This Reclamation Plan (RP) updates and reformats the previous DP to include changes made to accommodate public input, extensive review by NRC and its contractors, and additional studies and evaluations done by SFC since 1999. As such, it describes the decommissioning and reclamation of the Sequoyah Facility as an 11e.(2) byproduct materials site.

1.2 Purpose, Scope and Objectives of Site Reclamation

The Sequoyah Facility is planned for reclamation as an 11e.(2) byproduct material site under performance standards administered by the NRC. With the exception of raffinate sludge, and sediments from the north ditch, emergency basin, and sanitary lagoon (which may be shipped offsite for permanent disposal), all of the waste materials will be disposed on site. Upon successful demonstration to NRC of meeting these performance standards, the site will be transferred to the U.S. Department of Energy for long-term care and maintenance. SFC's proposed approach would result in the dismantlement of facility equipment and structures, removal of sludges, impoundments, buried wastes and impacted soils, and placement of resulting waste materials in an engineered disposal cell.

The drainages that exit the Institutional Control Boundary (ICB) to the west (001, 005, and 007) contain some residual radioactive materials from historic releases. However, doses from exposure to these materials without restrictions is not distinguishable from background. As a result, SFC plans no further cleanup in these drainages

The strategy for a groundwater protection plan will be developed under NRC guidelines. This will result in the preparation of a Groundwater Corrective Action Plan (CAP) for the site. This CAP will be developed independently of this Reclamation Plan and submitted to the NRC by June 15, 2003. As such, the groundwater protection plan is not addressed here.

The reclamation approach consists of the following elements:

- Construction of an above-grade, engineered disposal cell on the SFC site for permanent disposition of the SFC decommissioning and reclamation wastes.
- Removal of sludges and sediments from the ponds and lagoons, excavation of buried low-level wastes, removal of stored soils and debris, and placement of these materials into the disposal cell.
- Dismantlement of process equipment, followed by recovery of gross quantities of contained uranium.
- Size reduction/compaction of process equipment, piping and structural materials (including scrap metal, empty drums, and packaged wastes that will accumulate prior to decommissioning) to satisfy disposal requirements for maximum void volume.
- Dismantlement/demolition of structures excepting the new SFC administrative office building and the storm water impoundment.
- Demolition of concrete floors, foundations and storage pads, and asphalt or concrete paved roadways outside the footprint of the cell. Removal of clay liners and/or contaminated soils from under impoundments.
- Excavation of underground utilities, contaminated sand backfill from utility trenches and building foundation areas and more highly contaminated soils under the cell footprint.
- Excavation of contaminated soils lying outside the footprint of the disposal cell that exceed site-specific radiological cleanup criteria.
- Handling and treatment of produced ground water and storm water during cell construction.
- Placement of all SFC decommissioning wastes into the onsite disposal cell, followed by capping and closure of the cell.
- Re-grading the site, backfilling of excavations to the finished grade, and re-vegetation.

- Establishment of a fenced Institutional Control Boundary (ICB) around the cell, installation of additional monitoring wells as necessary, and initiation of a long-term site monitoring plan.
- Transfer title for the restricted property to DOE for long term care and maintenance.
- Termination of SFC's NRC license under the provisions of 10 CFR 40, Appendix A.

1.3 Criteria and Guidelines

The majority of the waste materials to be disposed on site are classified as 11e.(2) by-product materials and, as such, will be reclaimed under the criteria specified in Appendix A of 10 CFR 40. The remaining materials are not classified as 11e.(2) by-product materials, but have similar characteristics which make them candidates for disposal in the cell. This RP proposes to dispose of the non-11e.(2) byproduct materials in the cell. NRC Regulatory Information Summary 2000-23 (November 30, 2000) provides guidance on disposal in tailings impoundments of wastes that are not 11e.(2) byproduct material. Appendix A of this RP addresses each of the eight considerations of RIS-2000-23 and demonstrates that disposal of the SFC non-11e.(2) byproduct material wastes in the disposal cell is consistent with NRC policy. Therefore, no distinction is made between the 11e.(2) materials and the non-11e.(2) materials in the remainder of this RP.

The key design criteria for the disposal cell are to: (1) meet the performance standards for reclamation outlined in Appendix A of 10 CFR 40, (2) provide sufficient capacity for disposal of on-site materials, (3) result in a facility that blends in with the surrounding area (from a visual, hydrologic and vegetative standpoint), (4) have a negligible effect on underlying groundwater, and (5) facilitate site cleanup and reclamation activity. These criteria are outlined below.

1.3.1 Performance standards

The performance standards in Appendix A of 10 CFR 40 include: (1) isolation of the waste materials in a manner that protects human health and the environment,

(2) reduction of radon emanation from the cover to an average of 20 pCi/square meter-second or less, (3) having the reclamation be effective for a long period of time (200 to 1,000 years), and (4) minimizing reliance on active maintenance.

1.3.2 Disposal cell capacity

The disposal cell layout has been sized for a capacity (beneath the cover system) of approximately 9 million cubic feet which exceeds the estimated total volume of 8.3 million cubic feet. The cell design allows for adjustment of the capacity as needed over a range of 5 to 12 million cubic feet.

1.3.3 Surrounding area impact

The top surface of the cell will be limited to an elevation of approximately 590 feet AMSL to minimize the visual impact of the disposal cell from surrounding areas. In addition, the side slopes of the cell will be at 5:1 (horizontal:vertical) or less, with the corners of the cell rounded to create a topographic feature that is visually similar to the surrounding area. The surface of the completed cell will be vegetated with natural species similar to surrounding areas.

1.3.4 Effect on groundwater

The disposal cell cover design strategy includes minimizing infiltration of meteoric water. The cover design incorporates a uniform zone that promotes evapotranspiration from vegetation to achieve a zero water balance. Synthetic liner materials will be included in the cover to restrict infiltration into the underlying waste materials until the vegetative cover matures and the water balance approaches zero.

1.3.5 Facilitation of site cleanup

The siting and layout of the cell has been designed to accommodate stormwater management and construction activity during site cleanup.

1.3.6 Site Selection and Layout

The disposal cell was sited to be over the major areas of contamination at the facility. The disposal cell was also sited to be close to materials to be placed in

the cell to reduce handling costs. Appendix H, "Disposal Cell Design Siting Study For On-Site Disposal Cell" presents the results of SFC's siting evaluations.

1.3.7 Institutional Control

The disposal cell design is based on the site being transferred to the U.S. Department of Energy for long-term care and maintenance following completion of decommissioning. As with other 11e.(2) byproduct material sites, the U.S. Department of Energy will exercise institutional control of the site. This means that SFC will fence the site to limit unauthorized access. Activities within the ICB will be only those authorized by the U.S. Department of Energy or its contractors, such as monitoring or maintenance.

1.3.8 Post-Reclamation Dose

The dose to a member of the public from any activity undertaken on the unrestricted portions of SFC property (outside of the proposed ICB) will not be distinguishable from background.

The dose to a member of the public inside the ICB following completion of reclamation will satisfy not only the requirements of 10 CFR 40, Appendix A (the radium benchmark dose), but also the requirements of 10 CFR 20.1403 (less than 25 mrem/y or less than 100 mrem/y for restricted release with loss of institutional controls).

1.4 Plan Organization

This plan was developed from reports, studies and evaluations developed since 1990. Reliance was placed upon a decommissioning plan which proposed this approach under a different regulatory regime. Although not approved at the time of this writing, the decommissioning plan underwent significant technical and environmental review by the NRC since 1998. The resulting technical exchange between the NRC and SFC has led some refinements of the groundwater model, the dose model and the cell design which have been incorporated here.

This RP relies upon previous studies and reports, many of which have been submitted previously and are on the docket. The decommissioning and

reclamation approach is generally summarized in this plan with much of the details contained in the appendices and attachments. Evaluations, studies, reports, etc. that are relied upon for support of the reclamation plan are included here as Appendices. Program documents, specifications, and project plans, some of which are controlled documents used in field implementation of this RP, are included as Attachments. Information important to the decommissioning, as required by 10 CFR 40.36(f), including documentation of spills, cleanup of contamination, drawings or descriptions of modification of structures in the restricted area, and locations of possible inaccessible contamination, is maintained in the Administration Building at the Sequoyah Facility.

2.0 GENERAL DESCRIPTION OF THE FACILITY

2.1 Facility History

License SUB-1010, Docket No. 40-8027 was originally issued on October 14, 1969 for storage only of uranium ore concentrates. The license was amended on February 20, 1970, authorizing the operation of the Uranium Hexafluoride (UF_6) Conversion Plant. The license was amended on February 25, 1987 to authorize operation of the UF_6 Reduction Plant. The license was last renewed on September 20, 1985, and would have expired on September 30, 1990. The license has remained in effect based on submittal of a renewal application dated August 29, 1990, and provisions in 10 CFR 40.42(a).

By letter dated February 16, 1993, SFC notified NRC of its decision to suspend all production operations permanently, including uranium recovery by concentration and purification processes and subsequent conversion operations, and to decommission the facility. Since July 1993, the concentration and purification processes, the UF_6 conversion processes, and the DUF_4 reduction processes have been closed. By letter dated 11/26/93, NRC advised SFC that authorized activities were limited to those related to decommissioning, and routine environmental and effluent monitoring.

By letter dated January 5, 2001, Sequoyah Fuels Corporation (SFC) requested U.S. Nuclear Regulatory Commission (NRC) to determine if some of the waste material at the Gore, Oklahoma facility could be classified as byproduct material, as defined in Section 11e.(2) of the Atomic Energy Act. After review of the SFC position and the regulations, the Commission concluded that the front-end waste at the SFC Facility could be classified as 11e.(2) byproduct material, and that such waste may be disposed of in accordance with Appendix A to 10 CFR 40. SFC subsequently submitted a license amendment request to possess 11e.(2) byproduct materials which was approved on December 11, 2002.

2.2 Facility Location and Description

The SFC facility (Facility) is a 600-acre parcel of land containing the Industrial Area which occupies roughly 200 acres of the Facility. The Facility is located in Sequoyah County in mid-eastern Oklahoma about 150 miles east of Oklahoma City, Oklahoma, 40 miles west of Fort Smith, Arkansas, 25 miles southeast of Muskogee, Oklahoma, and 2.5 miles southeast of Gore, Oklahoma in Section 21 of Township 12 North, Range 21 East. Figure 2-1 shows the location of the Facility. The Facility is bounded on the north by private property, on the east by State Highway 10, on the south by Interstate 40 (I-40) and on the west by U.S. Government-owned land (managed by the U.S. Army Corps of Engineers [COE]) adjacent to the Illinois and Arkansas River tributaries of the Robert S. Kerr Reservoir. Figure 2-2 shows the topography of the Facility and surrounding area.

Most of the uranium-processing operations were conducted on an 85-acre portion of the Facility that is commonly referred to as the Process Area. SFC uses an additional 115 acres to manage storm water and store by-product materials. The reclamation activities will focus on the Process Area and the additional management areas that are collectively referred to as the Industrial Area. A location map of Facility designations is included in Figure 2-3. Most of the land outside of the Industrial Area is used either for grazing cattle or forage production.

Prior operations at the Facility can generally be summarized as follows. Following receipt of ore concentrates (yellowcake) at the Facility, the ore was subjected to concentration and purification processes to further purify the yellowcake. The purpose of the concentration and purification processes was to control the grade of materials entering the conversion process so as to avoid the contamination of the conversion processing system which if permitted to occur would lead to the production of off-specification material.

Following the concentration and purification processes, the materials were transferred to the conversion facility which produced high purity UF_6 using the purified yellowcake as feed material.

Also located at the Facility was a separate reduction facility which produced UF_4 using depleted UF_6 as feed material.

In addition to the facilities for concentration and purification, conversion, and reduction, the SFC site also includes: (1) a storage area for the yellowcake received from conventional uranium mills; (2) a yellowcake sampling facility; (3) a bulk storage area for chemicals such as ammonia (NH3), tributylphosphate-hexane solvent, and hydrofluoric (HF), nitric (HNO_3), and sulfuric (H_2SO_4) acids; (4) a facility for electrolytic production of fluorine from HF; (5) treatment systems and storage ponds for both radiological and non-radiological liquid effluent streams; and (6) a facility for the recovery and beneficial use of ammonium nitrate solution (which originated from the solvent extraction system) as fertilizer on SFC-owned land.

Additional facilities include the following: a yellowcake drum storage area, an electrical substation, UF_6 cylinder storage area, tank farm for liquid chemicals and fuel oil, cooling tower for waste heat dissipation, sanitary sewage facilities, retention ponds for calcium fluoride sludge, retention ponds for processing raffinate into fertilizer and raffinate sludge, a raffinate sludge concentration and loading facility, retention ponds for fertilizer, and a reservoir for an emergency water supply. A general Facility layout is presented in Figure 2-4.

2.3 Physical Characteristics of the Facility

The SFC site is located above the east bank of the Illinois River at its confluence with the Arkansas River. The site is on the western end of a broad upland area approximately 100 feet above the normal elevation of the Illinois River (as impounded by the Robert S. Kerr Reservoir). The physical characteristics of the site and surrounding areas have been the subject of several studies since 1990. The following sections summarize the findings of these studies. Additional details are available in Appendix B and Appendix D.

2.3.1 Surface Features

The Facility is situated on gently rolling to level land with several steep slopes to the northwest and wooded lands to the north and south. Elevations on or near the Facility range from 460 feet above mean sea level (AMSL) for the normal pool elevation of the Robert S. Kerr Reservoir to nearly 600 feet amsl (Figure 2-2). Slopes over most of the upland areas of the Facility are less than seven percent. Steeper slopes in creek ravines and on hillsides average roughly 28 percent. Near the Robert S. Kerr Reservoir, slopes are very steep. This area is owned by the federal government and is administrated by the COE.

2.3.2 Surface Water Hydrology

The Facility is located on the east bank of the Illinois River tributary of the Robert S. Kerr Reservoir. Southwest of the Facility the Illinois River joins with the Arkansas River tributary of the Robert S. Kerr Reservoir. Flow in the Illinois River arm of the Robert S. Kerr Reservoir is regulated by releases from the Tenkiller Ferry Reservoir, which is located on the Illinois River approximately seven miles upstream from the Facility. The annual average flow of the Illinois River at the gauging station between the Tenkiller Ferry Reservoir and the Facility is 1,610 cubic feet per second (cfs).

Significant differences occur in water quality between the Illinois and Arkansas Rivers. The Illinois River flows through a rugged, rocky watershed throughout much of its course in northeastern Oklahoma and is fed largely by releases from Lake Tenkiller Ferry Reservoir and from steep, spring-fed streams. This results in relatively clear waters, with an average specific conductance of 170 microsiemen per centimeter (microS/cm). In contrast, the Arkansas River, acquires sediment from farming areas along its course in Colorado, Kansas, and Oklahoma, resulting in relatively turbid waters. Specific conductance values from the Robert S. Kerr Reservoir dam are about 600 microS/cm (SFC, 1998a).

The Process Area is located on an upland area approximately 100 feet in elevation higher than the surface elevation of the Robert S. Kerr Reservoir. Relatively steep (28 percent average) surface gradients occur between the

Process Area and the Robert S. Kerr Reservoir and the floodplain area in the southwest portion of the SFC property. Several small ephemeral streams drain the Industrial Area to the Robert S. Kerr Reservoir, including the 001, 004, 005, 007, 008, and 009 streams in Figure 2-5, and the drainage associated with the Storm Water Reservoir. Several other drainages affect the SFC property. One stream, hereafter referred to as Creek A, drains the area south of the Fertilizer Ponds. This stream bends northwestward and follows along the eastern edge of the Agland area, and eventually joins with water from the Storm Water Reservoir drainage. A small, northeast flowing stream occurs east of Highway 10. This stream closely parallels the Carlile School Fault and drains much of the eastern portions of the SFC property (Figure 2-2). This small stream empties into Salt Branch (Figure 2-2), a northwestward flowing drainage that closely parallels the SFC northernmost property boundary.

2.3.3 Climatology and Meteorology

Sequoyah County has a warm, temperate, continental climate. Storms bring ample precipitation when moisture-laden air from the Gulf of Mexico meets cooler, dryer air from the western and northern regions. The most variable weather occurs in the spring, when local storms can be severe and bring large amounts of precipitation. The mean annual temperature is 61.5° F. The monthly average ranges from 40° F in January to 82° F in July. The average daily range in temperature is 24° F. The lowest temperature on record was -19° F in January 1930 and the highest was 115° F in August 1936. The mean annual precipitation ranges from 42.9 inches in the town of Sallisaw, to approximately 44.1 inches in the northeastern part of Sequoyah County. The seasonal distribution of rainfall is fairly even, with 31 percent in spring, 26 percent in summer, 23 percent in fall and 20 percent in winter.

The average amount of snowfall from November through April is about 5.2 inches. Lake evaporation averages about 47.5 inches annually. Of this, 72 percent occurs from May through October. Based on the precipitation and lake

evaporation values, there is a net annual evaporation rate of about 4 inches in the SFC area.

The most severe storms occur in the spring, although thunderstorms are also frequent during the summer months. Strong winds, heavy precipitation, and intense lightning may be associated with these storms.

The nearest Sequoyah County weather station is in the town of Sallisaw, Oklahoma. There is no national weather station in the immediate vicinity. Meteorological data may be obtained from the national weather station at Tulsa, Oklahoma, about 70 miles northwest, and at Fort Smith, Arkansas, about 40 miles east. Fort Smith, Arkansas is the closest data station having topographic and climatological characteristics similar to the Facility.

2.4 Geologic Setting

Based on historic information and data from recent site investigations, the following summarizes the geologic, hydrogeologic and geochemical conditions at the SFC Facility. For a detailed description, see Appendix B, section 6.

As described in Appendix B and Appendix D, the site rests on a ridge or upland area above the headwaters of the Robert S. Kerr Reservoir and the lower Illinois River. The SFC site is underlain by a sequence of approximately 400 feet of sedimentary siltstones and sandstones of the Atoka Formation. The Atoka formation is of the Pennsylvanian geologic period (with these sedimentary rocks formed approximately 280 to 325 million years ago. The bedding of these units is nearly horizontal, with varying depths of weathering and erosion. These units are mantled at varying depths with Pleistocene terrace deposits. The underlying soils and sedimentary rocks at the site have been investigated with regional geologic data and over 500 bore holes.

The site is located on the southwest flank of the Ozark Uplift, a regional structural feature. The site is in an area of low seismic activity with no significant faulting in the area within the last 35 million years. NRC has reviewed the seismic setting

and concluded that no active or capable faults exist around the facility. Appendix E provides the results of the site seismic evaluations.

The Atoka Formation sedimentary rocks beneath the site consist of alternating shale and sandstone layers, extending to depths of several hundred feet. The Atoka Formation sedimentary rocks are mantled or covered with alluvial terrace deposits of the Quaternary geologic period. These terrace deposits were placed during the Pleistocene epoch (approximately 10,000 to 1,000,000 years before present) during high-water stages of flow on the Arkansas and Illinois Rivers. These high-water stages were most likely from melting periods of Pleistocene glaciation. Subsequent downcutting of the Illinois and Arkansas Rivers has left these deposits above the current river elevations. More recent alluvial deposits are found along the banks of the Illinois and Arkansas Rivers.

Groundwater levels and water quality have been evaluated from over 300 wells that have been completed on site. This information is presented in Appendices B and E of this Reclamation Plan. The shale and sandstone units are both of relatively low hydraulic conductivity, so that although groundwater is present in these units, groundwater yield is low. The uppermost groundwater beneath the site is within the uppermost shale layer. A limited, transient amount of groundwater is perched on the uppermost shale within the terrace deposits.

Soils investigated from drilling on site consist of these terrace deposits and weathered zones of the Atoka Formation. These soils range from sandy, clayey gravels to silty clays. The materials are classified (according to the Unified Soil Classification System) as a low to moderate plasticity silt and clay as well as clayey sand and gravel.

2.5 Seismicity and Ground Motion Estimates

The maximum anticipated acceleration at the Site based upon general, published information is less than 0.05 g (Attachment E). Based on a maximum anticipated seismic acceleration of 0.05 g, the corresponding seismic coefficient for use in pseudo-static analyses of the cell and cover system would be 0.03 to 0.04. In the initial stability analyses, SFC used a seismic coefficient of 0.05 to

conservatively represent the conditions at this site, and also to be consistent with the generalized values for the area recommended by the U.S. Army Corps of Engineers (Appendix C).

The site area was evaluated in more detail in terms of (1) historical earthquake events in the region, (2) capable faults in the site area, and (3) probabilistic analyses of seismic events not associated with known faults. From this evaluation, the largest ground acceleration at the site from historical earthquake events was estimated to be 0.06 g. The review of capable faults in the site area showed no capable faults under criteria in 10 CFR 100 Appendix A. The probabilistic analysis of seismic events in the site area resulted in estimated peak ground acceleration values of 0.16 to 0.27 g, and corresponding seismic coefficient values of 0.11 to 0.18 g. The values from the probabilistic analyses were used in the stability analyses for the disposal cell (presented in Attachment E).

2.6 Erosional Stability

The topographic and geologic descriptions above indicate that the site is on an upland area of Pennsylvanian-age sedimentary rocks that have been mantled with Pleistocene epoch terrace deposits and recent alluvial deposits. Erosion during the Quaternary period has been limited to downcutting of the bed of the Arkansas and Illinois Rivers, with no significant erosion of the sedimentary rocks or overlying alluvial deposits at the western end of the upland area.

The SFC site as well as planned reclaimed features of the site are hydraulically separate and erosionally stable from extreme flood events on the Illinois and Arkansas Rivers, as summarized below.

1. The location of planned reclaimed site features are at an elevation approximately 100 feet above the normal and flood-stage elevations of the Illinois and Arkansas Rivers in the site area.

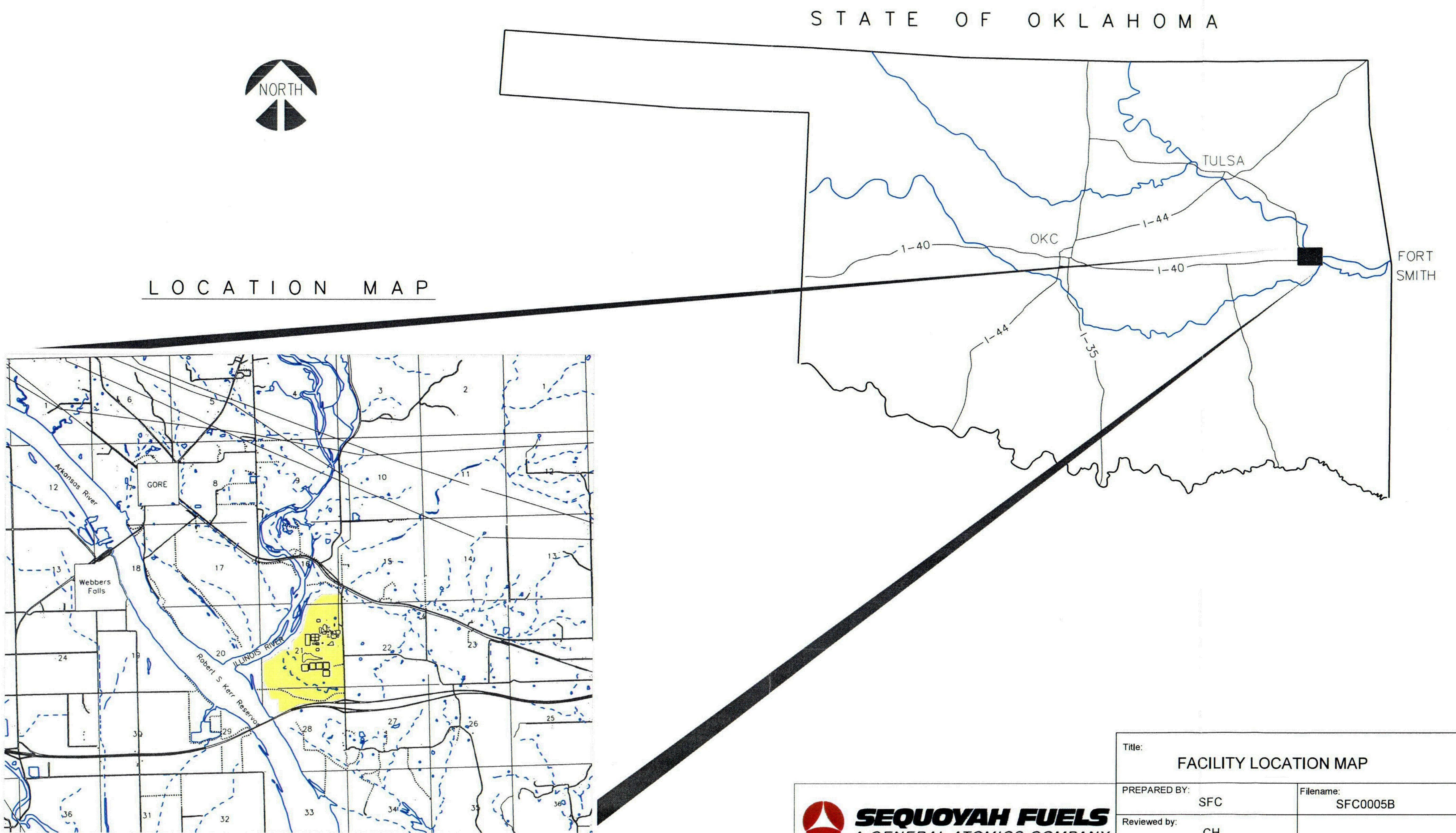
2. The recent geomorphologic history of the site indicates that the most significant periods of erosion and sediment deposition from

rivers in the site area coincided with glacial periods over 10,000 years ago. Estimated extreme flow events (under probable maximum precipitation calculation methods) are significantly lower than the Pleistocene epoch flows that were experienced over sustained periods at the site.

3. The Pennsylvanian-age sedimentary rocks that form the foundation for reclaimed features at the SFC site are not susceptible to rapid or significant erosion that would expose the planned reclaimed features at the site.

4. The current topography of the Arkansas and Illinois River basins in the site area shows a large area of lower elevation to the west of the site. There is not a constriction of flow or a bend in the bed of either river that would indicate significant flow velocities or a potential for riverbed migration toward the upland area where the site is located.

5. The relatively low seismic activity with no significant faulting in the area indicates that seismically-induced features that would be susceptible to erosion are not present.

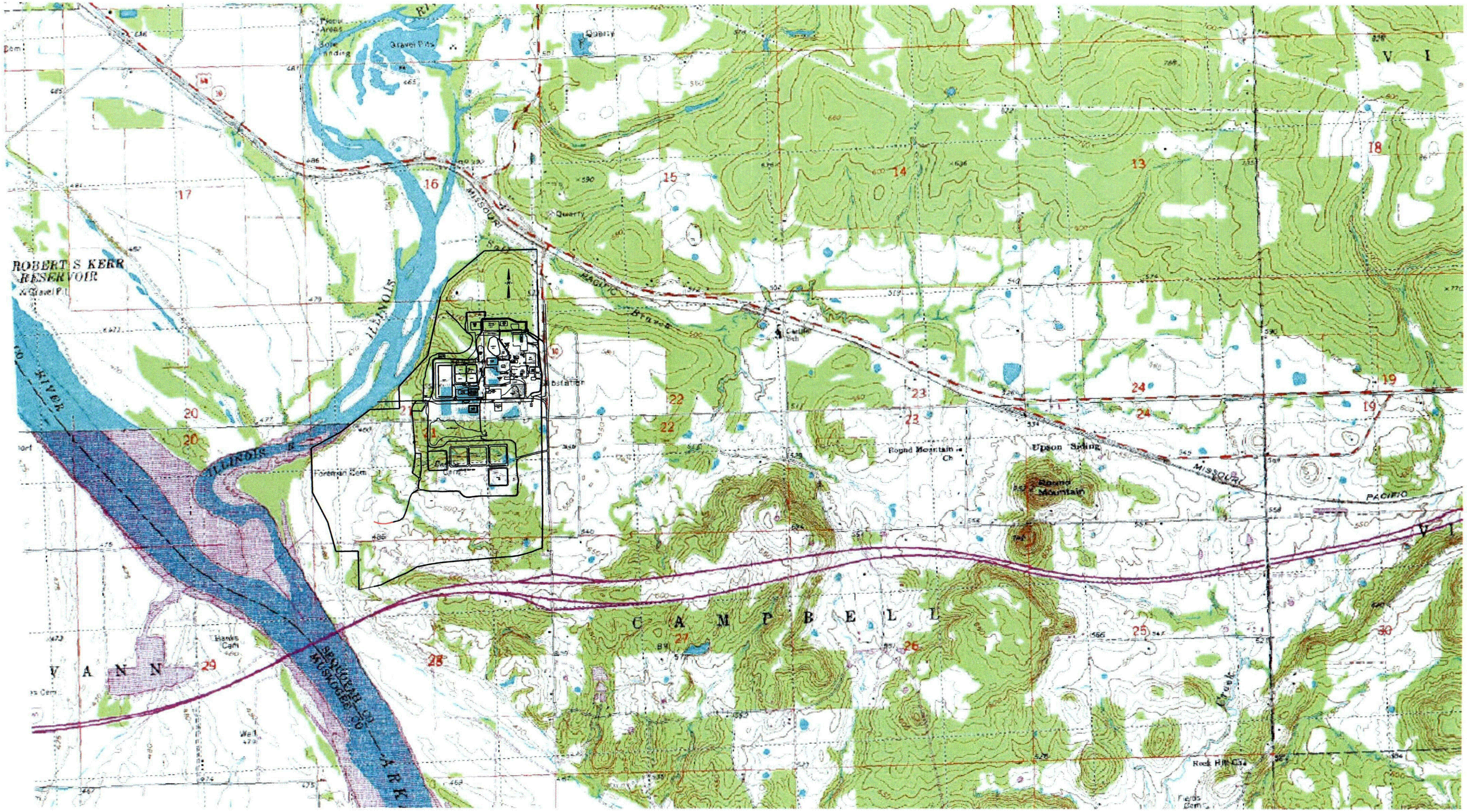


Title: FACILITY LOCATION MAP

SEQUOYAH FUELS
A GENERAL ATOMICS COMPANY
RECLAMATION PLAN

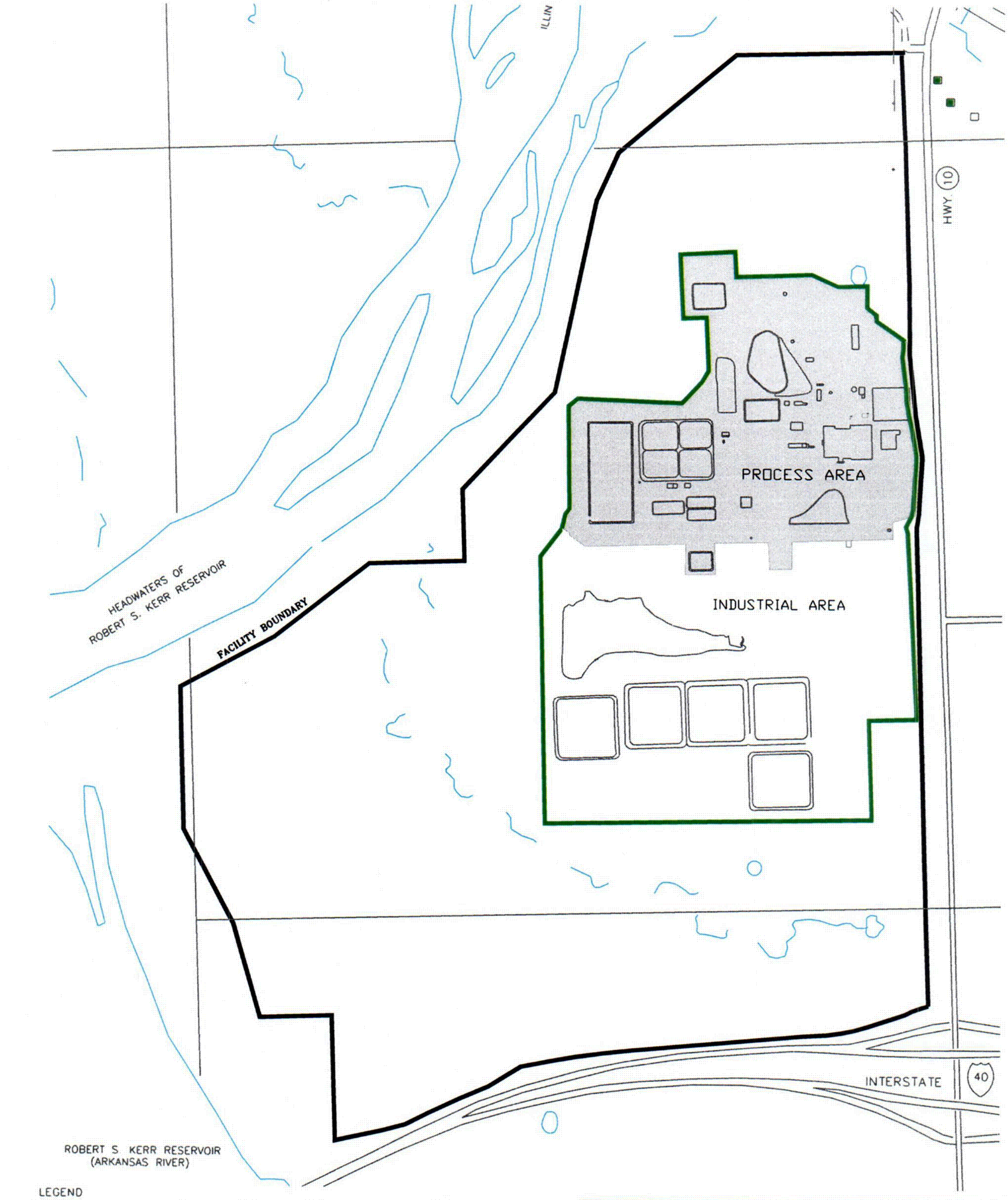
PREPARED BY: SFC	Filename: SFC0005B
Reviewed by: CH	Figure No.2-1
Date: 12/27/2002	

C24



Title:	TOPOGRAPHIC MAP	
SEQUOYAH FUELS A GENERAL ATOMICS COMPANY RECLAMATION PLAN	PREPARED BY: SFC	Filename: SFC0087A
	Reviewed by: CH	Figure No.2-2
	Date: 12/27/2002	

C25



LEGEND
- PROCESS AREA
- FACILITY BOUNDARY
- INDUSTRIAL AREA PERIMETER

Title:

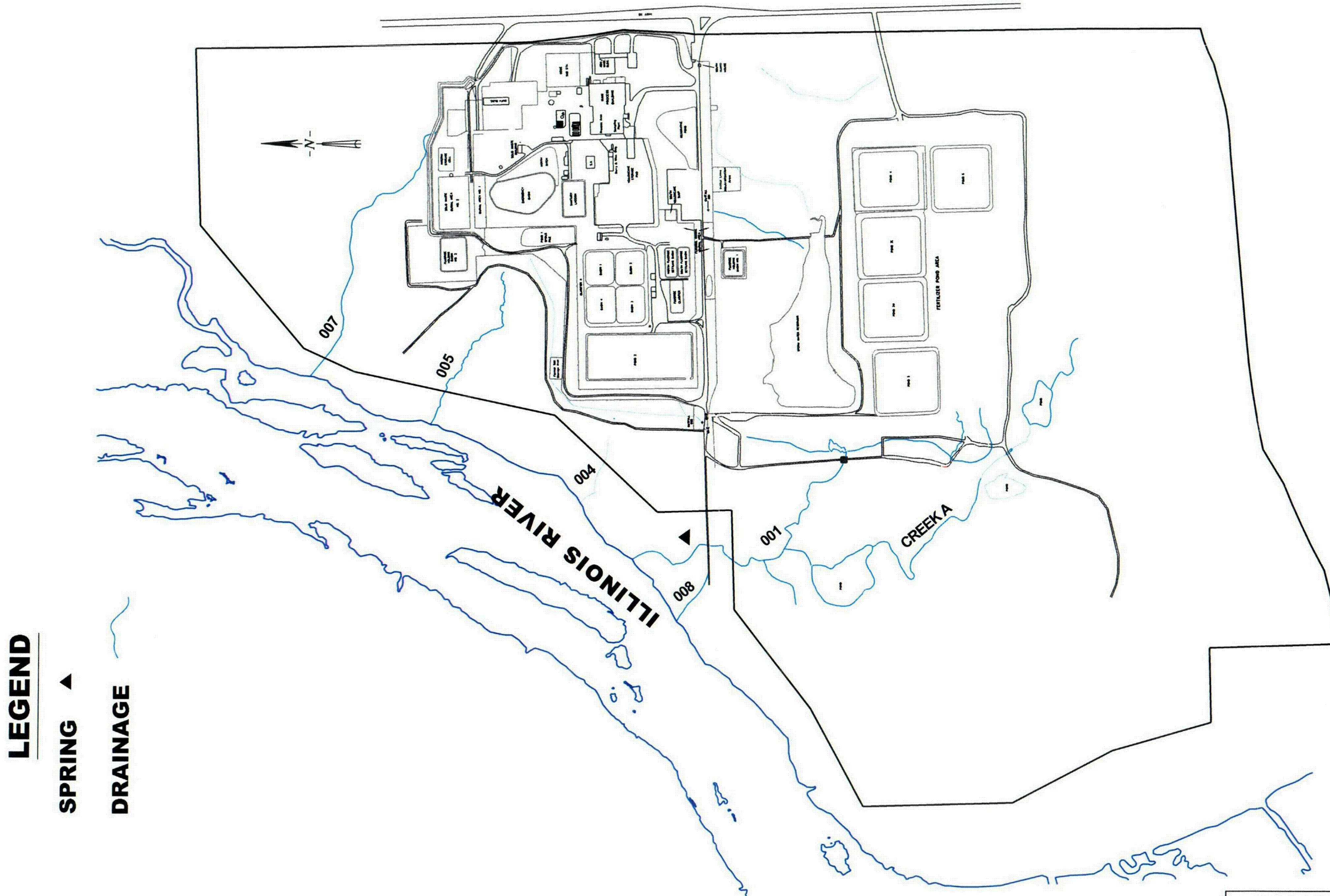
FACILITY AREA DESIGNATIONS

SEQUOYAH FUELS A GENERAL ATOMICS COMPANY RECLAMATION PLAN	PREPARED BY: SFC	Filename: SFC006B
	Reviewed by: CH	Figure No.2-3
	Date: 12/27/2002	

C26

SEQUOYAH FUELS
A GENERAL ATOMICS COMPANY
RECLAMATION PLAN

Title: GENERAL FACILITY LAYOUT	
PREPARED BY: SFC	Filename: SFC0088A
Reviewed by: CH	Figure No.2-4
Date: 12/27/2002	



Title: LOCATIONS OF FACILITY DRAINAGES AND SPRINGS

SEQUOYAH FUELS A GENERAL ATOMICS COMPANY RECLAMATION PLAN	PREPARED BY: SFC	Filename: SFC0089A
	Reviewed by: CH	Figure No.2-5
	Date: 12/27/2002	

3.0 FACILITY DECOMMISSIONING AND SURFACE RECLAMATION

3.1 Summary of Radiological Conditions

The Site Characterization Report (SCR) included as Appendix D, and the Facility Environmental Investigation (FEI) (RSA, 1991) provide thorough descriptions of Facility operations, along with the identification of source characteristics associated with various processes. Detailed historical information about the facility is provided in the documents listed in section 2.2.4 of the SCR. This section summarizes the extent and concentration of the contamination found during those studies.

The contamination at the Facility is a result of uranium processing activities that took place during the operation of the plant. Throughout the operating life of the plant, on-going evaluations of the impact of plant operations, including airborne and liquid discharges, and soil and groundwater sampling, occurred.

In the vicinity of the process buildings, process impoundments and uranium handling areas, concentrations of uranium in the soils exceed background and in many areas exceed the proposed soil cleanup criterion (see section 3.2.2). Uranium in soil at concentrations above 27 pCi/g is found to a maximum depth of about 31 feet beneath the Process Area. In addition, a few areas of limited extent are impacted by thorium-230 and/or radium-226. Soils containing thorium or radium in excess of the proposed limits are confined to areas where raffinate sludge was managed.

Groundwater beneath portions of the SFC site is impacted by uranium from past leaks and spills. The vertical extent of the groundwater impact is limited by an almost impervious sandstone layer, referred to as the Unit 4 Sandstone, that underlies the majority of the site. Monitoring wells in the groundwater zone immediately beneath Unit 4 Sandstone confirm that there is no significant impact below that level.

Groundwater flow on the site is generally to the southwest, conforming to the tilt of the bedrock strata in the area. Some localized areas of groundwater flow to

the south and northwest have been measured, however these flows appear to be influenced by erosional features and mounding of water in the vicinity of facility impoundments.

The groundwater is not currently a threat to human health or the environment. The strategy for a groundwater protection plan will be developed under NRC guidelines as the result of a Corrective Action Plan for the site. The groundwater protection plan was submitted June, 2003.

A characterization of structures and equipment in the restricted area was performed to provide information concerning the degree of radioactive contamination and radiation levels in order to provide a basis for identifying contamination control efforts that will be required during decommissioning. The characterization data was compiled from routine and special surveys performed during 1994, 1995, and 1996.

Areas identified as impacted by operation of the SFC Facility are the Process Area, portions of the 1986 Incident Plume pathway, Fertilizer Storage Pond Area, the historic Combination Stream, a drainage pathway south of the plant entrance, the drainage pathway designated as Outfall 005, and most structures within the restricted area. Figure 2-1, Attachment B, summarizes the impacts.

3.2 Decommissioning and Reclamation Activities

Decommissioning and reclamation plans and specifications are presented in Attachment A - F. This section provides an overview of the activities planned during decommissioning and reclamation for the site.

3.2.1 Description of Activities and Tasks

The scope of decommissioning activities includes the dismantlement and removal of systems and equipment, the deconstruction of structures, the removal and treatment of sludges and sediments, the removal of contaminated soils, and the treatment of wastewater. The placement of these materials in the disposal cell will be in layers by category of radioactivity, as well as in three areas of the cell in phases. The following summarizes these activities.

Structures, Systems and Equipment

A detailed volume estimate of the facility equipment and structural materials was made and the disposal volume was estimated to be 824,660 cf (after dismantlement and size reduction; 50% of the concrete left in place). This estimate was based on a review of drawings and other data for the facility structures, equipment, utilities, and concrete in order to determine the location of contamination, to understand the construction of the facility, and to facilitate planning of dismantlement methods. Appendix F describes the review described above.

The majority of the salvageable or recyclable equipment and materials have been removed and dispositioned. Only limited decontamination of materials for unconditional release is planned. All remaining equipment and structures will be dismantled and size reduced, as necessary. The dismantled equipment and structural components will be placed into the cell. Concrete and asphalt will be broken into manageable pieces and placed in the cell.

Soils, Sediments and Sludges

Raffinate Sludge

The raffinate sludge contains a significant fraction of the radionuclides presently on the SFC site (34% of the uranium or 60,800 kg, 76% of the thorium 230 or 156 Ci, and 38% of the radium 226 or 1.1 Ci.). The sludge has been removed from the Clarifier A Basin and processed to reduce the water content.

The de-watering method removed free water from the sludge resulting in a 50% reduction in the weight, approximately 11,000 tons of de-watered sludge. The de-watered sludge has been placed in bags for off-site disposal or placement into the disposal cell.

Calcium Fluoride (CaF_2) Sludge

Calcium fluoride (CaF_2) sludge will be dewatered to improve its structural strength prior to placement into the disposal cell.

Sediments

Sediments from the Emergency Basin, North Ditch and Sanitary Lagoon will be dewatered or stabilized to improve their structural strength prior to placement into the disposal cell.

Soils

Soils outside the footprint of the disposal cell which contain uranium, radium, or thorium in excess of the proposed site-specific cleanup criteria will be excavated and placed in the disposal cell. This volume is estimated to range from 0.5 to 3.0 million cf depending on the final soil cleanup criteria that is selected. At a minimum, soils under the footprint of the disposal cell that exceed the uranium DCGL (the concentration that would result in an equivalent dose from Ra-226 at 5 pCi/g) will also be excavated, and placed in the cell. The volume of these soils is estimated to be about 345,000 cf. The depth of excavation will be based initially on soil sampling data from characterization studies. Follow-up sampling will be done to determine if additional excavation is required, and to demonstrate that the cleanup criteria have been satisfied.

Additional soil will be excavated, most likely to the soil/bedrock interface, in those areas where the uranium concentration in the perched groundwater is elevated in excess of 150 pCi/l (the SFC license action level, 225 µg/l). This would be done to facilitate the removal and treatment of the impacted perched groundwater. It is likely that some of the soils in the areas of perched groundwater impact contain uranium in the forms of uranyl nitrate and related compounds, which are much more soluble than the oxide forms.

Soils collected from prior cleanup activities that are presently located in the Interim Storage Cell and in the Pond 1 Spoils Pile will also be removed and placed in the disposal cell. These materials have a volume of about 578,000 cf. An additional 952,000 cf of potentially contaminated clay and soil lies beneath the facility ponds, basins and clarifiers. The fraction of this soil exceeding the applicable cleanup criteria is expected to be less than 10% of the total volume, or 95,200 cf.

Soils from excavation areas will be transported to the disposal cell by haul trucks for long distances, or loaders for shorter distances. Existing roads will be used as much as possible; new haul roads will be constructed only if necessary.

Soils will be placed in the cell in lifts and mechanically compacted according to design requirements (Attachment A). Placement of this material will be sequenced with other materials to assure stability of the cell, to minimize voids and settlement, to limit leaching and to further restrict the emanation of radon from the cell. Attachment E, Disposal Cell Construction Plan, discusses the placement sequence.

Wastewater Management

Wastewater includes water from existing ponds and impoundments, storm water runoff from work areas, water used for processing operations, and recovered groundwater.

The Wastewater Treatment System, located south of the Clarifier Basins (Figure 2-4) is designed for batch treatment of wastewater to remove uranium. The system utilizes precipitation, filtration, and ion exchange processes to remove uranium prior to release of the water.

Treated water will be sampled and analyzed for uranium prior to discharge through permitted outfall 001. The cleanup goal for the Wastewater Treatment System is to reduce the uranium concentration to less than 30 µg/l, the drinking water MCL.

Site Restoration

After the removal of systems and equipment, structures, and soils and sediments, the site will be restored by backfilling (if necessary), grading and seeding with vegetation.

3.2.2 Cleanup Levels

The cleanup levels for this reclamation plan were either specified by regulations, or derived using guidance provided by the NRC. 10 CFR 40, Appendix A, Criterion 6 (6) limits the concentration of Ra-226 in soil, and concentrations of other radionuclides in soil based on the equivalent dose from Ra-226. Derived concentration guideline levels (DCGL) have been developed as concentrations of residual radioactivity in soils that are equivalent to the Ra-226 concentration. The detailed dose modeling is presented in Appendix G. The approach used is summarized here. Cleanup levels were subsequently chosen based on the DCGLs, application of the ALARA principle, and the limiting conditions of 10 CFR 40, Appendix A, Criterion 6 (6).

Identification of Constituents of Concern (CoC)

The CoCs were determined to be natural uranium and associated transformation products, thorium-230, and radium-226.

Exposure Methodology

The dose from residual radioactivity was determined by constructing a source term and exposure scenario, and using a computer model to simulate the release and transport of radionuclides and radiation in the environment on a site-specific basis. The assessment reflected the site-specific characteristics of the residual radioactivity (e.g. type, extent, concentration) and of the environment (e.g. soil, surface water, groundwater, and air) at the site. Exposure pathways relevant to the exposure scenario were chosen based on this information. The source term and exposure scenario are described in the following sections.

The dose was determined first for a Ra-226 concentration in surface soil of 5 pCi/g. This Ra-226 dose is hereafter referred to as the radium benchmark dose. The residual concentration in surface soil was subsequently determined for each of natural uranium and thorium-230 that resulted in a dose equal to the radium benchmark dose.

Source Term

The source term was assumed to be an uncovered contaminated surface soil zone of cylindrical shape. The CoCs for the radium benchmark dose are Ra-226 and Pb-210 each at 5 pCi/g. The CoCs are assumed homogeneously distributed within the contaminated zone. The contaminated zone is modeled as a 0.3 meter layer of unconsolidated soil. The contaminated soil is known to be underlain by one uncontaminated unsaturated zone; this zone is modeled as a 1.4 meter thick layer of unconsolidated soil. The next layer is an uncontaminated saturated zone; this zone is modeled as shale. The final layer is sandstone; this layer functions as an aquitard and is not included in the model. The relationship between Facility conditions and the source term parameters, and the physical characteristics (density, porosity, ...) of each layer are described in Appendix G.

Exposure Scenario

The exposure scenario modeled here, representing a residential farmer, is comprised of direct exposure to external radiation and inhalation and ingestion of radioactive material to an individual who lives on the site and ingests food grown on the site. The scenario is based on assumptions that tend to realistically estimate potential doses. The model used to assess the dose to the residential farmer was the RESRAD computer code. A justification and more complete description of the residential farmer scenario are provided in Appendix G.

The residential farmer scenario is unlikely since the DOE will restrict access and land use in the reclaimed area, but considered to be a

possibility if land use controls failed. Three primary exposure pathways were not considered. The rationale for excluding each is summarized as follows:

Drinking Water

The scenario assumes that readily available, nearby surface water is used for drinking and for irrigation. Use of groundwater is not considered because of the limited quantity and generally poor quality encountered near the SFC site.

A corrective action plan addressing groundwater is described elsewhere. By regulation, that plan includes engineering and/or institutional controls protective of human health and the environment. The plan will ensure that concentrations of groundwater at all locations outside the institutional control boundary, where it would be possible for groundwater to be accessed, will be acceptable for all potential future uses including human consumption. The alternatives for the plan include active, passive and institutional control mechanisms.

Cell Intrusion

Development of the DCGLs did not consider failure or intrusion of the cell's engineered cover. The cover is designed such that failure is not a credible event. The scenario assumes that an individual had access to the restricted area but would not disturb the disposal cell. DOE will ultimately take control of the site as long term custodian and will prevent any unauthorized intrusion into the cell.

Radon

The radon pathway was not considered because it is specifically excluded from the scope of the technical criteria.

Selection of Cleanup Levels

The radium benchmark dose resulting from the exposure scenario described above was 57 mrem per year to the resident farmer. The

DCGLs in surface soil for U-natural and Th-230 that result in 57 mrem/y for the same exposure scenario are 570 pCi/g and 66 pCi/g, respectively.

The technical criteria provide limits for Ra-226 in soil. Specifically, the concentration of Ra-226 in soil, averaged over areas of 100 square meters, cannot exceed the background level by more than: (i) 5 pCi/g averaged over the first 15 cm below surface, and (ii) 15 pCi/g averaged over 15 cm thick layers more than 15 cm below the surface. Application of the technical criteria includes consideration of the in-growth of Ra-226 from Th-230 over a 1000-year design period. The Th-230 concentration is limited such that it will not cause any $100m^2$ area to exceed the Ra-226 limit at 1000 years (i.e. current concentration of Th-230 is less than 14 pCi/g surface and 43 pCi/g subsurface, if Ra-226 is at approximately background levels).

Cleanup levels have been selected based on the ALARA principle, and regulatory requirement. Cleanup levels for uranium and thorium have been set at concentrations that are much lower than the DCGLs. Cleanup levels for radium have been set at the regulatory limit. Table 3-1 presents the DCGLs and the cleanup levels.

Table 3-1 Derived Concentration Guideline Levels (DCGL) and Cleanup Levels (CL)

Condition	Uranium-Nat pCi/g	Thorium-230 pCi/g*	Radium-226 pCi/g*
DCGL	570	66	5.0 / 15
CL	100	≤14 / ≤43	≤5.0 / ≤15

* first 15cm below surface / 15cm layers greater than 15cm below surface

The cleanup levels will be applied without subtracting background.

The subsurface cleanup level will be applied to small areas on site where Th-230 and Ra-226 are present as contaminants. These areas are depicted in Figure 2-1 of Attachment B as the Th-Ra areas. In these

areas, uranium, thorium, and radium will be considered in combination where the sum of ratios for the concentration of each radionuclide present to the respective cleanup level concentration will not exceed one (unity). At least 0.5 foot and likely several feet of clean fill will be placed over these areas following decontamination. The clean fill is expected to remain in place for the foreseeable future after reclamation.

In areas where radium and thorium are not present, the uranium cleanup level will be used.

Dose Assessment

Inside the ICB and using the DCGLs for radium, thorium, and uranium developed in Appendix G, the dose to a person carrying out authorized activities is estimated to be less than 2 mrem/y. For a resident farmer intruder inside the ICB (equivalent to loss of institutional control scenario in 10 CFR 20.1403) the dose will be 57 mrem/y, the SFC site radium benchmark dose. Utilizing the cleanup levels listed in Table 3-1, the dose rate to the industrial worker and the resident farmer would be approximately 20% of the dose from radium benchmark soil concentrations or 0.4 mrem/y and 11 mrem/y, respectively.

As demonstrated in Appendix G, the dose to a member of the public from contamination that is presently in the drainages that exit the ICB and cross U.S. Army Corps of Engineers property (drainages 001, 005, and 007) is less than 0.2 mrem/y.

3.2.3 Final Status Survey

The final status surveys have been designed from the guidance contained in NUREG-1575 "Multi-Agency Radiation Survey and Site Investigation Manual" (MARSSIM) and the requirements of 10 CFR 40, Appendix A, Criterion 6 (6). The surveys will demonstrate that the residual radioactivity in each survey unit satisfies the applicable criteria described in Section 3.2.2.

The survey designs began with the development of data quality objectives (DQOs). The DQOs were developed using guidance provided on the DQO Process in Appendix D of MARSSIM. On the basis of these objectives, applicable requirements of 10 CFR 40 Appendix A, and the known or anticipated radiological conditions at the site, a survey design was developed to determine the numbers and locations of measurement and sampling points to demonstrate compliance with the release criterion. Finally, survey techniques were selected appropriate for development of supporting data.

3.3 Disposal Cell Design

The preliminary disposal cell design is presented in Appendix C, Preliminary Design Report for the Disposal Cell at the Sequoyah Fuels Corporation Facility (December, 2002), based on the design criteria and strategy outlined in Section 1.3. The various calculations and analyses are presented in Appendix C. The 2002 preliminary design has been updated based upon additional characterization work and construction sequencing. The updated design is presented in Attachment E, Cell Construction Plan, and summarized in the following subsections.

3.3.1 Site Selection

SFC evaluated four possible locations within its property boundary for siting the disposal cell. All four locations were found to be acceptable, each having advantages and disadvantages. The Process Area location was chosen as the best option due to proximity to materials destined for disposal, pre-existing contamination of the sub-surface, and reduced material handling costs. Appendix H presents the siting evaluation.

3.3.2 Layout and Capacity

The disposal cell layout consists of a four-sided domed structure to contain the disposed materials beneath a multi-layered cover system. The direction of top surface drainage was chosen to be toward the highest ground elevation and away from the west side of the cell. The top surface of the structure drains to the

southeast at a one-percent slope. The side slopes of the cell are at 5:1 (20 percent), the maximum slope under NRC reclamation criteria.

The disposal cell layout for the estimated 8.3 million cubic feet of disposed materials (Table 3-2) is shown on Figure 3-1. Due to the variability in disposed material density and the amount of soils that may actually be excavated, the disposal cell location and layout has been planned to accommodate a range of disposed material volumes from 5 million to 12 million cubic feet. For this range of disposal volumes, the north, east and west sides remain in the same location and with the same height, while the location of the south side is adjusted. A typical cross section through the disposal cell (for any of these volumes) is shown in Figure 3-2.

3.3.3 Cover System

The disposal cell cover design is a layered system with a moisture retention, (store-and-deplete) zone and a vegetated surface. The cover is designed to promote long-term vegetative growth that optimizes evapotranspiration and subsequently minimizes infiltration. The total cover thickness is ten feet, and is sufficient for root zone development and radon attenuation. The cover system is shown in Figure 3-2.

The upper 18 inches of the cover system consists of an erosion protection and vegetation zone. On the top surface, the upper 18 inches of the cover thickness consists of a topsoil layer. On the side slopes, the upper 18 inches consists of an eight-inch thick topsoil layer above a ten-inch thick rock mulch layer. The cover surface will be vegetated, with the long-term vegetation being a native grass, forb and brush system. The bottom 2.0-foot thick zone of the cover system is a compacted clay overlain by a synthetic liner to provide infiltration control under short-term conditions. The remaining 6.5-foot thickness of the cover system will consist of a 5.0-foot thick zone of on-site soils to provide a root zone and long-term moisture retention zone for infiltrating meteoric water. Beneath this zone is a 1.5-foot thick drainage layer.

The reduction in emanation of radon-222 from disposed materials by the cover system was evaluated using calculation procedures outlined in NUREG 3.64. The evaluation results in Attachment E show that the cover system and sequence of disposed material placement in the cell reduces the average rate of radon-222 emanation to below the limit of 20 pCi/square meter-second (from Appendix A of 10 CFR 40).

The radon emanation calculations used the RADON model, with conservative parameters for the cover system and disposed materials. Ingrowth from thorium-230 to radium-226 under extreme long-term conditions was included as input for the disposed materials in the calculations.

3.3.4 Perimeter Area

The disposal cell perimeter will transition into the surrounding reclaimed site topography such that drainage from the toe of the side slopes is conveyed away from the cell. Outside the toe of the side slopes will be a 20-foot wide perimeter apron, consisting of a rock mulch designed for energy dissipation.

3.3.5 Erosional Stability

The erosional stability of the disposal cell design was evaluated according to procedures outlined in NRC guidance. The disposal cell surface was evaluated for peak runoff from the Probable Maximum Precipitation (PMP) event. The calculated velocity from the peak runoff was compared with acceptable, non-erosive velocities on the top surface and side slopes of the disposal cell.

On the top surface of the disposal cell, the one-percent slope with vegetated surface conditions provides sufficient resistance to erosion, even under conservative, poor vegetation conditions. On the side slopes of the disposal cell, flow velocities down the 5:1 slopes require rock for erosion protection from PMP runoff. The selected protection is a layer of rock mulch with a median particle size of 4.7 inches (sized for the peak flow from the PMP). In order to promote vegetative growth on the side slopes, the rock mulch layer will be below the topsoil layer. The perimeter apron (to be extended 20 feet from the toe of the

side slopes) will consist of a 20-foot layer of rock mulch with a median particle size of 8 inches.

3.3.6 Slope Stability

The slope stability of the disposal cell was evaluated under static and seismic conditions according to standard criteria outlined in NRC guidance. The stability analysis results are presented as calculated factors of safety, which are compared with accepted minimum factors of safety. The analysis results under static conditions show that calculated factors of safety are higher than the minimum long-term value of 1.5. The analysis results under seismic conditions (represented by pseudostatic analyses) show that calculated factors of safety are higher than the minimum value of 1.1. The stability analyses were conducted using conservative input values for material shear strength and density. A liquefaction analysis of materials in the disposal cell was conducted, with the results showing a negligible potential for liquefaction. The stability analysis results are presented in Attachment E.

3.3.7 Meteoric Water Infiltration

Infiltration of meteoric water and moisture migration through the cover system was evaluated using the TerreSIM model, an MFG model used for land use and ecosystem evaluation. The TerreSIM model uses a detailed method of tracking evapotranspiration and plant canopy evaporation, based on specific plant communities. Modeling was conducted under average climatic conditions for a simulation period of 200 years. The average rate of migration of meteoric water through the bottom of the cover was calculated to be approximately 7.8 inches/year or 17 percent of annual precipitation, for the first 45 years of simulation. For the next 155 years of simulation (after full development of the plant community), the calculated rate of migration through the cover was essentially zero. The calculated rate of meteoric water migration through the root zone of the cover averaged approximately 6.6 inches/year or 14 percent of annual precipitation, for the first 50 years of simulation. For the next 150 years of simulation (after plant community development), the calculated rate of meteoric

water migration through the root zone averaged 3.6 inches/year, or 8.7 percent of average precipitation.

The synthetic liner and clay layer beneath the root zone at the base of the cover would significantly reduce moisture migration through the cover under short-term conditions. For long-term conditions, moisture migration through the bottom of the cover would be limited by the clay layer at the base of the cover as well as the vegetation productivity and root zone depth. The actual rate of meteoric water migration through the bottom of the cover would be lower than the long-term average value calculated for the root zone.

3.4 Disposal Cell Construction

The strategy for disposal cell construction (from the base of the disposal cell to the bottom of the cover system) is outlined in the following subsections.

3.4.1 Construction Materials

In the preliminary disposal cell design (Appendix C), materials were grouped by radioactivity content for disposal sequencing to minimize leaching, and optimize shielding and radon attenuation. These groups or layers are summarized in Table 3-2. These groups are referred to as Layers A through D which are generally described below.

Layer A. Layer A materials consist of five components: (1) raffinate sludge, (2) Pond 2 residual materials, (3) Emergency Basin sediment, (4) North Ditch sediment, and (5) Sanitary Lagoon sediment. The raffinate sludge has been dewatered, packaged, and stored on-site until either shipment off-site or onsite disposal. Dewatering of the sludge reduced its volume to approximately one third of the original value.

Due to the relatively high activity concentration of radionuclides in Layer A materials, these materials would be the lowest layer in the disposal cell profile. In terms of estimated volume, Pond 2 residual materials comprises most of the Layer A materials (65.5 percent), followed by dewatered raffinate sludge (30.5 percent), and the remaining sediments (totaling 4 percent).

Layer B. Layer B materials consist of soil liner and subsoil materials beneath the clarifier, the calcium fluoride basins, Pond 3E, the Emergency Basin, the North Ditch and the Sanitary Lagoon, as well as Pond 1 spoils pile material. The Layer B materials (primarily contaminated soils) are listed second in the order, since they would be excavated after removal of Layer A materials and placed directly on top of Layer A materials in the disposal cell profile. In terms of estimated volume, the Pond 1 spoils pile (35 percent), clarifier liners (26 percent), and Emergency Basin soils (13 percent) comprise approximately 74 percent of the Layer B materials.

Layer C. Layer C materials consist of structural materials, concrete and asphalt, calcium fluoride basin materials, calcium fluoride sediments, and on-site buried materials. These materials would be placed with or above the Layer B materials, and covered with contaminated soils (Layer D materials). In terms of estimated volume, the calcium fluoride sediments (35 percent), structural materials (32 percent) and concrete and asphalt (14 percent) comprise approximately 81 percent of the Layer C materials.

Layer D. Layer D materials consist of contaminated soils and sedimentary rock that require cleanup. The cleanup level used for the estimated volume is a natural uranium activity concentration of 27 pCi/g.

The total layer material volumes estimated for each layer are presented in Table 3-2 below, in order of placement from bottom to top within the cell.

Table 3-2 Disposed Material Summary

Layer	Description	Estimated Volume (cu ft)	Fraction of Total Volume (%)	Natural Uranium (pCi/g)	Radium-226 (pCi/g)	Thorium-230 (pCi/g)
A	Sludge and sediment	1,162,735	14.5	357-12100	6-332	211-16300
B	Liner soils and subsoils	1,262,673	15.7	5-95	0.5-2.1	47-70
C	Calcium fluoride sediments, debris	2,035,362	25.3	168-520	0.2-0.8	2.1-4.8
D	Contaminated site soils	3,574,000	44.5	250	--	--
	Totals	8,034,770	100.0	--	--	--

3.4.2 Construction Sequence

In conjunction with the overall sequence and water management strategy above, the anticipated construction sequence for the disposal cell is outlined below.

The disposal cell is scheduled to be constructed in three phases to minimize double-handling of materials during cell construction. This phasing allows one area of the cell base to be prepared for receipt of materials excavated from another area of the cell. After all three base areas of the cell have been constructed, materials from outside the disposal cell footprint can be placed throughout the cell.

As shown on the Drawings (Attachment A), the cell base includes a three-foot high perimeter berm on the outside edges of the cell. The perimeter berm is designed with a 3:1 inside slope and 5:1 outside slope to tie into the synthetic liner and outside slope of the cover. The cell base includes a three-foot high internal berm on the inside edges of the cell. The internal berm is designed for the cell base liner system to tie into the adjoining phase of cell base. The perimeter and internal berms are designed to aid in leachate collection within each cell.

Stormwater management is accommodated by water retention with berms or embankments constructed primarily with contaminated site soils, other soils to be disposed in the cell, and minor amounts of broken concrete. The elevation of the retention berms will be maintained at a minimum of five feet above the top surface elevation of the interior materials. The berms will be placed in lifts and compacted to aid with moisture retention. As shown on the Drawings, the berms will be raised in an upstream manner (by constructing additional berm with the centerline toward the inside of the disposal area). Synthetic liner material will be installed on the inside slopes of the retention berms to enhance water retention.

Initial work consists of preparation for construction of the phase I cell base. This includes: (1) dewatering of raffinate sludge, (2) emptying and cleaning of the

clarifier ponds (for stormwater storage), (3) moving of UF6 cylinders from the phase I cell area, and (4) initiation of building demolition in the phase I cell area (incinerator building, solid waste building, and Bechtel building). The DUF4 building is just east of the phase I cell perimeter and can be demolished later.

The northeast corner of the disposal cell footprint is primarily concrete or asphalt that is unaffected by facility operations. The soil sampling and analysis program conducted by SFC in this area has verified that this area has not been contaminated. The northeast portion of the cell would comprise the first phase of the cell construction sequence.

Phase I of the disposal cell would be constructed on top of the concrete or asphalt pads, with the liner system and perimeter berms forming the cell base. Following base construction, excavation of materials from the phase II area of the disposal cell would be placed in the phase I area. The stormwater retention berm would be raised as soils are available and as needed for freeboard requirements.

After the phase II area foundation is cleaned up and the cell base is constructed, excavation of materials and building demolition debris from the phase III area would be placed in the phase II area of the cell. The stormwater retention berm would be raised as soils are available and as needed for freeboard requirements. Phase I and II areas may be joined into one working area.

After the phase III area foundation is cleaned up and the cell base is constructed, excavation of materials and building demolition debris from outside the cell footprint would be placed in the phase III area of the cell. The stormwater retention berm would be raised as soils are available and as needed for freeboard requirements. Phase I through III areas may be joined into one working area.

Work following phase III and prior to cover construction includes: (1) ensuring that materials to be disposed in the cell have been identified and placed in the cell; (2) ensuring that all contaminated site soils outside of the cell footprint have been identified, excavated, and placed in the cell; (3) grading the top surface of

the disposed materials to required bottom-of-cover slopes and grades; and (4) smoothing the final bottom-of-cover surface for clay layer installation.

3.5 Disposal Cell Base Construction

A multilayered liner system will be constructed to form the top zone of the entire disposal cell base. The base of the disposal cell will be sloped to drain to the outside of the cell from each phase to facilitate leachate collection and liner leak detection.

The excavated surface within the disposal cell footprint will be backfilled with random fill, placed in lifts and compacted to form the desired elevations and slopes for the disposal cell base and liner system. The liner system materials are described below (from bottom to top layers).

The lowest layer of the liner system is a 36-inch thick clay layer consisting of on-site silty clay placed in lifts and compacted. Above the clay layer is a 6-inch thick layer of sand (from off-site commercial sources) to provide a bedding layer for a synthetic liner (most likely 60-mil thickness high-density polyethylene). The sand bedding layer also serves as a potential zone for collection of leakage through the synthetic liner should leakage occur. Above the synthetic liner is the uppermost layer of the liner system, an 18-inch thick layer of sand from off-site commercial sources to provide a protective zone between the synthetic liner and subsequent disposed materials. This sand zone also serves as a leachate collection zone for liquids from the disposed materials and meteoric water within the perimeter of the disposal cell.

3.6 Disposal Cell Cover Construction

The cover system over the disposal cell consists of a 10-foot thick soil cover on both the top surface and side slopes of the cell. This cover system is summarized in Figure 3-2, Typical Cross-Section on East Side of Disposal Cell.

3.6.1 Construction Materials

The disposal cell cover construction materials are discussed in Attachment A. The material quantities are outlined below.

Cover system materials. The cover material volume (for the 10-foot thick cover) totals approximately 258,700 cubic yards. Significantly more material is available on site than is required for the cover material.

Topsoil. Approximately 30,000 cubic yards of topsoil would be required for the cover, and 4,000 cubic yards for the perimeter apron. Sufficient topsoil is available for this volume (and additional volume) from the agland area.

Rock mulch. The rock mulch volume totals 13,000 cubic yards for the cell cover and 8,000 cubic yards for the perimeter apron. Rock mulch material would be obtained from off-site sources.

Cover subsoil materials. The remaining cover material volume (subtracting the topsoil and rock mulch) is approximately 150,000 cubic yards, for the layout shown on the drawings. The likely sources of this material would be the tornado berm and settling pond berm materials, as well as the south borrow area.

Synthethic liner materials. Synthetic liner, most likely 60-mil thickness high density polyethylene, will be installed on top of the clay layer at the base of the cover (approximately 13 acres).

Clay Layer. The clay layer forms the base of the cover system and consists of a 24-inch thick layer of compacted silty clay. The clay layer material would be obtained from the borrow area at the south end of the site (approximately 42,000 cubic yards for the cover layer and 70,000 cubic yards for the disposal cell base.

3.6.2 Construction Sequence

The anticipated construction sequence for the disposal cell cover is outlined below.

1. Construction of the layers of cover on the side slopes of the disposal cell. The cover material could be placed in horizontal lifts or in lifts parallel to the outside 5:1 slopes. The rock mulch and topsoil would be placed as cover areas are completed to final slopes and grades.

2. Construction of the cover over the top surface of the cell, after the volume of contaminated soils has been established. The elevation of the top surface of the cell will be reduced if the final volume of material is less than 8 million cubic feet (due to higher compacted densities of disposed materials or lower actual volumes of materials).

3. Transition of the perimeter apron of the disposal cell with surrounding reclaimed topography to promote runoff away from the disposal cell.

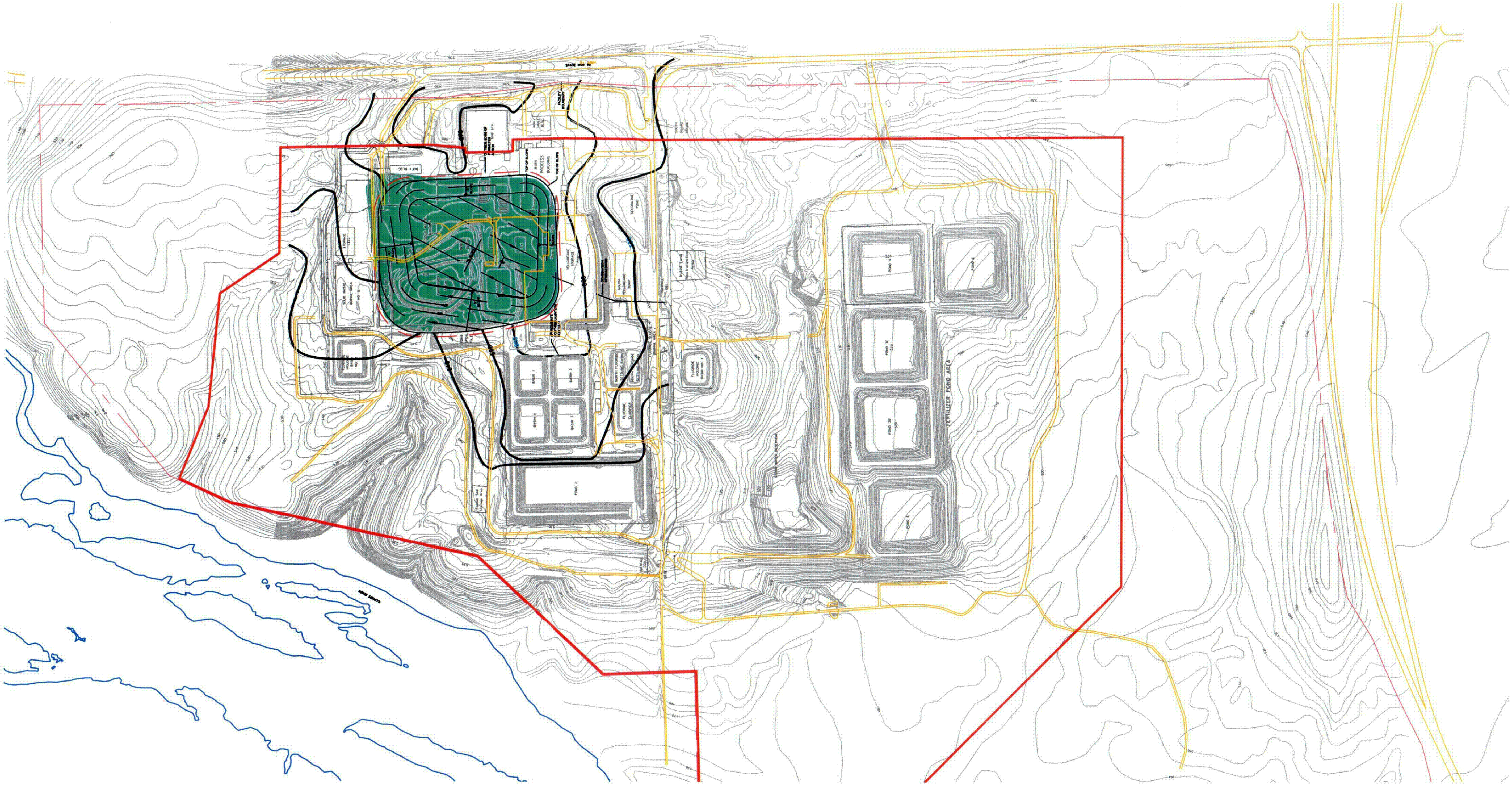
4. Establishment of vegetation on the disposal cell surface, consistent with the overall plan for mature vegetation development.

5. Establishment and marking of settlement monuments and other monitoring features on the cell surface and perimeter.

3.7 Institutional Control

Following successful completion of performance monitoring, the custody of the site will be transferred to the U.S. Department of Energy pursuant to the provisions of 10 CFR 40.28.

SFC will establish and fence the institutional control boundary (ICB) to limit unauthorized access. Activities within the institutional control boundary are only those authorized by the DOE or its contractors, such as monitoring or maintenance. The proposed institutional control boundary for the SFC facility after reclamation is shown on Figure 3-1.



	Title: DISPOSAL CELL LOCATION AND LAYOUT		
SEQUOYAH FUELS A GENERAL ATOMICS COMPANY RECLAMATION PLAN	PREPARED BY: SFC	Filename: SFC0091A	
	Reviewed by: CH	Figure No.3-1	
	Date: 12/27/2002		

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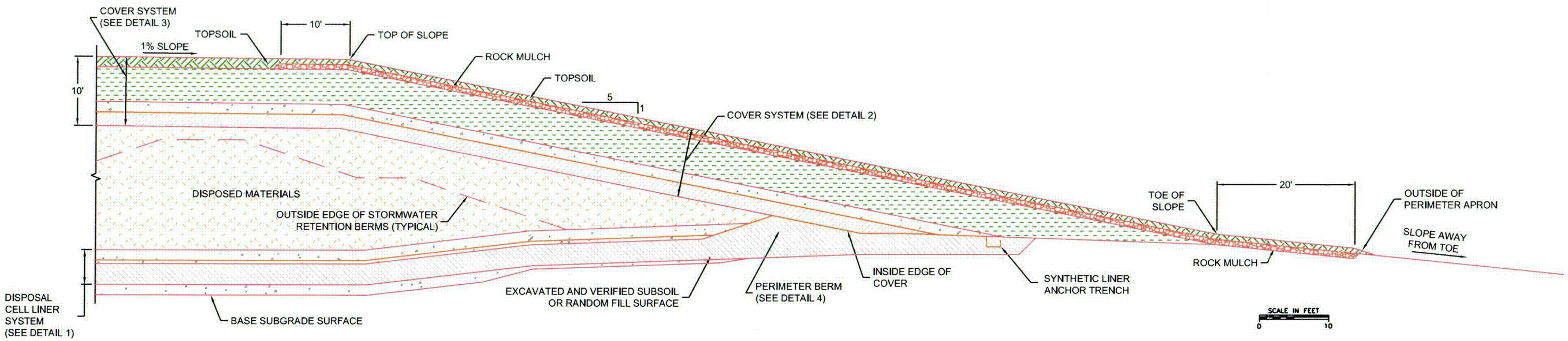

TYPICAL CROSS SECTION ON EAST SIDE OF DISPOSAL CELL

(LOOKING NORTH)

	Title: TYPICAL CROSS SECTION ON EAST SIDE OF DISPOSAL CELL	
SEQUOYAH FUELS A GENERAL ATOMICS COMPANY	PREPARED BY: SFC	Filename: SFC0090C
	Reviewed by: CH	Figure No.3-2
RECLAMATION PLAN	Date: 12/23/2005	

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4.0 QUALITY ASSURANCE

The quality assurance program for the decommissioning and reclamation is presented in Attachment C.

5.0 RADIATION PROTECTION

5.1 Cover Radon, Gamma Attenuation and Radioactivity Content

5.1.1 Radon Emanation

The disposal cell cover has been designed to limit the rate of emanation of radon-222 to the NRC technical criterion limit of 20 pCi/square meter-second, averaged over the entire cover as outlined in 10 CFR 40, Appendix A, Criterion 6. The disposal cell cover and underlying disposed materials were evaluated according to NRC guidelines, using the RADON model. The evaluation results (outlined in Appendix D of the disposal cell preliminary design report) show calculated radon emanation rates below the 20 pCi/square meter-second limit, under conservative input conditions.

As a confirmation of the cover evaluation for radon emanation, the actual rate of radon emanation will be measured after disposal cell cover construction is completed. Measurement of radon emanation will be conducted according to EPA procedures outlined in 40 CFR 61, Subpart T, Method 115. This consists of measuring radon emanation at a minimum of 100 locations on the cover surface, using canisters containing activated charcoal. The canisters are set on the cover surface for 24 hours, with the charcoal subsequently analyzed for adsorbed radon with gamma spectroscopy. The individual measured values are converted to an emanation rate at each canister location, and these rates are used to calculate an average for the entire cover surface.

5.1.2 Gamma Attenuation

The gamma radiation exposure was estimated at the surface of the disposal cell cover. The effect of a soil cover in reducing exposure from a gamma radiation source is calculated as the ratio of the shielded exposure rate to the unshielded exposure rate. Using coefficients for soil, the shielded exposure rate is approximately $1/10^9$ of the unshielded rate at a soil cover of ten feet which is essentially background. The calculations show that gamma radiation exposure is significantly reduced by a small thickness of soil cover.

5.1.3 Cover Radioactivity

The on-site borrow areas planned for disposal cell cover material have been chosen to provide the physical properties desired for the cover, including a moisture retention zone for evapotranspiration and material to attenuate emanating radon. These borrow areas have been selected to provide soils that are of similar radiological characteristics to native soils in the site area.

5.2 Radiation Safety Controls and Monitoring

A Radiation Safety Program describing measures to protect workers, the public, and the environment will be maintained and followed during decommissioning and reclamation. In recognition that the amount of radioactivity and therefore associated hazards will be reduced as the project progresses, the Radiation Safety Program may be modified commensurate with the activities being performed. SFC will review and approve the Radiation Safety Program, and any revisions that are made during the project. Any such adjustment to the requirements of the Radiation Safety Program shall be made in accordance with document control procedures. Attachment D presents the Radiation Safety Program.

6.0 CELL PERFORMANCE MONITORING AND VERIFICATION

The performance monitoring and verification tasks for the disposal cell are consistent with plans for overall site reclamation and review guidelines in NRC (2002). Key tasks are outlined in the following subsections, and address the period of time from site reclamation until property transfer to the U.S. Department of Energy.

6.1 Settlement

Since the disposal materials will be placed in lifts with compaction to minimize void spaces, cover settlement will not be as critical an issue as for uranium tailings impoundments. However, settlement will be monitored with survey monuments installed on a grid system on the cover surface. The monuments will be surveyed on a quarterly basis until four quarters of stable conditions (less than 0.1 foot of settlement per quarter) are measured.

6.2 Vegetative Cover

A vegetation plan for the disposal cell surface outlining the initial and mature species desired for the cell and the schedule and methods planned for achieving the mature vegetation (such as transplanting of seedlings and institution of weed control) is included in Attachment A. After establishment of the initial vegetation on the cover surface, the condition of the initial vegetation will be monitored for comparison with the schedule in the vegetation plan. The vegetation performance will be monitored until that responsibility is changed with property transfer to the U.S. Department of Energy.

6.3 Erosional Stability

The erosional stability of the cover surface will be monitored on a semi-annual basis, most likely at the same time as vegetation monitoring. Elements of the erosional stability monitoring are degree of vegetation cover (in terms of surface coverage), identification of settled or ponded areas (such as on the top surface), and identification of rills, gullies, or other areas of runoff concentration. Problem areas that are identified will be monitored to determine if corrective action is

necessary. Corrective action would include fill placement with topsoil or placement of erosion-resistant materials on the surface, such as rock mulch.

6.4 Groundwater Protection

Groundwater will be monitored in a two-step manner. First, the cell liner system has a leak detection component which will provide a more timely indication of leakage from the cell than a monitoring well system in the downgradient aquifer. Second, one upgradient and five downgradient point-of-compliance (POC) wells, will be installed once the cell construction is complete. The combination of the liner leak detection system and the POC wells will provide the earliest practical warning that the impoundment is releasing hazardous constituents to the groundwater.

The POC wells will be monitored on a quarterly basis for the complete list of hazardous constituents. The leak detection system will be visually monitored, with a water quality sample collected and analyzed, if leakage is present. Details are provided in Attachment E, Disposal Cell Construction Plan, including the parameters to be analyzed.

7.0 DECOMMISSIONING AND RECLAMATION COST

The costs associated with SFC's proposed decommissioning approach, as presented in Table 7-1, only reflect the direct costs for performing the various decommissioning activities. Costs that are included as direct costs include those associated with engineering, design and construction; excavation and handling of material; backfilling excavated areas; deconstruction of buildings, structures, and equipment; sludge and sediment treatment; cell filling; cell closure; wastewater handling and treatment; monitoring during remediation; and post-remediation monitoring, maintenance and security. General and Administrative costs such as SFC overhead, license and permit fees, taxes, routine environmental monitoring costs, etc., are not included.

The funding plan and assurance for the funds for decommissioning has been addressed by the settlement agreement between the NRC and SFC which was approved by the Commission on October 8, 1997 (CLI 97-13). SFC provided a decommissioning cash flow projection to the NRC on February 25, 1997 based on available decommissioning cost and schedule information, and has updated the cash flow projection several times since. The projection indicates that SFC will receive sufficient revenue to implement this reclamation plan provided that significant delays in the overall schedule do not occur. Table 7-2 provides the most recent estimate of decommissioning cash flow.

Table 7-1 Estimated Remaining Direct Costs For Proposed Decommissioning Approach

Activity	Direct Cost ($,000)	Notes
1. Complete Reclamation Plan and Supporting Documents	$479	Includes Responses to RAIs and Revisions to the Reclamation Plan, Groundwater Corrective Action Plan and Preparation of an Alternate Concentration Limit Application
2. NRC Charges for Reclamation Plan Review, EIS Preparation	$427	Includes Review and Approval Reclamation Plan and Groundwater Corrective Action Plan and Completion of EIS
3. Contractor mobilization and demobilization	$666	5% of lines 4, 5, 6, 7, 8, 9 and 11
4. Monitoring Well Removal and Replacement	$180	Abandon and plug 157wells, install 7 new wells
5. Disposal Cell Construction/Closure	$2,948	Updated to reflect 2004 Settlement Agreement revisions to Cell Design
6. Dewatering and Off-Site Disposal of Raffinate Sludge	$2,300	Includes Transportation and Processing of Sludge at Cotter (11,500 tons @ $209/ton - does not include possible share of recovered uranium value)
7. Other Sludge, Removal, Treatment and On-Site Disposal	$2,731	Excavation, treatment and placement of other sludges in the cell (1,307,700 cu-ft @$2.09/cu-ft)
8. Soil Remediation	$1,563	DASR Appendix I, Table 10-1, Item 200 Total adjusted for remediation of 434.000 cf of soil (>100 pCiU/g) (includes cost of cell placement). Unit costs are in 1995 $ from Table 10-1 of M-K Report in Appendix I.
		DUF4 Trash Drums 2,200 cf @ $12.05 = $ 26,510
		Soils > 100 pCiU/gm 434,000 cf @ $0.75 = $ 325,500
		CaF_2 Basin Clay Liners 95,290 cf @ $0.66 = $ 62,891
		Solid Waste Burials 51,100 cf @ $1.46 = $ 74,606
		Pond 1 Spoils Pile 437,000 cf @ $0.66 = $ 288,420
		Interim Soils Storage Cell 154,887 cf @ $0.66 = $ 102,225
		Pond 3E and 4 Clay Liners 219,100 cf @ $0.79 = $ 173,089
		Clarifier Clay Liners 332,400 cf @ $0.66 = $ 219,384
		Drummed LLW 4,050 cf @ $12.05 = $ 60,250
		Sanitary Lagoon Soil 56,400 cf @ $0.66 = $ 37,224
		Emergency Basin Soil 162,500 cf @ $0.66 = $ 107,250
		North Ditch Soil 87,500 cf @ $0.66 = $ 57,750
		Crushed Drums 2,000 cf @ $0.66 = $ 1,320
		Total 2,038,427 $ 1,536,420
9. Building and Equip. Demolition	$3,831	Estimate based on Old Cotter Mill demolition experience
10. Termination Survey	$375	2,000 soil samples @ $100 each plus gamma walkover survey – 500 hours @ $50/hr plus $150k assessment/NRC confirmation
11. Site Restoration	$1,330	Cost to grade, place topsoil and re-vegetate excavations and other affected areas. Based on dozing approximately 17,500,000 cf of dike material into impoundments at $0.071 per cf, grading 83 acres @ $3000/acre, applying 6 inches of topsoil to 124 acres (2,701,000 cf at $0.11/cf) and seeding 124 acres at $512/acre.

Activity	Direct Cost ($,000)	Notes
12. Groundwater Remediation	$1,124	$100,000 per year for 7 years plus $100,000 for recovery systems installation plus $350,000 for intercept trench expansion. Includes treatment of stormwater and waste water as necessary.
13. Engineering/Construction Management	$2,385	15% of lines 3 through 11
14. Post-Closure Monitoring Program	$81	Post-closure monitoring includes the cost of purging, sampling and analysis for 25 wells for an additional sampling event for the first three to five years after cell closure, cell settlement monitoring, radon emission measurement and cell cover inspection and repair.
15. SFC Staff	$7,301	SFC at current level of 6 plus management augmentation during decommissioning
16. Long-Term Site Control Fund	$1,125	Assumes an escrow fund at 2% interest to generate funds for the annual long-term maintenance costs of $21,868. Costs include annual sampling of 25 monitoring wells and analysis for uranium, nitrate and arsenic, preparation of an annual report, NRC inspection fees, mowing 6 times per year, and $500 annually for general maintenance. <u>Sampling Costs</u> Well Purging 16 h @ $ 35 = $ 560 Well Sampling 16 h @ $ 35 = $ 560 <u>Analytical Costs</u> Uranium 25 wells @ $ 20 $ 500 Nitrate 25 wells @ $ 15 $ 375 Arsenic 25 wells @ $ 25 $ 625 Sample Prep 25 wells @ $ 20 $ 500 <u>Annual Report</u> Manpower 80 h @ $ 90 $ 7,200 Copying Costs $ 200 <u>NRC Inspection Fees</u> Travel Time 8 h @ $ 156 $ 1,152 Inspection Time 4 h @ $ 156 $ 576 Report Preparation 40 h @ $ 156 $ 5,760 <u>Mowing</u> 6 mowings 96 h @ $ 35 $ 3,360 <u>General Maintenance</u> $ 500 Total $ 22,492
17. Long-term Groundwater Recovery and Treatment	$1,300	13 years @ $100,000/year
Total Cost	**$30,119**	

Table 7-2 Cash Flow Summary For Completion Of Reclamation

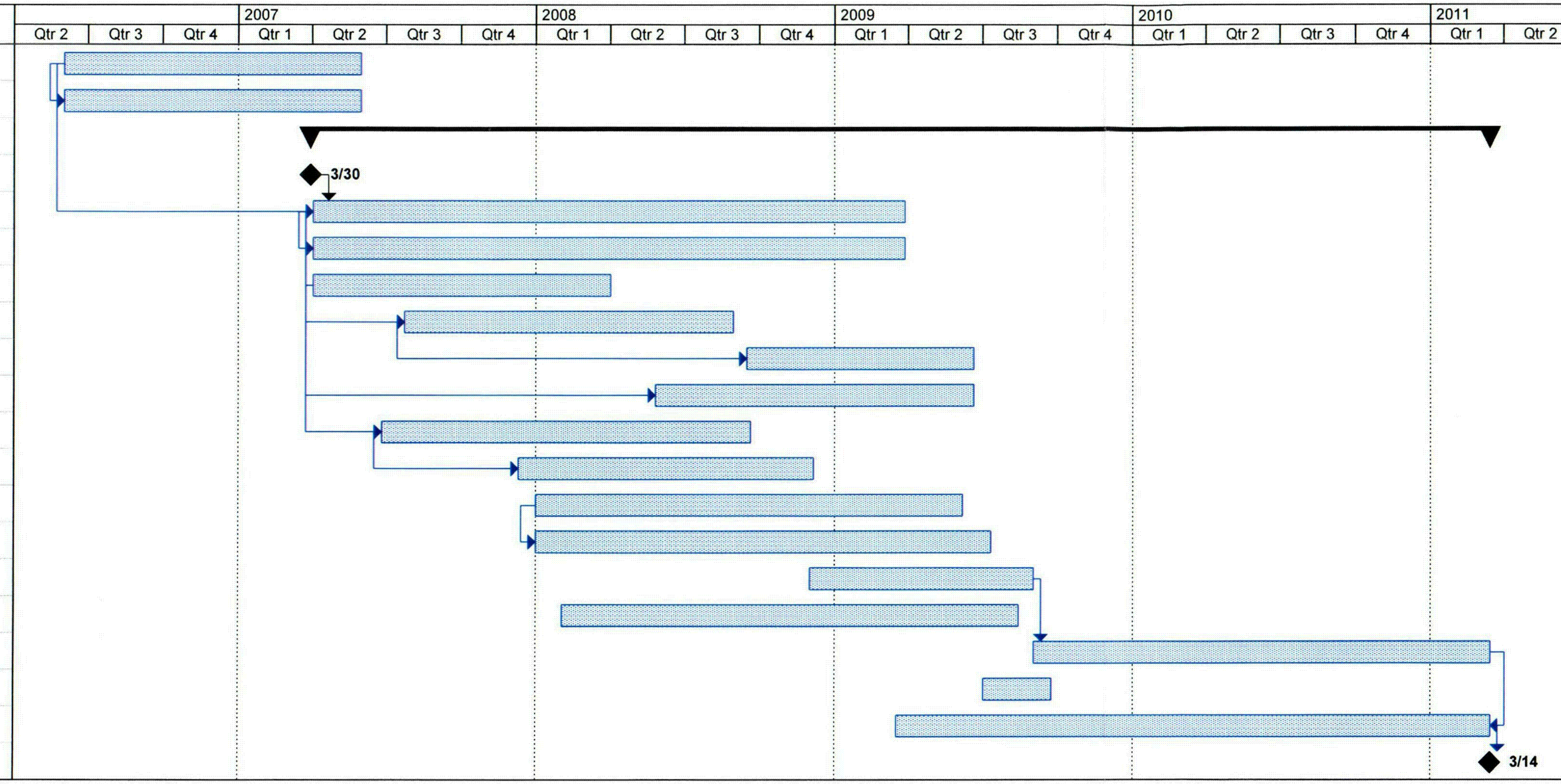
	2005	2006	2007	2008	2009	2010	2011	2012	TOTAL
INCOME									
Disposition Of Inventory	0	0	0	0	0	0	0	0	0
Ranch Revenue	273	215	215	215	215	215	215	215	1778
Converdyn Fees (W/O Int.)	0	0	0	7119	7187	7255	7323	5753	34637
Interest Income	252	242	95	3	32	11	9	97	741
Other Income	40	0	0	0	0	0	0	0	40
Ga Settlement Fund	0	0	0	0	0	0	0	5400	5400
TOTAL REVENUES	565	457	310	7337	7434	7481	7547	11465	42596
EXPENSES									
RECLAMATION TASKS									
Rec Plan Prep	209	150	100	50	50	50	50	29	688
NRC REVIEW (SER And EIS)	337	327	100	0	0	0	0	0	764
Mob/Demob	0	0	200	216	0	0	220	30	666
Monitor Well Rem/Replc	45	138	0	0	0	42	0	0	225
Cell Construction	0	0	0	800	500	0	1648	0	2948
Off-Site Disp Raff Sldg	2153	2300	0	0	0	0	0	0	4453
Other Sldg/Sed. Disp	0	0	320	0	1117	1294	0	0	2731
Soil Remediation	0	0	0	600	600	336	0	0	1536
Bldg/Eqp Demolition	0	0	0	500	1738	1593	0	0	3831
Termination Survey	0	0	0	0	0	0	0	375	375
Site Restoration	286	0	0		0	800	380	150	1616
Gw Remediation	21	124	200	200	200	150	125	125	1145
Engr./Constr. Mgmt	0	0	100	1000	983	300	0	0	2383
Post Closure Monit	0	0	0	0		26	27	28	81
Personnel	0	0	844	1526	1563	1573	1095	700	7301
Long-Term Site Contrl	0	0	0	0	0	0	0	1125	1125
Long-Term Gw Treatment	0	0	0	0	0	0	0	1300	1300
Total Reclamation Cost	3051	3039	1864	4892	6751	6164	3545	3862	33168
Recl Costs To Reserve	2484	2438	1864	4892	6751	6164	3545	3862	32000
GEN & ADMIN									
Personnel	1154	1200	600	490	490	495	495	495	5419
Nrc Region Inspections	6	6	8	18	30	15	9	9	101
Legal Fees	189	150	50	50	50	25	25	25	564
Taxes, Insurance & Other	923	867	800	800	800	800	500	300	5790
Ranch Costs	63	40	40	40	40	40	40	40	343
Fertilizer Ponds	84	48	48	48	0	0	0	0	228
Total Gen & Admin	2419	2311	1546	1446	1410	1375	1069	869	12445
TOTAL COSTS	5470	5350	3410	6338	8161	7539	4614	4731	45613
NET CASH FLOW	-4905	-4893	-3100	999	-727	-58	2933	6734	
CUM CASH BALANCE	8076	3183	83	1082	355	297	3230	9964	

8.0 SCHEDULE

The preliminary schedule for reclamation of the SFC facility is shown in Figure 8-1. The schedule incorporates the major elements of this proposed reclamation plan, and shows the interrelationships and estimated time required to complete these activities. The NRC approval date for this reclamation plan was chosen as a placeholder since a date certain is not currently available. Several tasks on the critical path are shown as starting prior to the approval date in order to complete the reclamation within the available resources.

Figure 8-1
Preliminary Reclamation Schedule

ID	Task Name
1	Excavate and Treat Material Under Cell Footprint
2	Recover and Treat Impacted Groundwater Encountered
3	**Sequoyah Facility Reclamation**
4	NRC Approval of Reclamation Plan
5	Construct Disposal Cell Base and Dike
6	Collect and Treat Stormwater
7	Dismantle Process Equipment
8	Dismantle/Demolish Structures
9	Demolish Concrete Floors, Foundations and Storage Pads
10	Size Reduction/Compaction of Structures, Systems and Components
11	Remove and Treat Sludges and Sediments
12	Remove Clay Liners/Soils Under Impoundments
13	Excavate Contaminated Soils Outside the Cell Footprints
14	Conduct Final Status Survey
15	Complete Capping and Closure of Cell
16	Backfill Excavations to a Finished Grade and Revegetate
17	Monitor Cell Performance
18	Establish Fenced Institutional Control Boundary
19	Transfer Title to DOE
20	Termination of SUB-1010



Project: Figure 8-1
Date: Dec 2005

Task | Split | Milestone ◆ | Summary

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ENCLOSURE 3

Reclamation Plan

Attachment A, Technical Specifications

Update Instructions:

1. Remove text from RP Attachment A tab
2. Insert text enclosed here
3. Remove Drawings 10 – 13 from RP Attachment A tab
4. Insert Drawings enclosed here

TECHNICAL SPECIFICATIONS FOR THE SEQUOYAH FUELS CORPORATION DISPOSAL CELL

Prepared For:
Sequoyah Fuels Corporation
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January 2006

consulting
scientists and
engineers

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1.0 SPECIAL PROVISIONS

1.1 SCOPE OF DOCUMENT

The following technical specifications have been prepared for the construction, operation, and closure of the on-site disposal cell at the proposed Sequoyah Fuels Corporation (SFC) site near Gore, Oklahoma. These technical specifications have been prepared for review and approval by the U.S. Nuclear Regulatory Commission (NRC), and will form part of contracts for reclamation of the site, for work tasks conducted by contractors selected by and under contract with SFC.

1.2 DEFINITIONS

These technical specifications are referred to in this document as the Specifications. Sections referred to in this document are specific sections of the technical specifications. The Drawings referred to in this document are the design drawings that form a necessary component of these Specifications. These Specifications and Drawings comprise Attachment A of the SFC Reclamation Plan.

For these Specifications, SFC is referred to as the Owner, with overall responsibility for disposal cell construction, operation, closure; as well as overall site reclamation.

The Contractor is defined as the group (or groups) selected by SFC and responsible for conducting the work tasks outlined in Section 1.3 under the direction of and under contract with SFC.

The QA Manager is defined as the person appointed by SFC responsible for inspection and Quality Assurance (QA) testing of construction work to ensure that the engineering aspects of site reclamation work are conducted as outlined in these Specifications.

The Reclamation Project Manager is defined as the person appointed by SFC responsible for ensuring that reclamation activities, including construction work and inspection and QA testing of construction, are conducted according to these Specifications and the intent of the design.

The Health and Safety Officer is defined as the person appointed by SFC responsible for worker safety and personnel monitoring. The Health and Safety Officer will be responsible for personnel safety training, personnel health monitoring, and documentation. These tasks will be conducted in accordance with the Health and Safety Plan for site reclamation work as well as pertinent sections of these Specifications.

1.3 SCOPE OF WORK

The work outlined in these Specifications consists of execution of the following tasks associated with construction and operation of the disposal cell and associated site reclamation.

1. Preparation of borrow areas for material excavation by removal of vegetation; and stripping, salvaging, and stockpiling of topsoil.

2. Preparation of material staging and stockpile areas by removal of vegetation; stripping, salvaging, and stockpiling of topsoil; and providing for stormwater diversion and internal water collection.

3. Staged preparation of the disposal cell base and liner system for placement of on-site materials and construction of stormwater diversion and internal water collection facilities.

4. Removal of residual process and waste materials from ponds and storage areas on site, with treatment or dewatering, and placement in the disposal cell.

5. Removal of liner materials and contaminated subsoils from beneath waste material pond and storage areas, and placement in the disposal cell.

6. Excavation of process area structure foundations, paved areas, concrete pads and roadways, and placement of these materials in the disposal cell.

7. Excavation of contaminated subsoils from the process area, and placement in the disposal cell.

8. Construction of the cover system over the disposal cell, with placement of rock mulch and topsoil over the disposal cell cover surface.

9. Regrading and placement of topsoil over excavated areas, stockpile and staging areas, and other disturbed areas of the site.

10. Establishment of vegetation on the disposal cell surface and surrounding reclaimed areas on site.

Work not included in these Specifications consists of pressure filtration and bagging of raffinate sludge, off-site removal of raffinate sludge and associated materials, salvage of facility equipment, demolition of facility structures, groundwater monitoring and remediation, and post-reclamation performance monitoring.

1.4 APPLICABLE REGULATIONS AND STANDARDS

The work shall conform to applicable Federal, State, and County environmental and safety regulations. The work shall conform to applicable conditions in the Radioactive Materials License with NRC. Geotechnical testing procedures shall conform to applicable ASTM standards, as documented in the edition of standards in force at the start of work (ASTM, 2003 or future annual edition). Personnel safety procedures and monitoring shall be conducted in accordance with the Health and Safety Plan for site reclamation.

1.5 INSPECTION AND QUALITY ASSURANCE

Full-time, on-site training, personnel monitoring, and inspection of construction activities shall be conducted by the Health and Safety Officer (and approved assistants as needed) while the site reclamation work is in progress. The Health and Safety Officer (and assistants) will be independent representatives of SFC, appointed by SFC. The responsibilities and duties of the Health and Safety Officer shall be as outlined in the Health and Safety Plan for site reclamation.

Full-time, on-site inspection of all construction activities and quality assurance (QA) testing outlined in these Specifications shall be conducted by the QA Manager (and approved assistants as needed) while the construction work is in progress. The QA Manager (and assistants) will be independent representatives of SFC, appointed by SFC. The inspection and QA testing conducted by the QA Manager shall be under the supervision of the Reclamation Project Manager. Inspection and QA testing shall include the tasks listed below.

1. Observation of construction practices and procedures for conformance with the Specifications.

2. Testing material characteristics to ensure that earthen materials used in the construction conform to the requirements in the Specifications.

3. Testing liner material characteristics and installation to ensure placement, compaction, deployment, seaming, and other work practices conform to the requirements in the Specifications.

4. Documentation of construction activities, test locations, samples, and test results.

5. Notification of results from quality assurance testing to SFC and the Contractor.

6. Documentation of field design modifications or approved construction work that deviates from the Specifications.

Documentation outlined above shall be recorded by the QA Manager on a daily basis. Deviations from the Specifications shall be approved by the Reclamation Project Manager and the SFC President, with notification to NRC or other appropriate Oklahoma state regulatory agency personnel.

1.6 CONSTRUCTION DOCUMENTATION

During construction, documentation of construction inspection work will be recorded by the QA Manager on a daily basis. Documentation will include the following items.

1. Work performed by the Contractor.

2. QA testing and surveying work conducted.

3. Discussions with SFC and the Contractor.

4. Key decisions, important communications, or design modifications.

5. General comments, including weather conditions, soil or liner surface conditions, visitors to the site.

All earthwork and synthetic liner QA test results will be documented on a daily basis (on separate reporting forms), with a copy of the results given to the QA Manager by the end of the following working day after the testing. Photographs of key construction activities and critical items for documentation will be taken by the QA Manager or his representative.

A final construction report documenting the as-built conditions of the disposal cell will be submitted to NRC after the completion of disposal cell construction. This report will include the following items.

1. All design modifications or changes to the specifications that were made during construction.

2. An as-built layout of the disposal cell prior to material disposal, and at the completion of cover construction.

3. An as-built layout of other reclaimed areas of the site.

4. Documentation of soil cleanup verification work (soil radiation survey and soil sampling and analyses) in areas of contaminated soil excavation.

1.7 DESIGN MODIFICATIONS

Design modifications (due to unanticipated site conditions or field improvements to the design) will be made following the protocol outlined below.

1. Communication of modification with the Reclamation Project Manager, and approval of modification by the SFC President.

2. Documentation of modification in the as-built construction report.

1.8 ENVIRONMENTAL REQUIREMENTS

The Contractor shall store materials, confine equipment, and maintain construction operations according to applicable laws, ordinances, or permits for the project site. Fuel, lubricating oils, and chemicals shall be stored and dispensed in such a manner as to prevent or contain spills and prevent said liquids from reaching local streams or ground water. If quantities of fuel, lubricating oils or chemicals exceed the threshold quantities specified in Oklahoma regulations, the Contractor shall prepare and follow a Spill Prevention Control and Countermeasures Plan (SPCCP), as prescribed in applicable Oklahoma regulations. SFC shall approve said plan. Used lubricating oils shall be disposed of or recycled at an appropriate facility.

1.9 WATER MANAGEMENT

The Contractor shall construct and maintain all temporary diversion and protective works required to divert stormwater from around work areas. The Contractor shall furnish, install, maintain, and operate all equipment required to keep excavations and other work areas free from water in order to construct the facilities as specified.

Water required by the Contractor for dust suppression or soil moisture conditioning shall be obtained from wells or surface water storage areas identified by the Owner. Contaminated water will not be used for disposal cell construction.

1.10 HISTORICAL AND ARCHEOLOGICAL CONSIDERATIONS

Due to construction and operational activity at the site, it is unlikely that materials of historical or archeological significance are present in the disposal cell area. However, if materials are discovered or uncovered that are of potential historical or archeological significance, the Contractor shall immediately notify the Owner. The Owner may stop work in a specific area until the materials can be evaluated for historical, cultural, or archeological significance. All materials determined to be of significance shall be protected as determined by appropriate regulatory agencies, including removal or adjustment of work areas.

1.11 HEALTH AND SAFETY REQUIREMENTS

Work outlined in these specifications shall be conducted under the Health and Safety Plan for site reclamation, as directed by the Health and Safety Officer.

The Contractor shall suspend construction or demolition operations or implement necessary precautions whenever (in the opinion of the Reclamation Project Manager or Health and Safety Officer), unsatisfactory conditions exist due to rain, snow, wind, cold temperatures, excessive water, or unacceptable traction or bearing capacity conditions. The QA Manager, Reclamation Project Manager, and Health and Safety Officer each have the authority to stop Contractor work if unsafe conditions or deviations from specifications are observed.

2.0 SITE CONDITIONS

2.1 SITE LOCATION AND LAYOUT

The SFC site is located in north-central Oklahoma, northeast of the confluence of the Illinois River with the Arkansas River (tributaries of the Robert S. Kerr Reservoir). The site encompasses approximately 600 acres on the east bank of the Illinois River, north of Interstate Highway 40 and west of Oklahoma State Highway 10. The SFC facilities are primarily located within the 85-acre process area (shown on the Drawings).

2.2 CLIMATE AND SOIL CONDITIONS

The site is in an area of warm, temperate, continental climate. Annual precipitation averages 39 to 45 inches, and is fairly evenly distributed throughout the year. Annual evaporation averages approximately 70 inches (for Class A pan data) and 50 inches (for shallow lake data).

The site is located on a ridge or upland area above the Illinois River, and is underlain by a horizontally bedded sequence of Pennsylvanian Atoka Formation sandstone, siltstone and shale. The Atoka Formation surface has been weathered and eroded, and mantled to varying depths with Pleistocene terrace deposits. Soils investigated from over 500 drill holes on site consist of the terrace deposits and weathered zones of the Atoka Formation. These soils range from sandy, clayey gravels to silty clays of moderate plasticity.

2.3 PAST SFC OPERATIONS

Uranium processing operations at the SFC site started in 1969 under a license with Kerr McGee Corporation. In 1993, SFC notified the NRC of its intent to terminate licensed activities at the site. The NRC license remains in effect until site decommissioning is completed.

2.4 FACILITIES DEMOLITION

Demolition of equipment, structures, and associated facilities at the SFC site will be conducted according to applicable conditions of the NRC license, the demolition plan for the facility, and the SFC Health and Safety Plan for site reclamation. Facilities demolition is not included in this document.

2.5 DISPOSED MATERIALS

The materials to be placed in the disposal cell consist of process waste materials, structural debris, and underlying liner materials and subsoils from planned site cleanup activities. The various materials to be placed in the disposal cell will be disposed in a planned sequence, depending on the timing of excavation. Materials with higher activity concentrations of radionuclides will generally be placed lower in the disposal cell. The four major types of materials are outlined below.

2.5.1 Type A Material

Type A materials consist of five components: (1) raffinate sludge, (2) Emergency Basin sediment, (3) North Ditch sediment, (4) Sanitary Lagoon sediment, and (5) Pond 2 residual materials. Due to the relatively high activity concentration of radionuclides in the first four components (the raffinate sludge and sediments from the Emergency Basin, North Ditch, and Sanitary Lagoon), priority will be given to

dispose of these materials at an appropriate offsite location. If it is determined that it is not economically possible to dispose of these materials offsite, these materials, along with the Pond 2 residual materials, shall comprise the lowest layer in the disposal cell profile, and will be placed over a prepared liner within the disposal cell.

Raffinate sludge and other selected Type A materials will be processed or "dewatered" by pressure filtration, with the resulting filtercake loaded by conveyor into polypropylene bags (approximately 3 feet by 3 feet by 4 feet), referred to as supersacks.

If the bagged filtercake is disposed on site, the bags will be placed in the south end of the disposal cell (shown on Drawings). The placed raffinate sludge bags will be encapsulated with an additional synthetic cover and liner system (Sections 5.2, 5.3 and 6.2.1).

2.5.2 Type B

Type B materials consist of soil liner and subsoil materials beneath the clarifier, calcium fluoride basin, Pond 3E, the Emergency Basin, the North Ditch and the Sanitary Lagoon, as well as Pond 1 spoils pile material. The Type B materials (primarily contaminated soils) are listed second in the order, since they will be excavated after removal of Type A materials and placed at the base of the disposal cell or directly on top of Type A materials in the disposal cell.

2.5.3 Type C

Type C materials consist of structural materials, concrete and asphalt, calcium fluoride basin materials, calcium fluoride sediments, and on-site buried materials. These materials will be placed with or above the Type B materials, and covered with contaminated soils (Type D materials).

2.5.4 Type D

Type D materials consist of contaminated soils and sedimentary rock on site that require excavation and placement in the disposal cell. Type D materials will be placed with and on top of Type C materials.

2.6 CELL CONSTRUCTION MATERIALS

Construction materials for disposal cell base and cover systems include soils and weathered sedimentary rock from on-site sources, and granular materials from off-site sources. These materials are outlined below, with selected source locations shown on the Drawings.

2.6.1 Cover Material

The subsoil zone of the cover will be obtained from on-site terrace deposit soils and weathered Atoka Formation shale and sandstone. Available sources of these materials are existing berms and embankments, underlying subsoils, and previously used borrow areas.

2.6.2 Liner Material

The clay liner in the disposal cell base and in the cover system will consist of fine-grained soils obtained from the soil borrow area at the south end of the site. These soils may be amended with off-site clays to meet liner permeability requirements.

2.6.3 Topsoil

Topsoil for the surface of the disposal cell and surrounding areas to be vegetated will be obtained from the Agland Area on the west side of the site.

2.6.4 Rock Mulch

A layer of rock mulch will form the erosion protection zone on the side slopes and perimeter apron of the disposal cell. The sources of rock are nearby commercial sources of limestone or alluvial gravel and cobbles. Rock mulch shall meet the particle-size distribution and durability requirements outlined in Sections 4 and 7.

2.6.5 Perimeter Apron Material

A layer of rock will form the erosion protection on the perimeter apron and as protection of Gully 005 from headward erosion. The sources of rock are nearby commercial sources of limestone or alluvial gravel and cobbles. Perimeter apron material shall meet the particle-size distribution and durability requirements outlined in Sections 4 and 7.

2.6.6 Granular Materials

Granular materials will be used for (1) filter material, and (2) the synthetic liner cover and bedding layer for the cell liner and cover systems. Granular materials may also be used for subsurface fill for the cell base. The sources of these materials are nearby commercial sources of alluvial sand and gravel.

2.7 STAGING AND STOCKPILE AREAS

Areas on site identified as staging areas or stockpile locations will be approved by SFC. These areas will be constructed and used in a manner consistent with SFC plans for stormwater management.

2.8 ACCESS AND SECURITY

Access to the SFC site will be controlled at gated entrances through the existing Protected Area fence. The gated entrances will be operated by SFC.

2.9 UTILITIES

Utilities on site will be maintained by SFC outside of work areas (areas to be demolished or reclaimed). Utilities inside of work areas may be connected to SFC systems as approved by SFC or provided by the contractor. Utilities inside of work areas will be maintained by the Contractor.

2.10 SANITATION FACILITIES

Sanitation facilities will be maintained by the Contractor, in accordance with the Health and Safety Plan for site reclamation.

3.0 WORK AREA PREPARATION

3.1 GENERAL

This Section describes the preparation of site areas for reclamation. This work will be conducted according to applicable sections of the Health and Safety Plan for site reclamation.

3.2 WATER MANAGEMENT

Preparation for work in the site area will include the water management tasks outlined below.

1. Removal and treatment of fluids and removal and filtration of raffinate sludge from the clarifier ponds. The clarifier ponds liners will be cleaned and repaired if necessary for affected stormwater storage and treatment.

2. Removal, treatment and permitted discharge of water in the remaining existing ponds.

3. Diversion of clean area stormwater runoff from work areas (where facilities demolition and material excavation will take place) and from the disposal cell footprint area.

4. Collection of stormwater runoff from within the work areas and the disposal cell footprint for treatment and permitted discharge, or for disposed material compaction or dust control. The planned storage location for this affected stormwater is the clarifier pond system (after the ponds have been cleaned).

5. Isolation of water used for processing operations associated with reclamation (such as liquids from pressure filtration) from stormwater runoff.

Water from processing operations or other contaminated water will not be used for disposal cell construction.

3.3 PHASED CELL CONSTRUCTION

The disposal cell base will be constructed in phases. The layout of the three phases of cell base construction, as well as areas and facilities to be removed by phase are shown on the Drawings, and outlined below.

3.3.1 Phase I Area

The phase I (northeast) area of the disposal cell footprint is relatively clean, requiring minimal structure demolition and minor contaminated material or subsoil removal. The phase I area will be prepared by removal and stockpiling of structures and contaminated materials, followed by construction of the disposal cell base (Section 4).

3.3.2 Phase II Area

The phase II (northwest) area of the disposal cell footprint will be prepared by removal of sediments, liner, and contaminated soils from the phase II area of the disposal cell footprint. These materials will be disposed on the prepared liner system in the phase I area of the disposal cell. The residual excavated

surface will be regraded or backfilled with subgrade fill to the desired subgrade surface. The phase II liner system will be constructed on the prepared subgrade surface (Section 4).

3.3.3 Phase III Area

The phase II (south) area of the disposal cell footprint will be prepared by removal of sediments, liner, and contaminated soils from the phase III area of the disposal cell footprint. These materials will be disposed on the prepared liner system in the phase II area of the disposal cell. The residual excavated surface will be regraded or backfilled with subgrade fill to the desired subgrade surface. The phase III liner system will be constructed on the prepared subgrade surface (Section 4).

3.3.4 Areas Outside of Cell

Materials from cleanup outside of the disposal cell will be disposed in the phase I, II, or III areas of the disposal cell.

3.4 COVER AND LINER SOIL BORROW AREAS

Disposal cell cover and liner system soils will be excavated from among the identified borrow areas on site. The identified borrow areas are listed below.

1. The soil borrow area south of the fertilizer ponds.
2. The tornado berm.
3. The cut area east of the DUF4 building.
4. Uncontaminated portions of the Settling pond (Pond 2) berms.
5. Fertilizer pond berms.

The use of specific soil borrow areas will be selected based on haul distance to the disposal cell, ease of excavation of cover material, geotechnical characteristics and uniformity of the borrow material, and acceptable radiological and geochemical characteristics.

Borrow area preparation will consist of setup for stormwater management (Section 3.2), clearing and stripping (Section 3.6).

3.5 TOPSOIL BORROW AREA

The topsoil borrow area will be located in a designated portion of the Agland Area on the west side of the site (shown on the Drawings). Borrow area preparation will include mowing or shredding of existing vegetation prior to topsoil excavation.

3.6 CLEARING AND STRIPPING

Many of the work areas have been used for processing or construction activities and are free from vegetation. For work areas that are vegetated, preparation work will include the tasks outlined below.

3.6.1 Clearing

Clearing of vegetation and grubbing of roots will be in identified work areas. Clearing and grubbing shall not extend beyond 20 feet from the edge of the work area, unless as shown on the Drawings or as approved by the Reclamation Project Manager.

Vegetation from clearing and grubbing shall be shredded, ground, or chipped to form mulch. Alternative methods of on-site or off-site disposal or burning of stripped vegetation shall be conducted only as approved by the Reclamation Project Manager.

3.6.2 Stripping

Stripping of salvageable topsoil (if present) shall be done within the entire work area. Stripping of topsoil shall not extend beyond 10 feet from the edge of the work area, unless approved by the Reclamation Project Manager. The depth of stripping of reclamation soil shall be based on the presence of suitable topsoil and approved by the Reclamation Project Manager. Water shall be added to the area of excavation if the soils are dry and stripping work is generating dust.

Topsoil shall be stockpiled in approved stockpile areas. The final stockpile surface shall be graded and smoothed to minimize erosion and facilitate interim revegetation of the stockpile surfaces.

4.0 DISPOSAL CELL BASE CONSTRUCTION

4.1 GENERAL

This section outlines the work associated with construction of the disposal cell base for receipt of materials (as described in Section 6.0). The base of the disposal cell will be lined with a compacted clay liner and synthetic liner system, with intermediate layers of granular materials that contain networks of perforated pipes. The cell base will be constructed in phases as shown on the Drawings and outlined in Section 3.3.

4.2 MATERIALS DESCRIPTION

4.2.1 Subgrade Fill

The disposal cell footprint is likely to have an irregular surface from areas that have been excavated for waste materials and sediments, contaminated liner soils and subsoils, and underground utilities. This excavated surface will be filled in low areas to form a smooth, competent foundation for liner system construction. Subgrade fill will be used for fill in excavated areas of the disposal cell footprint to meet desired grades and elevations for the disposal cell foundation (shown on the Drawings).

Subgrade fill will consist of off-site granular materials, or soils and weathered sedimentary rock from approved on-site excavation areas. Subgrade fill shall be minus 6-inch size, and shall be free from roots, branches, rubbish, and process area debris. Subgrade fill shall have radionuclide activity concentrations lower than the selected subsurface soil cleanup level.

4.2.2 Clay Liner

Clay liner material will consist of soils from approved on-site borrow areas. Clay liner material shall be minus 1-inch size, and shall be free from roots, branches, rubbish, and process area debris. Clay liner material shall have a minimum of 50 percent passing the No. 200 sieve and a minimum plasticity index of 10. Compacted clay material shall have a maximum saturated hydraulic conductivity of 1×10^{-7} cm/s (0.1 ft/yr). Clay liner material shall have radionuclide activity concentrations lower than the selected subsurface soil cleanup level.

4.2.3 Synthetic Liner Bedding Material

Synthetic liner bedding material shall consist of gravelly sand from off-site sources. Synthetic liner bedding material shall be free from roots, branches, rubbish, process area debris, and other angular or pointed materials that could damage the synthetic liner. Synthetic liner bedding material shall have radionuclide activity concentrations lower than the selected subsurface soil cleanup level. Synthetic liner bedding material shall meet the following particle-size specifications:

Sieve Size	Percent Passing
1 inch	100
No. 4	65-100
No. 16	25-85
No. 40	5-45
No. 200	0-10

4.2.4 Synthetic Liner

Synthetic liner material (geomembrane) shall be 60-mil nominal thickness HDPE, with smooth surfaces on both sides and material characteristics outlined in Section 5.2.1.

4.2.5 Synthetic Liner Cover

Synthetic liner cover material shall be placed over the synthetic liner to provide a cover material for protection of the synthetic liner during material placement.

Synthetic liner cover material shall consist of gravelly sand from off-site sources. Synthetic liner cover material shall be free from roots, branches, rubbish, process area debris, and other angular or pointed materials that could damage the synthetic liner. Synthetic liner cover material shall have radionuclide activity concentrations lower than the selected subsurface soil cleanup level. Synthetic liner cover material shall meet the following particle-size specifications:

Sieve Size	Percent Passing
1 inch	100
No. 4	65-100
No. 16	25-85
No. 40	5-45
No. 200	0-10

4.2.6 Synthetic Liner Anchor Backfill

Synthetic liner anchor backfill shall be placed and compacted in the anchor trenches excavated along the perimeter of the lined area of the disposal cell.

Synthetic liner anchor backfill shall consist of soils and weathered sedimentary rock from approved on-site excavation areas. Synthetic liner anchor backfill shall be minus 1-inch size, and shall be free from roots, branches, rubbish, process area debris, and other angular or pointed materials that could damage the synthetic liner.

4.2.7 Leak Detection System Pipe

Leak detection system pipe (to be installed in the synthetic liner bedding material) shall consist of 4-inch diameter HDPE pipe (or approved equivalent). Pipe connections shall be welded according to manufacturer's recommendations. Leak detection system pipe shall be perforated within the perimeter of the disposal cell, with perforated sections starting a minimum of 20 feet inside of the perimeter berm (as shown on the Drawings). Perforations in leak detection system pipe shall be 1/8 inch (3 mm) in maximum diameter, with a minimum inlet area of 0.3 square inches per linear foot (6 square centimeters per linear meter) of pipe.

4.2.8 Leachate Collection System Pipe

Leachate collection system pipe (to be installed in the liner cover layer) shall consist of 6-inch diameter, SDR-11 HDPE pipe (or approved equivalent). Pipe connections shall be welded according to manufacturer's recommendations. Leak detection system pipe shall be perforated within the perimeter of the disposal cell, with slotted sections starting within the inside toe of the perimeter berm (as shown on the Drawings). Perforations in leachate detection system pipe shall be 1/8 inch (3 mm) in maximum

diameter, with a minimum inlet area of 0.5 square inches per linear foot (10 square centimeters per linear meter) of pipe.

4.3 WORK DESCRIPTION

4.3.1 Foundation Preparation

The footprint of the disposal cell will consist of excavated areas, existing concrete pads, and areas with placed subgrade fill. The footprint of the disposal cell shall form a competent foundation for clay liner and cover construction. The surface of the disposal cell footprint shall be filled (where required) in low areas to form a smooth, competent foundation for clay liner and cover construction, as well as provide separation between the clay liner and underlying groundwater (where required). Subgrade fill (Section 4.2.1) shall be placed in lifts and compacted in excavated areas of the disposal cell footprint to meet desired grades and elevations for the disposal cell foundation (shown on the Drawings). The final filled surface shall be compacted with approved construction equipment to provide a foundation surface with uniform density for clay liner placement.

4.3.2 Subgrade Fill Placement

Subgrade fill (Section 4.2.1) shall be placed in lifts and compacted in excavated areas of the disposal cell footprint to meet desired grades and elevations for the disposal cell foundation. Subgrade fill may be (1) granular material from off-site commercial sources, or (2) soils and weathered sedimentary rock from approved on-site excavation areas.

For fine-grained subgrade fill (materials with more than 10 percent passing the No. 200 sieve), these materials will be placed in lifts not exceeding 8 inches in loose thickness. Each lift shall be compacted to a minimum of 90 percent of Standard Proctor density and within three percent of optimum moisture content for the material.

For coarse-grained or granular subgrade fill (materials with less than 10 percent passing the No. 200 sieve), these materials will be will be placed in lifts not exceeding 8 inches in loose thickness. Each lift shall be compacted by method specification to achieve a minimum relative density of 75 percent for the material. A test section will be established at the site to correlate the number of passes with vibratory equipment to the relative density of the granular material.

4.3.3 Disposal Cell Foundation Area

The disposal cell has been designed to accommodate a variation in total contaminated soil (Type D material) volume. The footprint of the disposal cell is established along the north, east, and west sides of the cell (shown on the Drawings). The location of the south side of the disposal cell (shown on the Drawings) will be based on a total disposed volume of approximately 9 million cubic feet. The final location of the south side of the disposal cell, the transition to the other sides of the cell, and the corresponding foundation area within the disposal cell will be established as the final volume of Type D material is determined during contaminated soil excavation.

4.3.4 Clay Liner Material Placement

Clay liner material (Section 4.2.2) shall be placed in lifts with maximum compacted thickness of 6 inches to form a continuous layer with a total minimum compacted layer thickness of 36 inches. Clay liner material shall be placed over the prepared subgrade surface of the disposal cell (Section 4.3.1). Along the

perimeter of the disposal cell, the clay liner material shall be used to construct the perimeter berm (shown on the Drawings).

Each lift of clay liner material shall be compacted to at least 95 percent of the maximum dry density for the material, as determined by the Standard Proctor test. During compaction, the material shall be within 2 percent above to 2 percent below optimum moisture content for the material, as determined by the Standard Proctor test. If water addition is required to achieve this range of moisture contents, the added water shall be thoroughly mixed into the material prior to compaction.

Compaction of the clay liner material shall be done with a sheepsfoot or tamping-foot roller of sufficient weight to achieve the required compaction specifications. Rubber-tired equipment shall not be used solely to compact the clay liner material.

The top surface of compacted clay liner shall be covered with the liner bedding layer material (Section 4.3.5) within 24 hours of liner testing and approval.

4.3.5 Leak Detection System Pipe Installation

Leak detection system pipe (Section 4.2.7) shall be placed on the completed clay layer surface in the general layout (oriented for gravity drainage) shown on the Drawings. The nominal pipe spacing within the perimeter of the disposal cell shall be 40 feet. The pipe layout may be modified during construction to improve the rate of drainage, based on completed top-of-clay surface elevations. The pipe layout for a particular phase of the disposal cell is not connected to the pipe layout for the other phases of the disposal cell.

4.3.6 Synthetic Liner Bedding Layer Material Placement

Synthetic liner bedding material shall be placed over the footprint of the prepared disposal cell liner area to provide a protective bedding material for placement and installation of the synthetic liner. Synthetic liner bedding material (Section 4.2.3) shall be placed in one or more lifts to form a zone a minimum of 6 inches thick. The final synthetic liner bedding material surface shall be rolled with approved compaction equipment to form a smooth base for synthetic liner installation.

4.3.7 Synthetic Liner Material Installation

Synthetic liner material (Section 4.2.4) shall be installed on the final surface of the clay liner as outlined in Section 5.3.

4.3.8 Leachate Collection System Pipe Installation

Leachate collection system pipe (Section 4.2.8) shall be placed on the completed synthetic liner surface in the general layout (oriented for gravity drainage) shown on the Drawings. The nominal pipe spacing within the perimeter of the disposal cell shall be 60 feet. The pipe layout may be modified during construction to improve the rate of drainage, based on completed top-of-clay surface elevations. The pipe layout for a particular phase of the disposal cell is not connected to the pipe layout for the other phases of the disposal cell.

4.3.9 Synthetic Liner Cover Placement

Synthetic liner cover material shall be placed over the completed synthetic liner to provide a protective cover for placement of disposal material. Synthetic liner cover material (Section 4.2.5) shall be placed in

one lift to form a zone a minimum of 18 inches thick. The lift of synthetic liner cover shall be placed with a small dozer or other approved equipment in a manner that does not tear, puncture, or otherwise damage the synthetic liner.

4.3.10 Synthetic Liner Anchor Backfill Placement

Synthetic liner anchor backfill (Section 4.2.6) shall be placed in lifts of 6-inch maximum loose thickness in the liner anchor trench and compacted by rolling with approved equipment or compaction with a manually-controlled compactor. Synthetic liner anchor backfill shall be compacted to 90 percent Standard Proctor density for the material, as determined by the Standard Proctor test.

Liner anchor backfill placement and compaction shall be done in a manner that does not tear, puncture, or damage the synthetic liner. The final liner anchor material surface shall be rolled with approved compaction equipment to match the adjacent synthetic liner cover surface.

4.4 PERFORMANCE STANDARDS AND TESTING

4.4.1 SubgradeTesting

Where required, checking of compaction of compacted subgrade fill and the final subgrade surface shall consist of a minimum of one field density test per 1,000 cubic yards of material compacted. Field density tests shall be compared with Standard Proctor tests (ASTM D-698 Method A or C) or Maximum Index Density tests (ASTM D-4253) on the same material. Where required, Standard Proctor or Maximum Index Density tests shall be conducted at a frequency of at least one test per 2,000 cubic yards of material compacted, or when material characteristics show significant variation.

Field density testing may be conducted with the sand cone test (ASTM D-1556) or a nuclear density gauge (ASTM D-3107 and D-2922, or as modified by the QA Manager). Calibration of the nuclear density gauge shall be by comparison with results from the sand cone test on the same material.

Subgrade fill shall be placed in low areas such that the completed top surface of subgrade fill shall be two feet above the highest level of groundwater in the terrace or Shale 1 unit.

4.4.2 Clay Liner Testing

Material specifications for the clay liner material shall be confirmed by gradation testing conducted by approved personnel. Testing shall consist of No. 200 sieve wash and maximum particle size testing (ASTM D-422), and Atterberg limit testing (ASTM D-4318) on samples of clay liner materials, at a frequency of at least one test per 2,000 cubic yards of fill placed, or when material characteristics show a significant variation.

Checking of compaction of the clay liner material shall consist of a minimum of one field density test per 1,000 cubic yards of material compacted. Field density tests shall be compared with Standard Proctor tests (ASTM D-698 Method A or C) on the same material. Standard Proctor tests shall be conducted at a frequency of at least one test per 2,000 cubic yards of material compacted, or when material characteristics show significant variation.

Field density testing may be conducted with the sand cone test (ASTM D-1556) or a nuclear density gauge (ASTM D-3107 and D-2922, or as modified by the QA Manager). Calibration of the nuclear density gauge shall be by comparison with results from the sand cone test on the same material.

Permeability of the compacted clay liner material shall be confirmed by performing back pressure permeability testing by constant head or flow pump (EPA 9100 or ASTM D-5084) on samples of clay liner material recompacted to density and moisture of field placed compacted clay liner. Testing shall be completed at a frequency of one test per phase of cell base liner construction, or when material characteristics show significant variation.

The completed clay liner shall have a minimum thickness of 3.0 feet. The completed clay liner and perimeter berm surfaces shall be constructed to within 1.0 foot of the lines as designed and shown on the Drawings, and within 0.1 foot of the elevations shown on the Drawings. The final surface of the clay liner shall be smoothed to avoid abrupt changes in surface grade.

4.4.3 Synthetic Liner Bedding Layer Testing

If used in the disposal cell base, the completed synthetic liner bedding layer surface shall be constructed to within 1.0 foot of the lines as designed and shown on the Drawings, and within 0.1 foot of the elevations shown on the Drawings. The final surface of the synthetic liner bedding material shall be smoothed or rolled to avoid abrupt changes in surface grade. The surface shall provide a smooth and unyielding foundation for the synthetic liner with no sharp or protruding objects. The final surface shall be inspected and approved by the QA Manager prior to initiation of liner installation.

4.4.4 Synthetic Liner Testing

The synthetic liner panels and seams shall be tested as outlined in Section 5.4. The final synthetic liner surface shall be inspected and approved by the QA Manager prior to initiation of synthetic liner cover placement.

4.4.5 Synthetic Liner Cover Testing

Material specifications for synthetic liner cover material (Section 4.2.5) shall be confirmed by gradation testing conducted by approved personnel. Testing shall consist of No. 200 sieve wash and maximum particle size testing (ASTM D-422) at a frequency of at least one test per 2,000 cubic yards of fill placed, or when material characteristics show a significant variation.

4.4.6 Synthetic Liner Anchor Backfill Testing

Material specifications for synthetic liner anchor backfill material (Section 4.2.6) shall be confirmed by gradation testing conducted by approved personnel. Testing shall consist of No. 200 sieve wash and maximum particle size testing (ASTM D-422) at a frequency of at least one test per 2,000 cubic yards of fill placed, or when material characteristics show a significant variation.

Checking of compaction of the liner anchor backfill shall consist of a minimum of one field density test per 1,000 cubic yards of material compacted. Field density tests shall be compared with Standard Proctor tests (ASTM D-698 Method A or C) on the same material. Standard Proctor tests shall be conducted at a frequency of at least one test per 2,000 cubic yards of material compacted, or when material characteristics show significant variation.

Field density testing may be conducted with the sand cone test (ASTM D-1556) or a nuclear density gauge (ASTM D-3107 and D-2922, or as modified by the QA Manager). Calibration of the nuclear density gauge shall be by comparison with results from the sand cone test on the same material.

5.0 SYNTHETIC MATERIAL INSTALLATION

5.1 GENERAL

This Specification Section describes the placement, seaming, testing, and protection of synthetic liner (geomembrane). Synthetic liner is to be installed: (1) at the base of the disposal cell, (2) surrounding the filtered raffinate sludge (if disposed on site), (3) in the cover system, and (4) on the inside slopes of the stormwater retention berms.

5.2 MATERIALS DESCRIPTION

5.2.1 Synthetic Liner

The synthetic liner shall be used on the base of the disposal cell, surrounding the filtered raffinate sludge, and in the bottom zone of the cover system (as shown on the Drawings). The synthetic liner shall consist of high-density polyethylene (HDPE) geomembrane. The nominal geomembrane thickness shall be 60 mil (0.060 inches). The synthetic liner at the base of the disposal cell and surrounding the filtered raffinate sludge (if disposed on site) shall have a smooth surface on both sides. The synthetic liner in the cover system shall have a textured surface on both sides.

The geomembrane shall be manufactured with products designed and manufactured for the purpose of liquid containment. The geomembrane shall conform to the following minimum physical requirements listed below:

Tensile strength at break	210 lbs/inch width
Elongation at break	700 percent

Labels on the geomembrane roll or panel shall identify the thickness, length, width, and manufacturer's mark number. Transport and storage of the geomembrane material shall be according to manufacturer's recommendations. Geomembrane rolls stored on site shall be kept off of the ground surface and covered. Prior to liner deployment, the outer liner surface of each roll shall be inspected for punctures, scratches or other damage. If the outer liner surface of the roll is damaged, the outer two wraps of the roll shall be removed and discarded prior to liner deployment.

The geomembrane shall be manufactured to be free of holes, blisters, undispersed raw materials, gels, or visible evidence of contamination by foreign matter. Any such defect shall render that roll or panel of material unacceptable for use and shall be replaced with material that is free of any such defects. Defects may be repaired in lieu of material replacement only upon approval of the QA Manager.

5.2.2 Stormwater Liner

The stormwater liner shall be used on the inside slopes of the stormwater retention berms in the disposal cell (as shown on the Drawings). The stormwater liner shall consist of high-density polyethylene (HDPE) geomembrane with a smooth surface on both sides, or approved equivalent new material or on-site used material. The nominal geomembrane thickness shall be 40 mil (0.040 inches). The geomembrane shall be manufactured with products designed and manufactured for the purpose of liquid containment. The geomembrane shall conform to the following minimum physical requirements listed below:

Tensile strength at break	150 lbs/inch width
Elongation at break	700 percent

Labels on the geomembrane roll or panel shall identify the thickness, length, width, and manufacturer's mark number. Transport and storage of the geomembrane material shall be according to manufacturer's recommendations. Geomembrane rolls stored on site shall be kept off of the ground surface and covered. Prior to liner deployment, the outer liner surface of each roll shall be inspected for punctures, scratches or other damage. If the outer liner surface of the roll is damaged, the outer two wraps of the roll shall be removed and discarded prior to liner deployment.

The geomembrane shall be manufactured to be free of holes, blisters, undispersed raw materials, gels, or visible evidence of contamination by foreign matter. Any such defect shall render that roll or panel of material unacceptable for use and shall be replaced with material that is free of any such defects. Defects may be repaired in lieu of material replacement only upon approval of the QA Manager.

5.2.3 Geogrid

Geogrid (if used to improve bearing capacity of soft disposed materials) shall be HDPE or polypropylene material specifically manufactured for the purpose of bearing capacity support. The geogrid shall have minimum unit weight of 6 ounces per square yard and a maximum aperture size of 1.5 inches.

Transport and storage of the geogrid shall be according to manufacturer's recommendations. Geogrid rolls stored on site shall be kept off of the ground surface and covered. Prior to geogrid deployment, the outer liner surface of each roll shall be inspected for punctures, scratches or other damage. If the outer liner surface of the roll is damaged, the outer wrap of the roll shall be removed and discarded prior to geogrid deployment.

5.3 WORK DESCRIPTION

Installation of geomembrane, filter fabric, or geogrid shall be only on areas approved by the Reclamation Project Manager, as outlined in the Drawings.

5.3.1 Geomembrane Deployment

Individual panels of geomembrane shall be laid out and overlapped a minimum of 4 inches prior to welding, or as recommended otherwise by the manufacturer. Where possible, the overlapping panels shall be shingled, such that the up-slope panel is on top on the down-slope panel. On the side slopes, panels shall be placed with the long dimension perpendicular to the slope contours. The liner panel and roll number shall be marked on the panel and recorded as the material is being deployed.

The geomembrane shall not be placed during precipitation, high winds, or in the presence of excessive liner bedding material moisture. Geomembrane that has been damaged due to wind uplift shall be discarded.

5.3.2 Geomembrane Seaming

All geomembrane panel seams shall be welded to form a continuous, watertight barrier. The seams to be welded shall be cleaned and prepared according to manufacturer's guidelines to be free from dust, debris, oil, moisture, or other material that would interfere with liner seaming.

Panel seams shall be hot wedge welded whenever possible. This shall consist of two parallel welds along the overlap between liner panels that allow pressure testing of the channel between welds. Where wedge welding is not possible, field welds for the remaining seams shall be by a heat extrusion process.

Field welding shall form a continuous bond between the extrudate and liner material, according to the guidelines of the manufacturer. The field welding equipment shall be capable of continuously monitoring and controlling the temperatures and pressures in zone of contact where the machine is actually fusing the lining material to prevent changes in environmental conditions from affecting the integrity of the weld. Field welding shall be conducted when the air temperature (measured 12 inches above the synthetic liner surface) is between 30°F and 110°F. When the measured air temperature is outside of this range, field welding may be conducted, but only if the Contractor can demonstrate that seaming performance is acceptable (in terms of shear and peel testing outlined in Specification Section 5.4.3).

5.3.3 Geomembrane Anchoring

Around the perimeter of the lined area of the disposal cell, the edge of the geomembrane shall be continuously anchored in a trench as shown in the Drawings. The geomembrane shall extend a minimum of five feet into the trench. Backfill material (Section 4.2.6) shall be placed in the trench and compacted (as outlined in Section 4.3.5) to anchor the geomembrane.

At the lined area perimeter, the edge of the geomembrane shall be continuously anchored. Along the liner anchor, welded panel seams shall extend a minimum of six inches beyond the inside edge of the anchor trench.

Backfilling of the liner anchor trench shall be done when the air temperature above the liner is relatively cool, in order to minimize liner shrinkage due to decreasing temperature after the liner is anchored.

5.3.4 Geomembrane Repairs

Geomembrane installation shall be done without puncturing, tearing, or otherwise damaging the geomembrane panels or seams. No vehicles shall be driven or parked on top of the uncovered geomembrane. Punctures, overlaps (fishmouths), or other unacceptable liner conditions shall be repaired with an overlapping patch bonded to the geomembrane by field welding. Geomembrane patching shall be done with the patch material extending a minimum of six inches beyond the puncture, tear, or joint in the liner. Repair of damage to the deployed geomembrane and testing of geomembrane patches will be the responsibility of Contractor.

5.3.5 Geomembrane Protection

Upon completion of geomembrane seaming, the liner shall be protected from uplift due to wind by placing sand bags or similar approved material on the liner surface. These protective materials shall be of a spacing and weight sufficient to prevent uplift or movement of the liner without puncturing, tearing, or otherwise damaging the geomembrane.

5.3.6 Geogrid Installation

Rolls of geogrid shall be handled and unrolled according to manufacturer's guidelines. The edges and ends of the geogrid rolls shall have a minimum overlap of six inches. Where necessary, the overlapped edges of the geogrid shall be tied together according to manufacturer's guidelines.

5.3.7 Liner Boot Installation

Where the leak detection pipe system (Section 4.3.9) or leachate collection pipe system (Section 4.3.10) penetrate the synthetic liner at the perimeter of the disposal cell, the penetrating pipes shall be sealed to the synthetic liner with an HDPE liner boot (as shown on the Drawings). The liner boot shall be installed and seamed to the synthetic liner and the HDPE pipe according to manufacturer's recommendations.

5.4 PERFORMANCE STANDARDS AND TESTING

5.4.1 General Requirements

Testing of the installed geomembrane shall consist of the following items.

1. Visual examination of the panels upon delivery to the site, with documentation of the panel thickness, length, width, and manufacturer's mark number and receipt of mill certification and material property data.

2. Physical examination of the panels upon unfolding and spreading, with checking of nominal widths and examination for material flaws or defects.

3. Pressure testing of the air channel between panel seam welds, as outlined in Specification Section 5.4.2.

4. Destructive (shear and peel) tests on seam samples extracted from all panel seams at a frequency equivalent to one sample collected from up to 1000 linear feet of seam. If the integrity of the seam, weather conditions, or welder operation are of concern to the QA Manager, the maximum spacing shall be reduced to one sample for 500 linear feet of seam. Tests are outlined in Specification Section 5.4.3.

5. Vacuum testing of all extrusion welded seams, as outlined in Specification Section 5.4.4.

6. Physical examination of the completed liner surface, checking for liner damage, punctures and defects in seaming.

5.4.2 Air Channel Testing

Each geomembrane panel seam shall be tested by air pressure testing of the air channel between parallel seams. The minimum air channel test pressure shall be 30 psi, with a maximum pressure drop of 3 psi over a 5-minute test period.

5.4.3 Shear and Peel Tests

Each sample cut from the seamed geomembrane shall be tested for both shear and peel tests. The shear (or bonded seam strength) test shall be conducted according to ASTM D-3083 and ASTM D-638, and have a shear strength of 120 lb/inch width of seam. The peel (or peel adhesion) test shall be conducted according to ASTM D-413 and ASTM D-638, and have a minimum peel strength of 70 lb/inch width of seam. Failure for both tests shall be in a ductile manner and observed at the film bond to be acceptable.

Each type of test shall be performed on five replicate specimens from each material sample (equivalent to five shear tests and five peel tests per material sample). The test results shall be reported individually, with four out of five tests meeting strength requirements being acceptable.

In the event of a failed test (less than four of five tests meeting strength requirements), additional samples shall be collected at 50-foot intervals along the seam on either side of the failed sample location, with additional sampling and testing conducted until tested seam conditions are acceptable. The seam in the failed test area between the acceptable test locations shall be extrusion welded and tested.

5.4.4 Vacuum Testing

All extrusion welded geomembrane seams shall be tested with a vacuum box. The minimum vacuum shall be equivalent to 5 psi (10 inches of mercury). Seam failure shall be assessed by complete loss of vacuum or presence of bubbles.

5.4.5 Testing Documentation

The QA Manager shall review all geomembrane liner test results made by the Contractor and conduct independent tests as necessary. All flaws in the seams or liner panels resulting from the installation shall be repaired and approved by the QA Manager prior to approval for covering with liner cover material.

Geomembrane panel and seam locations, seam test results, repair locations, and seam test results shall be marked on the liner surface and documented by the QA Manager. Final approval of the liner testing will be determined by the QA Manager, based on having acceptable QA test results.

6.0 MATERIAL DISPOSAL

6.1 GENERAL

This section outlines the work associated with placement of materials in the disposal cell. Material placement will be according to the phases of cell construction shown on the Drawings and outlined in Section 3.3.

6.2 MATERIALS DESCRIPTION

Similar process area materials have been organized into groups for disposal in specific layers within the disposal cell. Their location in the process area dictates the phase of the disposal cell area where the material will be placed. The four types of materials to be disposed in the cell are outlined below.

6.2.1 Type A Materials

Type A materials consist of five components: (1) raffinate sludge, (2) Emergency Basin sediment, (3) North Ditch sediment, (4) Sanitary Lagoon sediment, and (5) Pond 2 residual materials. The locations of these materials are shown on the Drawings.

Due to the relatively high activity concentration of radionuclides in the first four components (raffinate sludge and sediments from Emergency Basin, North Ditch and Sanitary Lagoon, priority will be given to dispose of these materials at an appropriate offsite location. If it is determined that it is not economically possible to dispose of these materials offsite, these materials, along with Pond 2 residual materials, will comprise the lowest layer in the disposal cell profile, and be placed early in the disposal sequence for each phase of the cell.

Raffinate sludge is being processed or "dewatered" by pressure filtration, with the resulting filtercake loaded by conveyor into polypropylene bags (approximately 3 feet by 3 feet by 4 feet), referred to as supersacks. The supersacks of filtercake are planned for removal from the site.

In the event that the resulting filtercake is disposed on site, the bags will be placed in the south end of the disposal cell (shown on Drawings). The placed raffinate sludge bags will be encapsulated with an additional synthetic liner system (Sections 5.2 and 5.3).

6.2.2 Type B Materials

Type B materials include soil liner and subsoil materials beneath the clarifier, Pond 4, the Emergency Basin, the North Ditch and the Sanitary Lagoon, as well as Pond 1 spoils pile material. Type B materials also include interim soil storage cell materials and soils from the equipment storage area. The locations of these materials are shown on the Drawings.

The Type B materials (primarily contaminated soils) are second in the disposal order, since these materials will be excavated after removal of Type A materials and will have the second highest activity concentrations of radionuclides. Type B materials will be placed over Type A materials in the disposal cell profile or over other prepared areas of the disposal cell liner system.

6.2.3 Type C Materials

Type C materials consist of structural materials, concrete and asphalt, calcium fluoride basin materials, calcium fluoride sediments, calcium fluoride basin liners and subsoils, and on-site buried materials. The locations of these materials are shown on the Drawings. Type C materials will be placed directly over Layer A materials, with Type B materials, or over other prepared areas of the disposal cell liner system.

6.2.4 Type D Materials

Type D materials consist of contaminated soils and sedimentary rock that require cleanup. The approximate area of Type D material cleanup is shown on the Drawings.

Type D materials will be placed over Type A, B, or C materials, or over other prepared areas of the disposal cell liner system. Type D materials will be used to cover plant equipment and structural debris (Type C materials) to minimize void spaces, and may be used for additional bedding material for plant equipment and structural debris. Type D materials will comprise the primary component of the stormwater retention berms for the disposal cell.

6.3 WORK DESCRIPTION

6.3.1 Type A Material Placement

Type A materials (Section 6.2.1) that are not filtered (if disposed on site), will be dewatered or solidified/stabilized to eliminate free water prior to placement in the cell. Type A materials will be placed within the disposal cell in lifts prior to covering with additional Type A materials or with Type B materials.

If disposed on site, raffinate sludge filtercake bags (Section 6.2.1) shall be placed at the south end of the disposal cell (shown on the Drawings). A supplemental liner and cover system shall be constructed around the filtercake bags, as outlined in Section 6.3.5.

6.3.2 Type B Material Placement

Type B materials will be placed within the disposal cell in lifts (if necessary) to allow consolidation and drying of wet materials. Type B materials (Section 6.2.2) will be placed directly over Type A materials, within the lined area of the disposal cell, or over other prepared areas of the disposal cell liner system.

6.3.3 Type C Material Placement

Type C materials will be placed within the disposal cell in lifts. Type C materials (Section 6.2.3) will be placed directly over Type A or B materials, or over other prepared areas of the disposal cell liner system. The placement of various Type C materials is outlined below.

6.3.3.1 Material Sizing and Preparation

Demolition debris to be placed in the disposal cell will consist of equipment and structural material from facilities demolition. The demolition procedures are outlined in the Facility Demolition Plan (Reclamation Plan attachment F). Because of the wide variety in shape and size of demolition debris, material of odd shapes will be cut or dismantled, to the extent practical, prior to disposal to facilitate handling and placement as well as minimize void spaces in the disposal cell. The maximum size of

dismantled or cut materials shall not exceed the dimensions necessary for loading, handling, hauling, and placement of material in the disposal cell.

6.3.3.2 Incompressible Debris

Material that is not compressible (steel columns, beams, concrete, and other solid material) will be reduced in size for handling and placed in the disposal cell without crushing or compacting. This material shall be placed in the disposal cell in a manner that minimizes void spaces below, between, and above these materials. Material will be placed in the disposal cell with the longest dimension oriented horizontally. Dismantled flat steel, sheet metal, and other large pieces shall not exceed the dimensions necessary for loading and hauling. Pipe, conduit, tanks, vats, and pressure vessels that cannot be crushed or dismantled shall be transported to the disposal cell, filled with sand or grout, and buried.

Soil and soil-like materials will also be used to minimize void spaces within and around incompressible demolition materials to reduce future settlement. Soils and soil-like material will be placed and compacted around the outside of partially-buried tanks and vessels, and in horizontal lifts over flat-lying demolition materials.

6.3.3.3 Compressible Debris

Materials that are compressible (such as thin-walled piping and thin-walled tanks) will be crushed prior to final placement in the disposal cell. Construction equipment will be utilized to crush or compact compressible materials. These materials will be laid out in a staging area or other area approved by SFC to facilitate crushing or compacting.

Compressible demolition materials will be placed in the disposal cell and spread to form a lift with a maximum thickness of three feet, resulting in structural materials laying flat and minimizing void spaces.

6.3.3.4 Soils and Similar Materials

Soils and soil-like materials to be placed in the disposal cell will be from on-site areas identified by SFC for excavation (Section 6.2.3). A cover of soil or soil-like material (Type C or D material) will be placed and compacted over each lift of demolition materials and other Type C materials prior to placement of additional lifts to reduce void spaces. The interim soil cover will also be used to minimize exposure of demolition materials and other Type C materials to air and meteoric water.

6.3.3.5 Material Placement and Compaction

Sediments and other loose or soft materials (such as pond sediments and calcium fluoride sludge) will either be solidified with cementing material or placed in lifts of 0.5-foot maximum thickness, covered with soil, and compacted.

Soil shall be placed in loose lifts not exceeding two feet and will be compacted with a minimum of six passes with vibratory compaction equipment to work the soil downward into the void spaces within the debris. The number of passes shall be confirmed with actual compaction equipment on site with a field test section of soil to establish a correlation between the field compaction method and 95 percent of maximum dry density for the soil, as determined by the Standard Proctor test.

6.3.4 Type D Material Placement

The disposal cell has been designed to accommodate a variation in total contaminated soil (Type D material) volume. The footprint of the disposal cell is established along the north, east, and west sides of the cell (shown on the Drawings). The final location of the south side of the disposal cell (as well as the transition to the north and west sides of the cell) will be established as the final volume of Type D material is determined during contaminated soil excavation.

Type D materials (Section 6.2.4) will be placed directly over Type A, B, or C materials, or over other prepared areas of the disposal cell liner system. Type D materials will also be used to cover equipment and structural debris (Type C materials) to minimize void spaces.

Type D soil shall be placed in loose lifts not exceeding two feet and will be compacted with a minimum of six passes with vibratory compaction equipment to work the soil downward into the void spaces within the debris. The number of passes shall be confirmed with actual compaction equipment on site with a field test section of soil to establish a correlation between the field compaction method and 95 percent of maximum dry density for the soil, as determined by the Standard Proctor test.

6.3.5 Raffinate Sludge Liner and Cover

If disposed on site, the raffinate sludge filtercake bags (supersacks) shall be placed in the designated area of the disposal cell, as shown on the Drawings. The bags shall be placed one or two bags high on top of seamed panels of synthetic liner (Section 5.2.1). Void spaces between bags (if present) shall be filled with selected disposed materials. The final bag surface (after voids have been filled) shall be covered with seamed panels of synthetic liner (Section 5.2.1) that are connected to the liner beneath the bags, as shown on the Drawings.

6.3.6 Stormwater Retention Berms

Type D and C soils shall be used to construct stormwater retention berms. The stormwater retention berms shall be initially constructed on top of the liner cover material inside the perimeter berms, as shown on the Drawings. Initial stormwater retention berm construction shall be on the lower sides of the phases of the disposal cell. As material is placed in the disposal cell, the stormwater retention berms are constructed on outside slopes of each phase to maintain capacity for storage of stormwater on the top of each phase of the cell.

The stormwater retention berm material shall be placed in lifts not exceeding 24 inches in compacted thickness, with slopes and crest widths as shown on the Drawings. The stormwater retention berms shall be constructed in phases or raises to maintain adequate freeboard (five feet minimum) for stormwater above the level of disposed materials inside the stormwater retention berms.

The inside slope of each lift of the stormwater retention berms shall be lined with stormwater liner material (Section 5.2.2). The stormwater liner shall be anchored on the berm crest and continued past the inside toe of the berm onto disposed materials or liner cover material, as shown on the Drawings.

6.4 PERFORMANCE STANDARDS AND TESTING

6.4.1 Stormwater Retention Berm

Each phase or raise of stormwater retention berm material shall be placed in lifts not exceeding 24 inches in compacted thickness. Phases or raises shall be constructed in an upstream manner, or inside of the

previous raise. The outside slopes of the stormwater retention berms shall be 3:1 (horizontal:vertical), and the berm crest width shall be a minimum of 15 feet. The crest elevation of the stormwater retention berm shall be a minimum of five feet above the level of disposed materials inside the stormwater berms.

6.4.2 Final Slope and Grades

The final disposed material surface shall have maximum side slopes of 5:1 and a top surface sloping in the direction shown on the drawings at a nominal slope of 1 percent. The side slopes and top surface shall be free from abrupt changes in grade or areas of runoff concentration. The final disposed material surface shall be compacted with approved construction equipment to form a smooth surface with uniform density for subsequent cover placement.

The upper six inches of the final disposed material surface shall be compacted to 90 percent of the maximum dry density for the material, as determined by the Standard Proctor test. During compaction, the material shall be within 1 percent above to 4 percent below optimum moisture content for the material, as determined by the Standard Proctor test. If water addition is required to achieve this range of moisture contents, the added water shall be thoroughly mixed into the material prior to compaction.

Checking of compaction of the final disposed material surface shall consist of a minimum of one field density test per 1,000 cubic yards of material compacted. Field density tests shall be compared with Standard Proctor tests (ASTM D-698 Method A or C) on the same material. Standard Proctor tests shall be conducted at a frequency of at least one test per 2,000 cubic yards of material compacted, or when material characteristics show significant variation.

Field density testing may be conducted with the sand cone test (ASTM D-1556) or a nuclear density gauge (ASTM D-3107 and D-2922, or as modified by the QA Manager). Calibration of the nuclear density gauge shall be by comparison with results from the sand cone test on the same material.

7.0 DISPOSAL CELL COVER CONSTRUCTION

7.1 GENERAL

This section outlines the work associated with construction of the disposal cell cover.

7.2 MATERIALS DESCRIPTION

7.2.1 Clay Liner

Clay liner material will consist of soils from approved on-site borrow areas (Section 3.4). Clay liner material shall be minus 1-inch size, and shall be free from roots, branches, rubbish, and process area debris. Clay liner material shall have a minimum of 50 percent passing the No. 200 sieve and a minimum plasticity index of 10. Compacted clay liner material shall have a maximum saturated hydraulic conductivity of 1×10^{-7} cm/s. Clay liner material shall have radionuclide activity concentrations lower than the selected subsurface soil cleanup level.

7.2.2 Synthetic Liner

Synthetic liner material shall be 60-mil nominal thickness HDPE, with textured surfaces on both sides and material characteristics outlined in Section 5.2.1.

7.2.3 Liner Cover Material

Synthetic liner cover material shall be placed over the synthetic liner to provide a cover material for protection of the synthetic liner during material placement.

Synthetic liner cover material shall consist of gravelly sand. Synthetic liner cover material shall be free from roots, branches, rubbish, process area debris, and other angular or pointed materials that could damage the synthetic liner, and meet the following particle-size specifications:

Sieve Size	Percent Passing
1 inch	100
No. 4	65-100
No. 16	25-85
No. 40	5-45
No. 200	0-10

7.2.4 Subsoil Zone

The subsoil zone of the cover will consist of soils from approved on-site borrow areas (Section 3.4). Subsoil zone material shall be minus 6-inch size, and shall be free from roots, branches, rubbish, and process area debris. Subsoil zone material shall have a minimum of 30 percent passing the No. 200 sieve.

7.2.5 Rock Mulch

Rock mulch will consist of granular materials from approved off-site areas. The rock mulch will be placed on the disposal cell side slopes and edge of top surface (as shown on the Drawings) for erosion protection. Rock mulch material shall meet NRC long-term durability requirements (a rock quality

designation of 60 or more, as outlined in Appendix D of the 1990 NRC Staff Technical Position, Design of Erosion Protective Covers). Rock mulch material shall be shall be free from roots, branches, rubbish, and debris. If limestone from the Souter Quarry is used for rock mulch, the median particle size shall be no less than 3.4 inches, and shall meet the following particle-size specifications:

Sieve Size	Percent Passing
9 inch	100
4 inch	35-65
1.5 inch	20-50
No. 4	0-25

If alluvial material from nearby commercial gravel pits is used for rock mulch, the median particle size shall be no less than 4.7 inches, and shall meet the following particle-size specifications:

Sieve Size	Percent Passing
12 inch	100
4 inch	35-65
1.5 inch	20-50
No. 4	0-25

7.2.6 Perimeter Apron Rock

Material for the perimeter apron and Gully 005 erosion protection will consist of granular materials from approved off-site areas. The perimeter apron rock will be placed along the toe of the disposal cell and in the Gully 005 erosion protection area (as shown on the Drawings). Perimeter apron rock shall meet NRC long-term durability requirements (a rock quality designation of 60 or more, as outlined in Appendix D of the 1990 NRC Staff Technical Position, Design of Erosion Protective Covers).

Perimeter apron rock shall be shall be free from roots, branches, rubbish, and debris. If limestone from the Souter Quarry is used for perimeter apron rock, the median particle size shall be no less than 6.8 inches, and shall meet the following particle-size specifications:

Sieve Size	Percent Passing
16 inch	100
8 inch	30-70
4 inch	20-50
1 ½ inch	0-25

If alluvial material from nearby commercial gravel pits is used for perimeter apron rock, the median particle size shall be no less than 8.0 inches, and shall meet the following particle-size specifications:

Sieve Size	Percent Passing
24 inch	100
8 inch	30-70
4 inch	20-50
1 ½ inch	0-25

7.2.7 Erosion Protection Filter

Erosion protection filter material will be placed under the perimeter apron rock at the head of the Gully 005 erosion protection feature (as shown on the Drawings). The material shall meet NRC long-term durability requirements (a rock quality designation of 60 or more, as outlined in Appendix D of the 1990 NRC Staff Technical Position, Design of Erosion Protective Covers).

Erosion protection filter material shall be shall be free from roots, branches, rubbish, and debris. If limestone from the Souter Quarry or alluvial material from nearby commercial gravel pits are used for erosion protection filter, the median particle size shall be no less than 0.5 inches, and shall and meet the following particle-size specifications:

Sieve Size	Percent Passing
3 inch	100
1 ½ inch	55-100
¾ inch	30-75
No. 4	0-45
No. 10	0-25

7.2.8 Topsoil

Topsoil will consist of select material of dark color from the on-site topsoil borrow area (Section 3.5).

7.3 WORK DESCRIPTION

7.3.1 Base Preparation

The final disposed material surface shall be prepared as outlined in Section 6.4.2, and shall be free from sharp objects that would interfere with clay liner placement.

7.3.2 Clay Liner Placement

Clay liner material (Section 7.2.1) shall be placed in lifts with maximum compacted thickness of 6 inches to form a continuous layer with a total minimum compacted layer thickness of 24 inches. Clay liner material shall be placed over the prepared surface of the disposal cell (Section 6.4.2).

Each lift of clay liner material shall be compacted to at least 95 percent of the maximum dry density for the material, as determined by the Standard Proctor test. During compaction, the material shall be within 2 percent above to 2 percent below optimum moisture content for the material, as determined by the Standard Proctor test. If water addition is required to achieve this range of moisture contents, the added water shall be thoroughly mixed into the material prior to compaction.

Compaction of the clay liner material shall be done with a sheepsfoot or tamping-foot roller of sufficient weight to achieve the required compaction specifications. Rubber-tired equipment shall not be used solely to compact the clay liner material.

Compacted clay liner shall be covered with the liner bedding layer material within 24 hours of any liner completion, testing and approval.

7.3.3 Synthetic Liner Installation

Synthetic liner material (Section 7.2.2) shall be installed on the final surface of the clay liner as outlined in Section 5.3.

7.3.4 Liner Cover Material Placement

Synthetic liner cover material shall be placed over the completed synthetic liner to provide a protective cover for placement of disposal material. Liner cover material (Section 7.2.3) shall be placed in one lift

to form a zone a minimum of 18 inches thick. The lift of synthetic liner cover shall be placed by dumping material on areas that are not underlain by synthetic liner, and pushing synthetic liner cover over synthetic liner with a small dozer or other approved equipment. Synthetic liner cover placement shall be done in a manner that does not tear, puncture, or otherwise damage the synthetic liner.

7.3.5 Subsoil Zone Placement

Subsoil zone material (Section 7.2.4) shall be placed in lifts of 12-inch maximum loose thickness to form a uniform subsoil layer for the cover system with a minimum thickness of 5.0 feet on the top surface of the disposal cell and a minimum thickness of 4.5 feet on the side slopes of the disposal cell.

7.3.6 Rock and Filter Material Placement

Rock mulch (Section 7.2.5), perimeter apron rock (Section 7.2.6), and erosion protection filter material (Section 7.2.7) shall be placed in one or more lifts to the depths outlined in the Drawings and using the methods outlined below.

Rock and filter material shall be handled, loaded, transported, stockpiled, and placed in a manner that minimizes segregation. Rock and filter material shall be placed in or near its final location by dumping, then spread with a small dozer, the bucket of a trackhoe, or other suitable equipment. Rock and filter material shall be placed and spread in a manner that minimizes displacement of underlying cover soils, natural soils, filter material, or bedding material.

The completed layer of rock and filter material shall be well-graded in particle-size distribution and free from pockets of smaller material and free from large voids or loose areas. The larger particles or rock shall be well-distributed throughout the layer. The desired particle-size distribution of a completed layer shall be obtained by selective loading of the material, by controlled dumping of loads, and controlled placement. Rearranging of individual rock by mechanical equipment or by hand may be required to obtain a well-graded particle-size distribution of interlocking particles. Each layer of rock and filter material shall be track-walked with a small dozer, tamped with the bucket of a trackhoe, or densified by other approved methods.

7.3.7 Topsoil Placement

Topsoil (Section 7.2.6) shall be placed in one or more lifts to form a uniform layer with a final thickness of nine inches on the side slopes and perimeter apron and 18 inches on the top surface of the disposal cell (shown on the Drawings).

7.4 PERFORMANCE STANDARD AND TESTING

7.4.1 Clay Liner Testing

Material specifications for the clay liner material shall be confirmed by gradation testing conducted by approved personnel. Testing shall consist of No. 200 sieve wash and maximum particle size testing (ASTM D-422), and Atterberg limit testing (ASTM D-4318) on samples of clay liner materials, at a frequency of at least one test per 2,000 cubic yards of fill placed, or when material characteristics show a significant variation.

Checking of compaction of the clay liner material shall consist of a minimum of one field density test per 1,000 cubic yards of material compacted. Field density tests shall be compared with Standard Proctor tests (ASTM D-698 Method A or C) on the same material. Standard Proctor tests shall be conducted at a

frequency of at least one test per 2,000 cubic yards of material compacted, or when material characteristics show significant variation.

Field density testing may be conducted with the sand cone test (ASTM D-1556) or a nuclear density gauge (ASTM D-3107 and D-2922, or as modified by the QA Manager). Calibration of the nuclear density gauge shall be by comparison with results from the sand cone test on the same material.

Permeability of the compacted clay liner material shall be confirmed by performing back pressure permeability testing by constant head or flow pump (EPA 9100 or ASTM D-5084) on samples of clay liner material recompacted to density and moisture of field placed compacted clay liner. One test shall be completed during cover construction, or when material characteristics show significant variation.

The completed clay liner shall have a minimum thickness of 2.0 feet. The completed clay liner surface shall be constructed to within 1.0 foot of the lines as designed and shown on the Drawings, and within 0.1 foot of the elevations shown on the Drawings. The final surface of the clay liner shall be smoothed to avoid abrupt changes in surface grade.

7.4.2 Synthetic Liner Testing

The synthetic liner panels and seams shall be tested as outlined in Section 5.4. The final synthetic liner surface shall be inspected and approved by the QA Manager prior to initiation of synthetic liner cover placement.

7.4.3 Synthetic Liner Cover Testing

Material specifications for synthetic liner cover material (Section 7.2.3) shall be confirmed by gradation testing conducted by approved personnel. Testing shall consist of No. 200 sieve wash and maximum particle size testing (ASTM D-422) at a frequency of at least one test per 2,000 cubic yards of fill placed, or when material characteristics show a significant variation.

7.4.4 Subsoil Zone Material Testing

Material specifications for the cover material shall be confirmed by gradation testing conducted by approved personnel. Testing shall consist of No. 200 sieve wash and maximum particle size testing (ASTM D-422) on samples of cover materials, at a frequency of at least one test per 2,000 cubic yards of fill placed, or when material characteristics show a significant variation. Cover material compaction will be verified by the maximum lift thickness outlined in Section 7.3.5.

7.4.5 Rock Mulch Testing

Material specifications for the rock mulch material shall be confirmed by gradation testing conducted by approved personnel. Testing shall consist of particle-size distribution testing (ASTM D-422) at a frequency of at least one test per 2,000 cubic yards of rock mulch placed, or when rock mulch characteristics show a significant variation.

The durability of the rock mulch material shall be verified upon selection of the rock mulch source by durability tests outlined in Appendix D of the 1990 NRC Staff Technical Position, Design of Erosion Protective Covers. The rock mulch material shall have a minimum rock quality designation of 60. Durability tests shall be conducted on two representative samples from the selected rock mulch source.

Rock mulch thickness will be established during construction with grade stakes placed on a grid pattern and layer thickness marks on each grade stake. The minimum thickness of the rock mulch layer will be verified by spot checking of layer thickness by hand excavation in selected locations.

7.4.6 Perimeter Apron Rock Testing

Material specifications for the perimeter apron rock shall be confirmed by gradation testing conducted by approved personnel. Testing shall consist of particle-size distribution testing (ASTM D-422) at a frequency of at least one test per 2,000 cubic yards of rock placed, or when rock characteristics show a significant variation.

The durability of the rock shall be verified upon selection of the rock source by durability tests outlined in Appendix D of the 1990 NRC Staff Technical Position, Design of Erosion Protective Covers. The rock material shall have a minimum rock quality designation of 60. Durability tests shall be conducted on two representative samples from the selected rock source.

Rock layer thickness will be established during construction with grade stakes placed on a grid or centerline and offset pattern and layer thickness marks on each grade stake. The minimum thickness of the rock mulch layer will be verified by spot checking of layer thickness by hand excavation in selected locations.

7.4.7 Erosion Protection Filter Testing

Material specifications for erosion protection filter material (Section 7.2.7) shall be confirmed by gradation testing conducted by approved personnel. Testing shall consist of No. 200 sieve wash and maximum particle size testing (ASTM D-422) at a frequency of at least one test per 2,000 cubic yards of fill placed, or when material characteristics show a significant variation.

The durability of the erosion protection filter material shall be verified upon selection of the material source by durability tests outlined in Appendix D of the 1990 NRC Staff Technical Position, Design of Erosion Protective Covers. The material shall have a minimum rock quality designation of 60. Durability tests shall be conducted on two representative samples from the selected material source.

Filter layer thickness will be established during construction with grade stakes placed on a grid or centerline and offset pattern and layer thickness marks on each grade stake. The minimum thickness of the layer will be verified by spot checking of layer thickness by hand excavation in selected locations.

7.4.6 Topsoil Testing

Material specifications for the topsoil shall be confirmed by observation of organic matter content, as characterized by visual observation of the color of the topsoil.

7.4.7 Surface Slopes and Grades

The final cover surface shall have maximum side slopes of 5:1 and a top surface sloping in the direction shown on the drawings at a nominal slope of 1 percent. The side slopes and top surface shall be free from abrupt changes in grade or areas of runoff concentration. The perimeter apron at the toe of the side slopes shall have a minimum width of 20 feet from the toe of the side slopes and slope away from the toe of the side slopes (as shown on the Drawings).

8.0 REVEGETATION

8.1 GENERAL

Following topsoil placement on the disposal cell, the cover surface will be revegetated. This section describes the requirements for vegetation establishment and where additional vegetation establishment efforts are required. This section may be revised as necessary based on field requirements and soil analysis.

8.2 MATERIALS DESCRIPTION

The following section describes the types of soil amendments, seed mixture, transplant species, and erosion control materials that will be used to achieve vegetation establishment. Submittals for each of the following products shall be provided to SFC for approval prior to use of such products.

8.2.1 Soil Amendments

In order for the cover to function properly as a plant growth media, soil amendments may be needed. Topsoil material will be tested to determine fertilizer requirements, for nutrient availability, pH, texture, and organic matter content. The results from these analyses will be used as a guide for determining site-specific topsoil amendment requirements.

8.2.2 Seed Mix

Species selection for the seed mixture was based on native vegetation found at the site area as well as soil and climatic conditions of the area. Tree species shall not be included in the seed mixture. Changes to the seed mixture will be approved by SFC. The following seed mixture shall be used on all seeded areas.

Scientific Name	Common Name	Seeding rate (lbs PLS /A)*
Andropogon gerardii	Big bluestem	6.0
Schizachyrium scoparium	Little bluestem	3.0
Panicum virgatum	Switchgrass	2.0
Sorghastrum nutans	Indiangrass	2.0
Elymus villosus	Hairy wildrye	2.0
Solidago altiplanities	High plains goldenrod	1.5
Helianthus petiolaris	Prairie sunflower	1.5
Silphium laciniatum	Compassplant	0.5
Liatris Gaertn. Ex Schreb.	Blazing star	0.5
Rhus microphylla	Littleleaf sumac	2.0
	TOTAL	21.0

* Pounds Pure Live Seed Per Acre

8.2.3 Erosion Control Materials

Certified weed-free straw shall be applied to all seeded areas at the rate of 2 tons per acre. Straw mulch shall be applied with a blower designed for such purposes.

8.3 WORK DESCRIPTION

Revegetation efforts shall be directed at all areas included in the disposal cell cover. The goal of the revegetation plan is to ensure that a self-sustaining vegetative community is established.

8.3.1 Soil Amendment Application

Following the final placement and grading of the cover, lime will be applied to those areas identified by soil analysis that require an increase in soil pH. The application of lime will be performed by broadcast spreader. Rates of application will be determined from the soil analysis report.

Organic amendments consisting of manure, sewage sludge, wood chips, or similar organic material will be applied to all seeded areas that are shown to contain less than 2 percent organic matter. Rates of application will be determined from the soil analysis report.

Inorganic sources of nitrogen, phosphorus, and potassium will be applied to the soil by broadcast spreader. Rates of application will be determined from previous soil analyses.

8.3.2 Growth Zone Preparation

A favorable seedbed shall be prepared prior to seeding operations. The soil should be loose and friable so as to maximize contact with the seed. Tillage operations not only prepare the seedbed, but also incorporate soil amendments. The soil will be tilled, following site contours with a disc (or similar approved equipment) to a depth of 6 inches. The depth of valleys and the height of ridges caused by the final tillage operations are not to exceed 2 inches. Thus, the total maximum difference from the top of ridges to the bottom of valleys will be 4 inches. Harrowing may be required to further prepare the soil for seeding.

8.3.3 Seed Application

Seeding will follow the application of soil amendments and seedbed preparation, either by drill seeding or broadcast spreading. Seed shall be drilled to a depth of 0.25 to 0.75 inches by a conventional drill; drilling orientation shall follow the contour of the land. Seed shall be drilled at the specified application rate. Seed shall be applied by broadcast spreader at two times the specified application rate. Broadcast seed shall be harrowed into the soil to a depth of 0.25 to 0.75 inches.

8.3.4 Erosion Control Material Application

Immediately following seeding operations, straw shall be blown over the seeded area. The rate of application shall be 2 tons per acre. Straw should be applied in a uniform manner with no obvious clumping of straw at the soil surface. Following the application of straw, plantago based tackifier (or approved equivalent) shall be applied by a hydromulcher at the rate of 150 pounds per acre. Sufficient water shall be used to apply the tackifier in a uniform manner.

8.4 PERFORMANCE STANDARD AND TESTING

The following section describes performance-based criteria for successful revegetation.

8.4.1 Vegetation Establishment Performance

Total vegetative cover sampling shall be performed at a future date to ascertain vegetation establishment success. The revegetation effort shall be deemed successful if the total vegetation cover on the disposal cell cover is at least 70 percent of the total cover of a nearby background reference area for two consecutive years. Areas that do not meet this performance criterion will be reseeded.

8.4.2 Erosion Control

The disposal cell cover shall be inspected two times per year for eroded areas. Any area that has experienced erosion shall be backfilled and reseeded. Straw shall also be applied over the reseeded area.

8.4.3 Weed Control

The cover shall be inspected for the presence of weedy species at least two times per year: once in late spring, and once in mid-summer. Weed species should be identified and the approximate coverage should be noted. Spot-spraying of weeds may be necessary to control unwanted species. Growth of trees on the cover shall be prevented as long as SFC retains control of the site.

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D04

ENCLOSURE 4
Reclamation Plan
Attachment B, Final Status Survey

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ATTACHMENT B

Final Status Survey

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Figure Att. B-1 Classification of Areas for Final Status Survey

1.0 INTRODUCTION

This attachment presents the final status surveys for the Facility. The surveys were designed from the guidance contained in NUREG-1575 "Multi-Agency Radiation Survey and Site Investigation Manual" (MARSSIM) or were designed with respect to 10 CFR 40, Appendix A, Criterion 6. The surveys will demonstrate that the residual radioactivity in each survey unit satisfies the applicable criteria described in the Reclamation Plan, Section 3.2.2.

2.0 SURVEY DESIGN

The introduction to 10 CFR40, Appendix A, states that, "Licensees or applicants may propose alternatives to the specific requirements in this appendix." SFC is proposing an alternative strategy for the verification survey post-reclamation. The final status survey plan was developed recognizing that contamination of soil may have occurred from different and independent parts of processing at SFC. The NRC has previously concluded that the "activity at the front-end of the ... processing was uranium milling, and thus produced 11e.(2) byproduct material as its waste."[1] The back-end of the operation was a uranium conversion process, and thus produced source material (non-11e.(2)) as its waste. Areas of soil contaminated by either end of the process are readily identified by knowledge-of-process and results of site characterization.

SFC will apply the requirements of 10 CFR 40, Appendix A to areas of soil contaminated by the front end of the process. Contamination of soil from the front-end of the process is characterized by the presence of Th-230 in excess of uranium. The following sections classify these areas as "Th-Ra" areas and describe a final status survey consistent with 10 CFR 40, Appendix A, Criterion 6 (6). Particularly, the final status survey of "Th-Ra" areas will be performed on units of 100 m^2.

SFC will use a MARSSIM approach for final status survey of soil contaminated by the back end of the process. NRC recognizes MARSSIM as the

[1] U.S. Nuclear Regulatory Commission, Memorandum, Staff Requirements - SECY-02-0095 - Applicability of Section 11e.(2) of the Atomic Energy Act to Material at the Sequoyah Fuels Corporation Uranium Conversion Facility, July 25, 2002.

survey method of choice for license termination in all cases that do not include 11e.(2) by product material. Contamination of soil from the back-end of the process is characterized by the relative absence of Th-230 in the presence of uranium. The following sections classify these areas as class 1, 2, or 3 areas and describe final status survey requirements consistent with MARSSIM. The final status survey of class 1, 2, or 3 areas will be completed relative the respective MARSSIM guidance for size of units.

The survey designs began with the development of data quality objectives (DQOs). The DQOs were developed using guidance provided on the DQO Process in Appendix D of MARSSIM. On the basis of these objectives, applicable requirements of 10 CFR 40 Appendix A, and the known or anticipated radiological conditions at the site, a survey design was developed to determine the numbers and locations of measurement and sampling points to demonstrate compliance with the release criterion. Finally, survey techniques were selected appropriate for development of supporting data.

2.1 Radionuclides of Concern

The Site Characterization Report (SCR) identified the primary radionuclide of concern as natural uranium (U-nat). The SCR also established areas where thorium-230 (Th-230) and radium-226 (Ra-226) must be considered as contaminants. The SCR is included in the Reclamation Plan as Appendix D.

2.2 Cleanup Levels

For the purpose of the final status surveys, the cleanup levels (CLs) described in the Reclamation Plan represent contamination conditions that are approximately uniform across the survey unit and will be specifically referred to as CL_W. Table B-1 identifies the CL_W used in this survey plan for each radionuclide.

A separate CL will be derived for small areas of elevated activity and will be specifically referred to as CL_{EMC} (elevated measurement comparison).

Table B-1 Cleanup Levels

Condition	Uranium-Nat pCi/g	Thorium-230 pCi/g	Radium-226 pCi/g
CL_W	100	≤14 / ≤43	≤5.0 / ≤15

* first 15cm below surface / 15cm layers more than 15cm below surface

2.3 Classification of Areas based on Contamination

All areas of the Facility do not have the same potential for contamination and, accordingly, do not need the same level of survey coverage to demonstrate that residual radioactivity in the area satisfies the applicable criteria. The surveys were designed so that areas with higher potential for contamination receive a higher degree of survey effort.

The survey designs fall into one of two categories, non-impacted and impacted. Areas that have no reasonable potential for residual contamination are designated as non-impacted areas and are not provided any level of survey coverage. Areas that have some potential for containing contaminated material are designated as impacted areas. Impacted areas are subdivided into four classes according to known or suspected levels of contamination and with regard to the classification guidance of MARSSIM. Specific and thorough consideration was given to site operating history and/or known contamination based on site characterization efforts:

- Class 1 areas: These areas are known to not have thorium-230 or radium-226 as a significant contaminant. These areas are known or suspected to have contamination in excess of the criterion for U-nat.
- Class 2 areas: These areas are known to not have thorium-230 or radium-226 as contaminants. These areas are known or suspected to have contamination less than the criterion for U-nat.
- Class 3 areas: Any impacted areas that are not expected to contain any residual radioactivity, or are expected to contain levels of residual radioactivity at a small fraction of the criterion for U-nat, based on site operating history and previous radiological surveys. These are areas

with very low potential for residual contamination but insufficient information to justify a non-impacted classification. These areas are known to not have thorium-230 or radium-226 as contaminants.

- Th-Ra areas: These areas are known to have thorium-230 and radium-226 as contaminants. These areas are known or suspected to have contamination in excess of the criterion for U-nat, thorium-230, and radium-226.

Class 1 and Th-Ra areas have the greatest potential for contamination and, therefore, receive the highest degree of survey effort, followed by Class 2, and then Class 3 areas. Class 1 and Class 2 areas may be further subdivided into units in accordance with the guidance in MARSSIM or to better facilitate assessment of the area. Th-Ra areas will be divided into $100m^2$ units in accordance with 10 CFR 40, Appendix A, Criterion 6. Figure Att. B-1 depicts the boundaries of the different areas.

2.4 Investigation Levels

Radionuclide-specific investigation levels will be used to indicate when additional investigations may be necessary. The investigation levels will also serve as a quality control check for the measurement process. The investigation levels to be used at the Facility are provided in Table B-2.

Table B-2 Final Status Survey Investigation Levels

Survey Unit Classification	Investigate When Sample Result:	Investigate When Scanning Measurement:
Class 1 & Th-Ra	> CL_{EMC}	> CL_{EMC}
Class 2	> CL_W	> CL_W
Class 3	> 0.33 CL_W	> Detection Sensitivity

2.5 Survey Techniques

Measurement methods used to generate data during the surveys can be classified into three categories commonly known as scanning surveys, direct

measurements, and soil sampling. These survey techniques are combined in an integrated survey design.

The instruments and procedures described here are the same as those used to determine background radioactivity. Instrumentation used for final status survey will be managed as described in this reclamation plan, Attachment D, *Radiation Safety Program*, Section 2.7.

2.5.1 Scanning Surveys

Scanning will be performed to identify areas of elevated activity that may not be detected by other measurement methods. Scanning will be performed of structure surfaces and land areas. Structure surfaces will be scanned for both alpha and beta/gamma radiations. Land areas will be scanned for gross gamma radiations. The types of instruments used for scanning and their typical performance characteristics are provided in Table B-3. Scanning measurements will be conducted in accordance with written operating procedures.

Table B-3 Identification Of Radiation Detection Instruments For The Final Status Surveys Of The Sequoyah Facility

Measurement	Instrumentation Detector	Meter	Background[1] (cpm)	4 π[a] Efficiency (%)	Detection Sensitivity[b, c]
Scan alpha Direct alpha	Large area gas prop., Ludlum Meas., Inc., Model 239-1F.	Count rate meter and digital scaler, Ludlum Meas.,Inc., Model 2221.	16	20	300 dpm/100cm² 37 dpm/100cm²
Scan beta/gamma Direct beta/gamma	Large area gas prop., Ludlum Meas., Inc., Model 239-1F.	Count rate meter and digital scaler, Ludlum Meas.,Inc., Model 2221.	1220	20	1300 dpm/100cm² 280 dpm/100cm²
Scan Soil	NaI scintillation Ludlum Meas., Inc., Model 44-10	Countrate meter, Ludlum Meas., Inc., Model 2221.	10000	n/a	80 pCi/g as natural uranium[d] 3 pCi/g as Ra-226[d]

[a]Nominal values.
[b]Monitoring audible signal during scanning.
[c]One-half minute integrated count for direct measurements.
[d]MARSSIM Table 6.7
n/a - not applicable

Structure Surfaces

Scanning measurements of structure surfaces will be made with a radiation detector coupled to a handheld scaler/ratemeter. Scanning measurements will be performed by placing the detector as near as reasonable to the surface to be measured and moving the detector across the surface at a few centimeters per second. Each measurement will be recorded as the maximum for the area surveyed. The measurement location will be recorded with respect to physical features of the area surveyed.

Land Areas

Gamma scanning measurements will be used to support the final status surveys for Class 1, 2, and 3 areas, and may be used to support final status surveys for Th-Ra areas.

For Class 1, 2, and 3 areas, the use of gamma measurements will be to support a soil sampling scheme. The intent is to provide an integrated survey strategy of gamma scanning and soil sampling to determine compliance with a cleanup level of total uranium in soil. Use of the gamma scan in these cases will not be based on a quantitative correlation but either on a detection sensitivity assumed from MARSSIM Table 6.7, or a qualitative assessment by comparison to background. The scan is intended to find areas of elevated activity not detected by soil sampling on a systematic pattern, or to provide a qualitative level of confidence that no areas of elevated activity were missed by sampling on a random pattern and no error was made in classification of the area. Biased samples may be collected based on elevated scanning results.

Gross gamma measurements of land areas will made with a NaI(Tl) radiation detector coupled to a handheld scaler/ratemeter. Measurements will be collected by keeping the detector within two feet above ground surface while walking or driving over the area at a rate comparable to a casual walk. In open areas, the measurements will be made along a straight path between opposite borders of the area being surveyed and the distance between paths will be

approximately five feet. In wooded areas, the measurements will be made along paths allowed by brush and trees.

The scaler/ratemeter, along with global positioning system (GPS) equipment, may be coupled to a data logger. A gamma measurement taken from the ratemeter and a location reading from the GPS unit will be recorded approximately every two seconds by the data logger. Each measurement will be recorded as gross counts per minute. The location will be recorded with respect to the reference coordinate system described below. The expected density of measurements for an area is 60 to 80 measurements per 100 square meters.

For Th-Ra Areas, gamma measurements will be used in lieu of soil sample results if a quantitative relationship can be established between instrument response and soil activity. Such a relation cannot be established at this time because a soil sampling/gamma measurement data set has not been developed in accordance with the guidance in NUREG 1620. The primary areas from which the data would be gathered are currently inaccessible: the footprints of Pond 1 Spoils Pile, Clarifier A Basin, and Pond 2. Noting that Th-230 is the primary contaminant within the scope of Th-Ra Areas, SFC does not expect to be able to rely on gamma measurements in place of soil samples.

2.5.2 Direct and Removable Measurements

Direct measurements will only be made of structural surfaces. Direct measurements will be limited to alpha and beta/gamma measurements. The types of instruments used for direct measurements and their typical performance characteristics are provided in Table B-3. Direct measurements will be conducted in accordance with written operating procedures.

Direct measurements of structure surfaces will be made with a radiation detector coupled to a handheld scaler/ratemeter. The measurements will be performed by placing the detector on or near the surface to be measured and completing a one-minute integrated count. Each measurement will be recorded as gross counts per minute. The measurement results will be converted to transformations per minute per 100cm^2 using instrument specific calibration data.

The measurement location will be recorded with respect to physical features of the area surveyed.

Removable activity measurements will not be performed for the final status survey.

2.5.3 Soil Sampling

Soil sampling will be performed of land areas. Soil sampling will be conducted in accordance with written operating procedures.

Soil samples will be collected in a known and consistent fashion. The location will be recorded with respect to the reference coordinate system described below. The soil sample will typically be collected from the top six inches of soil.

A single soil plug will be collected from each sample location for the class 1, 2, and 3 areas. The plug from a six inch layer will create one soil sample.

Soil plugs will be collected from five evenly spaced locations across a $100m^2$ grid for Th-Ra areas. The five plugs from a six inch layer will be combined to create one composite soil sample.

Sample collection activities will include documentation of sampling activities on a field log, decontamination of equipment between sample locations, and collection of replicate samples at a rate of one per 10. Sample collection will also include creation of duplicate samples at a rate of one per 10. Chain-of-custody procedures will be applied beginning at the time of sample collection.

Soil samples will be sent to a laboratory for preparation and analysis. The preparation will include removing rocks and vegetation, drying, grinding, mixing/blending, and then acid leaching an aliquot of the prepared soil. These preparation techniques will be carried out in accordance with laboratory-specific procedures.

Samples of soil will be analyzed for the radionuclides of concern, as applicable. The analysis technique and typical detection limit for each radionuclide of concern is provided in Table B-4.

Table B-4 Identification Of Radioanalytical Methods For Final Status Surveys Of The Sequoyah Facility

Radionuclide	Analytical Method	Detection Limit[1] (pCi/g)
Total Uranium	kinetic phosphorescence analysis	0.7
Thorium-230	alpha spectrometry	0.5
Radium-226	co-precipitation, gross alpha and gross beta	0.1

[1] nominal values

The references for the analytical methods used, or equivalent, are:

Total uranium: ASTM D 5174, "Standard Test Method for Trace Uranium in Water by Pulsed-Laser Phosphorimetry", ASTM International.

Th-230: NAS/DOE 3004/RP, "Isotopic Thorium by Alpha Spectroscopy", National Academy of Sciences, DOE Methods for Evaluating Environmental and Waste Management Samples.

Th-01-RC, "Thorium in Urine", U.S. Department of Energy, Environmental Measurements Laboratory Procedures Manual, HASL-300, DE91-010178.

Ra-226: 903.0, "Alpha-Emitting Radium Isotopes", U.S. Environmental Protection Agency, Prescribed Procedures for Measurement of Radioactivity in Drinking Water, EPA 600/4-80-032.

903.1, "Radium-226 in Drinking Water Radon Emanation Technique", U.S. Environmental Protection Agency, Prescribed Procedures for Measurement of Radioactivity in Drinking Water, EPA 600/4-80-032.

Upon termination of reclamation activities, stored samples and sample remains will be disposed.

2.6 Reference (Background) Areas

The reference areas used for the conduct of the final status surveys for land areas will be as described in the SCR. The reference for structural surfaces will be determined at the time of the survey as part of instrument calibration.

2.7 Reference Coordinate System

Reference coordinates systems will be used to facilitate selection of measurement and sampling locations, and to provide a mechanism for relocating a survey point. Land area scanning surveys and soil sample locations will be referenced to the Oklahoma State Plane (NAD 1983(93) horizontal, NGVD 29 vertical). Scanning surveys and direct measurements of structural surfaces will be referenced to prominent building features.

2.8 Measurement Evaluation

The Wilcoxen Rank Sum (WRS) statistical test will be used to evaluate the data from the final status surveys of the Class 1, Class 2, and Class 3 areas. Measurements from a survey unit will be compared to equivalent measurements from the reference areas. In general, the comparison will be whether the survey unit exceeds the reference area by more than the CL_W for U-nat.

In addition, a comparison will be performed against each measurement in a Class 1 unit to determine whether the measurement result exceeds the relevant investigation level provided in Table B-2. If any measurement exceeds the investigation level, then additional investigation will be completed regardless of the outcome of the applicable WRS test.

The unity rule will be applied to the measurement results from each unit of the Th-Ra areas. In general, the comparison will be whether the sum of the fractions for each of U-nat, Th-230, and Ra-226 to it's respective CL_W is less than or equal to one.

2.9 Area Factor

The area factor is used to adjust the CL_W to estimate the CL_{EMC}. The area factor is the magnitude by which the concentration within a small area of elevated activity can exceed the CL_W while maintaining compliance with the release criterion. If the CL_W is multiplied by the area factor, the resulting concentration distributed over the specified smaller area delivers the same calculated dose.

Table B-5 provides the area factors to be used at the Facility. The area factors were developed from RESRAD. Other than changing the area (i.e. 1.0, 2.0, 2.5, 3.0, ... or 10000 m^2), the RESRAD values used to develop the release criteria were not changed. The area factors were then computed by taking the ratio of the dose per unit concentration generated by RESRAD for the area of the contaminated zone to that generated for the other areas listed.

Table B-5 Outdoor Area Factors

	Area Factor										
Radionuclide	**1m²**	**2m²**	**3m²**	**10m²**	**30m²**	**100m²**	**300m²**	**1000m²**	**3000m²**	**10000m²**	**25000m²**
U-Nat	2.6	2.4	2.2	1.7	1.5	1.3	1.2	1.1	1.1	1.1	1.0

3.0 SURVEY DESCRIPTIONS

The following sections describe the final status surveys to be completed for each of the area classifications previously described. As necessary, the following sections are further subdivided to provide description of the survey for a particular unit of an area. As an element of conservatism, the surveys were designed relative to the CL_W.

3.1 Class 1

3.1.1 Survey Units

This area is described as the entirety of the current main restricted area at the Facility, excluding the portions contaminated with thorium-230 and radium-226 and the area that will be occupied by the disposal cell. This area may otherwise be described as Restricted Area No. 1 except for Pond 1 Spoils Pile; the footprint of Clarifier A Basin; the footprint of Pond 2. The final status survey will be applied independently to each 2000 m^2 unit of this area.

3.1.2 Estimated Number of Data Points

The estimated number of sample locations will be derived in accordance with Section 5.5.2.2 of MARSSIM. Surface soil sample results from site

characterization and/or remediation control surveys for the area will be used to provide an estimate of the standard deviation (σ_s) for uranium in this area.

3.1.3 Calculate Relative Shift

The relative shift (Δ/σ_s) will be calculated using an upper bound of the gray region (UBGR) equal to the CL_W= 100 pCi/g, a lower bound of the gray region (LBGR) of ½CL = 50 pCi/g, and σ_s.

3.1.4 Decision Error Percentiles

The null hypothesis for this Class 1 area is that each survey unit does not meet the release criteria. Acceptable decision error probabilities for testing the hypothesis were chosen as $\alpha = 0.05$ and $\beta = 0.25$.

3.1.5 Number of Data Points for WRS test

The number of data points will be obtained directly from MARSSIM Table 5.3. The concern for detection of small areas of elevated activity will be addressed in accordance with MARSSIM Section 5.5.2.4. A triangular grid size will be determined for the number of data points and a survey unit size of 2000 m^2. The required scan minimum detectable concentration (MDC) will be determined per MARSSIM Equation 5-3 using the CL_W in Table B-1 and the Area Factor in Table B-5. The grid size will be adjusted as necessary to account for small areas of elevated activity.

3.1.6 Determining Survey Locations

Units will be surveyed on a random-start triangular grid pattern.

3.1.7 Integrated Survey Strategy

Sampling will be completed on the previously described grid. Scanning will be completed for 100% of each unit. Biased samples will be collected based on elevated scanning results.

3.2 Class 2

3.2.1 Survey Units

There are five areas in this classification. The five areas are: the drainage south of the South Guard House, former 001 drainage between the Protected Area fence and the Storm Water Reservoir, Initial Lime Neutralization Area, the former Sod Storage Area, and the front lawn. The final status survey will be applied independently to each 10000 m^2 unit of each area.

3.2.2 Estimated Number of Data Points

The estimated number of sample locations will be derived in accordance with Section 5.5.2.2 of MARSSIM. Surface soil sample results from site characterization and/or remediation control surveys for the area will be used to provide an estimate of the standard deviation (σ_s) for uranium in this area.

3.2.3 Calculate Relative Shift

The relative shift (Δ/σ_s) will be calculated using an upper bound of the gray region (UBGR) equal to the CL_W= 100 pCi/g, a lower bound of the gray region (LBGR) of ½CL = 50 pCi/g, and σ_s.

3.2.4 Decision Error Percentiles

The null hypothesis for these Class 2 areas is that each survey unit does not meet the release criteria. Acceptable decision error probabilities for testing the hypothesis were arbitrarily chosen as $\alpha = \beta = 0.05$.

3.2.5 Number of Data Points for WRS test

The number of data points will be obtained directly from MARSSIM Table 5.3.

3.2.6 Determining Survey Locations

Units will be surveyed on a random-start triangular grid pattern.

3.2.7 Integrated Survey Strategy

Sampling will be completed on the previously described grid. Scanning will be completed for nearly 100% of each unit. Biased samples may be collected based on elevated scanning results.

3.3 Class 3

3.3.1 Survey Units

There are three units in this classification. The three units are: sediment of the Storm Water Reservoir, inside the fertilizer ponds, and the remainder of the Class 3 area. The final status survey will be applied independently to each unit.

3.3.2 Estimated Number of Data Points

The estimated number of sample locations will be derived in accordance with Section 5.5.2.2 of MARSSIM. Surface soil sample results from site characterization and/or remediation control surveys for the area will be used to provide an estimate of the standard deviation (σ_s) for uranium in these units.

3.3.3 Calculate Relative Shift

The relative shift (Δ/σ_s) will be calculated using an upper bound of the gray region (UBGR) equal to the CL_W= 100 pCi/g, a lower bound of the gray region (LBGR) of ½CL = 50 pCi/g, and σ_s.

3.3.4 Decision Error Percentiles

The null hypothesis for these Class 3 units is that each survey unit does not meet the release criteria. Acceptable decision error probabilities for testing the hypothesis were arbitrarily chosen as $\alpha = \beta = 0.05$.

3.3.5 Number of Data Points for WRS test

The number of data points will be obtained directly from MARSSIM Table 5.3.

3.3.6 Determining Survey Locations

Samples will be collected at random locations.

3.3.7 Integrated Survey Strategy

The number of samples determined in Section 3.3.5 will be collected from each unit. Scanning will be completed for a majority of the accessible portions of each unit. Biased samples may be collected based on elevated scanning results.

3.4 Class 3-Office Building

3.4.1 Survey Units

There will be only one structure remaining at the site after decommissioning is completed. That structure is the existing office building which was constructed for office and warehouse space. This building was erected outside the restricted area in 1991 and occupied in mid-1992, only months before the permanent shutdown of the Sequoyah Facility. The building has been surveyed routinely for contamination, and no radioactive material or contamination has ever been found.

The Class 3-Office Building will be considered as several units. The choice of units is based on the limited time the Facility was in operation after the structure was built and the results of routine contamination surveys inside the structure. The units are the roof, the west exterior warehouse wall, the west exterior office building wall, the warehouse floor, and the first floor of the office building.

Surface activity limits were not derived for the Office building. NUREG-1620, Appendix H, Section H2.2.3(8) is applied here. Otherwise, the surface activity limits will default to those provided in Source Materials License SUB-1010, Section 3.3.4.7 for the Sequoyah Facility.

The CL_W is 2000 transformations per minute per 100 cm^2 (tpm/100cm^2) total (fixed plus removable) [direct] gross alpha and total (fixed plus removable) [direct] gross beta/gamma, measured independently. The CL_W will be applied as the total activity concentration; background will not be subtracted from the measurement result before comparison to the CL_W.

3.4.2 Estimated Number of Data Points

The estimated number of sample locations will be derived in accordance with Section 5.5.2.2 of MARSSIM. Data from routine contamination surveys for this structure do not indicate the presence of any residual contamination. As a conservative starting point, a coefficient of variation (CV) of 30% is assumed for survey data and the mean is assumed to be ½CL_W.

3.4.3 Calculate Relative Shift

The relative shift (Δ/σ_s) was calculated using an upper bound of the gray region (UBGR) equal to the CL= 2000 tpm/100cm^2, a lower bound of the gray region (LBGR) of ½ CL = 1000 tpm/100cm^2, and σ_s = 1000 * 0.30 tpm/100cm^2: Δ/σ_s = 3.33 rounded down to 3.

3.4.4 Decision Error Percentiles

The null hypothesis for this Class 3-Office building survey is that each survey unit does not meet the release criteria. Acceptable decision error probabilities for testing the hypothesis were arbitrarily chosen as $\alpha = \beta = 0.05$.

3.4.5 Number of Data Points for WRS test

The number of data points were obtained directly from MARSSIM Table 5.3. For $\alpha = \beta = 0.05$, and $\Delta/\sigma_s = 3$, then N/2 = 10.

3.4.6 Integrated Survey Strategy

Ten direct alpha and ten direct beta/gamma measurements will be collected at random locations in each unit. Scanning will be performed in areas of highest potential for residual contamination; e.g. corners, drains, steps, ledges. The measurement results will be evaluated against the CL_W for direct surface radioactivity.

3.5 Class Th-Ra

3.5.1 Survey Units

There are five areas in this classification. The four areas are: the footprint of Pond 1 Spoils Pile; the footprint of Clarifier A Basin; the footprint of Pond 2;

and outside the fence at Pond 2 to the south, west and north. The final status survey will be applied independently to each $100m^2$ unit of these areas.

3.5.2 Number of Data Points

At least 30 composite soil samples will be collected from each area. A composite soil sample will be collected with respect to a unit of each area. Surface soil sample results from site characterization and/or remediation control surveys for the area will be used when available. Gamma measurements may be substituted for soil samples.

3.5.3 Determining Survey Locations

The measurement and/or sample location will be recorded as the approximate center of each unit.

3.5.4 Integrated Survey Strategy

Sampling will be completed as described previously.

Gamma measurements, as count rate, may be substituted for some uranium and Ra-226 analyses. The gamma measurement threshold will be established from a correlation between sample result and count rate. The correlation will be derived from at least 30 soil samples from 2 to 25 pCi/g Ra-226. The correlation pairs will each represent a $100m^2$ unit. The gamma measurement threshold will be applied in a manner to provide a 95% level of confidence that the subject $100m^2$ unit meets the cleanup level. A correlation will be independently derived for each Th-Ra area.

Thorium-230 results may be developed from a correlation with Ra-226 or uranium analyses. The Th-230 correlation will be derived from at least 30 soil sample result pairs from 2 to 25 pCi/g Ra-226. The sample result pairs will each represent a $100m^2$ unit. The Th-230 correlation will be applied in a manner to provide a 95% level of confidence that the subject $100m^2$ unit meets the Th-230 cleanup level. A Th-230 correlation will be independently derived for each Th-Ra area.

Final status survey units that fail the gamma measurement threshold or unity rule will be tracked. Neighboring units to failed units that were subjected only to gamma measurement will be sampled for direct evaluation of the unity rule. Additional cleanup will be completed on the 100m^2 unit until the unity rule is satisfied. If the number of failed units is excessive, the gamma measurement threshold will be adjusted downward and units further remediated, as necessary.

4.0 QUALITY ASSURANCE AND QUALITY CONTROL

4.1 Introduction

SFC will use the quality assurance program described elsewhere in this Reclamation Plan as a quality system. The quality system will ensure that the final status survey decisions will be supported by sufficient data of adequate quality and usability for their intended purpose, and further ensure that such data are authentic, appropriately documented, and technically defensible.

4.2 Development of a Quality Assurance Project Procedure

SFC will develop a Quality Assurance Project Procedure (QAPP) as a tool to document the type and quality of data needed for Final Status Survey (FSS) decisions and to describe the methods for collecting and assessing those data. The QAPP will be developed consistent with EPA guidance for development of quality assurance project plans. The development, review, approval, and implementation of the QAPP will occur within SFC's existing system for management of operating procedures. The QAPP will be part of SFC's quality system.

The QAPP shall be composed of standardized, recognizable elements covering the entire project from planning, through implementation, to assessment. These elements are arranged for convenience into four general groups: project management, data generation and acquisition, assessment and oversight, and data validation and usability. If an element in whole or part is not applicable, such will be described in the QAPP. The groups and associated elements are described below.

Documentation, such as an approved Work Plan, Standard Operating Procedures, industry standards or methodology, etc., may be referenced in response to a particular required QAPP element. Current versions of all referenced documents will be available for routine use.

Project management The basic area of project management will be addressed, including the project history and objectives, roles and responsibilities of the participants, administrative functions, etc. These elements ensure that the project has a defined goal, that the participants understand the goal and the approach to be used, and that the planning outputs have been documented.

Data generation and acquisition This area will be described to ensure that appropriate methods for sampling, measurement and analysis, data collection or generation, data handling, and QC activities are employed and documented. These elements describe the requirements related to the actual methods or methodology to be used for the FSS.

Assessment and oversight These activities will be completed to determine whether the QAPP is being implemented as approved (conformance/nonconformance), to increase confidence in the information obtained, and ultimately to determine whether the information may be used for their intended purpose. These activities will be conducted in accordance with SFC's existing quality assurance program.

Data Assessment (Data validation and usability) This section addresses the QA activities that occur after the data collection phase of the project is completed. Implementation of these elements determines whether or not the data conform to the specified criteria, thus satisfying the project objectives. Additional description of these matters is provided below.

4.3 Data Assessment

Assessment of the final status survey data will be made to determine if the data meet the objectives of the surveys, and to whether the data are sufficient to determine compliance with the CL_W. The assessment will consist of three phases: data verification, data validation, and data quality assessment.

4.3.1 Data Verification

Data verification efforts will be completed to ensure that requirements stated in planning documents are implemented as prescribed. Identified deficiencies or problems that occur during implementation will be documented and reported. Activities performed during the implementation phase will be assessed regularly with findings documented and reported to management. Corrective actions will be reviewed for adequacy and appropriateness and documented in response to the findings. Data verification activities are expected to include inspections, QC checks, surveillance, and audits.

4.3.2 Data Validation

Data validation activities will be performed to ensure that the results of data collection activities support the objectives of the surveys, or support a determination that these objectives should be modified. The data validation effort will be conducted in consideration of the guidance provided in Appendix N of MARSSIM.

4.3.3 Data Quality Assessment

An assessment of data quality will be performed to determine if the data are of the right type, quality, and quantity to support their intended use. The assessment will include assessment of data quality, application of the statistical tests used in the decision-making process, and the evaluation of the test results. The data quality assessment effort will be conducted in consideration of the guidance provided in Chapter 8 and Appendix E of MARSSIM.

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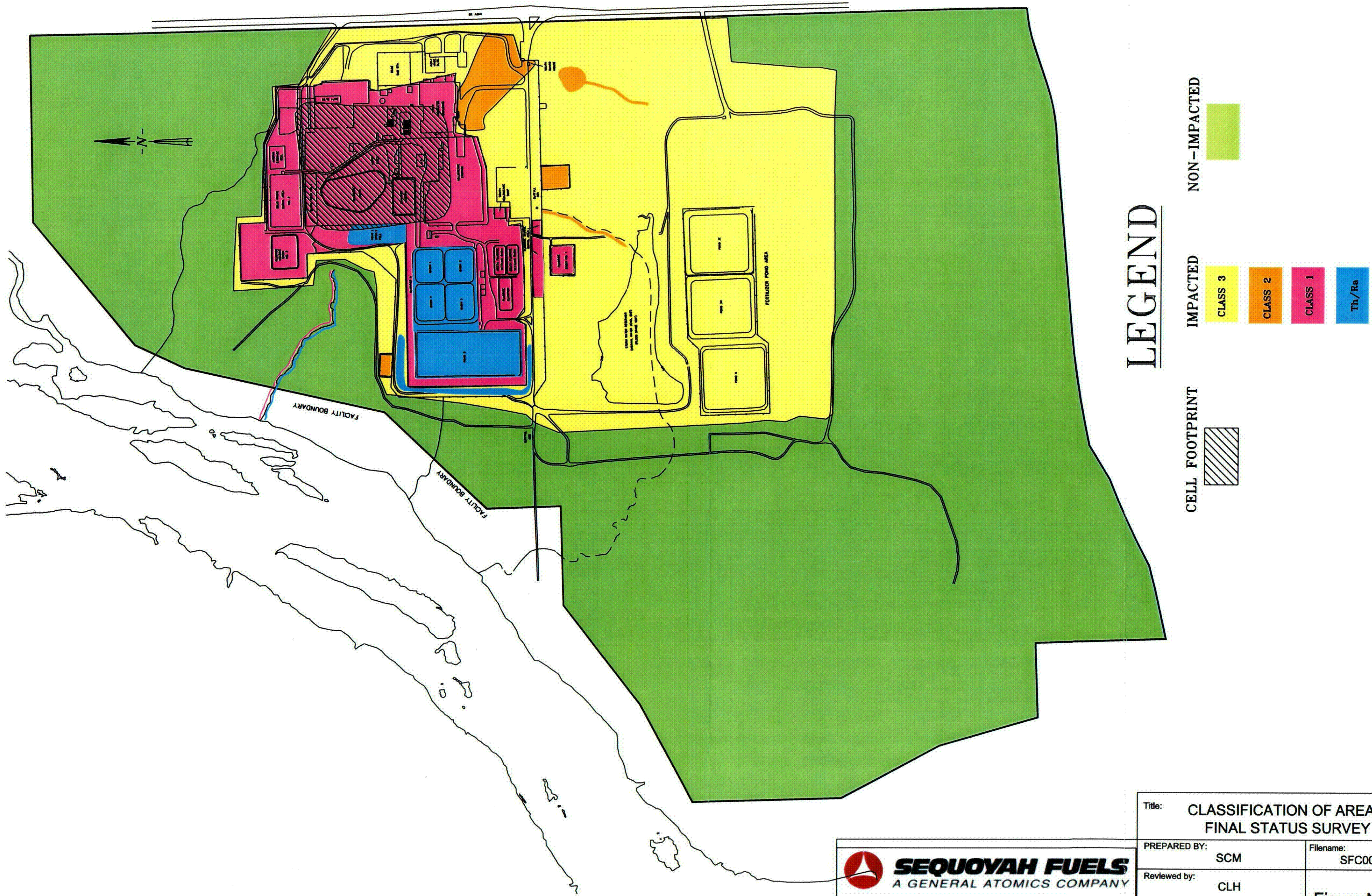

SEQUOYAH FUELS A GENERAL ATOMICS COMPANY	Title: CLASSIFICATION OF AREAS FOR FINAL STATUS SURVEY	
	PREPARED BY: SCM	Filename: SFC0092D
	Reviewed by: CLH	Figure No. Att. B-1
RECLAMATION PLAN	Date: December 2005	

ENCLOSURE 5

Reclamation Plan

Attachment E, Cell Construction Plan

Update Instructions:

1. Remove entire section from RP Attachment E tab
2. Insert entire section enclosed here

DISPOSAL CELL CONSTRUCTION PLAN FOR THE SEQUOYAH FUELS CORPORATION FACILITY

JANUARY 2006

Prepared for:

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1.0 INTRODUCTION

1.1 Purpose of Report

This report presents the construction plan for the on-site disposal cell at the Sequoyah Fuels Corporation (SFC) facility near Gore (Sequoyah County), Oklahoma. This report has been prepared for SFC by MFG, Inc. to address comments and provide additional detail for U.S. Nuclear Regulatory Commission (NRC) review and licensing of the reclamation plan for the SFC facility. This report is organized as Attachment E of the Reclamation Plan compiled by SFC.

1.2 Background

The conceptual design for the on-site disposal cell was documented in Morrison Knudson (MK, 1996b), ESCI (1996) and ESCI (1998). The on-site disposal cell location was selected in the process area, based on siting studies documented in Appendix H of the Reclamation Plan (MK, 1996a). The preliminary design of the disposal cell was described in MFG (2002b). The 2002 preliminary design was based on (1) additional site characterization data (including SFC, 1998 and MFG, 2002a), (2) modifications in disposal cell construction strategy by SFC, and (3) a disposal cell cover design incorporating a store-and-deplete infiltration control strategy with a vegetated surface. This report presents an update of the preliminary design in Appendix C of the Reclamation Plan (MFG, 2002b), and outlines the sequence for phased construction and filling of the disposal cell.

The disposal cell has been designed to meet the performance criteria for 11e.(2) byproduct material reclamation outlined in Appendix A of 10 CFR 40 and administered by the U.S. Nuclear Regulatory Commission (NRC). The technical analysis of the design has followed procedures outlined in NRC (1990) for long-term stability of 11e.(2) byproduct material sites. This report has been structured to present the updated disposal cell design and supporting technical analyses in a format and level of detail consistent with technical guidelines in NRC (1990), as well as reclamation plan review guidelines in NRC (2002).

1.3 Scope of Report

This report presents an update of the preliminary cell design in MFG (2002b), with design modifications as listed below.

1. The disposal cell construction plan is based on a perimeter embankment of compacted soils and granular materials from on-site cleanup operations. Stormwater and the remaining disposed materials will be managed within this perimeter embankment. The inside slopes of the perimeter embankment will be synthetically lined.

2. The cell base will be constructed across the disposal cell footprint, consisting of a multilayered synthetic and clay liner system. This liner system includes a provision for

leachate collection above the liner system and leak detection within the liner system. The outside perimeter of the liner system includes a synthetically lined clay berm.

3. The disposal cell base will be constructed in phases, with corresponding disposed material placement in phases of the cell.

4. The raffinate sludge will be treated with pressure filtration. If the raffinate sludge is disposed on site, the filtercake will be placed within the disposal cell with an additional liner and cover system.

Specific aspects of the disposal cell design are presented in additional documents that are organized as attachments of the Reclamation Plan. The specifications for construction of the disposal cell base and cover systems are outlined in the Technical Specifications for Cell Construction (Attachment A of the Reclamation Plan). The procedures for demolition of facility structures are outlined in the Demolition Plan (Attachment F of the Reclamation Plan). The sequencing of disposal cell base construction and material filling is presented in this report (Attachment E of the Reclamation Plan). The construction, filling, and covering of the disposal cell are illustrated in the Drawings (Attachment A of the Reclamation Plan).

2.0 SITE CONDITIONS

Site conditions pertinent to the disposal cell design are summarized in MFG (2002b). Site conditions pertinent to waste materials and site hydrogeology are described in MFG (2002a), SFC (1998), SFC (1997), and RSA (1991). These general conditions are not reproduced in this report. However, an update of the construction materials and materials to be disposed are summarized in the following subsections.

2.1 Liner System

A multi-layered liner system is proposed within the footprint of the disposal cell. This liner system consists of (from bottom to top): (1) a compacted three-foot clay layer, (2) a bedding layer of sand containing a leak detection system, (3) a synthetic liner, and (4) a cover layer of sand containing a leachate collection system. The soil used for the compacted clay layer will be obtained from the soil borrow area at the south end of the site (shown on the Drawings). The bedding layer and cover layer sands will be obtained from offsite sources (such as nearby aggregate production operations).

2.2 Cover System

A multi-layered cover system is proposed. This cover system will consist of (from bottom to top): (1) a compacted two-foot clay layer, (2) a textured synthetic liner, (3) a cover layer of sand, (4) a subsoil zone, and (5) a topsoil layer. The cover on the side slopes will have a layer of rock mulch placed at the base of the topsoil layer. Construction materials for the disposal cell cover system include soils and weathered sedimentary rock from on-site sources, and rock from off-site sources. These materials are discussed in MFG (2002b) and are summarized below.

2.3 Liner and Cover Construction Material

Clay Liner Material. The soil used for the compacted clay layer in the liner system and cover system will be a silty clay obtained from the soil borrow area at the south end of the site (shown on the Drawings).

Liner bedding and cover material. Sand for the liner bedding and cover material in the liner system and cover system will be screened sands obtained from offsite sources (such as nearby aggregate production operations).

Subsoil layer. Subsoil layer material will be obtained from on-site terrace deposit soils and weathered Atoka Formation shale and sandstone. From material balance calculations in MFG (2002b), there is significantly more material available for subsoil cover material than required volume of material. If the sources of cover material were prioritized by proximity to the disposal cell, the existing berm materials and subsoils in the process area are the preferred cover construction materials. These locations are shown on the Drawings.

Topsoil. Topsoil for the surface of the disposal cell cover and surrounding areas to be vegetated will be obtained from the Agland area on the west side of the site (shown on the Drawings). As discussed in MFG (2002b), there is sufficient topsoil available in the Agland area for the disposal cell cover system and surrounding areas.

Rock mulch and perimeter apron rock. As described in subsequent sections, a layer of rock mulch is planned as an erosion protection zone on the side slopes of the disposal cell. A layer of rock is planned as an erosion protection zone along the perimeter of the cell. Rock of acceptable size and durability for both applications is available from nearby commercial sources of limestone or alluvial gravel and cobbles (MFG, 2002b).

2.4 Disposed Materials

The materials to be placed in the disposal cell consist of process waste materials, structural debris, and underlying liner materials and subsoils from planned site cleanup and reclamation activities. The disposal cell is a "dry" cell, where all of the materials to be placed in the cell are solid materials ranging in moisture content from dry to nearly saturated conditions. No process liquids will be disposed in the cell.

The results of previous characterization of the chemical, radiological and physical properties of these materials are presented in RSA (1991) and SFC (1997), with the most current information compiled in Appendix D of the Reclamation Plan (SFC, 1998). The characterization data in (SFC, 1998) is presented in terms of site characterization units (SCUs), representing specific processing areas or facilities on site. The locations of the SCUs are shown on the Drawings, and pertinent data for each SCU are summarized in Appendix A of this report.

In the preliminary disposal cell design, SFC has grouped similar materials from individual SCUs together for disposal sequencing. Due to the planned placement of these materials in layers in the cell, these groups are referred to as Material Types A through D. The relationships between the SCU numbers and layer numbers are presented in Appendix A of this report, along with estimated volumes of these materials. The material types are described below.

Type A. Type A materials consist of five components: (1) raffinate sludge, (2) Pond 2 residual materials, (3) Emergency Basin sediment, (4) North Ditch sediment, and (5) Sanitary Lagoon sediment. The locations of these materials are shown on the Drawings. The raffinate sludge, Emergency Basin sediment, North Ditch sediment, and Sanitary Lagoon sediment are currently being "dewatered" by pressure filtration for planned disposal at an approved offsite location. If it is not economically possible to dispose of these materials offsite,

these materials, along with Pond 2 residual materials, will be disposed in a specifically designed area of the disposal cell.

The resulting physical properties of the filtered raffinate sludge (filtercake) are presented in Appendix B of this report. The filtercake is placed in polypropylene bags (supersacks) for temporary storage on the yellowcake storage pad at the site. The sacks of filtercake will either be shipped off site or placed in the disposal cell. The filtercake disposal cell will have a separate liner and cover system within the disposal cell liner and cover system (as shown on the Drawings).

The other major component of the Type A materials is the Pond 2 residual materials. The materials will be solidified by mixing with cement, fly ash, or bentonite. The mixed, solidified material for the cell capacity calculations is conservatively estimated to be 20 percent larger than the volume currently in Pond 2.

In terms of estimated volume placed in the disposal cell, Pond 2 residual materials comprise most of Type A materials (65.5 percent), followed by filtered raffinate sludge (30.5 percent), and the remaining sediments (totaling 4 percent).

Type B. Type B materials consist of soil liner and subsoil materials beneath the clarifier, the calcium fluoride basin, Pond 3E, the Emergency Basin, the North Ditch and the Sanitary Lagoon, as well as Pond 1 spoils pile material. The Type B materials (primarily contaminated soils) are listed second in the order, since they will be excavated after removal of Type A materials and placed directly on top of Type A materials in the disposal cell profile. In terms of estimated volume, the Pond 1 spoils pile (35 percent), clarifier liners (26 percent), and Emergency Basin soils (13 percent) comprise approximately 74 percent of the Type B materials.

Type C. Type C materials consist of structural materials, concrete and asphalt, calcium fluoride basin materials, calcium fluoride sediments, and on-site buried materials. These materials will be placed with or above the Type B materials, and placed with or covered with contaminated soils (Type D materials). In terms of estimated volume, the calcium fluoride sediments (44 percent), structural materials (38 percent) and concrete and asphalt (15 percent) comprise approximately 97 percent of the Type C materials.

Type D. Type D materials consist of contaminated soils and sedimentary rock that require cleanup. The approximate area of contaminated soil cleanup is shown on the Drawings.

The total layer material volumes from the estimates of disposed volumes in Appendix A are presented in Table 2.1 below.

Table 2.1 Disposed Material Summary

Type	Description	Estimated Volume (cu ft)	Fraction of Total Volume (%)	Natural Uranium (pCi/g)	Radium-226 (pCi/g)	Thorium-230 (pCi/g)
A	Sludge and sediment	1,162,735	14.5	357-12100	6-332	211-16300
B	Liner soils and subsoils	1,262,673	15.7	5-95	0.5-2.1	47-70
C	Calcium fluoride sediments, debris	2,035,362	25.3	168-520	0.2-0.8	2.1-4.8
D	Contaminated site soils	3,574,000	44.5	250	--	--
Totals		8,034,770	100.0	--	--	--

From the materials listed in Table 2.1, the contaminated site soils, subsoils, and selected demolition debris (concrete and asphalt) will comprise the materials to be used as the stormwater retention berm material for the disposal cell. These materials are primarily Type D materials, with minor amounts of Type B and C materials.

3.0 DESIGN STRATEGY

3.1 Design Criteria

The SFC site is planned for reclamation as an 11e.(2) byproduct material site under performance standards administered by the NRC. All of the waste materials disposed in the cell will be from on-site cleanup and reclamation. Upon successful demonstration to NRC of meeting these performance standards, the site will be transferred to the U.S. Department of Energy for long-term care and maintenance. The proposed boundary of the area to be transferred to the Department of Energy is the institutional control boundary shown on the Drawings.

The key design criteria for the disposal cell are to: (1) meet the performance standards for reclamation outlined in Appendix A of 10 CFR 40, (2) have a facility profile and shape that blends in with the surrounding area (from a visual, hydrologic and vegetative standpoint), (3) have a negligible effect on underlying groundwater, and (4) facilitate site cleanup and reclamation activity. These criteria are outlined below.

Performance standards. The performance standards in Appendix A of 10 CFR 40 include: (1) isolating the 11e.(2) material, (2) reducing the rate of radon emanation from the cover to an average of 20 picocuries per square meter per second, (3) providing effective protection over the design period (200 to 1,000 years), and (4) minimizing reliance on active maintenance.

Surrounding area impact. The top surface of the cell will be limited to an elevation of approximately 590 feet to minimize the visual impact of the disposal cell from surrounding areas. In addition, the side slopes of the cell will be at 5:1 (horizontal:vertical) or less, with the corners of the cell rounded to create a topographic feature that is visually similar to the surrounding area. The surface of the completed cell will be vegetated with natural grass and forb species similar to surrounding areas.

Effect on groundwater. The disposal cell cover design strategy includes minimizing infiltration of meteoric water. This is consistent with Appendix A of 10 CFR 40 as well as the conceptual design (MK, 1996a and ESCI, 1996). The cover design includes a compacted clay and synthetic liner system for initial infiltration control and a subsoil zone (five feet thick) for long-term infiltration control that promotes evapotranspiration from vegetation.

Facilitation of site cleanup. The siting and layout of the cell has been designed to accommodate stormwater management and construction activity during site cleanup without double-handling of materials, as described in subsequent sections of this report.

3.2 Capacity

The disposal cell has been designed to have sufficient capacity for the on-site materials described in Section 2.4. The estimated volumes listed in Table 2.1 total approximately 8.0 million cubic feet. The disposal cell layout shown on the Drawings has been sized for a capacity (beneath the cover system) for this volume.

The actual capacity required for the disposal cell depends on the volume of material excavated during site soil cleanup and the density of the material after placement in the cell. From the material volume estimates in Table 2.1, the materials with the largest potential variability are the contaminated soils (Type D). Due to this variability, the preliminary disposal cell design in MFG (2002b) incorporated a range of volumes (from 5 million to 12 million cubic feet). The geometric limits on the disposal cell are: (1) a maximum top surface elevation of approximately 590 feet (to minimize visual impact); (2) a minimum elevation of synthetic liner in the cell base five feet above groundwater and (3) the fixed location of the north, east, and west sides of the cell. The variability in disposed material volume is accommodated by reducing or extending the location of the south side of the cell, or reducing the elevation of the cell cover.

3.3 Site Selection

The disposal cell site was selected based on an evaluation of four potential sites identified on SFC property. The disposal cell site selected by SFC was in the process area. This site was chosen based on a ranking process outlined in Appendix H of the Reclamation Plan, and included hydrologic and erosional stability factors as well as cost and potential for expansion.

The location of the disposal cell within the process area was chosen to (1) provide the required capacity for disposed materials (Section 3.2), with the provision for additional contaminated soils; (2) be out of the way of major building demolition and subsurface excavations; (3) be located away from natural drainages, and (4) facilitate phased construction.

3.4 Cell Layout

The disposal cell layout consists of a four-sided, domed structure. The final surfaces are designed to meet NRC performance criteria for slope and erosional stability, with analyses presented in MFG (2002b). The disposal cell is designed for containment of the disposed materials under construction and long-term conditions. The cover system is designed for attenuation of radon-222 from the disposed materials under conservative, long-term emanation and radionuclide ingrowth conditions (described in MFG, 2002b).

3.5 Containment System

The cell is designed to contain the disposed materials and associated pore fluids with a multilayered liner system at the base of the cell, a perimeter embankment system, and a multilayered cover system over the disposed materials. This containment system includes soil and synthetic liner components, as described in Section 4 and shown on the Drawings.

3.6 Water Management

The design strategy for water management is outlined below.

1. Prior to disposal cell construction, stormwater and residual process liquids are handled under current SFC permit procedures and license requirements.
2. During cell construction and disposal operations, precipitation falling on the disposal cell footprint will be contained within the cell behind stormwater retention embankments. The embankments are designed with sufficient freeboard to contain precipitation from the Probable Maximum Precipitation (PMP) event.
3. Meteoric water collected within the disposal cell during construction and disposal operations will be drawn from the cell as necessary and pumped to cleaned ponds on site for treatment and permitted discharge.
4. As cell construction is completed, the outside slopes of the cell will be covered with clean soils where possible to allow discharge of stormwater runoff.
5. After cover construction, stormwater runoff will be diverted away from the cell and discharged without treatment. The cover surfaces have been designed to withstand the peak runoff from the PMP event.

4.0 DISPOSAL CELL DESCRIPTION

This section describes the general layout of the disposal cell.

4.1 General Layout

The four-sided cell will cover approximately 16 acres. Approximately half of the cover surface area consists of side slopes, and the remainder is the top surface. The top surface of the cell drains to the southeast (the corner with the highest ground surface elevation) at a one-percent slope. The direction of top surface drainage was chosen to be toward the highest ground elevation and away from the west side of the cell. The side slopes of the cell are at 5:1 (20 percent), the maximum slope under NRC reclamation criteria.

The estimated volume of disposed materials in Table 2.1 is approximately 8 million cubic feet. Due to the variability in disposed material density, the amount of stabilizing additives that may be added to some materials, and the volume of soils that may actually be excavated, the disposal cell location and layout has been planned to accommodate a range of disposed material volumes. The disposal cell layout shown on the Drawings is based on a disposed material capacity of 8 million cubic feet. For a larger volume of disposed materials, the cell footprint would be extended to the south. For a smaller volume of disposed materials, the final elevation of the cell would be lowered, or the south side of the cell would be moved to the north.

The disposal cell layout has a similar shape and area to the design in MK (1996) and ESCI (1996), but with the following modifications.

1. The layout incorporates rounded corners to facilitate earthmoving construction techniques as well as produce a feature that blends in with surrounding topography.
2. The facility was moved to the north to utilize the topography of the emergency basin area for leachate collection and leak detection.
3. The facility was moved to the east, with the west side angled to reduce the length of slope and area draining into the gully west of the emergency basin.
4. The layout was adjusted to tie into natural ground or anticipated post-reclamation contours to provide drainage away from the toe of the slopes along the perimeter of the cell.
5. The top surface slope of the cell was modified to drain to the southeast with a top elevation of approximately 590 feet. This allows runoff to flow over the side slope on the sides with the shortest slope lengths.

4.2 Disposal Cell Base

The base of the disposal cell will contain a multi-layered liner system, with an upper and lower liner, separated by a leak detection system layer. The liner system is designed to contain leachate from disposed materials

above the upper liner as well as provide a leak detection system for the upper (synthetic) liner. The components of the cell base and liner system are outlined below (from bottom to top).

Subsurface fill. The foundation of the cell will include concrete pad surfaces, excavated soil or weathered sedimentary rock surfaces, or undisturbed soil surfaces, based on the extent of subsurface contamination and material cleanup. Subgrade fill will be placed over the excavated foundation surface (where required). Subgrade fill will be placed and compacted to provide a firm base for the liner system and fill in areas to create desired gradients for leak detection system flow. Subgrade fill will also raise the elevation of the cell base such that the elevation of synthetic liner is at least five feet above groundwater levels. This subgrade fill will consist of clean fill from on-site or off-site sources.

Clay layer. A compacted clay layer (36 inches thick) will be placed on the subsurface fill or foundation surface to form the secondary or lower liner for the liner system. As mentioned in Section 2, the soil for the clay layer will be excavated from on-site sources. At the perimeter of the cell, the clay layer forms the perimeter berm for leachate retention.

Bedding layer. A bedding layer of sand (6 inches thick) will be placed on the top surface of the clay layer to form a free-draining bedding layer for the synthetic liner as well as a leak detection zone above the clay layer (if leakage through the upper liner would occur). The leak detection system will consist of a series of 4-inch diameter perforated pipes installed in the bedding layer, as shown on the Drawings. As mentioned in Section 2, the sand for the bedding layer will be obtained from off-site sources.

Synthetic liner. A synthetic liner will be installed on top of the bedding layer surface to form the primary or upper liner for the liner system. The synthetic liner will be smooth, 60-mil thick, high-density polyethylene (HDPE) or similar approved material of appropriate low permeability, puncture resistance, and resistance to oxidation. The synthetic liner will extend over the clay berm along the perimeter of the cell, as shown on the Drawings.

Cover layer. A cover layer of sand (18 inches thick) will be placed on the synthetic liner surface to form a protective layer for the synthetic liner as well as a leachate collection zone above the synthetic liner. As mentioned in Section 2, the sand for the cover layer will be obtained from off-site sources. The leachate collection system will consist of a series of 6-inch diameter perforated pipes installed in the cover layer, as shown on the Drawings.

Collection system discharge. The leak detection and leachate collection system pipe layouts are designed to flow by gravity to the lowest corner of each phase of the disposal cell. Each pipeline system transitions into a

single solid pipe that conveys liquid by gravity to an external sump (as shown on the Drawings). These pipeline systems are independent, so for the three phases of the disposal cell there are three separate leak detection systems and sumps as well as three separate leachate collection systems and sumps. This allows independent subsurface water management for each phase of disposal cell construction.

4.3 Disposal Cell Construction

The strategy for disposal cell construction is to place the materials with the higher shear strength around the perimeter of the cell as a compacted embankment or berm (the stormwater retention berm), then place lower shear-strength materials and demolition debris inside of the stormwater retention berm. As mentioned in Section 2.3, the materials to be placed in the disposal cell are solid materials, with no process liquid discharge. The only water to be handled during disposal cell construction will be meteoric water from precipitation directly on the cell.

As outlined in Section 3.6, meteoric water collected within the cell will be temporarily stored within the cell. The crest of the stormwater retention berms around the cell will be maintained with a minimum of five feet above the elevation of the interior materials. This freeboard is conservatively chosen to provide capacity for meteoric water from the PMP event (26 inches). At the initial stage of disposal for each phase, the initial berm will have a height of 8 feet. Subsequently, the minimum freeboard requirement will be maintained at 5 feet to account for the sloping cell base surface. In addition, the catchment area of Phase II will be initially limited to 100,000 square feet by the construction of diversion ditches along the upper portion of the Phase II area.

As the level of the interior of the cell rises with material disposal, the elevation of the stormwater retention berm will be raised as necessary to maintain this stormwater storage requirement. The stormwater retention berm will be raised in an upstream manner, with the centerline of the retention berm inside the centerline of the previous berm. The inside face of each raise of the stormwater retention berm will be covered with a synthetic liner to prevent moisture migration through the berm.

The stormwater retention berms will be constructed by placing material in lifts and compacting. The material in the interior of the cell will be placed in lifts and compacted or filled with disposed materials to minimize void spaces. The final surface of the disposed materials will be graded and compacted to minimize void spaces and reduce the potential for future differential settlement of the cover.

4.4 Cell Cover System

The cover system over the disposal cell consists of a 10-foot thick soil cover on both the top surface and side slopes of the cell. The components of the cover system are shown on the Drawings and are described below (from top to bottom).

Erosion protection zone. The upper 18 inches of the cover system consists of an erosion protection and vegetation zone. On the top surface, the upper 18 inches of the cover thickness consists of a topsoil layer. On the side slopes, the upper 18 inches consists of a 9-inch thick topsoil layer above a 9-inch thick rock mulch layer. The cover surface will be vegetated, with the long-term vegetation being a native grasses and forbs.

Subsoil zone. A five-foot thick subsoil zone of the cover system will consist of on-site soils to provide a root zone and moisture retention zone for infiltrating meteoric water.

Liner cover material. Underlying the subsoil zone will be 18 inches of sand. The liner cover provides a lateral drain for infiltrating meteoric water (that has passed through the subsoil zone), and provides a protective cover for the underlying synthetic liner.

Synthetic liner. A synthetic liner will be installed at the bottom of the cover system on both the top surface and side slopes. The synthetic liner will be anchored with the synthetic liner at the base of the cell (along the perimeter of the cell) to provide the containment as described in Section 3.5. The synthetic liner will be a textured, 60-mil thick HDPE (or similar approved material).

Compacted clay liner. The base of the cover will be a two-foot thick compacted clay layer.

Cell perimeter apron. The disposal cell will have a perimeter apron designed to transition into the surrounding reclaimed site topography. The perimeter apron is designed for energy dissipation of runoff from the cell side slopes and to direct drainage away from the cell. The perimeter apron will consist of a zone of rock two feet thick and 20 feet wide. One the east side of the cell, the perimeter apron will be extended to the east into a broad channel to direct runoff around the northeast and southeast corners of the cell (and away from State Highway 10).

The cover system and underlying disposed materials have been evaluated for erosional stability, slope stability, radon emanation, infiltration and settlement. The evaluation results are presented as Appendices C through G of this document, and show acceptable results relative to NRC design and performance criteria.

5.0 CELL CONSTRUCTION SEQUENCE

A phased cell construction plan has been prepared to demonstrate that the cell can be constructed in the process area while minimizing double-handling of materials. This plan is illustrated on the Drawings and outlined in the following subsections.

5.1 Phased Components

The disposal cell will be constructed using the perimeter embankment strategy outlined in Section 4.3, with disposed materials placed within the stormwater retention berms. The disposal cell will be constructed in three phases to allow one area of the cell base to be prepared for receipt of materials excavated from another area of the cell. After all three base areas of the cell have been constructed, materials from outside the disposal cell footprint can be placed throughout the cell.

Perimeter and internal berms. A key factor in the phased disposal cell construction is the stormwater, sediment, and leachate retention along perimeter of each phase of the cell. As shown on the Drawings, the cell base includes a three-foot high perimeter berm on the outside edges of the cell. The perimeter berm is designed with a 3:1 inside slope and 5:1 outside slope to tie into the synthetic liner and outside slope of the cover. The cell base includes a three-foot high internal berm on the inside edges of the cell. The internal berm is designed for the cell base liner system to tie into the adjoining phase of cell base. The perimeter and internal berms are designed to aid in leachate collection within each cell.

Stormwater retention berms. Stormwater management is accommodated by water retention with berms or embankments constructed primarily with contaminated site soils, other soils to be disposed in the cell, and minor amounts of broken concrete. As outlined in Section 3.6, the elevation of the retention berms will be maintained at a minimum of five feet above the top surface elevation of the interior materials, with an initial berm height of 8 feet. The berms will be placed in lifts and compacted to aid with moisture retention. As shown on the Drawings, the berms will be raised in an upstream manner (with additional berms constructed with the berm centerline inside of the previous berm). Synthetic liner will be installed on the inside slopes of the retention berms to enhance water retention.

5.2 Water Management

Water management during disposal cell construction will be based on containing water within the cell that is affected by disposed materials, and discharge of stormwater that is unaffected by disposed materials. This includes the elements outlined below.

1. Diversion of stormwater runoff from clean work areas away from areas where material excavation will take place and from the disposal cell footprint.

2. Preparation of the clarifier ponds for stormwater retention, by removal of raffinate sludge and cleaning or re-lining the pond surfaces. The clarifier ponds have an operating capacity of approximately 10 million gallons or 1.37 million cubic feet. The PMP event (26 inches in 6 hours) over the disposal cell footprint prior to cover placement is slightly less than this volume.

3. Collection of stormwater runoff from work areas affected by disposed materials and within the disposal cell perimeter. This water will be pumped or routed to the clarifier ponds for treatment and permitted discharge or use for disposed material compaction or dust control.

4. Operation of the disposal cell with stormwater retention berms surrounding the interior disposed materials. The elevation of the stormwater retention berm crest will be a minimum of five feet above the level of the disposed materials within the cell, or (during initial cell filling) with additional freeboard to provide sufficient capacity for stormwater storage capacity.

5. Removal of collected stormwater within the cell by pumping to the clarifier ponds. This water will be drawn from the cell using a floating intake and piped to the clarifier ponds with high-capacity pumps maintained by SFC on site.

6. Placement of clean fill on the outside slopes of the cell where possible to allow clean stormwater discharge.

5.3 Phases of Construction

The materials to be placed in the disposal cell are listed in the tables in Appendix A by their current location relative to the cell and the phase of the cell where they will be disposed. From the volumes of soils identified for berm material and remaining internal materials, the ratio of berm material volume to internal material volume is: 2.46, 1.49, and 1.33 for phases I through III, respectively. The higher ratio for phase I is designed for the additional material required around the perimeter of the first phase of cell. Lower ratios are required for subsequent phases of cell construction. The tables also outline the schedule of cell construction by: (1) initial work, (2) phase I, (3) phase II, (4) phase III, and (5) post-cell construction. This schedule is summarized in the following paragraphs.

Initial work. Initial work consists of preparatory work prior to construction of the phase I cell base. This includes: (1) pressure filtration of sludges and sediments requiring dewatering, (2) emptying and cleaning of

the clarifier ponds (for stormwater storage), (3) moving of UF6 cylinders from the phase I cell area, and (4) initiation of building demolition in the phase I cell area (incinerator building, solid waste building, and Bechtel building). The DUF4 building is just east of the phase I cell perimeter and can be demolished later.

The northeast corner of the disposal cell footprint is primarily concrete or asphalt that is unaffected by facility operations. The soil sampling and analysis program conducted by SFC in this area has verified that soils in this area meet cleanup criteria. The northeast portion of the cell would comprise the first phase of the cell construction sequence.

Phase I of the disposal cell would be constructed on top of the concrete or asphalt pads, with the liner system and perimeter berms forming the cell base. Following base construction, excavation of materials from the phase II area of the disposal cell would be placed in the phase I area. The stormwater retention berm would be raised as soils are available and as needed for freeboard requirements.

Phase II. After the phase II area foundation is cleaned up and the cell base is constructed, excavation of materials and building demolition debris from the phase III area would be placed in the phase II area of the cell. The stormwater retention berm would be raised as soils are available and as needed for freeboard requirements. Phase I and II areas may be joined into one working area.

If the filtered raffinate sludge is disposed on site, the disposal cell for the supersacks of filtercake would be disposed in the phase II area of the cell (as shown on the Drawings). The raffinate sludge disposal area would have an additional synthetic liner installed over the cover layer. This synthetic liner would be extended over the top of the supersacks of filtercake, to completely enclose the raffinate sludge within the disposal cell.

Phase III. After the phase III area foundation is cleaned up and the cell base is constructed, excavation of materials and building demolition debris from outside the cell footprint would be placed in the phase III area of the cell. The stormwater retention berm would be raised as soils are available and as needed for freeboard requirements. Phase I through III areas may be joined into one working area (as shown on the Drawings).

Work Prior to Cover Construction. Work at the end of disposal operations and prior to cover construction includes: (1) ensuring that materials to be disposed in the cell have been identified and placed in the cell; (2) ensuring that all contaminated site soils outside of the cell footprint have been identified, excavated, and placed in the cell; (3) grading and compacting the top surface of the disposed materials to required bottom-of-cover slopes and grades; and (4) smoothing the final bottom-of-cover surface for synthetic liner installation.

6.0 COVER CONSTRUCTION

The cover system is described in Section 4.4, and analysis of the cover performance with respect to NRC criteria is presented in MFG (2002b).

6.1 Construction Sequence

The construction sequence for the disposal cell cover is outlined below.

1. Compaction of the top surface and side slopes of material forming the base of the cover.
2. Construction of the cover on the side slopes of the disposal cell. The cover material could be placed in horizontal lifts or in lifts parallel to the outside 5:1 slopes. The rock mulch and topsoil would be placed as cover areas are completed to final slopes and grades.
3. Construction of the cover over the top surface of the cell, after the volume of contaminated soils has been established. The elevation of the top surface of the cell will be reduced if the final volume of material is less than 8 million cubic feet (due to higher compacted densities of disposed materials or lower actual volumes of materials).
4. Construction of the perimeter apron of the disposal cell to promote runoff away from the disposal cell and transition with surrounding reclaimed topography.
5. Establishment of vegetation on the disposal cell surface, consistent with the overall plan for revegetation.
6. Establishment and marking of settlement monuments, wells, sumps, and other monitoring features on the cell surface and perimeter.

6.2 Institutional Control

As described above, the disposal cell design is based on the site being transferred to the U.S. Department of Energy for long-term care and maintenance. As with other 11e.(2) byproduct material sites, the U.S. Department of Energy will exercise institutional control of the site. This means that the site will be fenced to limit unauthorized access. Activities within the institutional control boundary are only those authorized by the U.S. Department of Energy or its contractors, such as monitoring or maintenance. The proposed institutional control boundary for the SFC facility after reclamation is shown on the Drawings.

7.0 PERFORMANCE MONITORING AND VERIFICATION

The performance monitoring and verification tasks for the disposal cell are consistent with plans for overall site reclamation and review guidelines in NRC (2002). Key tasks are outlined in the following subsections, and address the period of time from site reclamation until property transfer to the U.S. Department of Energy.

7.1 Settlement

Since the soil-like disposal materials will be placed in lifts and compacted to minimize void spaces (as described above) and sludges will be pressure filtered or solidified, differential settlement will not be as critical an issue as for slurried uranium tailings impoundments. Disposal cell cover settlement has been evaluated and is documented in Appendix G. However, settlement will be monitored with survey monuments installed on a grid system on the cover surface. The monuments will be surveyed on a quarterly basis until four quarters of stable conditions (less than 0.1 foot of settlement) are measured.

7.2 Vegetative Cover

A revegetation plan has been prepared for the disposal cell surface outlining the species desired for the cell and the schedule and methods planned for achieving mature vegetation (such as institution of weed control). This revegetation plan is presented in the Technical Specifications. After establishment of the initial vegetation on the cover surface, the condition of the initial vegetation will be monitored for comparison with the revegetation plan. SFC will monitor the vegetation performance until that responsibility is changed with property transfer to the U.S. Department of Energy.

7.3 Erosional Stability

The erosional stability of the cover surface will be monitored on a semi-annual basis, most likely at the same time as vegetation monitoring. Elements of the erosional stability monitoring are degree of vegetation cover (in terms of surface coverage), identification of settled or ponded areas (such as on the top surface), and identification of rills, gullys, or other areas of runoff concentration. Areas that are identified will be monitored to determine if corrective action is necessary. Corrective action would include fill placement with topsoil or placement of erosion-resistant materials on the surface, such as rock mulch.

7.4 Groundwater Protection

The primary groundwater protection mechanism is the use of a liner that is "designed, constructed and installed to prevent any migration of wastes out of the impoundment to the adjacent subsurface soil, groundwater or surface water at any time during the active life (including the closure period) of the impoundment (10 CFR 40 Appendix A 5A[1])." The migration of wastes out of the impoundment is impeded by three design components. First, the cover system is designed to minimize meteoric water from infiltrating into the cell, by

using both a moisture retention and evapotranspiration zone and low permeability layer at the base of the cover. Secondly, any leachate from infiltrating meteoric water or drain down from disposed material within the cell will be collected in the leachate collection system and removed from the cell. Thirdly, a composite liner system, consisting of compacted clay and a synthetic liner will be in place as an additional barrier at the base of the cell.

Groundwater beneath and downgradient from the cell will be monitored in a two-step manner. First, the cell liner system has a leak detection component, as described in Section 4. The leak detection system will provide a timely indication should leakage from the cell occur. Second, five point-of-compliance (POC) wells downgradient and one upgradient, will be installed once the cell construction is complete. The wells will be completed in the clean fill that will replace excavated, contaminated soils. The wells will be completed in the clean fill material, above the underlying aquiclude (the Unit 1 Sandstone of the Atoka Formation) at the base of the well. Leakage from liner system would accumulate on the top of the Unit 1 Sandstone and be detected in these downgradient POC wells. The combination of the leak detection system and the wells placed in the clean fill comprise the groundwater monitoring for the cell that will "provide the earliest practical warning that the impoundment is releasing hazardous constituents to the groundwater."

The leak detection system will be visually monitored, with a water quality samples collected and analyzed, if leakage is present, for the parameters listed in Table 7.1. The POC wells will be monitored on a quarterly basis for the constituents listed in Table 7.1. These constituents are from the Groundwater Monitoring Plan (GWMP) and were incorporated into NRC License SUB-1010 as Condition 49.B. from Amendment 31 dated August 2005. The GWMP also includes a discussion of background groundwater quality, and well construction details. The GWMP will be revised to include the POC wells when they have been installed.

Table 7.1 Groundwater Monitoring Constituents

Antimony	Nickel
Arsenic	Nitrate (as N)
Barium	Selenium
Beryllium	Silver
Cadmium	Thallium
Chromium	Radium-226 and 228
Fluoride	
Lead	Thorium-230
Mercury	Uranium-Natural
Molybdenum	

8.0 REFERENCES

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APPENDIX A

MATERIAL PLACEMENT SEQUENCE

The materials to be disposed are summarized in Table A-1, based on tables in MFG (2002b) and information presented in SFC (1998). The planned disposal locations within the cell are included in the table. The planned construction and material sequence is presented in Table A.2, based on the material list in Table A.1.

Table A.1 Disposal Material Placement and Volume Summary

Material	SCU No.[a]	Layer No.[b]	Current Location	Current Volume (cu ft)[c]	In-Cell Volume (cu ft)	Weight (10^9 g)[c]	Handling or Treatment	Disposal Location	Comments
SLUDGES & SEDIMENTS									
Raffinate sludge	17	A	Outside cell	1,064,000	355,000 (33%)	6.76	Pressure filtered	Phase II cell (or off site)	Temporarily stored on yellowcake storage pad
Pond 2 residual materials	18	A	Outside cell	635,000	762,000 (120%)	17.8	Mixed with additive	Phase II cell	Mixed and transferred by contractor
Emergency basin sediment	6	A	Phase II cell	14,600	14,600	0.139	Excavated	Phase I cell (or off site)	Interior material
North ditch sediment	9	A	Phase II cell	20,770	20,770	0.198	Excavated	Phase I cell (or off site)	Interior material
Sanitary lagoon sediment	7	A	Phase II cell	10,365	10,365	0.099	Excavated	Phase I cell (or off site)	Interior material
Fluoride holding basin #1	13	C	Outside cell	171,400	171,400	2.62	Excavated	Phase III cell	Interior material
Fluoride holding basin #2	12	C	Outside cell	186,000	186,000	2.85	Excavated	Phase III cell	Interior material
Fluoride settling basins & clarifier	14	C	Outside cell	114,300	114,300	1.79	Excavated	Phase III cell	Interior material
Buried calcium fluoride	15	C	Outside cell	96,380	96,380	--	Excavated	Phase III cell	Interior material
Buried fluoride holding basin #1	15	C	Outside cell	57,200	57,200	0.875	Excavated	Phase III cell	Interior material
LINER SOILS & SUBSOILS									
Clarifier liners	17	B	Outside cell	332,400	332,400	16.6	Cleaned	-----	Used for stormwater
Calcium fluoride basin liner	12 - 14	B	Outside cell	95,285	95,285	4.76	Excavated	Phase III cell	-----
Pond 3E clay liner	24	B	Outside cell	88,232	88,232	4.41	Covered	Outside of cell	Reclaimed in place
Emergency basin soils	6	B	Phase II cell	162,500	162,500	8.12	Excavated	Phase I cell	Interior material
North ditch soils	9	B	Phase II cell	87,500	87,500	4.37	Excavated	Phase I cell	Interior material
Sanitary lagoon liner	7	B	Phase II cell	56,356	56,356	2.81	Excavated	Phase I cell	Interior material
BURIED MATERIALS/DRUMS									
Pond 1 spoils pile	8	B	Outside cell	437,400	437,400	21.8	Excavated	Phase II cell	Berm material
Interim storage cell	35	C	Outside cell	154,887	154,887	7.74	Excavated	Phase II cell	Berm material
Solid waste burials (No. 1)	5	C	Phase II cell	43,000	43,000	--	Excavated	Phase I cell	Berm & interior material
Solid waste burials (No. 2)	20	C	Outside cell	8,100	8,100	--	Excavated	Phase II cell	Berm material
UF6 cylinders	---	C	Phase I cell	155,000	15,500[d]	--	Moved	Phase III cell	Interior material
DUF_4 drummed contam. trash	29	C	Phase I cell	2,200	2,200	--	Moved	Phase I-III	Interior material
Other drummed contam. trash	--	C	Various	4,050	4,050	--	Moved	Phase I-III	Interior material
Empty contam. drums	--	C	Various	2,000	2,000	--	Moved	Phase I-III	Interior material

Table A.1 Disposal Material Placement and Volume Summary

Material	SCU No.[a]	Layer No.[b]	Current Location	Current Volume	In-Cell Volume (cu ft)	Weight (10^9 g)[c]	Handling or Treatment	Disposal Location	Comments
STRUCTURAL MATERIALS					568,660	51.6	--	--	--
Main process building	1	C	Phase III Cell	[2,178,000]	436,600	--	Demolished	Phase II Cell	--
Solvent extraction building	2	C	Phase III Cell	[180,000]	36,000	--	Demolished	Phase II Cell	--
DUF_4 building	29	C	Outside Cell	[281,000]	56,200	--	Demolished	Phase II Cell	--
ADU/Misc. digestion bldg	21	C	Phase III Cell	[75,000]	15,000	--	Demolished	Phase II Cell	--
Laundry building	17	C	Outside Cell	[12,500]	2,500	--	Demolished	Phase II Cell	--
Centrifuge building	17	C	Outside Cell	[15,000]	3,000	--	Demolished	Phase II Cell	--
Bechtel building	30	C	Phase I Cell	[27,000]	5,400	--	Demolished	Phase II Cell	Stored prior to Phase II
Solid waste building	10	C	Phase I Cell	[18,000]	3,600	--	Demolished	Phase II Cell	Stored prior to Phase II
Cooling tower	2	C	Phase III Cell	[30,000]	6,000	--	Demolished	Phase II Cell	--
RCC evaporator	2	C	Phase III Cell	[18,750]	3,750	--	Demolished	Phase II Cell	--
Incinerator	10	C	Phase I Cell	[7,500]	1,500	--	Demolished	Phase II Cell	Stored prior to Phase II
Concrete and asphalt	Various	C	Various	511,795	511,795	--	Excavated	Phase I-III	Stored as necessary
Scrap metal	--	C	Various	100,000	50,000	--	Moved	Phase I-III	Stored as necessary
Chipped pallets	--	B	Various	3,000	3,000	--	Moved	Phase I-III	Stored as necessary
SUBSOILS AND BEDROCK									
Contaminated materials	Various	D	Inside and Outside Cell	3,574,000	3,574,000	178.5	Excavated	Phase I - III Cells	Berm material

a Site characterization unit number from Section 4 of SCR (SFC, 1998).
b Layer number in general disposal sequence.
c Values are from Attachment III of SCR; values in brackets are calculated building volumes from floor area and building height; disposal volume is 20 percent of building volume.
d UF6 cylinders filled with calcium fluoride slurry or grout.

Table A.2 Disposal Cell Construction Sequence and Volume Summary

Phase	Cell Construction	Structure Demolition	Material Removal	Material Placement	Volume (cu ft)
Initial work	None		Remove raffinate sludge from clarifier ponds; pressure filter raffinate sludge and place in shipping bags	Store bags of filtered raffinate sludge on prepared area of yellowcake storage pad	355,000
			Clean clarifier pond liner and repair or re-line as necessary	Use cleaned clarifier ponds for storage of stormwater runoff from disposal cell	-----
			Move UF6 cylinders	Store on pad near DUF4 building	15,500
		Incinerator building	-----	Store debris on pad near DUF4 building	1,500
		Solid waste building	-----	Store debris on pad near DUF4 building	3,600
		Bechtel building	-----	Store debris on pad near DUF4 building	5,400
Phase I	Phase I cell base	-----	Constructed with on-site and off-site materials	Cell base constructed as multilayered system	[135,490 ft^2]
	Phase I berm	-----	Constructed with berm materials listed below	Berm materials placed on downhill sides of cell	-----
			Excavate Solid Waste Burial Area No. 1 soil cover	Dispose in Phase I area of cell, as berm material	23,000
			Excavate Solid Waste Burial Area No. 1 drums	Dispose in interior of Phase I area of cell	20,000
			Excavate Emergency Basin sediments	Dispose in interior of Phase I area of cell, Or ship offsite for uranium recovery	14,600
			Excavate Emergency Basin soils	Dispose in interior of Phase I area of cell	162,500
			Excavate North Ditch sediments	Dispose in interior of Phase I area of cell, Or ship offsite for uranium recovery	20,700
			Excavate North Ditch soils	Dispose in interior of Phase I area of cell	87,500
			Excavate Sanitary Lagoon sediments	Dispose in interior of Phase I area of cell, Or ship offsite for uranium recovery	10,365
			Excavate Sanitary Lagoon soil liner	Dispose in interior of Phase I area of cell	56,356
			Excavate contaminated soils in Phase II area (25% of contaminated soil volume)	Dispose in Phase I area of cell, as berm material	893,500
			PHASE I VOLUME TOTALS:	berm material: 916,500 cu ft; interior material: 372,021 cu ft	

Table A.2. Disposal Cell Construction Sequence and Volume Summary

Phase	Cell Construction	Structure Demolition	Material Removal	Material Placement	Volume (cu ft)
Phase II	Phase II cell base	-----	Constructed with on-site and off-site materials	Cell base constructed as multilayered system	[254,740 ft²]
	Phase II berm	-----	Constructed with berm materials listed below	Berm materials placed on downhill sides of cell	-----
			Excavate Pond 1 Spoil Pile material	Dispose in Phase II area of cell as berm material	437,400
			Excavate Solid Waste Burial Area No. 2 material	Dispose in Phase II area of cell as berm material	8,100
			Excavate Interim Storage Cell material	Dispose in Phase II area of cell as berm material	154,887
			Excavate contaminated soils north of disposal cell (10% of contaminated soil volume)	Dispose in Phase II area of cell as berm material	357,400
			Mix Pond 2 sediments and excavate	Dispose in interior of Phase II area of cell	762,000
		(Stockpiled debris)	Building debris from initial work	Dispose in interior of Phase II area of cell	10,500
		DUF4 building	-----	Dispose in interior of Phase II area of cell	56,200
		Evaporator	-----	Dispose in interior of Phase II area of cell	3,750
		Cooling tower	-----	Dispose in interior of Phase II area of cell	6,000
		SX building	-----	Dispose in interior of Phase II area of cell	36,000
		ADU/misc. dgst. Bldg	-----	Dispose in interior of Phase II area of cell	15,000
		Tank area	-----	Dispose in interior of Phase II area of cell	-----
		Laundry building	-----	Dispose in interior of Phase II area of cell	2,500
		Centrifuge building	-----	Dispose in interior of Phase II area of cell	3,000
		Main process bldg	-----	Dispose in interior of Phase II area of cell	435,600
	Raffinate sludge cell	-----	Constructed with on-site and off-site materials (if filtered sludge is disposed on site)	Sludge cell liner system inside of cell base liner system	-----
			Move bags of filtered raffinate sludge from yellowcake storage pad	Place bags in raffinate sludge cell inside Phase II area of cell (if disposed on site)	355,000
			Excavate concrete and soil from north side of yellowcake storage pad	Dispose in Phase I or II area of cell as berm material	120,000
			Excavate contaminated soils in Phase III area (40% of contaminated soil volume)	Dispose in Phase I or II area of cell as berm material	1,429,600
			PHASE II VOLUME TOTALS:	berm material: 2,507,387 cu ft; interior material: 1,680,050 cu ft	

Table A.2. Disposal Cell Construction Sequence and Volume Summary

Phase	Cell Construction	Structure Demolition	Material Removal	Material Placement	Volume (cu ft)
Phase III	Phase III cell base	-----	Constructed with on-site and off-site materials	Cell base constructed as multilayered system	[179,170 ft²]
	Phase III berm	-----	Constructed with berm materials listed below	Berm materials placed on downhill sides of cell	-----
		None	Excavate concrete and soil from south side of yellowcake storage pad	Dispose in Phase II or III area of cell as berm material	180,000
			Excavate contaminated soils south of disposal cell (25% of contaminated soil volume)	Dispose in Phase I-III areas of cell as berm material or subgrade fill for cover	893,500
			Move UF6 cylinders and cut end of cylinder	Place in Phase III area of cell for filling with CaF grout	15,500
			Excavate Calcium Fluoride Holding Basin No. 1	Dispose in interior of Phase III area of cell	171,400
			Excavate Calcium Fluoride Holding Basin No. 2	Dispose in interior of Phase I-II areas of cell	186,000
			Excavate North Calcium Fluoride Settling Basin	Dispose in interior of Phase III area of cell	44,300
			Excavate South Calcium Fluoride Settling Basin	Dispose in interior of Phase III area of cell	45,000
			Excavate Calcium Fluoride Clarifier	Dispose in interior of Phase III area of cell	25,000
			Excavate Calcium Fluoride Burial Area	Dispose in interior of Phase III area of cell	96,380
			Excavate remaining concrete and asphalt	Dispose in Phase I-III areas of cell as berm material or subgrade fill for cover	211,795
			Excavate clarifier pond liners	Dispose in Phase I-III areas of cell	332,400
			Move scrap metal and pallets	Dispose in interior of Phase III area of cell	53,000
Post Cell Const.	Cell subgrade fill	None	Berm materials above bottom-of-cover line moved	Cover subgrade surface based on amount of fill	-----
	Cell cover		Constructed with on-site and off-site materials	Cell cover constructed as multilayered system	-----
	Site regrading		-----	Exterior areas regraded for erosional stability	
			PHASE III VOLUME TOTALS:	berm material: 1,285,295 cu ft; internal material:	968,980 cu ft

APPENDIX B

RAFFINATE SLUDGE CHARACTERISTICS

B.1 BACKGROUND

This appendix summarizes the results of pressure filtration testing of raffinate sludge samples conducted by SFC. This work was done to assess methods of handling the sludge for subsequent on-site or off-site disposal. Pressure filtration (to pressures of over 200 psi) was found to be the most effective method of removing excess water from the raffinate sludge. Photographs by SFC of the filtered material are presented at the end of this appendix.

B.2 INITIAL CHARACTERISTICS

Based on moisture content testing of raffinate sludge in ESCI (1998), the oven-dried moisture content (by weight) of a sludge sample was 676.5 percent. Based on a specific gravity of solids of 2.7, the void ratio of this sample was 18.3, the corresponding solids content was 12.9 percent, and the dry density was 8.7 pcf.

From testing by SFC, the solids content of a raffinate sludge sample was 18 percent. Using a specific gravity of solids of 2.7, the corresponding void ratio is 12.3, the moisture content (by weight) is 456 percent, and the dry density is 12.7 pcf.

B.3 FILTERED CHARACTERISTICS

From testing by SFC in 2003, the filtered sludge or filtercake has a solids content of 42 percent. At a specific gravity of solids of 2.7, this corresponds to a moisture content (by weight) of 138 percent, a void ratio of 3.73, and a dry density of 35.6 pcf.

Other SFC data include a filtercake wet density of 1.36 grams/cc or 84.9 pcf. At a moisture content by weight (based on a 42 percent solid content) of 138 percent, the resulting dry density is 35.7 pcf, which is very similar to the 35.6 pcf value in the previous paragraph.

B.4 VOLUME CHANGE

In order to estimate the volume of filtered raffinate sludge if placed in the disposal cell, the difference in dry density (or void ratio) from the values above were used. The range of unfiltered dry densities is 8.7 to 12.7 pcf. The measured filtered dry density is 35.6 pcf, for filtercake immediately out of the filter press, as shown on the photographs. Assuming that the filtercake placed in the disposal cell would be 10 percent less dense, the disposed density would be 32 pcf. The ratios of dry densities before and after

filtration range from 2.5 to 3.7, with a mean value of 3.0. This means that the volume occupied by filtered sludge in the disposal cell is roughly 1/3 of the volume occupied by the same weight of sludge currently in the clarifier ponds.

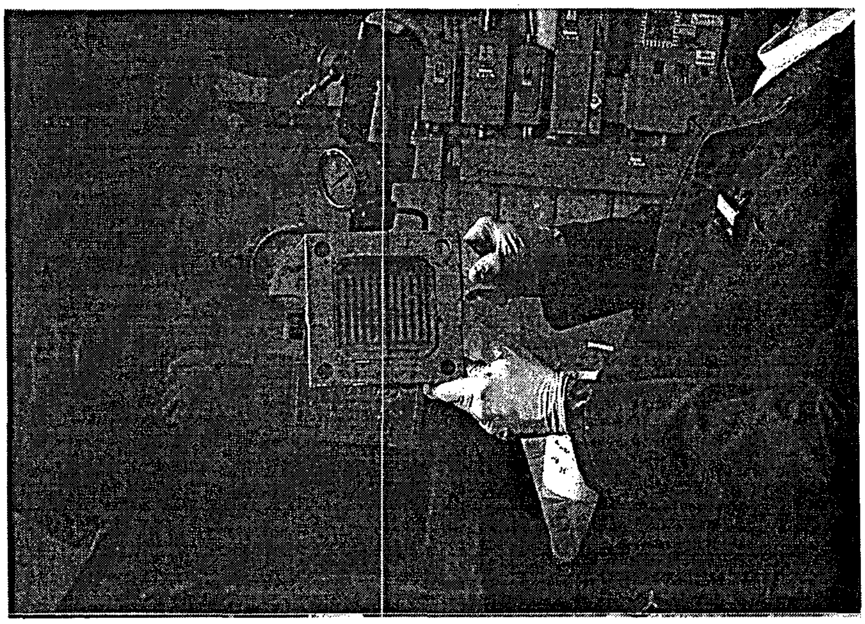

Photo B.1 Raffinate sludge after pressure filtration

Photo B.2 Raffinate sludge filtercake

APPENDIX C

RADON EMANATION

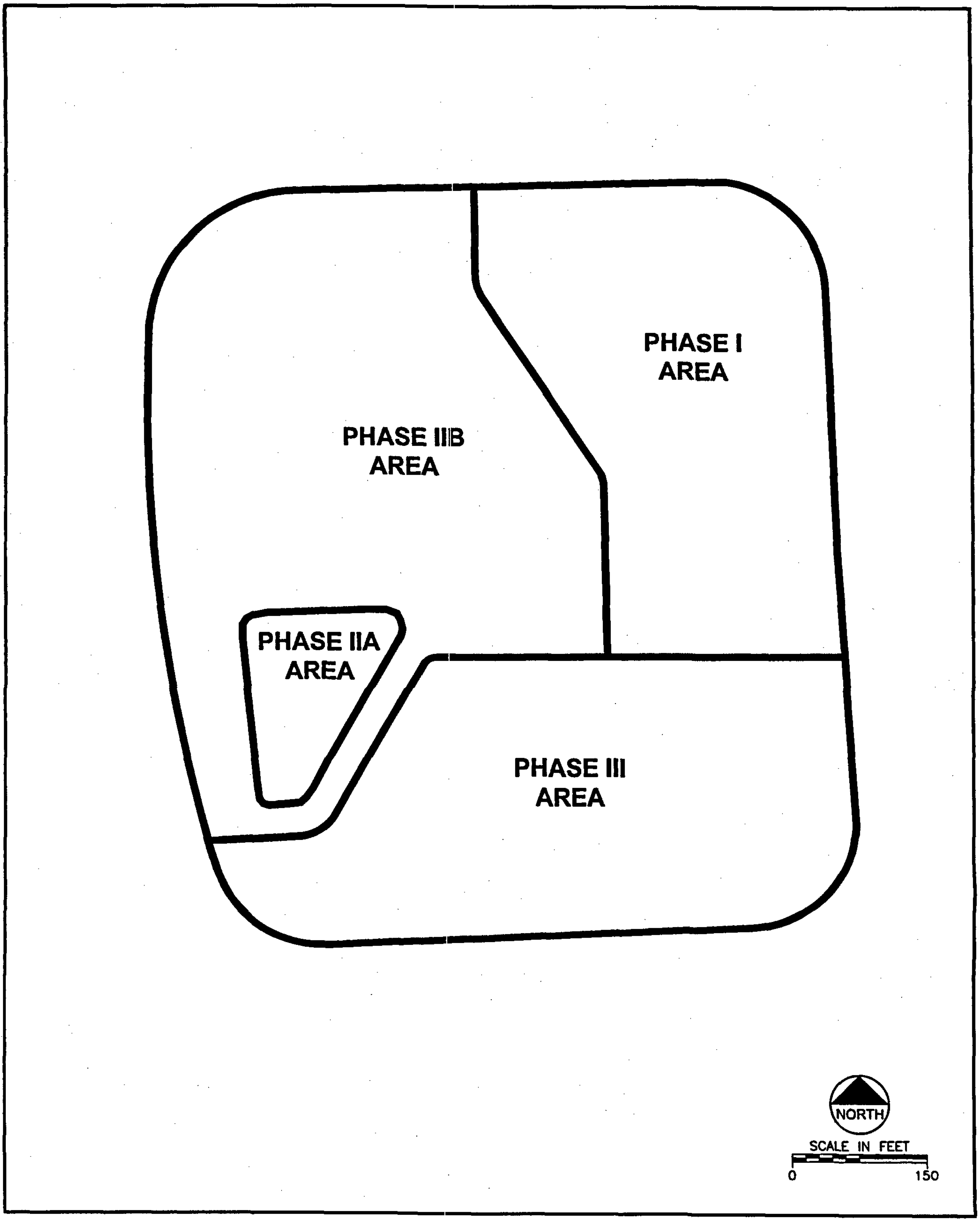

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FIGURE C.1
PLAN OF CELL SHOWING PHASE AREAS

Date:	APRIL 2005
Project:	180734
File:	CELL-FIG-PLAN

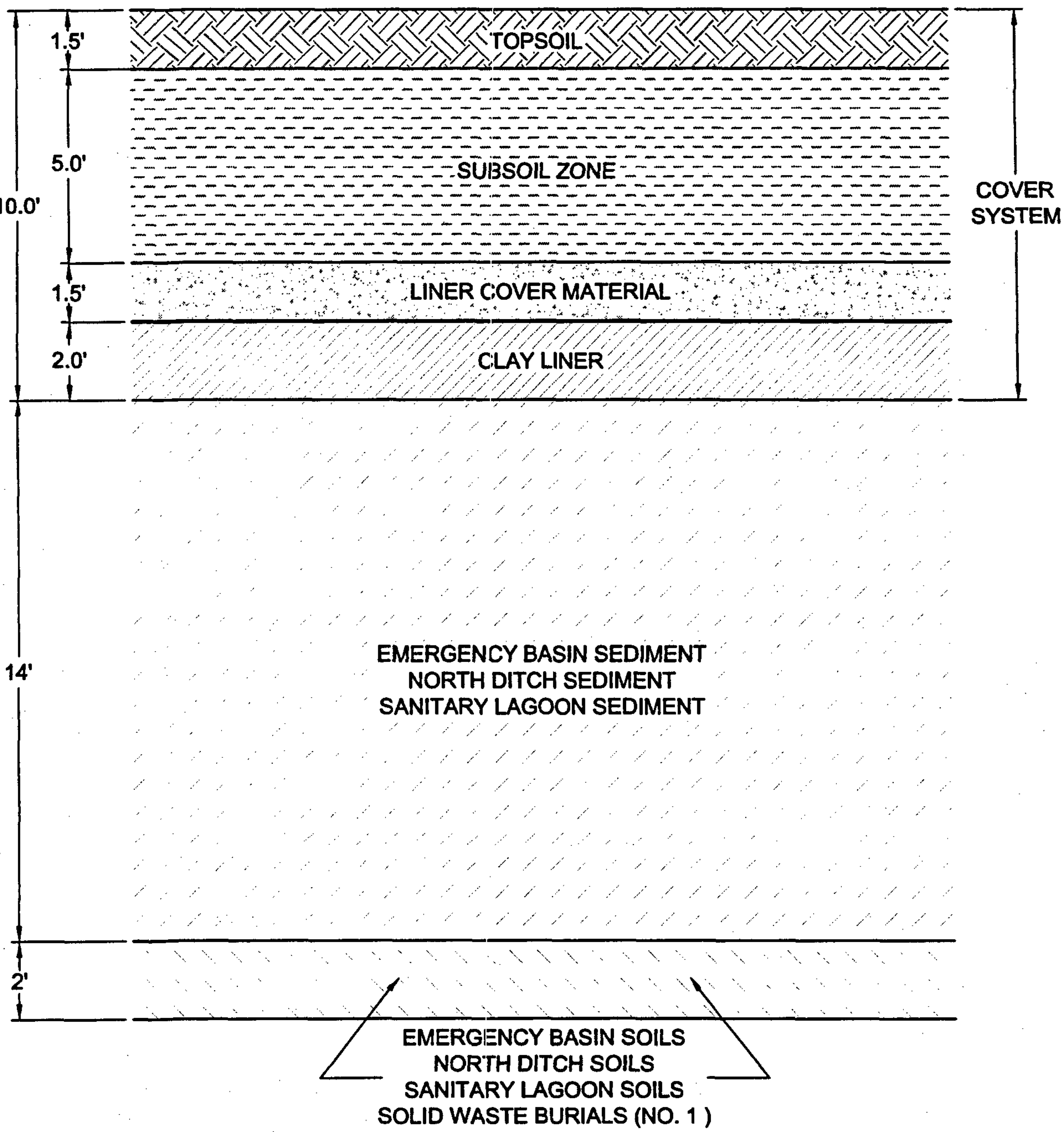

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FIGURE C.2
PHASE I AREA
TYPICAL INTERIOR CELL PROFILE

Date:	APRIL 2005
Project:	180734
File:	CELL-FIG-XS.DWG

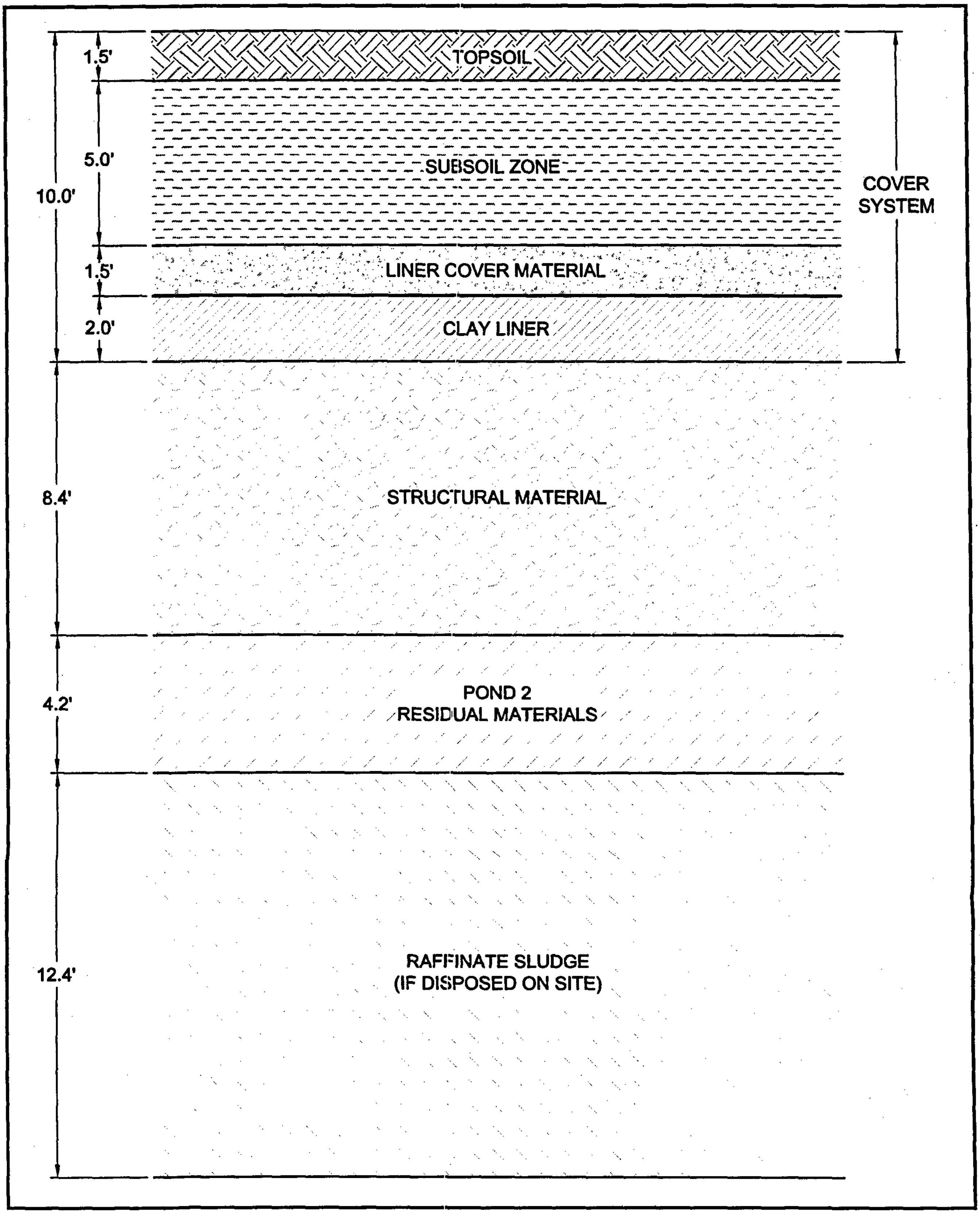

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FIGURE C.3
PHASE IIA AREA
TYPICAL INTERIOR CELL PROFILE

Date:	APRIL 2005
Project:	180734
File:	CELL-FIG-XS.DWG

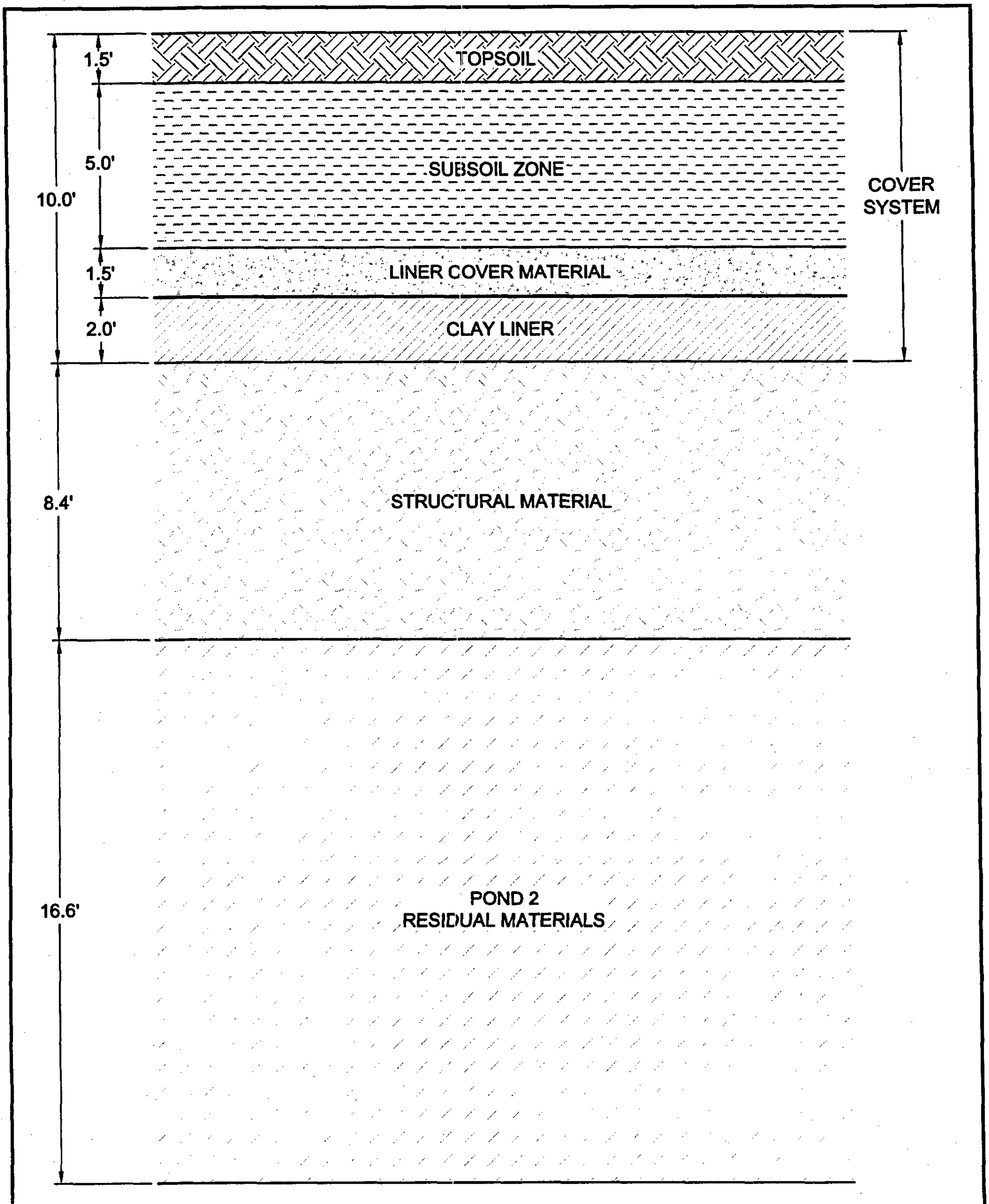

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FIGURE C.4
PHASE IIB AREA
TYPICAL INTERIOR CELL PROFILE

Date:	APRIL 2005
Project:	180734
File:	CELL-FIG-XS.DWG

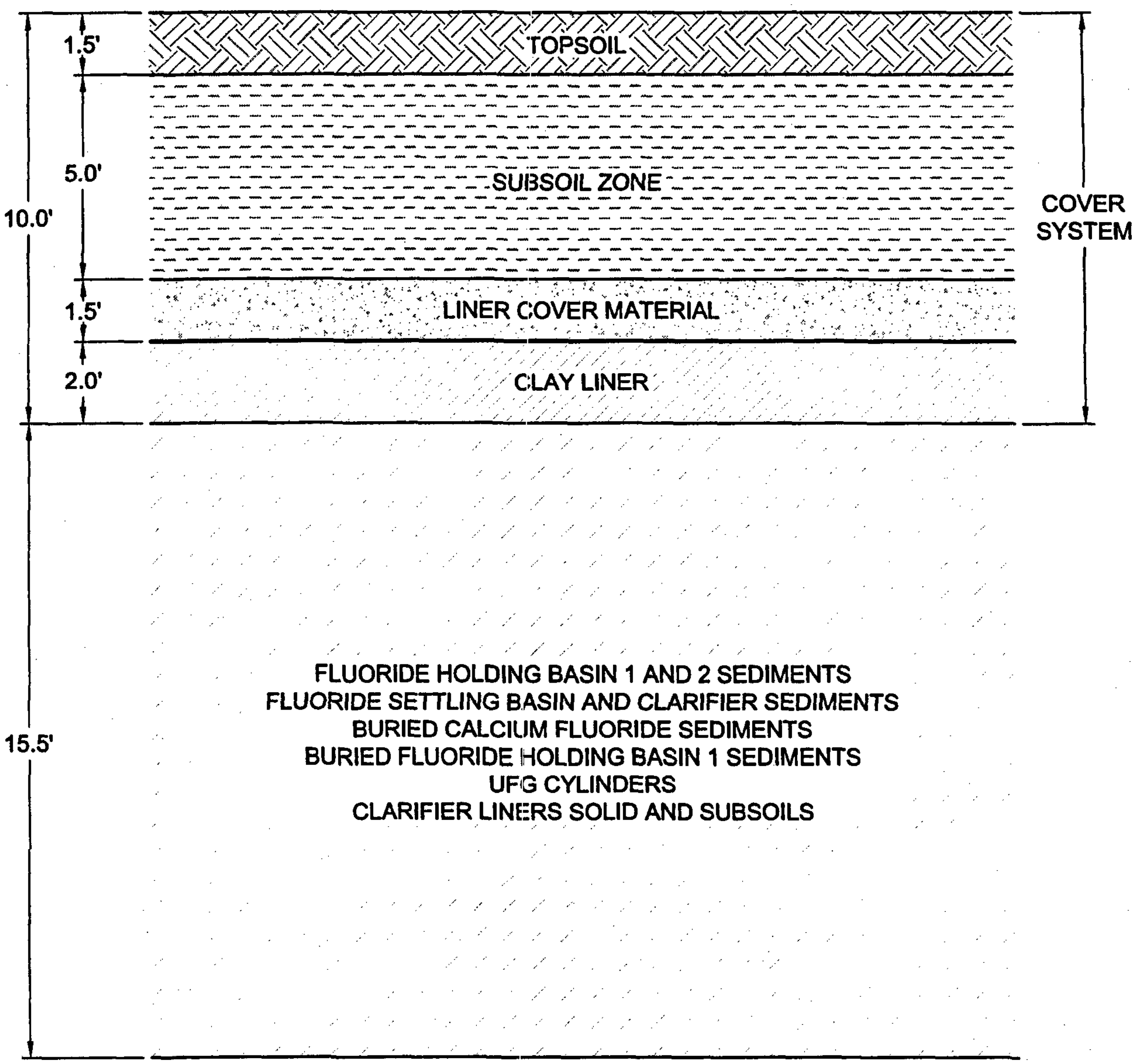

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FIGURE C.5
PHASE III AREA
TYPICAL INTERIOR CELL PROFILE

Date:	APRIL 2005
Project:	180734
File:	CELL-FIG-XS.DWG

ATTACHMENT C.2

RADON MODEL OUTPUT

-----*****! RADON !*********-----

Version 1.2 - MAY 22, 1989 - G.F. Birchard tel.# (301)492-7000
U.S. Nuclear Regulatory Commission Office of Research

RADON FLUX, CONCENTRATION AND TAILINGS COVER THICKNESS ARE CALCULATED FOR MULTIPLE LAYERS

OUTPUT FILE: phase I 95% ucl

AREA I

DESCRIPTION: no

CONSTANTS

RADON DECAY CONSTANT	.0000021	s^-1
RADON WATER/AIR PARTITION COEFFICIENT	.26	
DEFAULT SPECIFIC GRAVITY OF COVER & TAILINGS		2.65

GENERAL INPUT PARAMETERS

LAYERS OF COVER AND TAILINGS	6	
NO LIMIT ON RADON FLUX		
LAYER THICKNESS NOT OPTIMIZED		
DEFAULT SURFACE RADON CONCENTRATION	0	pCi l^-1
SURFACE FLUX PRECISION	.1	pCi m^-2 s^-1

LAYER INPUT PARAMETERS

LAYER 1 layer A

THICKNESS	61	cm
POROSITY	.7	
CALCULATED MASS DENSITY	.795	g cm^-3
MEASURED RADIUM ACTIVITY	3542	pCi/g^-1
DEFAULT LAYER EMANATION COEFFICIENT	.35	
CALCULATED SOURCE TERM CONCENTRATION	2.957D-03	pCi cm^-3 s^-1
WEIGHT % MOISTURE	15	%
MOISTURE SATURATION FRACTION	.170	
CALCULATED DIFFUSION COEFFICIENT	4.942D-02	cm^2 s^-1

LAYER 2 layer b-d

THICKNESS	426	cm
POROSITY	.4	
CALCULATED MASS DENSITY	1.59	g cm^-3
MEASURED RADIUM ACTIVITY	74.3	pCi/g^-1
DEFAULT LAYER EMANATION COEFFICIENT	.35	
CALCULATED SOURCE TERM CONCENTRATION	2.171D-04	pCi cm^-3 s^-1
WEIGHT % MOISTURE	6	%
MOISTURE SATURATION FRACTION	.238	
CALCULATED DIFFUSION COEFFICIENT	3.131D-02	cm^2 s^-1

LAYER 3 clay liner

THICKNESS	61	cm
POROSITY	.39	
CALCULATED MASS DENSITY	1.6165	g cm^-3
MEASURED RADIUM ACTIVITY	0	pCi/g^-1
DEFAULT LAYER EMANATION COEFFICIENT	.35	
CALCULATED SOURCE TERM CONCENTRATION	0.000D+00	pCi cm^-3 s^-1
WEIGHT % MOISTURE	15	%
MOISTURE SATURATION FRACTION	.622	
CALCULATED DIFFUSION COEFFICIENT	5.861D-03	cm^2 s^-1

LAYER 4 liner cover

THICKNESS	46	cm
POROSITY	.4	
CALCULATED MASS DENSITY	1.59	g cm^-3
MEASURED RADIUM ACTIVITY	0	pCi/g^-1
DEFAULT LAYER EMANATION COEFFICIENT	.35	
CALCULATED SOURCE TERM CONCENTRATION	0.000D+00	pCi cm^-3 s^-1
WEIGHT % MOISTURE	6	%
MOISTURE SATURATION FRACTION	.238	
CALCULATED DIFFUSION COEFFICIENT	3.131D-02	cm^2 s^-1

LAYER 5 subsoil

THICKNESS	152	cm
POROSITY	.45	
CALCULATED MASS DENSITY	1.4575	g cm^-3
MEASURED RADIUM ACTIVITY	0	pCi/g^-1
DEFAULT LAYER EMANATION COEFFICIENT	.35	
CALCULATED SOURCE TERM CONCENTRATION	0.000D+00	pCi cm^-3 s^-1
WEIGHT % MOISTURE	15	%
MOISTURE SATURATION FRACTION	.486	
CALCULATED DIFFUSION COEFFICIENT	1.334D-02	cm^2 s^-1

LAYER 6 topsoil

THICKNESS	46	cm
POROSITY	.49	
CALCULATED MASS DENSITY	1.3515	g cm^-3
MEASURED RADIUM ACTIVITY	0	pCi/g^-1
DEFAULT LAYER EMANATION COEFFICIENT	.35	
CALCULATED SOURCE TERM CONCENTRATION	0.000D+00	pCi cm^-3 s^-1
WEIGHT % MOISTURE	6	%
MOISTURE SATURATION FRACTION	.165	
CALCULATED DIFFUSION COEFFICIENT	4.231D-02	cm^2 s^-1

DATA SENT TO THE FILE 'RNDATA' ON DRIVE A:

N	F01	CN1	ICOST	CRITJ	ACC
6	-1.000D+00	0.000D+00	0	0.000D+00	1.000D-01

LAYER	DX	D	P	Q	XMS	RHO
1	6.100D+01	4.942D-02	7.000D-01	2.957D-03	1.704D-01	0.795
2	4.260D+02	3.131D-02	4.000D-01	2.171D-04	2.385D-01	1.590
3	6.100D+01	5.861D-03	3.900D-01	0.000D+00	6.217D-01	1.617
4	4.600D+01	3.131D-02	4.000D-01	0.000D+00	2.385D-01	1.590
5	1.520D+02	1.334D-02	4.500D-01	0.000D+00	4.858D-01	1.458
6	4.600D+01	4.231D-02	4.900D-01	0.000D+00	1.655D-01	1.352

BARE SOURCE FLUX FROM LAYER 1: 1.021D+03 pCi m^-2 s^-1

RESULTS OF THE RADON DIFFUSION CALCULATIONS

LAYER	THICKNESS (cm)	EXIT FLUX (pCi m^-2 s^-1)	EXIT CONC. (pCi l^-1)
1	6.100D+01	4.935D+02	6.192D+05
2	4.260D+02	3.175D+01	1.018D+05
3	6.100D+01	1.412D+01	1.151D+04
4	4.600D+01	8.192D+00	1.351D+04
5	1.520D+02	2.139D+00	3.347D+02
6	4.600D+01	2.031D+00	0.000D+00

-----*****! RADON !*****-----

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RADON FLUX, CONCENTRATION AND TAILINGS COVER THICKNESS ARE CALCULATED FOR MULTIPLE LAYERS

OUTPUT FILE: raff storage 95% UCL for Ra

AREA II A

DESCRIPTION: no

CONSTANTS

RADON DECAY CONSTANT	.0000021	s^-1
RADON WATER/AIR PARTITION COEFFICIENT	.26	
DEFAULT SPECIFIC GRAVITY OF COVER & TAILINGS	2.65	

GENERAL INPUT PARAMETERS

LAYERS OF COVER AND TAILINGS	7	
NO LIMIT ON RADON FLUX		
LAYER THICKNESS NOT OPTIMIZED		
DEFAULT SURFACE RADON CONCENTRATION	0	pCi l^-1
SURFACE FLUX PRECISION	.1	pCi m^-2 s^-1

LAYER INPUT PARAMETERS

LAYER 1 *raff sludge*

THICKNESS	377	cm
POROSITY	.8	
CALCULATED MASS DENSITY	.5299999999999999	g cm^-3
MEASURED RADIUM ACTIVITY	7183	pCi/g^-1
DEFAULT LAYER EMANATION COEFFICIENT	.35	
CALCULATED SOURCE TERM CONCENTRATION	3.498D-03	pCi cm^-3 s^-1
WEIGHT % MOISTURE	100	%
MOISTURE SATURATION FRACTION	.662	
CALCULATED DIFFUSION COEFFICIENT	1.618D-02	cm^2 s^-1

LAYER 2 pond 2

THICKNESS	128	cm
POROSITY	.7	
CALCULATED MASS DENSITY	.795	g cm^-3
MEASURED RADIUM ACTIVITY	1038	pCi/g^-1
DEFAULT LAYER EMANATION COEFFICIENT	.35	
CALCULATED SOURCE TERM CONCENTRATION	8.665D-04	pCi cm^-3 s^-1
WEIGHT % MOISTURE	15	%
MOISTURE SATURATION FRACTION	.170	
CALCULATED DIFFUSION COEFFICIENT	4.942D-02	cm^2 s^-1

LAYER 3 struct debris

THICKNESS	256	cm
POROSITY	.2	
CALCULATED MASS DENSITY	2.12	g cm^-3
MEASURED RADIUM ACTIVITY	30.9	pCi/g^-1
DEFAULT LAYER EMANATION COEFFICIENT	.35	
CALCULATED SOURCE TERM CONCENTRATION	2.407D-04	pCi cm^-3 s^-1
WEIGHT % MOISTURE	6	%
MOISTURE SATURATION FRACTION	.636	
CALCULATED DIFFUSION COEFFICIENT	4.015D-03	cm^2 s^-1

LAYER 4 clay liner

THICKNESS	61	cm
POROSITY	.39	
CALCULATED MASS DENSITY	1.6165	g cm^-3
MEASURED RADIUM ACTIVITY	0	pCi/g^-1
DEFAULT LAYER EMANATION COEFFICIENT	.35	
CALCULATED SOURCE TERM CONCENTRATION	0.000D+00	pCi cm^-3 s^-1
WEIGHT % MOISTURE	15	%
MOISTURE SATURATION FRACTION	.622	
CALCULATED DIFFUSION COEFFICIENT	5.861D-03	cm^2 s^-1

LAYER 5 liner cover

THICKNESS	46	cm
POROSITY	.4	
CALCULATED MASS DENSITY	1.59	g cm^-3
MEASURED RADIUM ACTIVITY	0	pCi/g^-1
DEFAULT LAYER EMANATION COEFFICIENT	.35	
CALCULATED SOURCE TERM CONCENTRATION	0.000D+00	pCi cm^-3 s^-1
WEIGHT % MOISTURE	6	%
MOISTURE SATURATION FRACTION	.238	
CALCULATED DIFFUSION COEFFICIENT	3.131D-02	cm^2 s^-1

LAYER 6 subsoil

THICKNESS	152	cm
POROSITY	.45	
CALCULATED MASS DENSITY	1.4575	g cm^-3
MEASURED RADIUM ACTIVITY	0	pCi/g^-1
DEFAULT LAYER EMANATION COEFFICIENT	.35	
CALCULATED SOURCE TERM CONCENTRATION	0.000D+00	pCi cm^-3 s^-1
WEIGHT % MOISTURE	15	%
MOISTURE SATURATION FRACTION	.486	
CALCULATED DIFFUSION COEFFICIENT	1.334D-02	cm^2 s^-1

LAYER 7 topsoil

THICKNESS	46	cm
POROSITY	.49	
CALCULATED MASS DENSITY	1.3515	g cm^-3
MEASURED RADIUM ACTIVITY	0	pCi/g^-1
DEFAULT LAYER EMANATION COEFFICIENT	.35	
CALCULATED SOURCE TERM CONCENTRATION	0.000D+00	pCi cm^-3 s^-1
WEIGHT % MOISTURE	6	%
MOISTURE SATURATION FRACTION	.165	
CALCULATED DIFFUSION COEFFICIENT	4.231D-02	cm^2 s^-1

DATA SENT TO THE FILE `RNDATA' ON DRIVE A:

N	F01	CN1	ICOST	CRITJ	ACC
7	-1.000D+00	0.000D+00	0	0.000D+00	1.000D-01

LAYER	DX	D	P	Q	XMS	RHO
1	3.770D+02	1.618D-02	8.000D-01	3.498D-03	6.625D-01	0.530
2	1.280D+02	4.942D-02	7.000D-01	8.665D-04	1.704D-01	0.795
3	2.560D+02	4.015D-03	2.000D-01	2.407D-04	6.360D-01	2.120
4	6.100D+01	5.861D-03	3.900D-01	0.000D+00	6.217D-01	1.617
5	4.600D+01	3.131D-02	4.000D-01	0.000D+00	2.385D-01	1.590
6	1.520D+02	1.334D-02	4.500D-01	0.000D+00	4.858D-01	1.458
7	4.600D+01	4.231D-02	4.900D-01	0.000D+00	1.655D-01	1.352

BARE SOURCE FLUX FROM LAYER 1: 2.422D+03 pCi m^-2 s^-1

RESULTS OF THE RADON DIFFUSION CALCULATIONS

LAYER	THICKNESS (cm)	EXIT FLUX (pCi m^-2 s^-1)	EXIT CONC. (pCi l^-1)
1	3.770D+02	1.350D+03	7.273D+05
2	1.280D+02	8.971D+01	9.950D+05
3	2.560D+02	1.565D+01	3.224D+04
4	6.100D+01	6.960D+00	5.673D+03
5	4.600D+01	4.037D+00	6.657D+03
6	1.520D+02	1.054D+00	1.649D+02
7	4.600D+01	1.001D+00	0.000D+00

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RADON FLUX, CONCENTRATION AND TAILINGS COVER THICKNESS ARE CALCULATED FOR MULTIPLE LAYERS

OUTPUT FILE: phase 2 wo raff

AREA II B

DESCRIPTION: no

CONSTANTS

RADON DECAY CONSTANT	.0000021	s^-1
RADON WATER/AIR PARTITION COEFFICIENT	.26	
DEFAULT SPECIFIC GRAVITY OF COVER & TAILINGS	2.65	

GENERAL INPUT PARAMETERS

LAYERS OF COVER AND TAILINGS	6	
NO LIMIT ON RADON FLUX		
LAYER THICKNESS NOT OPTIMIZED		
DEFAULT SURFACE RADON CONCENTRATION	0	pCi l^-1
SURFACE FLUX PRECISION	.1	pCi m^-2 s^-1

LAYER INPUT PARAMETERS

LAYER 1 pond 2

THICKNESS	505	cm
POROSITY	.7	
CALCULATED MASS DENSITY	.795	g cm^-3
MEASURED RADIUM ACTIVITY	1038	pCi/g^-1
DEFAULT LAYER EMANATION COEFFICIENT	.35	
CALCULATED SOURCE TERM CONCENTRATION	8.665D-04	pCi cm^-3 s^-1
WEIGHT % MOISTURE	15	%
MOISTURE SATURATION FRACTION	.170	
CALCULATED DIFFUSION COEFFICIENT	4.942D-02	cm^2 s^-1

LAYER 2 struct debris

THICKNESS	256	cm
POROSITY	.2	
CALCULATED MASS DENSITY	2.12	g cm^-3
MEASURED RADIUM ACTIVITY	30.9	pCi/g^-1
DEFAULT LAYER EMANATION COEFFICIENT	.35	
CALCULATED SOURCE TERM CONCENTRATION	2.407D-04	pCi cm^-3 s^-1
WEIGHT % MOISTURE	6	%
MOISTURE SATURATION FRACTION	.636	
CALCULATED DIFFUSION COEFFICIENT	4.015D-03	cm^2 s^-1

LAYER 3 clay liner

THICKNESS	61	cm
POROSITY	.39	
CALCULATED MASS DENSITY	1.6165	g cm^-3
MEASURED RADIUM ACTIVITY	0	pCi/g^-1
DEFAULT LAYER EMANATION COEFFICIENT	.35	
CALCULATED SOURCE TERM CONCENTRATION	0.000D+00	pCi cm^-3 s^-1
WEIGHT % MOISTURE	15	%
MOISTURE SATURATION FRACTION	.622	
CALCULATED DIFFUSION COEFFICIENT	5.861D-03	cm^2 s^-1

LAYER 4 liner cover

THICKNESS	46	cm
POROSITY	.4	
CALCULATED MASS DENSITY	1.59	g cm^-3
MEASURED RADIUM ACTIVITY	0	pCi/g^-1
DEFAULT LAYER EMANATION COEFFICIENT	.35	
CALCULATED SOURCE TERM CONCENTRATION	0.000D+00	pCi cm^-3 s^-1
WEIGHT % MOISTURE	6	%
MOISTURE SATURATION FRACTION	.238	
CALCULATED DIFFUSION COEFFICIENT	3.131D-02	cm^2 s^-1

LAYER 5 subsoil

THICKNESS	152	cm
POROSITY	.45	
CALCULATED MASS DENSITY	1.4575	g cm^-3
MEASURED RADIUM ACTIVITY	0	pCi/g^-1
DEFAULT LAYER EMANATION COEFFICIENT	.35	
CALCULATED SOURCE TERM CONCENTRATION	0.000D+00	pCi cm^-3 s^-1
WEIGHT % MOISTURE	15	%
MOISTURE SATURATION FRACTION	.486	
CALCULATED DIFFUSION COEFFICIENT	1.334D-02	cm^2 s^-1

LAYER 6 topsoil

THICKNESS	46	cm
POROSITY	.49	
CALCULATED MASS DENSITY	1.3515	g cm^-3
MEASURED RADIUM ACTIVITY	0	pCi/g^-1
DEFAULT LAYER EMANATION COEFFICIENT	.35	
CALCULATED SOURCE TERM CONCENTRATION	0.000D+00	pCi cm^-3 s^-1
WEIGHT % MOISTURE	6	%
MOISTURE SATURATION FRACTION	.165	
CALCULATED DIFFUSION COEFFICIENT	4.231D-02	cm^2 s^-1

DATA SENT TO THE FILE `RNDATA' ON DRIVE A:

N	F01	CN1	ICOST	CRITJ	ACC
6	-1.000D+00	0.000D+00	0	0.000D+00	1.000D-01

LAYER	DX	D	P	Q	XMS	RHO
1	5.050D+02	4.942D-02	7.000D-01	8.665D-04	1.704D-01	0.795
2	2.560D+02	4.015D-03	2.000D-01	2.407D-04	6.360D-01	2.120
3	6.100D+01	5.861D-03	3.900D-01	0.000D+00	6.217D-01	1.617
4	4.600D+01	3.131D-02	4.000D-01	0.000D+00	2.385D-01	1.590
5	1.520D+02	1.334D-02	4.500D-01	0.000D+00	4.858D-01	1.458
6	4.600D+01	4.231D-02	4.900D-01	0.000D+00	1.655D-01	1.352

BARE SOURCE FLUX FROM LAYER 1: 8.948D+02 pCi m^-2 s^-1

RESULTS OF THE RADON DIFFUSION CALCULATIONS

LAYER	THICKNESS (cm)	EXIT FLUX (pCi m^-2 s^-1)	EXIT CONC. (pCi l^-1)
1	5.050D+02	2.220D+01	3.880D+05
2	2.560D+02	1.537D+01	3.166D+04
3	6.100D+01	6.835D+00	5.571D+03
4	4.600D+01	3.964D+00	6.537D+03
5	1.520D+02	1.035D+00	1.620D+02
6	4.600D+01	9.829D-01	0.000D+00

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RADON FLUX, CONCENTRATION AND TAILINGS COVER THICKNESS ARE CALCULATED FOR MULTIPLE LAYERS

OUTPUT FILE: phase 3

AREA III

DESCRIPTION: no

CONSTANTS

RADON DECAY CONSTANT	.0000021	s^-1
RADON WATER/AIR PARTITION COEFFICIENT	.26	
DEFAULT SPECIFIC GRAVITY OF COVER & TAILINGS		2.65

GENERAL INPUT PARAMETERS

LAYERS OF COVER AND TAILINGS	5	
NO LIMIT ON RADON FLUX		
LAYER THICKNESS NOT OPTIMIZED		
DEFAULT SURFACE RADON CONCENTRATION	0	pCi l^-1
SURFACE FLUX PRECISION	.1	pCi m^-2 s^-1

LAYER INPUT PARAMETERS

LAYER 1 layer b-d

THICKNESS	457	cm
POROSITY	.7	
CALCULATED MASS DENSITY	.795	g cm^-3
MEASURED RADIUM ACTIVITY	32.9	pCi/g^-1
DEFAULT LAYER EMANATION COEFFICIENT	.35	
CALCULATED SOURCE TERM CONCENTRATION	2.746D-05	pCi cm^-3 s^-1
WEIGHT % MOISTURE	15	%
MOISTURE SATURATION FRACTION	.170	
CALCULATED DIFFUSION COEFFICIENT	4.942D-02	cm^2 s^-1

LAYER 2 clay liner

THICKNESS	61	cm
POROSITY	.39	
CALCULATED MASS DENSITY	1.6165	g cm^-3
MEASURED RADIUM ACTIVITY	0	pCi/g^-1
DEFAULT LAYER EMANATION COEFFICIENT	.35	
CALCULATED SOURCE TERM CONCENTRATION	0.000D+00	pCi cm^-3 s^-1
WEIGHT % MOISTURE	15	%
MOISTURE SATURATION FRACTION	.622	
CALCULATED DIFFUSION COEFFICIENT	5.861D-03	cm^2 s^-1

LAYER 3 liner cover

THICKNESS	46	cm
POROSITY	.4	
CALCULATED MASS DENSITY	1.59	g cm^-3
MEASURED RADIUM ACTIVITY	0	pCi/g^-1
DEFAULT LAYER EMANATION COEFFICIENT	.35	
CALCULATED SOURCE TERM CONCENTRATION	0.000D+00	pCi cm^-3 s^-1
WEIGHT % MOISTURE	6	%
MOISTURE SATURATION FRACTION	.238	
CALCULATED DIFFUSION COEFFICIENT	3.131D-02	cm^2 s^-1

LAYER 4 subsoil

THICKNESS	152	cm
POROSITY	.45	
CALCULATED MASS DENSITY	1.4575	g cm^-3
MEASURED RADIUM ACTIVITY	0	pCi/g^-1
DEFAULT LAYER EMANATION COEFFICIENT	.35	
CALCULATED SOURCE TERM CONCENTRATION	0.000D+00	pCi cm^-3 s^-1
WEIGHT % MOISTURE	15	%
MOISTURE SATURATION FRACTION	.486	
CALCULATED DIFFUSION COEFFICIENT	1.334D-02	cm^2 s^-1

LAYER 5 topsoil

THICKNESS	46	cm
POROSITY	.49	
CALCULATED MASS DENSITY	1.3515	g cm^-3
MEASURED RADIUM ACTIVITY	0	pCi/g^-1
DEFAULT LAYER EMANATION COEFFICIENT	.35	
CALCULATED SOURCE TERM CONCENTRATION	0.000D+00	pCi cm^-3 s^-1
WEIGHT % MOISTURE	6	%
MOISTURE SATURATION FRACTION	.165	
CALCULATED DIFFUSION COEFFICIENT	4.231D-02	cm^2 s^-1

DATA SENT TO THE FILE 'RNDATA' ON DRIVE A:

N	F01	CN1	ICOST	CRITJ	ACC
5	-1.000D+00	0.000D+00	0	0.000D+00	1.000D-01

LAYER	DX	D	P	Q	XMS	RHO
1	4.570D+02	4.942D-02	7.000D-01	2.746D-05	1.704D-01	0.795
2	6.100D+01	5.861D-03	3.900D-01	0.000D+00	6.217D-01	1.617
3	4.600D+01	3.131D-02	4.000D-01	0.000D+00	2.385D-01	1.590
4	1.520D+02	1.334D-02	4.500D-01	0.000D+00	4.858D-01	1.458
5	4.600D+01	4.231D-02	4.900D-01	0.000D+00	1.655D-01	1.352

BARE SOURCE FLUX FROM LAYER 1: 2.793D+01 pCi m^-2 s^-1

RESULTS OF THE RADON DIFFUSION CALCULATIONS

LAYER	THICKNESS (cm)	EXIT FLUX (pCi m^-2 s^-1)	EXIT CONC. (pCi l^-1)
1	4.570D+02	3.236D+00	1.101D+04
2	6.100D+01	1.439D+00	1.173D+03
3	4.600D+01	8.349D-01	1.377D+03
4	1.520D+02	2.180D-01	3.411D+01
5	4.600D+01	2.070D-01	0.000D+00

-----*****! RADON !*********-----

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RADON FLUX, CONCENTRATION AND TAILINGS COVER THICKNESS ARE CALCULATED FOR MULTIPLE LAYERS

OUTPUT FILE: raff sludge - lower debris density

DESCRIPTION: no   AREA II A – Low Debris Density

CONSTANTS

RADON DECAY CONSTANT	.0000021	s^-1
RADON WATER/AIR PARTITION COEFFICIENT	.26	
DEFAULT SPECIFIC GRAVITY OF COVER & TAILINGS	2.65	

GENERAL INPUT PARAMETERS

LAYERS OF COVER AND TAILINGS	7	
NO LIMIT ON RADON FLUX		
LAYER THICKNESS NOT OPTIMIZED		
DEFAULT SURFACE RADON CONCENTRATION	0	pCi l^-1
SURFACE FLUX PRECISION	.1	pCi m^-2 s^-1

LAYER INPUT PARAMETERS

LAYER 1   raff sludge

THICKNESS	377	cm
POROSITY	.8	
CALCULATED MASS DENSITY	.5299999999999999	g cm^-3
MEASURED RADIUM ACTIVITY	7183	pCi/g^-1
DEFAULT LAYER EMANATION COEFFICIENT	.35	
CALCULATED SOURCE TERM CONCENTRATION	3.498D-03	pCi cm^-3 s^-1
WEIGHT % MOISTURE	100	%
MOISTURE SATURATION FRACTION	.662	
CALCULATED DIFFUSION COEFFICIENT	1.618D-02	cm^2 s^-1

LAYER 2   pond 2

THICKNESS	128	cm
POROSITY	.7	
CALCULATED MASS DENSITY	.795	g cm^-3
MEASURED RADIUM ACTIVITY	1038	pCi/g^-1
DEFAULT LAYER EMANATION COEFFICIENT	.35	
CALCULATED SOURCE TERM CONCENTRATION	8.665D-04	pCi cm^-3 s^-1
WEIGHT % MOISTURE	15	%
MOISTURE SATURATION FRACTION	.170	
CALCULATED DIFFUSION COEFFICIENT	4.942D-02	cm^2 s^-1

LAYER 3 struc debris

THICKNESS	256	cm
POROSITY	.4	
CALCULATED MASS DENSITY	1.59	g cm^-3
MEASURED RADIUM ACTIVITY	30.9	pCi/g^-1
DEFAULT LAYER EMANATION COEFFICIENT	.35	
CALCULATED SOURCE TERM CONCENTRATION	9.028D-05	pCi cm^-3 s^-1
WEIGHT % MOISTURE	6	%
MOISTURE SATURATION FRACTION	.238	
CALCULATED DIFFUSION COEFFICIENT	3.131D-02	cm^2 s^-1

LAYER 4 clay liner

THICKNESS	61	cm
POROSITY	.39	
CALCULATED MASS DENSITY	1.6165	g cm^-3
MEASURED RADIUM ACTIVITY	0	pCi/g^-1
DEFAULT LAYER EMANATION COEFFICIENT	.35	
CALCULATED SOURCE TERM CONCENTRATION	0.000D+00	pCi cm^-3 s^-1
WEIGHT % MOISTURE	15	%
MOISTURE SATURATION FRACTION	.622	
CALCULATED DIFFUSION COEFFICIENT	5.861D-03	cm^2 s^-1

LAYER 5 liner cover

THICKNESS	46	cm
POROSITY	.4	
CALCULATED MASS DENSITY	1.59	g cm^-3
MEASURED RADIUM ACTIVITY	0	pCi/g^-1
DEFAULT LAYER EMANATION COEFFICIENT	.35	
CALCULATED SOURCE TERM CONCENTRATION	0.000D+00	pCi cm^-3 s^-1
WEIGHT % MOISTURE	6	%
MOISTURE SATURATION FRACTION	.238	
CALCULATED DIFFUSION COEFFICIENT	3.131D-02	cm^2 s^-1

LAYER 6 subsoil

THICKNESS	152	cm
POROSITY	.45	
CALCULATED MASS DENSITY	1.4575	g cm^-3
MEASURED RADIUM ACTIVITY	0	pCi/g^-1
DEFAULT LAYER EMANATION COEFFICIENT	.35	
CALCULATED SOURCE TERM CONCENTRATION	0.000D+00	pCi cm^-3 s^-1
WEIGHT % MOISTURE	15	%
MOISTURE SATURATION FRACTION	.486	
CALCULATED DIFFUSION COEFFICIENT	1.334D-02	cm^2 s^-1

LAYER 7 topsoil

THICKNESS	46	cm
POROSITY	.49	
CALCULATED MASS DENSITY	1.3515	g cm^-3
MEASURED RADIUM ACTIVITY	0	pCi/g^-1
DEFAULT LAYER EMANATION COEFFICIENT	.35	
CALCULATED SOURCE TERM CONCENTRATION	0.000D+00	pCi cm^-3 s^-1
WEIGHT % MOISTURE	6	%
MOISTURE SATURATION FRACTION	.165	
CALCULATED DIFFUSION COEFFICIENT	4.231D-02	cm^2 s^-1

DATA SENT TO THE FILE 'RNDATA' ON DRIVE A:

N	F01	CN1	ICOST	CRITJ	ACC
7	-1.000D+00	0.000D+00	0	0.000D+00	1.000D-01

LAYER	DX	D	P	Q	XMS	RHO
1	3.770D+02	1.618D-02	8.000D-01	3.498D-03	6.625D-01	0.530
2	1.280D+02	4.942D-02	7.000D-01	8.665D-04	1.704D-01	0.795
3	2.560D+02	3.131D-02	4.000D-01	9.028D-05	2.385D-01	1.590
4	6.100D+01	5.861D-03	3.900D-01	0.000D+00	6.217D-01	1.617
5	4.600D+01	3.131D-02	4.000D-01	0.000D+00	2.385D-01	1.590
6	1.520D+02	1.334D-02	4.500D-01	0.000D+00	4.858D-01	1.458
7	4.600D+01	4.231D-02	4.900D-01	0.000D+00	1.655D-01	1.352

BARE SOURCE FLUX FROM LAYER 1: 2.422D+03 pCi m^-2 s^-1

RESULTS OF THE RADON DIFFUSION CALCULATIONS

LAYER	THICKNESS (cm)	EXIT FLUX (pCi m^-2 s^-1)	EXIT CONC. (pCi l^-1)
1	3.770D+02	1.493D+03	6.307D+05
2	1.280D+02	6.337D+02	7.093D+05
3	2.560D+02	4.683D+01	1.501D+05
4	6.100D+01	2.083D+01	1.698D+04
5	4.600D+01	1.208D+01	1.992D+04
6	1.520D+02	3.154D+00	4.937D+02
7	4.600D+01	2.996D+00	0.000D+00

-----*****! RADON !*****-----

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RADON FLUX, CONCENTRATION AND TAILINGS COVER THICKNESS ARE CALCULATED FOR MULTIPLE LAYERS

OUTPUT FILE: raff sludge - lower water content

DESCRIPTION: no

AREA II A- low Sludge w

CONSTANTS

RADON DECAY CONSTANT	.0000021	s^-1
RADON WATER/AIR PARTITION COEFFICIENT	.26	
DEFAULT SPECIFIC GRAVITY OF COVER & TAILINGS	2.65	

GENERAL INPUT PARAMETERS

LAYERS OF COVER AND TAILINGS	7	
NO LIMIT ON RADON FLUX		
LAYER THICKNESS NOT OPTIMIZED		
DEFAULT SURFACE RADON CONCENTRATION	0	pCi l^-1
SURFACE FLUX PRECISION	.1	pCi m^-2 s^-1

LAYER INPUT PARAMETERS

LAYER 1 raff sludge

THICKNESS	377	cm
POROSITY	.8	
CALCULATED MASS DENSITY	.5299999999999999	g cm^-3
MEASURED RADIUM ACTIVITY	7183	pCi/g^-1
DEFAULT LAYER EMANATION COEFFICIENT	.35	
CALCULATED SOURCE TERM CONCENTRATION	3.498D-03	pCi cm^-3 s^-1
WEIGHT % MOISTURE	50	%
MOISTURE SATURATION FRACTION	.331	
CALCULATED DIFFUSION COEFFICIENT	4.276D-02	cm^2 s^-1

LAYER 2 pond 2

THICKNESS	128	cm
POROSITY	.7	
CALCULATED MASS DENSITY	.795	g cm^-3
MEASURED RADIUM ACTIVITY	1038	pCi/g^-1
DEFAULT LAYER EMANATION COEFFICIENT	.35	
CALCULATED SOURCE TERM CONCENTRATION	8.665D-04	pCi cm^-3 s^-1
WEIGHT % MOISTURE	15	%
MOISTURE SATURATION FRACTION	.170	
CALCULATED DIFFUSION COEFFICIENT	4.942D-02	cm^2 s^-1

LAYER 3 struct debris

THICKNESS	256	cm
POROSITY	.2	
CALCULATED MASS DENSITY	2.12	g cm^-3
MEASURED RADIUM ACTIVITY	30.9	pCi/g^-1
DEFAULT LAYER EMANATION COEFFICIENT	.35	
CALCULATED SOURCE TERM CONCENTRATION	2.407D-04	pCi cm^-3 s^-1
WEIGHT % MOISTURE	6	%
MOISTURE SATURATION FRACTION	.636	
CALCULATED DIFFUSION COEFFICIENT	4.015D-03	cm^2 s^-1

LAYER 4 clay liner

THICKNESS	61	cm
POROSITY	.39	
CALCULATED MASS DENSITY	1.6165	g cm^-3
MEASURED RADIUM ACTIVITY	0	pCi/g^-1
DEFAULT LAYER EMANATION COEFFICIENT	.35	
CALCULATED SOURCE TERM CONCENTRATION	0.000D+00	pCi cm^-3 s^-1
WEIGHT % MOISTURE	15	%
MOISTURE SATURATION FRACTION	.622	
CALCULATED DIFFUSION COEFFICIENT	5.861D-03	cm^2 s^-1

LAYER 5 liner cover

THICKNESS	46	cm
POROSITY	.4	
CALCULATED MASS DENSITY	1.59	g cm^-3
MEASURED RADIUM ACTIVITY	0	pCi/g^-1
DEFAULT LAYER EMANATION COEFFICIENT	.35	
CALCULATED SOURCE TERM CONCENTRATION	0.000D+00	pCi cm^-3 s^-1
WEIGHT % MOISTURE	6	%
MOISTURE SATURATION FRACTION	.238	
CALCULATED DIFFUSION COEFFICIENT	3.131D-02	cm^2 s^-1

LAYER 6 subsoil

THICKNESS	152	cm
POROSITY	.45	
CALCULATED MASS DENSITY	1.4575	g cm^-3
MEASURED RADIUM ACTIVITY	0	pCi/g^-1
DEFAULT LAYER EMANATION COEFFICIENT	.35	
CALCULATED SOURCE TERM CONCENTRATION	0.000D+00	pCi cm^-3 s^-1
WEIGHT % MOISTURE	15	%
MOISTURE SATURATION FRACTION	.486	
CALCULATED DIFFUSION COEFFICIENT	1.334D-02	cm^2 s^-1

LAYER 7 topsoil

THICKNESS	46	cm
POROSITY	.49	
CALCULATED MASS DENSITY	1.3515	g cm^-3
MEASURED RADIUM ACTIVITY	0	pCi/g^-1
DEFAULT LAYER EMANATION COEFFICIENT	.35	
CALCULATED SOURCE TERM CONCENTRATION	0.000D+00	pCi cm^-3 s^-1
WEIGHT % MOISTURE	6	%
MOISTURE SATURATION FRACTION	.165	
CALCULATED DIFFUSION COEFFICIENT	4.231D-02	cm^2 s^-1

DATA SENT TO THE FILE `RNDATA' ON DRIVE A:

N	F01	CN1	ICOST	CRITJ	ACC
7	-1.000D+00	0.000D+00	0	0.000D+00	1.000D-01

LAYER	DX	D	P	Q	XMS	RHO
1	3.770D+02	4.276D-02	8.000D-01	3.498D-03	3.312D-01	0.530
2	1.280D+02	4.942D-02	7.000D-01	8.665D-04	1.704D-01	0.795
3	2.560D+02	4.015D-03	2.000D-01	2.407D-04	6.360D-01	2.120
4	6.100D+01	5.861D-03	3.900D-01	0.000D+00	6.217D-01	1.617
5	4.600D+01	3.131D-02	4.000D-01	0.000D+00	2.385D-01	1.590
6	1.520D+02	1.334D-02	4.500D-01	0.000D+00	4.858D-01	1.458
7	4.600D+01	4.231D-02	4.900D-01	0.000D+00	1.655D-01	1.352

BARE SOURCE FLUX FROM LAYER 1: 3.693D+03 pCi m^-2 s^-1

RESULTS OF THE RADON DIFFUSION CALCULATIONS

LAYER	THICKNESS (cm)	EXIT FLUX (pCi m^-2 s^-1)	EXIT CONC. (pCi l^-1)
1	3.770D+02	1.257D+03	1.027D+06
2	1.280D+02	8.513D+01	9.538D+05
3	2.560D+02	1.563D+01	3.220D+04
4	6.100D+01	6.952D+00	5.666D+03
5	4.600D+01	4.032D+00	6.649D+03
6	1.520D+02	1.053D+00	1.647D+02
7	4.600D+01	9.997D-01	0.000D+00

-----*****! RADON !*****-----

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RADON FLUX, CONCENTRATION AND TAILINGS COVER THICKNESS ARE CALCULATED FOR MULTIPLE LAYERS

OUTPUT FILE: 10000 I   AREA I, 10,000 YRS

DESCRIPTION: no

CONSTANTS

RADON DECAY CONSTANT	.0000021	s^-1
RADON WATER/AIR PARTITION COEFFICIENT	.26	
DEFAULT SPECIFIC GRAVITY OF COVER & TAILINGS		2.65

GENERAL INPUT PARAMETERS

LAYERS OF COVER AND TAILINGS	6	
NO LIMIT ON RADON FLUX		
LAYER THICKNESS NOT OPTIMIZED		
DEFAULT SURFACE RADON CONCENTRATION	0	pCi l^-1
SURFACE FLUX PRECISION	.1	pCi m^-2 s^-1

LAYER INPUT PARAMETERS

LAYER 1   layer A

THICKNESS	61	cm
POROSITY	.7	
CALCULATED MASS DENSITY	.795	g cm^-3
MEASURED RADIUM ACTIVITY	9013	pCi/g^-1
DEFAULT LAYER EMANATION COEFFICIENT	.35	
CALCULATED SOURCE TERM CONCENTRATION	7.524D-03	pCi cm^-3 s^-1
WEIGHT % MOISTURE	15	%
MOISTURE SATURATION FRACTION	.170	
CALCULATED DIFFUSION COEFFICIENT	4.942D-02	cm^2 s^-1

LAYER 2   layer b-d

THICKNESS	426	cm
POROSITY	.4	
CALCULATED MASS DENSITY	1.59	g cm^-3
MEASURED RADIUM ACTIVITY	81.5	pCi/g^-1
DEFAULT LAYER EMANATION COEFFICIENT	.35	
CALCULATED SOURCE TERM CONCENTRATION	2.381D-04	pCi cm^-3 s^-1
WEIGHT % MOISTURE	6	%
MOISTURE SATURATION FRACTION	.238	
CALCULATED DIFFUSION COEFFICIENT	3.131D-02	cm^2 s^-1

LAYER 3 clay layer

THICKNESS	61	cm
POROSITY	.39	
CALCULATED MASS DENSITY	1.6165	g cm^-3
MEASURED RADIUM ACTIVITY	0	pCi/g^-1
DEFAULT LAYER EMANATION COEFFICIENT	.35	
CALCULATED SOURCE TERM CONCENTRATION	0.000D+00	pCi cm^-3 s^-1
WEIGHT % MOISTURE	15	%
MOISTURE SATURATION FRACTION	.622	
CALCULATED DIFFUSION COEFFICIENT	5.861D-03	cm^2 s^-1

LAYER 4 liner cover

THICKNESS	46	cm
POROSITY	.4	
CALCULATED MASS DENSITY	1.59	g cm^-3
MEASURED RADIUM ACTIVITY	0	pCi/g^-1
DEFAULT LAYER EMANATION COEFFICIENT	.35	
CALCULATED SOURCE TERM CONCENTRATION	0.000D+00	pCi cm^-3 s^-1
WEIGHT % MOISTURE	6	%
MOISTURE SATURATION FRACTION	.238	
CALCULATED DIFFUSION COEFFICIENT	3.131D-02	cm^2 s^-1

LAYER 5 subsoil

THICKNESS	152	cm
POROSITY	.45	
CALCULATED MASS DENSITY	1.4575	g cm^-3
MEASURED RADIUM ACTIVITY	0	pCi/g^-1
DEFAULT LAYER EMANATION COEFFICIENT	.35	
CALCULATED SOURCE TERM CONCENTRATION	0.000D+00	pCi cm^-3 s^-1
WEIGHT % MOISTURE	15	%
MOISTURE SATURATION FRACTION	.486	
CALCULATED DIFFUSION COEFFICIENT	1.334D-02	cm^2 s^-1

LAYER 6 topsoil

THICKNESS	46	cm
POROSITY	.49	
CALCULATED MASS DENSITY	1.3515	g cm^-3
MEASURED RADIUM ACTIVITY	0	pCi/g^-1
DEFAULT LAYER EMANATION COEFFICIENT	.35	
CALCULATED SOURCE TERM CONCENTRATION	0.000D+00	pCi cm^-3 s^-1
WEIGHT % MOISTURE	6	%
MOISTURE SATURATION FRACTION	.165	
CALCULATED DIFFUSION COEFFICIENT	4.231D-02	cm^2 s^-1

DATA SENT TO THE FILE `RNDATA' ON DRIVE A:

N	F01	CN1	ICOST	CRITJ	ACC
6	-1.000D+00	0.000D+00	0	0.000D+00	1.000D-01

LAYER	DX	D	P	Q	XMS	RHO
1	6.100D+01	4.942D-02	7.000D-01	7.524D-03	1.704D-01	0.795
2	4.260D+02	3.131D-02	4.000D-01	2.381D-04	2.385D-01	1.590
3	6.100D+01	5.861D-03	3.900D-01	0.000D+00	6.217D-01	1.617
4	4.600D+01	3.131D-02	4.000D-01	0.000D+00	2.385D-01	1.590
5	1.520D+02	1.334D-02	4.500D-01	0.000D+00	4.858D-01	1.458
6	4.600D+01	4.231D-02	4.900D-01	0.000D+00	1.655D-01	1.352

BARE SOURCE FLUX FROM LAYER 1: 2.599D+03 pCi m^-2 s^-1

RESULTS OF THE RADON DIFFUSION CALCULATIONS

LAYER	THICKNESS (cm)	EXIT FLUX (pCi m^-2 s^-1)	EXIT CONC. (pCi l^-1)
1	6.100D+01	1.327D+03	1.493D+06
2	4.260D+02	4.602D+01	1.475D+05
3	6.100D+01	2.047D+01	1.669D+04
4	4.600D+01	1.187D+01	1.958D+04
5	1.520D+02	3.100D+00	4.852D+02
6	4.600D+01	2.944D+00	0.000D+00

-----*****! RADON !*****-----

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RADON FLUX, CONCENTRATION AND TAILINGS COVER THICKNESS ARE CALCULATED FOR MULTIPLE LAYERS

OUTPUT FILE: 10000 IIA

AREA II A. - 10,000 YRS

DESCRIPTION: no

CONSTANTS

RADON DECAY CONSTANT	.0000021	s^-1
RADON WATER/AIR PARTITION COEFFICIENT	.26	
DEFAULT SPECIFIC GRAVITY OF COVER & TAILINGS	2.65	

GENERAL INPUT PARAMETERS

LAYERS OF COVER AND TAILINGS	7	
NO LIMIT ON RADON FLUX		
LAYER THICKNESS NOT OPTIMIZED		
DEFAULT SURFACE RADON CONCENTRATION	0	pCi l^-1
SURFACE FLUX PRECISION	.1	pCi m^-2 s^-1

LAYER INPUT PARAMETERS

LAYER 1 raff sludge

THICKNESS	377	cm
POROSITY	.8	
CALCULATED MASS DENSITY	.5299999999999999	g cm^-3
MEASURED RADIUM ACTIVITY	18587	pCi/g^-1
DEFAULT LAYER EMANATION COEFFICIENT	.35	
CALCULATED SOURCE TERM CONCENTRATION	9.051D-03	pCi cm^-3 s^-1
WEIGHT % MOISTURE	100	%
MOISTURE SATURATION FRACTION	.662	
CALCULATED DIFFUSION COEFFICIENT	1.618D-02	cm^2 s^-1

LAYER 2 pond 2

THICKNESS	128	cm
POROSITY	.7	
CALCULATED MASS DENSITY	.795	g cm^-3
MEASURED RADIUM ACTIVITY	2568	pCi/g^-1
DEFAULT LAYER EMANATION COEFFICIENT	.35	
CALCULATED SOURCE TERM CONCENTRATION	2.144D-03	pCi cm^-3 s^-1
WEIGHT % MOISTURE	15	%
MOISTURE SATURATION FRACTION	.170	
CALCULATED DIFFUSION COEFFICIENT	4.942D-02	cm^2 s^-1

LAYER 3 struc debris

THICKNESS	256	cm
POROSITY	.2	
CALCULATED MASS DENSITY	2.12	g cm^-3
MEASURED RADIUM ACTIVITY	75.3	pCi/g^-1
DEFAULT LAYER EMANATION COEFFICIENT	.35	
CALCULATED SOURCE TERM CONCENTRATION	5.867D-04	pCi cm^-3 s^-1
WEIGHT % MOISTURE	6	%
MOISTURE SATURATION FRACTION	.636	
CALCULATED DIFFUSION COEFFICIENT	4.015D-03	cm^2 s^-1

LAYER 4 clay liner

THICKNESS	61	cm
POROSITY	.39	
CALCULATED MASS DENSITY	1.6165	g cm^-3
MEASURED RADIUM ACTIVITY	0	pCi/g^-1
DEFAULT LAYER EMANATION COEFFICIENT	.35	
CALCULATED SOURCE TERM CONCENTRATION	0.000D+00	pCi cm^-3 s^-1
WEIGHT % MOISTURE	15	%
MOISTURE SATURATION FRACTION	.622	
CALCULATED DIFFUSION COEFFICIENT	5.861D-03	cm^2 s^-1

LAYER 5 liner cover

THICKNESS	46	cm
POROSITY	.4	
CALCULATED MASS DENSITY	1.59	g cm^-3
MEASURED RADIUM ACTIVITY	0	pCi/g^-1
DEFAULT LAYER EMANATION COEFFICIENT	.35	
CALCULATED SOURCE TERM CONCENTRATION	0.000D+00	pCi cm^-3 s^-1
WEIGHT % MOISTURE	6	%
MOISTURE SATURATION FRACTION	.238	
CALCULATED DIFFUSION COEFFICIENT	3.131D-02	cm^2 s^-1

LAYER 6 subsoil

THICKNESS	152	cm
POROSITY	.45	
CALCULATED MASS DENSITY	1.4575	g cm^-3
MEASURED RADIUM ACTIVITY	0	pCi/g^-1
DEFAULT LAYER EMANATION COEFFICIENT	.35	
CALCULATED SOURCE TERM CONCENTRATION	0.000D+00	pCi cm^-3 s^-1
WEIGHT % MOISTURE	15	%
MOISTURE SATURATION FRACTION	.486	
CALCULATED DIFFUSION COEFFICIENT	1.334D-02	cm^2 s^-1

LAYER 7 topsoil

THICKNESS	46	cm
POROSITY	.49	
CALCULATED MASS DENSITY	1.3515	g cm^-3
MEASURED RADIUM ACTIVITY	0	pCi/g^-1
DEFAULT LAYER EMANATION COEFFICIENT	.35	
CALCULATED SOURCE TERM CONCENTRATION	0.000D+00	pCi cm^-3 s^-1
WEIGHT % MOISTURE	6	%
MOISTURE SATURATION FRACTION	.165	
CALCULATED DIFFUSION COEFFICIENT	4.231D-02	cm^2 s^-1

DATA SENT TO THE FILE 'RNDATA' ON DRIVE A:

N	F01	CN1	ICOST	CRITJ	ACC
7	-1.000D+00	0.000D+00	0	0.000D+00	1.000D-01

LAYER	DX	D	P	Q	XMS	RHO
1	3.770D+02	1.618D-02	8.000D-01	9.051D-03	6.625D-01	0.530
2	1.280D+02	4.942D-02	7.000D-01	2.144D-03	1.704D-01	0.795
3	2.560D+02	4.015D-03	2.000D-01	5.867D-04	6.360D-01	2.120
4	6.100D+01	5.861D-03	3.900D-01	0.000D+00	6.217D-01	1.617
5	4.600D+01	3.131D-02	4.000D-01	0.000D+00	2.385D-01	1.590
6	1.520D+02	1.334D-02	4.500D-01	0.000D+00	4.858D-01	1.458
7	4.600D+01	4.231D-02	4.900D-01	0.000D+00	1.655D-01	1.352

BARE SOURCE FLUX FROM LAYER 1: 6.268D+03 pCi m^-2 s^-1

RESULTS OF THE RADON DIFFUSION CALCULATIONS

LAYER	THICKNESS (cm)	EXIT FLUX (pCi m^-2 s^-1)	EXIT CONC. (pCi l^-1)
1	3.770D+02	3.520D+03	1.865D+06
2	1.280D+02	2.315D+02	2.540D+06
3	2.560D+02	3.818D+01	7.867D+04
4	6.100D+01	1.698D+01	1.384D+04
5	4.600D+01	9.851D+00	1.624D+04
6	1.520D+02	2.572D+00	4.025D+02
7	4.600D+01	2.442D+00	0.000D+00

-----*****! RADON !*****-----

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RADON FLUX, CONCENTRATION AND TAILINGS COVER THICKNESS ARE CALCULATED FOR MULTIPLE LAYERS

OUTPUT FILE: 10000 IIB

AREA IIB - 10,000 YRS

DESCRIPTION: no

CONSTANTS

RADON DECAY CONSTANT	.0000021	s^-1
RADON WATER/AIR PARTITION COEFFICIENT	.26	
DEFAULT SPECIFIC GRAVITY OF COVER & TAILINGS		2.65

GENERAL INPUT PARAMETERS

LAYERS OF COVER AND TAILINGS	6	
NO LIMIT ON RADON FLUX		
LAYER THICKNESS NOT OPTIMIZED		
DEFAULT SURFACE RADON CONCENTRATION	0	pCi l^-1
SURFACE FLUX PRECISION	.1	pCi m^-2 s^-1

LAYER INPUT PARAMETERS

LAYER 1 pond 2

THICKNESS	505	cm
POROSITY	.7	
CALCULATED MASS DENSITY	.795	g cm^-3
MEASURED RADIUM ACTIVITY	2568	pCi/g^-1
DEFAULT LAYER EMANATION COEFFICIENT	.35	
CALCULATED SOURCE TERM CONCENTRATION	2.144D-03	pCi cm^-3 s^-1
WEIGHT % MOISTURE	15	%
MOISTURE SATURATION FRACTION	.170	
CALCULATED DIFFUSION COEFFICIENT	4.942D-02	cm^2 s^-1

LAYER 2 struc debris

THICKNESS	256	cm
POROSITY	.2	
CALCULATED MASS DENSITY	2.12	g cm^-3
MEASURED RADIUM ACTIVITY	75.3	pCi/g^-1
DEFAULT LAYER EMANATION COEFFICIENT	.35	
CALCULATED SOURCE TERM CONCENTRATION	5.867D-04	pCi cm^-3 s^-1
WEIGHT % MOISTURE	6	%
MOISTURE SATURATION FRACTION	.636	
CALCULATED DIFFUSION COEFFICIENT	4.015D-03	cm^2 s^-1

LAYER 3 clay liner

THICKNESS	61	cm
POROSITY	.39	
CALCULATED MASS DENSITY	1.6165	g cm^-3
MEASURED RADIUM ACTIVITY	0	pCi/g^-1
DEFAULT LAYER EMANATION COEFFICIENT	.35	
CALCULATED SOURCE TERM CONCENTRATION	0.000D+00	pCi cm^-3 s^-1
WEIGHT % MOISTURE	15	%
MOISTURE SATURATION FRACTION	.622	
CALCULATED DIFFUSION COEFFICIENT	5.861D-03	cm^2 s^-1

LAYER 4 liner cover

THICKNESS	46	cm
POROSITY	.4	
CALCULATED MASS DENSITY	1.59	g cm^-3
MEASURED RADIUM ACTIVITY	0	pCi/g^-1
DEFAULT LAYER EMANATION COEFFICIENT	.35	
CALCULATED SOURCE TERM CONCENTRATION	0.000D+00	pCi cm^-3 s^-1
WEIGHT % MOISTURE	6	%
MOISTURE SATURATION FRACTION	.238	
CALCULATED DIFFUSION COEFFICIENT	3.131D-02	cm^2 s^-1

LAYER 5 subsoil

THICKNESS	152	cm
POROSITY	.45	
CALCULATED MASS DENSITY	1.4575	g cm^-3
MEASURED RADIUM ACTIVITY	0	pCi/g^-1
DEFAULT LAYER EMANATION COEFFICIENT	.35	
CALCULATED SOURCE TERM CONCENTRATION	0.000D+00	pCi cm^-3 s^-1
WEIGHT % MOISTURE	15	%
MOISTURE SATURATION FRACTION	.486	
CALCULATED DIFFUSION COEFFICIENT	1.334D-02	cm^2 s^-1

LAYER 6 topsoil

THICKNESS	46	cm
POROSITY	.49	
CALCULATED MASS DENSITY	1.3515	g cm^-3
MEASURED RADIUM ACTIVITY	0	pCi/g^-1
DEFAULT LAYER EMANATION COEFFICIENT	.35	
CALCULATED SOURCE TERM CONCENTRATION	0.000D+00	pCi cm^-3 s^-1
WEIGHT % MOISTURE	6	%
MOISTURE SATURATION FRACTION	.165	
CALCULATED DIFFUSION COEFFICIENT	4.231D-02	cm^2 s^-1

DATA SENT TO THE FILE 'RNDATA' ON DRIVE A:

N	F01	CN1	ICOST	CRITJ	ACC
6	-1.000D+00	0.000D+00	0	0.000D+00	1.000D-01

LAYER	DX	D	P	Q	XMS	RHO
1	5.050D+02	4.942D-02	7.000D-01	2.144D-03	1.704D-01	0.795
2	2.560D+02	4.015D-03	2.000D-01	5.867D-04	6.360D-01	2.120
3	6.100D+01	5.861D-03	3.900D-01	0.000D+00	6.217D-01	1.617
4	4.600D+01	3.131D-02	4.000D-01	0.000D+00	2.385D-01	1.590
5	1.520D+02	1.334D-02	4.500D-01	0.000D+00	4.858D-01	1.458
6	4.600D+01	4.231D-02	4.900D-01	0.000D+00	1.655D-01	1.352

BARE SOURCE FLUX FROM LAYER 1: 2.214D+03 pCi m^-2 s^-1

RESULTS OF THE RADON DIFFUSION CALCULATIONS

LAYER	THICKNESS (cm)	EXIT FLUX (pCi m^-2 s^-1)	EXIT CONC. (pCi l^-1)
1	5.050D+02	5.565D+01	9.596D+05
2	2.560D+02	3.745D+01	7.717D+04
3	6.100D+01	1.666D+01	1.358D+04
4	4.600D+01	9.662D+00	1.593D+04
5	1.520D+02	2.523D+00	3.948D+02
6	4.600D+01	2.396D+00	0.000D+00

-----*****! RADON !*********-----

Version 1.2 - MAY 22, 1989 - G.F. Birchard tel.# (301)492-7000
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RADON FLUX, CONCENTRATION AND TAILINGS COVER THICKNESS ARE CALCULATED FOR MULTIPLE LAYERS

OUTPUT FILE: 10000 III

AREA III - 10,000 YRS

DESCRIPTION: no

CONSTANTS

RADON DECAY CONSTANT	.0000021	s^-1
RADON WATER/AIR PARTITION COEFFICIENT	.26	
DEFAULT SPECIFIC GRAVITY OF COVER & TAILINGS		2.65

GENERAL INPUT PARAMETERS

LAYERS OF COVER AND TAILINGS	5	
NO LIMIT ON RADON FLUX		
LAYER THICKNESS NOT OPTIMIZED		
DEFAULT SURFACE RADON CONCENTRATION	0	pCi l^-1
SURFACE FLUX PRECISION	.1	pCi m^-2 s^-1

LAYER INPUT PARAMETERS

LAYER 1 layer b-d

THICKNESS	457	cm
POROSITY	.7	
CALCULATED MASS DENSITY	.795	g cm^-3
MEASURED RADIUM ACTIVITY	38.4	pCi/g^-1
DEFAULT LAYER EMANATION COEFFICIENT	.35	
CALCULATED SOURCE TERM CONCENTRATION	3.205D-05	pCi cm^-3 s^-1
WEIGHT % MOISTURE	15	%
MOISTURE SATURATION FRACTION	.170	
CALCULATED DIFFUSION COEFFICIENT	4.942D-02	cm^2 s^-1

LAYER 2 clay liner

THICKNESS	61	cm
POROSITY	.39	
CALCULATED MASS DENSITY	1.6165	g cm^-3
MEASURED RADIUM ACTIVITY	0	pCi/g^-1
DEFAULT LAYER EMANATION COEFFICIENT	.35	
CALCULATED SOURCE TERM CONCENTRATION	0.000D+00	pCi cm^-3 s^-1
WEIGHT % MOISTURE	15	%
MOISTURE SATURATION FRACTION	.622	
CALCULATED DIFFUSION COEFFICIENT	5.861D-03	cm^2 s^-1

LAYER 3 liner cover

THICKNESS	46	cm
POROSITY	.4	
CALCULATED MASS DENSITY	1.59	g cm^-3
MEASURED RADIUM ACTIVITY	0	pCi/g^-1
DEFAULT LAYER EMANATION COEFFICIENT	.35	
CALCULATED SOURCE TERM CONCENTRATION	0.000D+00	pCi cm^-3 s^-1
WEIGHT % MOISTURE	6	%
MOISTURE SATURATION FRACTION	.238	
CALCULATED DIFFUSION COEFFICIENT	3.131D-02	cm^2 s^-1

LAYER 4 subsoil

THICKNESS	152	cm
POROSITY	.45	
CALCULATED MASS DENSITY	1.4575	g cm^-3
MEASURED RADIUM ACTIVITY	0	pCi/g^-1
DEFAULT LAYER EMANATION COEFFICIENT	.35	
CALCULATED SOURCE TERM CONCENTRATION	0.000D+00	pCi cm^-3 s^-1
WEIGHT % MOISTURE	15	%
MOISTURE SATURATION FRACTION	.486	
CALCULATED DIFFUSION COEFFICIENT	1.334D-02	cm^2 s^-1

LAYER 5 topsoil

THICKNESS	46	cm
POROSITY	.49	
CALCULATED MASS DENSITY	1.3515	g cm^-3
MEASURED RADIUM ACTIVITY	0	pCi/g^-1
DEFAULT LAYER EMANATION COEFFICIENT	.35	
CALCULATED SOURCE TERM CONCENTRATION	0.000D+00	pCi cm^-3 s^-1
WEIGHT % MOISTURE	6	%
MOISTURE SATURATION FRACTION	.165	
CALCULATED DIFFUSION COEFFICIENT	4.231D-02	cm^2 s^-1

DATA SENT TO THE FILE `RNDATA' ON DRIVE A:

N	F01	CN1	ICOST	CRITJ	ACC
5	-1.000D+00	0.000D+00	0	0.000D+00	1.000D-01

LAYER	DX	D	P	Q	XMS	RHO
1	4.570D+02	4.942D-02	7.000D-01	3.205D-05	1.704D-01	0.795
2	6.100D+01	5.861D-03	3.900D-01	0.000D+00	6.217D-01	1.617
3	4.600D+01	3.131D-02	4.000D-01	0.000D+00	2.385D-01	1.590
4	1.520D+02	1.334D-02	4.500D-01	0.000D+00	4.858D-01	1.458
5	4.600D+01	4.231D-02	4.900D-01	0.000D+00	1.655D-01	1.352

BARE SOURCE FLUX FROM LAYER 1: 3.260D+01 pCi m^-2 s^-1

RESULTS OF THE RADON DIFFUSION CALCULATIONS

LAYER	THICKNESS (cm)	EXIT FLUX (pCi m^-2 s^-1)	EXIT CONC. (pCi 1^-1)
1	4.570D+02	3.777D+00	1.285D+04
2	6.100D+01	1.680D+00	1.369D+03
3	4.600D+01	9.744D-01	1.607D+03
4	1.520D+02	2.544D-01	3.982D+01
5	4.600D+01	2.416D-01	0.000D+00

Parameters	Area I, 10,000 Years	
Layer A		
Specific Gravity	0.80	0.80
Porosity	0.7	0.7
Density (g/cc)	0.795	0.795
Density (pcf)	49.6	49.6
Moisture Content (%)	15	16
Degree of Saturation (%)	0.17	0.17
Radium Activity (pCi/g)	9013	9013
Diffusion Coef (cm^2/sec)	0.04942	0.04942
Thickness (cm)	61	61
Thickness (ft)	2.0	2.0
Radon Flux (pCi/m^2-sec)	1327	1327
Layer b-d		
Specific Gravity	1.59	1.59
Porosity	0.4	0.4
Density (g/cc)	1.59	1.59
Density (pcf)	99.3	99.3
Moisture Content (%)	6	6
Degree of Saturation (%)	0.238	0.238
Radium Activity (pCi/g)	81.5	81.5
Diffusion Coef (cm^2/sec)	0.03131	0.03131
Thickness (cm)	426	426
Thickness (ft)	14.0	14.0
Radon Flux (pCi/m^2-sec)	46.02	42.04
Clay Liner		
Specific Gravity	1.62	1.62
Porosity	0.39	0.39
Density (g/cc)	1.6165	1.6165
Density (pcf)	100.9	100.9
Moisture Content (%)	15	15
Degree of Saturation (%)	0.662	0.662
Radium Activity (pCi/g)	0	0
Diffusion Coef (cm^2/sec)	0.005861	0.005861
Thickness (cm)	61	61
Thickness (ft)	2.0	2.0
Radon Flux (pCi/m^2-sec)	20.47	22.65
Liner Cover		
Specific Gravity	1.59	1.59
Porosity	0.4	0.4
Density (g/cc)	1.59	1.59
Density (pcf)	99.3	99.3
Moisture Content (%)	6	6
Degree of Saturation (%)	0.238	0.238
Radium Activity (pCi/g)	0	0
Diffusion Coef (cm^2/sec)	0.03131	0.03131
Thickness (cm)	46	46
Thickness (ft)	1.5	1.5
Radon Flux (pCi/m^2-sec)	11.87	16.92
Subsoil		
Specific Gravity	1.46	1.46
Porosity	0.45	0.45
Density (g/cc)	1.4575	1.4575
Density (pcf)	91.0	91.0
Moisture Content (%)	15	6
Degree of Saturation (%)	0.486	0.194
Radium Activity (pCi/g)	0	0
Diffusion Coef (cm^2/sec)	0.01334	0.0376
Thickness (cm)	152	152
Thickness (ft)	5.0	5.0
Radon Flux (pCi/m^2-sec)	3.1	8.109
Topsoil		
Specific Gravity	1.35	1.35
Porosity	0.49	0.49
Density (g/cc)	1.3515	1.3515
Density (pcf)	84.4	84.4
Moisture Content (%)	6	6
Degree of Saturation (%)	0.165	0.165
Radium Activity (pCi/g)	0	0
Diffusion Coef (cm^2/sec)	0.04231	0.04231
Thickness (cm)	46	46
Thickness (ft)	1.5	1.5
Radon Flux (pCi/m^2-sec)	2.944	7.701

Parameters	Area IIA, 10,000 Years	
Raff Sludge		
Specific Gravity	0.53	0.53
Porosity	0.8	0.8
Density (g/cc)	0.53	0.53
Density (pcf)	33.1	33.1
Moisture Content (%)	100	100
Degree of Saturation (%)	0.662	0.662
Radium Activity (pCi/g)	18587	18587
Diffusion Coef (cm^2/sec)	0.01618	0.01618
Thickness (cm)	377	377
Thickness (ft)	12.4	12.4
Radon Flux (pCi/m^2-sec)	3520	3520
Pond 2		
Specific Gravity	0.80	0.80
Porosity	0.7	0.7
Density (g/cc)	0.795	0.795
Density (pcf)	49.6	49.6
Moisture Content (%)	15	15
Degree of Saturation (%)	0.17	0.17
Radium Activity (pCi/g)	2568	2568
Diffusion Coef (cm^2/sec)	0.0494	0.0494
Thickness (cm)	128	128
Thickness (ft)	4.2	4.2
Radon Flux (pCi/m^2-sec)	231.5	231.5
Struc Debris		
Specific Gravity	2.12	2.12
Porosity	0.2	0.2
Density (g/cc)	2.12	2.12
Density (pcf)	132.3	132.3
Moisture Content (%)	6	6
Degree of Saturation (%)	0.636	0.636
Radium Activity (pCi/g)	75.3	75.3
Diffusion Coef (cm^2/sec)	0.004015	0.004015
Thickness (cm)	256	256
Thickness (ft)	8.4	8.4
Radon Flux (pCi/m^2-sec)	38.18	38.48
Clay Liner		
Specific Gravity	1.62	1.62
Porosity	0.39	0.39
Density (g/cc)	1.6165	1.6165
Density (pcf)	100.9	100.9
Moisture Content (%)	15	15
Degree of Saturation (%)	0.622	0.622
Radium Activity (pCi/g)	0	0
Diffusion Coef (cm^2/sec)	0.00586	0.00586
Thickness (cm)	61	61
Thickness (ft)	2.0	2.0
Radon Flux (pCi/m^2-sec)	16.98	18.53
Liner Cover		
Specific Gravity	1.59	1.59
Porosity	0.4	0.4
Density (g/cc)	1.59	1.59
Density (pcf)	99.3	99.3
Moisture Content (%)	6	6
Degree of Saturation (%)	0.238	0.238
Radium Activity (pCi/g)	0	0
Diffusion Coef (cm^2/sec)	0.03131	0.03131
Thickness (cm)	46	46
Thickness (ft)	1.5	1.5
Radon Flux (pCi/m^2-sec)	9.851	13.84
Subsoil		
Specific Gravity	1.46	1.46
Porosity	0.45	0.45
Density (g/cc)	1.4575	1.4575
Density (pcf)	91.0	91.0
Moisture Content (%)	15	6
Degree of Saturation (%)	0.486	0.194
Radium Activity (pCi/g)	0	0
Diffusion Coef (cm^2/sec)	0.01334	0.0376
Thickness (cm)	152	152
Thickness (ft)	5.0	5.0
Radon Flux (pCi/m^2-sec)	2.572	6.633
Topsoil		
Specific Gravity	1.35	1.35
Porosity	0.49	0.49
Density (g/cc)	1.3515	1.3515
Density (pcf)	84.4	84.4
Moisture Content (%)	6	6
Degree of Saturation (%)	0.165	0.165
Radium Activity (pCi/g)	0	0
Diffusion Coef (cm^2/sec)	0.04231	0.04231
Thickness (cm)	46	46
Thickness (ft)	1.5	1.5
Radon Flux (pCi/m^2-sec)	2.442	6.3

Parameters	Area IIB, 10,000 Years	
Pond 2		
Specific Gravity	0.80	0.80
Porosity	0.7	0.7
Density (g/cc)	0.795	0.795
Density (pcf)	49.6	49.6
Moisture Content (%)	15	15
Degree of Saturation (%)	0.17	0.17
Radium Activity (pCi/g)	2568	2568
Diffusion Coef (cm^2/sec)	0.04942	0.04942
Thickness (cm)	505	505
Thickness (ft)	16.6	16.6
Radon Flux (pCi/m^2-sec)	55.65	55.65
Struc Debris		
Specific Gravity	2.12	2.12
Porosity	0.2	0.2
Density (g/cc)	2.12	2.12
Density (pcf)	132.3	132.3
Moisture Content (%)	6	6
Degree of Saturation (%)	0.636	0.636
Radium Activity (pCi/g)	75.3	75.3
Diffusion Coef (cm^2/sec)	0.0040	0.0040
Thickness (cm)	256	256
Thickness (ft)	8.4	8.4
Radon Flux (pCi/m^2-sec)	37.45	37.87
Clay Liner		
Specific Gravity	1.62	1.62
Porosity	0.39	0.39
Density (g/cc)	1.6165	1.6165
Density (pcf)	100.9	100.9
Moisture Content (%)	15	15
Degree of Saturation (%)	0.622	0.622
Radium Activity (pCi/g)	0	0
Diffusion Coef (cm^2/sec)	0.005861	0.005861
Thickness (cm)	61	61
Thickness (ft)	2.0	2.0
Radon Flux (pCi/m^2-sec)	16.66	18.8
Liner Cover		
Specific Gravity	1.59	1.59
Porosity	0.4	0.4
Density (g/cc)	1.59	1.59
Density (pcf)	99.3	99.3
Moisture Content (%)	6	6
Degree of Saturation (%)	0.238	0.238
Radium Activity (pCi/g)	0	0
Diffusion Coef (cm^2/sec)	0.03131	0.03131
Thickness (cm)	46	46
Thickness (ft)	1.5	1.5
Radon Flux (pCi/m^2-sec)	9.662	15.21
Subsoil		
Specific Gravity	1.46	1.46
Porosity	0.45	0.45
Density (g/cc)	1.4575	1.4575
Density (pcf)	91.0	91.0
Moisture Content (%)	15	6
Degree of Saturation (%)	0.486	0.194
Radium Activity (pCi/g)	0	0
Diffusion Coef (cm^2/sec)	0.01334	0.0376
Thickness (cm)	46	46
Thickness (ft)	1.5	1.5
Radon Flux (pCi/m^2-sec)	2.523	3.523
Topsoil		
Specific Gravity	1.35	1.35
Porosity	0.49	0.49
Density (g/cc)	1.3515	1.3515
Density (pcf)	84.4	84.4
Moisture Content (%)	6	6
Degree of Saturation (%)	0.165	0.165
Radium Activity (pCi/g)	0	0
Diffusion Coef (cm^2/sec)	0.04231	0.04231
Thickness (cm)	46	46
Thickness (ft)	1.5	1.5
Radon Flux (pCi/m^2-sec)	2.396	12.53

Parameters	Area III 10,000 Years	
Layer b-d		
Specific Gravity	0.80	0.80
Porosity	0.7	0.7
Density (g/cc)	0.795	0.795
Density (pcf)	49.6	49.6
Moisture Content (%)	15	15
Degree of Saturation (%)	0.17	0.17
Radium Activity (pCi/g)	38.4	38.4
Diffusion Coef (cm^2/sec)	0.04942	0.04942
Thickness (cm)	457	457
Thickness (ft)	15.0	15.0
Radon Flux (pCi/m^2-sec)	3.777	3.777
Clay Liner		
Specific Gravity	1.62	1.62
Porosity	0.39	0.39
Density (g/cc)	1.6165	1.6165
Density (pcf)	100.9	100.9
Moisture Content (%)	15	15
Degree of Saturation (%)	0.622	0.622
Radium Activity (pCi/g)	0	0
Diffusion Coef (cm^2/sec)	0.0059	0.0059
Thickness (cm)	61	61
Thickness (ft)	2.0	2.0
Radon Flux (pCi/m^2-sec)	1.68	1.865
Layer 3		
Specific Gravity	1.59	1.59
Porosity	0.4	0.4
Density (g/cc)	1.59	1.59
Density (pcf)	99.3	99.3
Moisture Content (%)	6	6
Degree of Saturation (%)	0.238	0.238
Radium Activity (pCi/g)	0	0
Diffusion Coef (cm^2/sec)	0.03131	0.03131
Thickness (cm)	46	46
Thickness (ft)	1.5	1.5
Radon Flux (pCi/m^2-sec)	0.9744	1.393
Subsoil		
Specific Gravity	1.46	1.46
Porosity	0.45	0.45
Density (g/cc)	1.4575	1.4575
Density (pcf)	91.0	91.0
Moisture Content (%)	15	6
Degree of Saturation (%)	0.486	0.194
Radium Activity (pCi/g)	0	0
Diffusion Coef (cm^2/sec)	0.01334	0.0376
Thickness (cm)	152	152
Thickness (ft)	5.0	5.0
Radon Flux (pCi/m^2-sec)	0.2544	0.6677
Topsoil		
Specific Gravity	1.35	1.35
Porosity	0.49	0.49
Density (g/cc)	1.3515	1.3515
Density (pcf)	84.4	84.4
Moisture Content (%)	6	6
Degree of Saturation (%)	0.165	0.165
Radium Activity (pCi/g)	0	0
Diffusion Coef (cm^2/sec)	0.04231	0.04231
Thickness (cm)	46	46
Thickness (ft)	1.5	1.5
Radon Flux (pCi/m^2-sec)	0.2416	0.6341

AREA I 1

-----*****! RADON !*****-----

Version 1.2 - MAY 22, 1989 - G.F. Birchard tel.# (301)492-7000
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RADON FLUX, CONCENTRATION AND TAILINGS COVER THICKNESS
ARE CALCULATED FOR MULTIPLE LAYERS

OUTPUT FILE: Area I 10000 Years 6%WC Subsoil

DESCRIPTION: Subsoil is 6% WC instead of 15%

CONSTANTS

RADON DECAY CONSTANT	.0000021	s^-1
RADON WATER/AIR PARTITION COEFFICIENT	.26	
DEFAULT SPECIFIC GRAVITY OF COVER & TAILINGS		2.65

GENERAL INPUT PARAMETERS

LAYERS OF COVER AND TAILINGS	6	
DEFAULT RADON FLUX LIMIT	20	pCi m^-2 s^-1
LAYER THICKNESS NOT OPTIMIZED		
DEFAULT SURFACE RADON CONCENTRATION	0	pCi l^-1
SURFACE FLUX PRECISION	.001	pCi m^-2 s^-1

LAYER INPUT PARAMETERS

LAYER 1 Layer A

THICKNESS	61	cm
POROSITY	.7	
MEASURED MASS DENSITY	.795	g cm^-3
MEASURED RADIUM ACTIVITY	9013	pCi/g^-1
DEFAULT LAYER EMANATION COEFFICIENT	.35	
CALCULATED SOURCE TERM CONCENTRATION	7.524D-03	pCi cm^-3 s^-1
WEIGHT % MOISTURE	15	%
MOISTURE SATURATION FRACTION	.170	
CALCULATED DIFFUSION COEFFICIENT	4.942D-02	cm^2 s^-1

LAYER 2 Layer b-d

THICKNESS	426	cm
POROSITY	.4	
MEASURED MASS DENSITY	1.59	g cm^-3
MEASURED RADIUM ACTIVITY	81.5	pCi/g^-1
DEFAULT LAYER EMANATION COEFFICIENT	.35	
CALCULATED SOURCE TERM CONCENTRATION	2.381D-04	pCi cm^-3 s^-1
WEIGHT % MOISTURE	6	%
MOISTURE SATURATION FRACTION	.238	
CALCULATED DIFFUSION COEFFICIENT	3.131D-02	cm^2 s^-1

LAYER 3 Clay Liner

AREA I 1		
THICKNESS	61	cm
POROSITY	.39	
MEASURED MASS DENSITY	1.6165	g cm^-3
MEASURED RADIUM ACTIVITY	0	pCi/g^-1
DEFAULT LAYER EMANATION COEFFICIENT	.35	
CALCULATED SOURCE TERM CONCENTRATION	0.000D+00	pCi cm^-3 s^-1
WEIGHT % MOISTURE	15	%
MOISTURE SATURATION FRACTION	.622	
CALCULATED DIFFUSION COEFFICIENT	5.861D-03	cm^2 s^-1

LAYER 4 Liner Cover

THICKNESS	46	cm
POROSITY	.4	
MEASURED MASS DENSITY	1.59	g cm^-3
MEASURED RADIUM ACTIVITY	0	pCi/g^-1
DEFAULT LAYER EMANATION COEFFICIENT	.35	
CALCULATED SOURCE TERM CONCENTRATION	0.000D+00	pCi cm^-3 s^-1
WEIGHT % MOISTURE	6	%
MOISTURE SATURATION FRACTION	.238	
CALCULATED DIFFUSION COEFFICIENT	3.131D-02	cm^2 s^-1

LAYER 5 Subsoil

THICKNESS	152	cm
POROSITY	.45	
MEASURED MASS DENSITY	1.4575	g cm^-3
MEASURED RADIUM ACTIVITY	0	pCi/g^-1
DEFAULT LAYER EMANATION COEFFICIENT	.35	
CALCULATED SOURCE TERM CONCENTRATION	0.000D+00	pCi cm^-3 s^-1
WEIGHT % MOISTURE	6	%
MOISTURE SATURATION FRACTION	.194	
CALCULATED DIFFUSION COEFFICIENT	3.762D-02	cm^2 s^-1

LAYER 6 Topsoil

THICKNESS	46	cm
POROSITY	.49	
MEASURED MASS DENSITY	1.3515	g cm^-3
MEASURED RADIUM ACTIVITY	0	pCi/g^-1
DEFAULT LAYER EMANATION COEFFICIENT	.35	
CALCULATED SOURCE TERM CONCENTRATION	0.000D+00	pCi cm^-3 s^-1
WEIGHT % MOISTURE	6	%
MOISTURE SATURATION FRACTION	.165	
CALCULATED DIFFUSION COEFFICIENT	4.231D-02	cm^2 s^-1

0

DATA SENT TO THE FILE `RNDATA' ON DRIVE A:

N	F01	CN1	ICOST	CRITJ	ACC
6	-1.000D+00	0.000D+00	0	2.000D+01	1.000D-03

LAYER	DX	D	P	Q	XMS	RHO

AREA I 1

1	6.100D+01	4.942D-02	7.000D-01	7.524D-03	1.704D-01	0.795
2	4.260D+02	3.131D-02	4.000D-01	2.381D-04	2.385D-01	1.590
3	6.100D+01	5.861D-03	3.900D-01	0.000D+00	6.217D-01	1.617
4	4.600D+01	3.131D-02	4.000D-01	0.000D+00	2.385D-01	1.590
5	1.520D+02	3.762D-02	4.500D-01	0.000D+00	1.943D-01	1.458
6	4.600D+01	4.231D-02	4.900D-01	0.000D+00	1.655D-01	1.352

BARE SOURCE FLUX FROM LAYER 1: 2.599D+03 pCi m^-2 s^-1

RESULTS OF THE RADON DIFFUSION CALCULATIONS

LAYER	THICKNESS (cm)	EXIT FLUX (pCi m^-2 s^-1)	EXIT CONC. (pCi l^-1)
1	6.100D+01	1.327D+03	1.493D+06
2	4.260D+02	4.704D+01	1.465D+05
3	6.100D+01	2.265D+01	1.219D+04
4	4.600D+01	1.692D+01	1.141D+04
5	1.520D+02	8.109D+00	1.697D+03
6	4.600D+01	7.701D+00	0.000D+00

AREA 2A

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RADON FLUX, CONCENTRATION AND TAILINGS COVER THICKNESS
ARE CALCULATED FOR MULTIPLE LAYERS

OUTPUT FILE: Area 2A 10000 Years

DESCRIPTION: Subsoil with 6% wc instead of 15%

CONSTANTS

RADON DECAY CONSTANT	.0000021	s^-1
RADON WATER/AIR PARTITION COEFFICIENT	.26	
DEFAULT SPECIFIC GRAVITY OF COVER & TAILINGS	2.65	

GENERAL INPUT PARAMETERS

LAYERS OF COVER AND TAILINGS	7	
DEFAULT RADON FLUX LIMIT	20	pCi m^-2 s^-1
LAYER THICKNESS NOT OPTIMIZED		
DEFAULT SURFACE RADON CONCENTRATION	0	pCi l^-1
SURFACE FLUX PRECISION	.001	pCi m^-2 s^-1

LAYER INPUT PARAMETERS

LAYER 1 Raff Sludge

THICKNESS	377	cm
POROSITY	.8	
MEASURED MASS DENSITY	.53	g cm^-3
MEASURED RADIUM ACTIVITY	18587	pCi/g^-1
DEFAULT LAYER EMANATION COEFFICIENT	.35	
CALCULATED SOURCE TERM CONCENTRATION	9.051D-03	pCi cm^-3 s^-1
WEIGHT % MOISTURE	100	%
MOISTURE SATURATION FRACTION	.662	
CALCULATED DIFFUSION COEFFICIENT	1.618D-02	cm^2 s^-1

LAYER 2 Pond 2

THICKNESS	128	cm
POROSITY	.7	
MEASURED MASS DENSITY	.795	g cm^-3
MEASURED RADIUM ACTIVITY	2568	pCi/g^-1
DEFAULT LAYER EMANATION COEFFICIENT	.35	
CALCULATED SOURCE TERM CONCENTRATION	2.144D-03	pCi cm^-3 s^-1
WEIGHT % MOISTURE	15	%
MOISTURE SATURATION FRACTION	.170	
CALCULATED DIFFUSION COEFFICIENT	4.942D-02	cm^2 s^-1

LAYER 3 Struc Debris

AREA 2A

THICKNESS	256	cm
POROSITY	.2	
MEASURED MASS DENSITY	2.12	g cm^-3
MEASURED RADIUM ACTIVITY	75.3	pCi/g^-1
DEFAULT LAYER EMANATION COEFFICIENT	.35	
CALCULATED SOURCE TERM CONCENTRATION	5.867D-04	pCi cm^-3 s^-1
WEIGHT % MOISTURE	6	%
MOISTURE SATURATION FRACTION	.636	
CALCULATED DIFFUSION COEFFICIENT	4.015D-03	cm^2 s^-1

LAYER 4 Clay Liner

THICKNESS	61	cm
POROSITY	.39	
MEASURED MASS DENSITY	1.6165	g cm^-3
MEASURED RADIUM ACTIVITY	0	pCi/g^-1
DEFAULT LAYER EMANATION COEFFICIENT	.35	
CALCULATED SOURCE TERM CONCENTRATION	0.000D+00	pCi cm^-3 s^-1
WEIGHT % MOISTURE	15	%
MOISTURE SATURATION FRACTION	.622	
CALCULATED DIFFUSION COEFFICIENT	5.861D-03	cm^2 s^-1

LAYER 5 Liner Cover

THICKNESS	46	cm
POROSITY	.4	
MEASURED MASS DENSITY	1.59	g cm^-3
MEASURED RADIUM ACTIVITY	0	pCi/g^-1
DEFAULT LAYER EMANATION COEFFICIENT	.35	
CALCULATED SOURCE TERM CONCENTRATION	0.000D+00	pCi cm^-3 s^-1
WEIGHT % MOISTURE	6	%
MOISTURE SATURATION FRACTION	.238	
CALCULATED DIFFUSION COEFFICIENT	3.131D-02	cm^2 s^-1

LAYER 6 Subsoil

THICKNESS	152	cm
POROSITY	.45	
MEASURED MASS DENSITY	1.4575	g cm^-3
MEASURED RADIUM ACTIVITY	0	pCi/g^-1
DEFAULT LAYER EMANATION COEFFICIENT	.35	
CALCULATED SOURCE TERM CONCENTRATION	0.000D+00	pCi cm^-3 s^-1
WEIGHT % MOISTURE	6	%
MOISTURE SATURATION FRACTION	.194	
CALCULATED DIFFUSION COEFFICIENT	3.762D-02	cm^2 s^-1

LAYER 7 Topsoil

THICKNESS	46	cm
POROSITY	.49	
MEASURED MASS DENSITY	1.3515	g cm^-3
MEASURED RADIUM ACTIVITY	0	pCi/g^-1
DEFAULT LAYER EMANATION COEFFICIENT	.35	
CALCULATED SOURCE TERM CONCENTRATION	0.000D+00	pCi cm^-3 s^-1

	AREA 2A	
WEIGHT % MOISTURE	6	%
MOISTURE SATURATION FRACTION	.165	
CALCULATED DIFFUSION COEFFICIENT	4.231D-02	cm^2 s^-1

BARE SOURCE FLUX FROM LAYER 1: 6.268D+03 pCi m^-2 s^-1

RESULTS OF THE RADON DIFFUSION CALCULATIONS

LAYER	THICKNESS (cm)	EXIT FLUX (pCi m^-2 s^-1)	EXIT CONC. (pCi l^-1)
1	3.770D+02	3.520D+03	1.865D+06
2	1.280D+02	2.315D+02	2.540D+06
3	2.560D+02	3.848D+01	7.705D+04
4	6.100D+01	1.853D+01	9.972D+03
5	4.600D+01	1.384D+01	9.335D+03
6	1.520D+02	6.633D+00	1.388D+03
7	4.600D+01	6.300D+00	0.000D+00

AREA 2B

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RADON FLUX, CONCENTRATION AND TAILINGS COVER THICKNESS
ARE CALCULATED FOR MULTIPLE LAYERS

OUTPUT FILE: Area 2B 10000 Years

DESCRIPTION: Subsoil with 6%wc instead of 15%

CONSTANTS

RADON DECAY CONSTANT	.0000021	s^-1
RADON WATER/AIR PARTITION COEFFICIENT	.26	
DEFAULT SPECIFIC GRAVITY OF COVER & TAILINGS		2.65

GENERAL INPUT PARAMETERS

LAYERS OF COVER AND TAILINGS	6	
DEFAULT RADON FLUX LIMIT	20	pCi m^-2 s^-1
LAYER THICKNESS NOT OPTIMIZED		
DEFAULT SURFACE RADON CONCENTRATION	0	pCi l^-1
SURFACE FLUX PRECISION	.001	pCi m^-2 s^-1

LAYER INPUT PARAMETERS

LAYER 1 Pond 2

THICKNESS	505	cm
POROSITY	.7	
MEASURED MASS DENSITY	.795	g cm^-3
MEASURED RADIUM ACTIVITY	2568	pCi/g^-1
DEFAULT LAYER EMANATION COEFFICIENT	.35	
CALCULATED SOURCE TERM CONCENTRATION	2.144D-03	pCi cm^-3 s^-1
WEIGHT % MOISTURE	15	%
MOISTURE SATURATION FRACTION	.170	
CALCULATED DIFFUSION COEFFICIENT	4.942D-02	cm^2 s^-1

LAYER 2 Struc Debris

THICKNESS	256	cm
POROSITY	.2	
MEASURED MASS DENSITY	2.12	g cm^-3
MEASURED RADIUM ACTIVITY	75.3	pCi/g^-1
DEFAULT LAYER EMANATION COEFFICIENT	.35	
CALCULATED SOURCE TERM CONCENTRATION	5.867D-04	pCi cm^-3 s^-1
WEIGHT % MOISTURE	6	%
MOISTURE SATURATION FRACTION	.636	
CALCULATED DIFFUSION COEFFICIENT	4.015D-03	cm^2 s^-1

LAYER 3 Clay Liner

AREA 2B

THICKNESS	61	cm
POROSITY	.39	
MEASURED MASS DENSITY	1.6165	g cm^-3
MEASURED RADIUM ACTIVITY	0	pCi/g^-1
DEFAULT LAYER EMANATION COEFFICIENT	.35	
CALCULATED SOURCE TERM CONCENTRATION	0.000D+00	pCi cm^-3 s^-1
WEIGHT % MOISTURE	15	%
MOISTURE SATURATION FRACTION	.622	
CALCULATED DIFFUSION COEFFICIENT	5.861D-03	cm^2 s^-1

LAYER 4 Liner Cover

THICKNESS	46	cm
POROSITY	.4	
MEASURED MASS DENSITY	1.59	g cm^-3
MEASURED RADIUM ACTIVITY	0	pCi/g^-1
DEFAULT LAYER EMANATION COEFFICIENT	.35	
CALCULATED SOURCE TERM CONCENTRATION	0.000D+00	pCi cm^-3 s^-1
WEIGHT % MOISTURE	6	%
MOISTURE SATURATION FRACTION	.238	
CALCULATED DIFFUSION COEFFICIENT	3.131D-02	cm^2 s^-1

LAYER 5 Subsoil

THICKNESS	46	cm
POROSITY	.45	
MEASURED MASS DENSITY	1.4575	g cm^-3
MEASURED RADIUM ACTIVITY	0	pCi/g^-1
DEFAULT LAYER EMANATION COEFFICIENT	.35	
CALCULATED SOURCE TERM CONCENTRATION	0.000D+00	pCi cm^-3 s^-1
WEIGHT % MOISTURE	6	%
MOISTURE SATURATION FRACTION	.194	
CALCULATED DIFFUSION COEFFICIENT	3.762D-02	cm^2 s^-1

LAYER 6 Topsoil

THICKNESS	46	cm
POROSITY	.49	
MEASURED MASS DENSITY	1.3515	g cm^-3
MEASURED RADIUM ACTIVITY	0	pCi/g^-1
DEFAULT LAYER EMANATION COEFFICIENT	.35	
CALCULATED SOURCE TERM CONCENTRATION	0.000D+00	pCi cm^-3 s^-1
WEIGHT % MOISTURE	6	%
MOISTURE SATURATION FRACTION	.165	
CALCULATED DIFFUSION COEFFICIENT	4.231D-02	cm^2 s^-1

▯

BARE SOURCE FLUX FROM LAYER 1: 2.214D+03 pCi m^-2 s^-1

RESULTS OF THE RADON DIFFUSION CALCULATIONS

LAYER	THICKNESS	EXIT FLUX	EXIT CONC.

AREA 2B

	(cm)	(pCi m^-2 s^-1)	(pCi l^-1)
1	5.050D+02	5.565D+01	9.596D+05
2	2.560D+02	3.787D+01	7.491D+04
3	6.100D+01	1.880D+01	8.198D+03
4	4.600D+01	1.521D+01	6.331D+03
5	4.600D+01	1.320D+01	2.761D+03
6	4.600D+01	1.253D+01	0.000D+00

AREA 3 1

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RADON FLUX, CONCENTRATION AND TAILINGS COVER THICKNESS ARE CALCULATED FOR MULTIPLE LAYERS

OUTPUT FILE: Area 3 10000 Years

DESCRIPTION: Subsoil with 6%wc instead of 15%

CONSTANTS

RADON DECAY CONSTANT	.0000021	s^-1
RADON WATER/AIR PARTITION COEFFICIENT	.26	
DEFAULT SPECIFIC GRAVITY OF COVER & TAILINGS		2.65

GENERAL INPUT PARAMETERS

LAYERS OF COVER AND TAILINGS	5	
DEFAULT RADON FLUX LIMIT	20	pCi m^-2 s^-1
LAYER THICKNESS NOT OPTIMIZED		
DEFAULT SURFACE RADON CONCENTRATION	0	pCi l^-1
SURFACE FLUX PRECISION	.001	pCi m^-2 s^-1

LAYER INPUT PARAMETERS

LAYER 1 Layer b-d

THICKNESS	457	cm
POROSITY	.7	
MEASURED MASS DENSITY	.795	g cm^-3
MEASURED RADIUM ACTIVITY	38.4	pCi/g^-1
DEFAULT LAYER EMANATION COEFFICIENT	.35	
CALCULATED SOURCE TERM CONCENTRATION	3.205D-05	pCi cm^-3 s^-1
WEIGHT % MOISTURE	15	%
MOISTURE SATURATION FRACTION	.170	
CALCULATED DIFFUSION COEFFICIENT	4.942D-02	cm^2 s^-1

LAYER 2 Clay Liner

THICKNESS	61	cm
POROSITY	.39	
MEASURED MASS DENSITY	1.6165	g cm^-3
MEASURED RADIUM ACTIVITY	0	pCi/g^-1
DEFAULT LAYER EMANATION COEFFICIENT	.35	
CALCULATED SOURCE TERM CONCENTRATION	0.000D+00	pCi cm^-3 s^-1
WEIGHT % MOISTURE	15	%
MOISTURE SATURATION FRACTION	.622	
CALCULATED DIFFUSION COEFFICIENT	5.861D-03	cm^2 s^-1

LAYER 3 Layer 3

AREA 3 1

THICKNESS	46	cm
POROSITY	.4	
MEASURED MASS DENSITY	1.59	g cm^-3
MEASURED RADIUM ACTIVITY	0	pCi/g^-1
DEFAULT LAYER EMANATION COEFFICIENT	.35	
CALCULATED SOURCE TERM CONCENTRATION	0.000D+00	pCi cm^-3 s^-1
WEIGHT % MOISTURE	6	%
MOISTURE SATURATION FRACTION	.238	
CALCULATED DIFFUSION COEFFICIENT	3.131D-02	cm^2 s^-1

LAYER 4 Subsoil

THICKNESS	152	cm
POROSITY	.45	
MEASURED MASS DENSITY	1.4575	g cm^-3
MEASURED RADIUM ACTIVITY	0	pCi/g^-1
DEFAULT LAYER EMANATION COEFFICIENT	.35	
CALCULATED SOURCE TERM CONCENTRATION	0.000D+00	pCi cm^-3 s^-1
WEIGHT % MOISTURE	6	%
MOISTURE SATURATION FRACTION	.194	
CALCULATED DIFFUSION COEFFICIENT	3.762D-02	cm^2 s^-1

LAYER 5 Topsoil

THICKNESS	46	cm
POROSITY	.49	
MEASURED MASS DENSITY	1.3515	g cm^-3
MEASURED RADIUM ACTIVITY	0	pCi/g^-1
DEFAULT LAYER EMANATION COEFFICIENT	.35	
CALCULATED SOURCE TERM CONCENTRATION	0.000D+00	pCi cm^-3 s^-1
WEIGHT % MOISTURE	6	%
MOISTURE SATURATION FRACTION	.165	
CALCULATED DIFFUSION COEFFICIENT	4.231D-02	cm^2 s^-1

0

BARE SOURCE FLUX FROM LAYER 1: 3.260D+01 pCi m^-2 s^-1

RESULTS OF THE RADON DIFFUSION CALCULATIONS

LAYER	THICKNESS (cm)	EXIT FLUX (pCi m^-2 s^-1)	EXIT CONC. (pCi l^-1)
1	4.570D+02	3.873D+00	1.280D+04
2	6.100D+01	1.865D+00	1.004D+03
3	4.600D+01	1.393D+00	9.396D+02
4	1.520D+02	6.677D-01	1.397D+02
5	4.600D+01	6.341D-01	0.000D+00

0

APPENDIX D

EROSIONAL STABILITY

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D.1 INTRODUCTION

This appendix presents the hydrologic analyses and evaluation of erosion protection for the cover of the disposal cell. This appendix is an update of analyses documented in the 2002 Preliminary Design Report (Reclamation Plan Appendix C). The analyses encompass the following tasks:

1. Determine the PMP event for the disposal cell area.
2. Determine the peak unit discharge from the PMP on the drainage basins of the disposal cells.
3. Evaluate erosional stability of the disposal cell cover surface using the peak unit discharge.
4. Calculate the median rock size for erosion protection materials on the disposal cell cover using the peak unit discharge.
5. Calculate the median rock size for erosion protection materials of the rock apron at the toe of the disposal cell.
6. Calculate the median rock size required for scour protection at the head of Gully 005.
7. Evaluate filter criteria between granular material and surrounding materials.
8. Evaluate wind erosion potential of disposal cell cover.

These analysis tasks are described in the following sections.

D.2 PROBABLE MAXIMUM PRECIPITATION EVENT

One of the technical criteria for the stability of the disposal cell is acceptable erosional stability from extreme storm events (Appendix A of 10 CFR 40). The NRC has interpreted this criterion to be able to safely pass the peak runoff from storms up to the Probable Maximum Precipitation (PMP) event (NRC, 1990; Johnson, 1999, Johnson, 2002). This section discusses the precipitation event used to predict the peak discharges for design of the disposal cell cover.

The depth of the PMP is derived from Hydrometerological Report 51 (HMR 51, USCOE, 1978). HMR 51 provides depths for the all-season PMP for basins with an area of 10 square miles or larger. Figure 18 from HMR 51 indicates a PMP depth of 29 inches over a duration of 6 hours for a drainage basin of 10 square miles. For this analysis, it was necessary to derive the PMP event for a smaller duration and smaller drainage area. This was accomplished by using the Hydrometerological Report 52 (HMR 52, USCOE, 1982). HMR 52 takes the PMP estimates from HMR 51 and applies them to specific drainage

areas both temporally and spatially. From Figures 23 and 24 in HMR 52, the 1-hour PMP for a drainage area of one square mile is 0.65 times smaller than the 6-hour PMP for 10 square mile drainage areas. This results in a 1-hour PMP of 19 inches, which was used for this analysis. Factors for durations less than one hour where taken from Hydrometeorological Report No. 52 for durations of 5, 15 and 30 minutes. The rainfall intensity was determined by multiplying the PMP depth by its corresponding duration based on the time of concentration for that specific drainage basin.

D.3 RUNOFF FROM THE PMP (PEAK DISCHARGE)

The Rational Method was used to determine the peak discharge from the PMP for evaluation of cover erosion protection. Five drainage areas were delineated on the cover of the disposal cell; four on the side slopes (north, south, east and west), and one on the top surface. The area of these drainage basins was calculated using computer-aided design (CAD) tools.

Time of Concentration. The time of concentration is computed using the Kirpich (1940) equation (give below) as recommended in the NRC STP.

$$T_c = 0.0078L^{0.77}(L/H)^{0.385}$$

Where:

T_c = time of concentration (minutes)
L = slope length (feet)
H = slope height (feet)

Table D.1 (below) shows the areas of each drainage basin, the slope, and slope length, which are used for the time of concentration calculation. As seen in Table D.1, all calculated times of concentration are less than 5 minutes except for the cover, which is 5.4 minutes. As recommended in the Urban Drainage and Flood Control District Strom Drainage Criteria Manual (UDFCD, 2001) and Nelson and others (1986), time of concentration less than 5 minutes does not lead to realistic runoff estimates, and therefore a T_c of 5 minutes was used for each basin.

Table D.1 Results of Time of Concentration Calculations

Description	Drainage Area (acres)	Slope (feet/feet)	Slope Length (feet)	Time of Concentration (minutes)
Top	7.8	0.01	500	5.4
North	2.5	0.20	190	0.9
South	1.4	0.20	110	0.6
East	1.8	0.20	100	0.5
West	3.6	0.20	225	1.0

The rainfall intensity for each basin is 75.2 inches per hour based on a T_c of 5 minutes. From Figure 36 of the Hydrometeorological Report No. 52 (Schriener and Riedel, 1978), a ratio of 0.33 is multiplied to the 1-hour PMP depth for a duration of 5 minutes. Rainfall intensities for each basin are determined as follows:

$$I = \frac{P_{pmp} \times F \times 60\,\mathrm{min}/hr}{T_c}$$

Where:

I = intensity
P_{pmp} = 19 inches (depth of 1 hour PMP)
F = ratio of 5 minute duration to 1-hour duration = 0.33
T_c = time of concentration (minutes) = 5 minutes

Peak flow. The peak flow was calculated with the Rational Formula, as follows:

$$Q = CIA$$

Where:

Q = peak flow (cfs)
C = runoff coefficient = 0.8
I = rainfall intensity (inches/hour)
A = area (acres)

The NRC STP recommends using a conservative runoff coefficient of 0.8 when evaluating erosion protection for cover systems. Peak flow was then divided by the downstream width of the appropriate drainage area as follows:

$$q = Q/w$$

Where:

q = unit discharge (cfs/foot)
w = unit width (feet)

Table D.2 shows the results of the peak flow and unit discharge calculations for each drainage basin.

Table D.2 Results of Peak Flow and Unit Discharge for Each Drainage Basin

Description	Drainage Area (acres)	Rainfall Intensity (in/hr)	Peak Flow (cfs)	Downstream Width (feet)	Unit Discharge (cfs/acre)	Unit Discharge (cfs/foot)
Top	7.8	75.2	469.2	1200	60	0.39
North	2.5	75.2	150.4	575	60	0.26
South	1.4	75.2	84.2	600	60	0.14
East	1.8	75.2	108.3	830	60	0.13
West	3.6	75.2	216.6	850	60	0.25

For the top surface of the disposal cell, the peak flow in Table D.2 (469.2 cfs) represents the flow over the top of the east and south side slopes. The unit discharge (0.39 cfs/foot) is this flow distributed over the slope width at the top of the east and south side slopes (1,200 feet).

For sizing riprap for erosion protection on the side slopes, the unit discharge values in Table D.2 were used in evaluating the north and west side slopes. On the east and south side slopes, the unit discharge from the top surface (0.39 cfs/foot) was used, since this value was larger than the unit discharge for runoff from precipitation on the slope itself (0.13 and 0.14 cfs/foot). Due to the differences in time of concentration between the top surface and side slope runoff, the peak flows on the east and south side slopes were not added to the peak flow from the top surface.

D.4 TOP SURFACE EROSIONAL STABILITY

The top surface of the disposal cell was evaluated for erosional stability without a rock layer. As outlined in NRC (1990) and Johnson (1999), the peak discharge over the top surface (from Table D.2) was first converted to a peak velocity and depth of flow using Manning's Equation. The peak unit discharge flow (0.39 cfs/foot) was multiplied by a concentration factor of 3. Depending on surface roughness (due to vegetation conditions), peak velocities range from approximately 1.4 to 2.3 feet per second and the corresponding depths of flow are 0.87 to 0.50 feet (for Manning's roughness coefficient values ranging from 0.10 to 0.04). Permissible velocities presented in Johnson (1999) for these depths of flow range

from approximately 2.0 to 2.4 feet per second. This indicates that some of the peak velocities from the PMP are less than permissible velocities, but not under all of the surface roughness conditions that were analyzed. As the next step of evaluation, procedures for vegetated surfaces outlined in Temple and others (1987) were used (as recommended in the NRC STP).

Method of Analysis. Temple and others (1987) outlines procedures for channel design, including calculation of channel velocities and depths of flow. These procedures include methods for estimating stresses on channel vegetation as well as the channel surface soils. The evaluation for the disposal cell used the peak discharge values from the PMP (summarized in Table D.2) to conservatively represent the effective stresses from runoff on the cover surface. The stresses on both the vegetation and soils were evaluated.

The erosional stability of the cover surface was evaluated by calculating a factor of safety against erosion due to the peak runoff from the PMP. Factor-of-safety values were calculated as the ratio of the allowable stresses (the resisting strength of the cover vegetation or soils) to the effective stresses (the stresses impacted by the runoff flowing over the cover). The stress calculations are summarized below.

Allowable stresses. Allowable stresses for the cover soils were calculated using the equations in Temple and others (1987). Materials planned for cover soils range from silty clays to gravelly sandy silts (depending on how much of the underlying sandstone and siltstone is present in the cover material). For cohesive soils, the resistance is based on the plastic limit and void ratio of the material. From testing of on-site silty clay in 1996 (classified as a low-plasticity clay or CL), the plastic limit was 16 and the void ratio (at 90 percent of Standard Proctor density) was 0.723. The equation for allowable shear strength for cohesive soils is:

$$\tau_a = \tau_{ab} C_e^2$$

Where:

τ_a = allowable shear strength (in psf)
τ_{ab} = basis allowable shear strength (for a CL) = $(1.07 [PL]^2+14.3[PL]+47.7)\times10^{-4}$
C_e = soil parameter = $1.48 - 0.57e$
PL = plastic limit = 16
e = void ratio = 0.723

For the plastic limit and void ratio values given above, $\tau_{ab} = 0.055$, $C_e = 1.07$ and $\tau_a = 0.063$ psf.

For non-cohesive soils, the resistance is based on particle size, specifically the size where 75 percent of the material is finer, or d_{75}. For a d_{75} larger than 0.05 inches (1.27 mm, No. 14 sieve size, or a medium-grained sand), the allowable shear strength is:

$$\tau_a = 0.4\, d_{75}, \text{ where } d_{75} \text{ is in inches}$$

For a soil cover d_{75} of 0.157 inches (4 mm, No. 4 sieve size, or a coarse-grained sand), the allowable shear strength is 0.063 psf.

For a vegetated surface primarily of mixed grasses, the allowable vegetation shear strength is:

$$\tau_{va} = 0.75\, C_I$$

Where:

τ_{va} = allowable vegetation shear strength (in psf)
C_I = cover index = $2.5\, [h(M)^{1/2}]^{1/3}$
h = stem length (in ft)
M = stem density factor

For average vegetation conditions, h=1.0, M=200 and C_I=6.05. For poor conditions, h=0.5, M=150, and C_I=4.57. The resulting vegetation shear stress values are 4.53 to 3.43 psf for average to poor vegetation conditions, respectively.

Effective stresses. The effective shear stress on soil due to peak runoff from the PMP was calculated as:

$$\tau_e = \gamma d S(1-C_F)(n_s/n)^2$$

Where:

τ_e = effective shear stress (in psf)
γ = unit weight of water = 62.4 pcf
d = depth of flow (in ft)
S = slope of cover surface (0.01)
C_F = cover factor (0.7 for average vegetation, 0.5 for poor vegetation)
n_s = soil grain roughness factor (0.0156 for cohesive soil, 0.018 for soil with a d_{75} of 4 mm)
n = Manning's roughness coefficient (0.10 to 0.04)

The effective shear stress on vegetation is calculated as:

$$\tau_v = \gamma d S - \tau_e, \text{ where } \tau_v = \text{effective vegetal stress (in psf)}$$

Varying the vegetation conditions and the soil grain roughness factors, the effective shear stresses for Manning's n values are summarized below.

Manning's n value	0.10	0.10	0.10	0.10	0.04	0.04	0.04	0.04
Depth of flow, d (ft)	0.87	0.87	0.87	0.87	0.50	0.50	0.50	0.50
Cover factor, C_F	0.7	0.5	0.7	0.5	0.7	0.5	0.7	0.5
Soil grain roughness factor, n_s	0.0156	0.0156	0.018	0.018	0.0156	0.0156	0.018	0.018
Effective shear stress, τ_e (psf)	0.004	0.007	0.005	0.009	0.014	0.024	0.019	0.032
Effective vegetal stress, τ_v (psf)	0.539	0.536	0.538	0.534	0.298	0.288	0.293	0.280

Factors of safety. The calculated factors of safety from the shear stresses above are outlined below.

Condition	Allowable Strength (psf)	Effective Stress (psf)	Factor of Safety (allowable/effective)
Vegetation on cover surface			
(average)	4.53	0.539	8.4
(poor)	3.43	0.536	6.4
Soils on cover surface			
(cohesive)	0.0627	0.024	2.6
(granular)	0.063	0.032	2.0

The calculated factors of safety above show that for average to poor vegetation conditions, the allowable shear strengths are higher than the effective shear stresses on vegetation due to peak discharge from the PMP (with factors of safety above 6). For the conservative condition of no vegetation with the topsoil eroded away, the underlying cover soil shear strengths are higher than the effective shear strengths due to peak discharge for the PMP (with factors of safety at or above 2).

These analyses indicate that the cover on the top surface of the disposal cell can be vegetated without a riprap or rock mulch layer and meet the erosional stability criteria outlined in NRC (1990), Johnson (1999), and Johnson (2002). In the following section, riprap sizing calculations are included on the cover surface for comparative purposes.

D.5 RIPRAP SIZING FOR THE COVER SURFACES

The design unit discharge from each drainage basin was used to size riprap for the protective cover. The design unit discharge is based on the assumption of uniform sheet flow across the entire drainage basin. The NRC STP recommends using the Safety Factors Method for top surfaces (less than 10 percent) and Stephenson's method for side slopes (greater than 10 percent). Johnson (1999) recommends the use of

the Abt method for side slopes, so this method was used for riprap sizing on the side slopes, with comparison with Stephenson's method.

The equation for the Safety Factors Method (Richardson et al., 1975) and Stephenson Method (Stephenson, 1979) are outlined in NUREG CR-4620 (Nelson et al., 1986). The key parameters used in the riprap sizing calculations are outlined below.

Flow Characteristics. The peak unit discharge values from Table D.2 were used to represent flow conditions on the cover surface. Where applicable, a concentration factor of 3 was used.

Rock Characteristics. Properties for durable rock from nearby gravel pits were used in the calculations. The rock specific gravity was 2.65, with a friction angle or angle of repose of 37 degrees (representing rounded rock, consistent with Table 4.8 of NUREG CR-4620), and a porosity of 0.33.

The riprap sizing results are summarized in Table D.3 below.

Table D.3 Results of Riprap Sizing Calculations for Cover Protection

Drainage Basin	Design Unit Discharge (cfs/ft)	Slope (ft/ft)	Slope Length (ft)	Flow Concentration Factor, C_f	Coefficient of Movement, C_m	Adjusted Design Unit Discharge q_f (cfs/ft)	Median Rock Size (inches) Stephenson	Median Rock Size (inches) Abt
Top	0.39	0.01	500	1.0	1.35	0.47	1.2[a]	---
North	0.26	0.20	190	2.0	1.35	0.70	2.6	3.2
South	0.39[b]	0.20	110	3.0	1.35	1.42	3.3	4.7
East	0.39[b]	0.20	100	3.0	1.35	1.42	3.3	4.7
West	0.25	0.20	225	2.0	1.35	0.68	2.5	2.9

[a] - Safety Factors Method
[b] – From discharge off of top surface

Using Abt's method for the side slopes (at 20 percent) the median rock size ranges from 2.9 inches on the west slope to 4.7 inches on the east and south slopes of the disposal cell (based on runoff from the top surface flowing over the east and south slopes).

For the disposal cell cover design, two modifications are made from standard surface riprap design, as outlined below.

Rock mulch. A rock mulch will be used for the riprap, utilizing alluvial (rounded) gravel or quarried (angular) limestone from nearby sources, with smaller materials to fill the void spaces. Using the median size for the east and south sides of the cell of 4.7 inches, the median rock mulch size for all of the side slopes was conservatively chosen to be 4.7 inches. This median size is for rounded rock. The median size for angular rock is 40 percent smaller (with no oversizing for durability considerations). The maximum size (based on available screen size) is 9 inches. The rock mulch layer thickness (recommended to be 1.5 to 2 times the median size or at the maximum size in the NRC STP) is 9 inches.

Below-surface layer. In order to promote establishment and maintenance of vegetation on the side slopes, the rock mulch layer will not be on the cover surface. A layer of topsoil (9 inches thick) will be the top layer on the side slopes, followed by the rock mulch layer (9 inches thick). The topsoil will provide the seed bed and "A" horizon for plant establishment and growth, and the rock mulch layer will allow root penetration. The rock mulch layer will provide an erosion protection layer in the event that the topsoil is eroded.

D.6 RIPRAP SIZING FOR THE PERIMETER APRON

Additional erosion protection will be provided for runoff from the side slopes of the disposal cell with a rock apron. This perimeter apron will (1) serve as an impact basin and provide for energy dissipation of runoff, (2) provide erosion protection, and (3) transition flow from side slopes to natural ground. On the north, south, and west sides of the cell, flow will transition from the rock apron to natural ground. On the east side of the cell, the rock apron will also serve as a diversion channel as flow is received from both the east side slopes of the disposal cell and from approximately 5.4 acres of upstream ground between the property boundary and the east toe of the disposal cell.

The median rock size required in the perimeter apron was calculated using the equations derived by Abt et al. (1998) as outlined in NUREG 1623 as follows:

$$D_{50energydissipation} = 10.46S^{0.43}(C_f q_d)^{0.56}$$
$$D_{50diversionchannel} = 5.23S^{0.43}(C_f q_d)^{0.56}$$

Where S is the slope, C_f is the concentration factor, and q_d is the design unit discharge. The median rock size was increased by 40 percent to account for the use of rounded alluvial rock.

Table D.4 Results of Rock Sizing Calculations for Perimeter Apron for Energy Dissipation

Drainage Basin	Design Unit Discharge (cfs/ft)	Slope Upstream of Toe (ft/ft)	Flow Concentration Factor, C_f	Median Rock Size, Angular (inches)	Median Rock Size, Rounded (inches)
North	0.26	0.20	3.0	4.6	6.4
South	0.39	0.20	3.0	5.7	8.0
East	0.39	0.20	3.0	5.7	8.0
West	0.25	0.20	3.0	4.5	6.2

Peak flow along the east toe was calculated using the Rational Formula, as described in section D.3. Flow over the east side slope is combined with overland flow. The maximum flow in each reach of the toe/diversion is calculated using the parameters in Table D.5..

Table D.5 Results of Peak Flow along Toe of East Side Slope

Flow Area	Side Slope Unit Discharge (cfs/foot)	Linear Length of Side-Slope (ft)	Overland Flow Runoff Coef. (acre)	Rainfall Intensity (in/hr)	Overland Flow Area (acre)	Peak Flow (cfs)
A1	0.39	390	0.3	75.2	1.78	192
A2	0.39	450	0.3	75.2	3.54	255

The median rock size was calculated using equation presented by Abt et al. (1998) for embankment side slopes, as recommended in NUREG 1623. The parameters used in this calculation are shown in Table D.6.

Table D.6 Results of Riprap Sizing Calculations for Diversion Channel Along East Toe

Diversion Reach	Maximum Channel Flow (cfs)	Channel Bottom Width (ft)	Design Unit Discharge (cfs/ft)	Flow Concentration Factor, C_f	Channel Slope (ft/ft)	Median Rock Size, Angular (inches)	Median Rock Size, Rounded (inches)
North Channel	192	40	4.8	3	0.029	5.1	7.1
South Channel	255	40	6.38	3	0.024	5.5	7.7

Based on Tables D.4 and D.6, the rock apron should have a median rock size of 5.7 inches if angular rock is used, and 8.0 inches if rounded rock is used. The channel along the east side of the disposal cell should

have a width of 40 feet and a minimum depth for flow of 1.0 foot. The rock apron thickness (recommended to be 3 times the median stone size) will be 18 to 24 inches.

The maximum unit flow off the toe is 0.39 cfs/ft. Using this maximum flow, and an assumed slope of the rock apron of one percent, the maximum scour depth was calculated using procedures outlined in NUREG 1623 and U.S. Department of Transportation in Hydrologic Engineering Circular 14 (calculation discussed further in Section D.7). The maximum scour depth from flow coming off the rock apron of the disposal cell is estimated to be 0.46 feet. The rock apron thickness is therefore adequate to protect against scour.

D.7 ROCK SIZING FOR SCOUR PROTECTION AT THE HEAD OF GULLY 005

A rock apron to protect against headward erosion has been sized according to procedures specified in NUREG 1623. The rock apron will be constructed at the point where water discharges to natural ground at the head of Gully 005. Scour depth was estimated using the procedures presented in the U.S. Department of Transportation in Hydrologic Engineering Circular 14. These calculations indicate that the theoretical maximum depth of scour exceeds the depth of bedrock. Boring holes drilled near the head of Stream 005 (BH-42 and BH-47 from SFC FEIF, 1991) indicate that sandstone bedrock is located at a depth of less than 7 feet. Therefore, the erosion apron will be constructed by excavating the alluvial soils at a 1V:5H slope until keyed into bedrock. The median rock size is calculated by the following equation:

$$D_{50} = 5.23S^{0.43}(C_f q_d)^{0.56}$$

Where:

- S = slope of the placed rock protection = 0.20,
- C_f = flow concentration factor = 3.0, and
- q_d = design unit discharge.

As calculated in section D.3, flow off the west slope has a unit flow of 0.25 cfs/ft. The 50-foot channel at the toe of the west side slope receives flow from approximately 200 linear feet of slope. In addition, approximately 0.13 acres of land surrounding the gully protection apron will drain past the downstream edge of the gully protection. Therefore, the design unit discharge for gully erosion protection is estimated to be approximately 1.1 cfs per foot. The median rock size for Gully 005 erosion protection should have a minimum size of 5.1 inches for angular rock, and 7.2 for rounded rock.

D.8 FILTER CRITERIA

Filter requirements between components of the disposal cell materials need to be met. Specific areas evaluated include (1) filter between disposed material, liner cover material, and leachate collection pipe, (2) rock mulch of side slope and base material, (3) rock of toe apron and base material, (4) rock of toe apron/diversion channel on the east side of the disposal cell, and (5) rock of Gully 005 erosion protection. The gradations of the various materials are shown in Figure D.2

Disposed material, liner cover material, and leachate collection pipe. Filter criteria of these materials need to meet minimum requirements to prevent clogging and to meet permeability requirements. Therefore, criteria as specified in USDA (1994) were used as follows:

Step 1: Correct base (disposed material) gradation for oversized material (>#4).
Step 2: Using Table 26-1, base soil is category 2 (sands, silts, clays, and silty and clayey sands)
Step 3: Maximum D_{15} is <=0.7 mm
Step 4: For permeability requirements, minimum D_{15}>=4*d_{15} of base soil. D_{15}>=0.012 mm
Step 5: For percentage passing of 60 or less, so ratio of maximum and minimum bands of filter are less than 5. Minimum D_{15}>=0.14 mm.
Step 6: To prevent gap-grading, set coefficient of uniformity (CU=D_{60}/D_{10}) <= 6. Maximum D_{10}=Maximum D_{15}/1.2. Maximum D_{10}=0.7/1.2=0.58 mm. Maximum D_{60}= 0.58*6=3.5 mm. Minimum D_{60}=3.5/5=0.7 mm.
Step 7: Minimum D_5=0.075 mm
Step 8: Maximum D_{100}=1 inch (protection of synthetic liner)
Step 9: Perforations in pipe <= D_{85} filter. Perforations 2-3 mm.

Rock mulch of side slope and subsoil. NUREG 1623, Appendix D, recommends a filter or bedding layer be placed under riprap when interstitial velocities are greater than 0.5 to 1.0 ft/sec. Interstitial velocities are calculated by procedures presented by Abt et al. (1991) as given in the following equation:

$$V_i = 0.23 * (g * D_{10} * S)^{\frac{1}{2}}$$

Where:

V_i = interstitial velocities in ft/s,
g = acceleration of gravity in ft/s^2,
D_{10} = stone diameter at which 10% is finer in inches, and
S = gradient in decimal form.

Using a D_{10} of ¾ in, and a side slope of 0.20, the calculated velocity is 0.5 ft/s. Therefore, a bedding layer is not required beneath the rock mulch of the side slopes. A bedding layer is not conditionally required unless D_{10} is greater than 2.9 inches.

Rock mulch of toe apron and native alluvial material. Rock sizing calculations for the toe apron specify a minimum D_{50} of 8 inches. The grain size distribution for the rock was determined using guidance given in NUREG 4620, Section 4.4. The toe apron serves primarily to dissipate energy of the flow coming from the slopes of the cell, and will be constructed relatively flat. Assuming a 1% slope of the toe, and using the above equation to calculate the interstitial velocities, the velocities for a D_{10} of 7.8 inches or less are below 0.5 ft/s. Therefore, no filter layer is required beneath the toe apron.

Rock of toe apron/diversion channel on the east side of the disposal cell and native alluvial material. Rock of the toe apron/diversion channel on the east side of the disposal cell will have the same gradation as the rock at the toe of the slopes on the north, west, and south of the disposal cell (minimum D_{50} of 8 inches). However, on the east side of the cell, water will collect at the toe and flow north and south around the east toe until it is intercepted by the diversion channels and diverted away from the disposal cell. The maximum slope along the east side of the disposal cell is approximately 2.9 percent. The calculated interstitial velocities are 0.6 ft/s. Therefore, a filter layer is not required beneath the toe apron/diversion channel along the east side of the disposal cell.

Rock of Gully 005 erosion protection and native alluvial material. The rock of Gully 005 erosion protection will have the same gradation as the rock at the toe of the slopes (minimum D_{50} of 8 inches). The erosion protection will be placed by excavating at a 5:1 (horizontal:vertical) slope until keyed into bedrock. If scour were to reach the base of this protective layer, the velocities of flow into the gully would require filter between the rock protection and the native alluvial soils.

The rock protection and native alluvial soils would require two filters. The native alluvial soils would first be overlain by material meeting specifications for liner cover/liner bedding gradations. The second filter (erosion protection filter) material is designed to meet minimum requirements of $D_{15}(coarser)/D_{85}(finer)<=5$ of both the liner cover/liner bedding material, and the D_{50} of 8 inch rock gradations, as discussed in NUREG 4620, section 4.4. In addition, the erosion protection filter is shown to have a maximum coefficient of uniformity of 6. Each filter layer should have a minimum thickness of 12 inches.

D.9 WIND EROSION

The potential for wind erosion of the top surface of disposal cell during drought conditions was evaluated using procedures given in NUREG 4620 (Nelson et al. 1986). The soil loss equation was calculated as follows:

$$A = R \times K \times LS \times VM$$

Where:

A = soil loss in tons per acre per year,
R = rainfall factor,
K = soil erodibility factor,
LS = topographic factor, and
VM = dimensionless erosion control factor relating to vegetative and mechanical factors.

The rainfall factor was conservatively modeled as 100. The soil erodibility factor was estimated based on percent silt and very fine sand to range between 26 and 36 percent, the percent sand (0,10 – 2.0 mm) to range between 5 and 22 percent. The percent organic matter was estimated at 2 percent, the soil structure was considered to be fine granular (No. 2) and the permeability was considered moderate (No. 3). Using the nomograph given in Figure 5.1 of NUREG 4620, the soil erodibility factor was estimated to be 0.12.

The topographic factor is calculated by the following equation:

$$LS = \frac{650 + 450 \times s + 65 \times s^2}{10{,}000 + s^2} \times \left(\frac{L}{72.6}\right)^m$$

Where:

s = slope steepness in percent,
L = slope length in feet, and
m = exponent dependent upon slope steepness.

For a slope of 1 percent, a length of 500 feet, LS is calculated to be 0.17. VM was set at 0.4, which is the value given for seedings, permanent 0-60 days, to represent drought conditions. During non-drought conditions, seedings older than 12 months would be represented by a VM value of 0.01.

The calculated soil loss is 0.822 tons per acre per year. Assuming a dry density of soil of 100 pcf, the soil loss is equivalent to 3.8×10^{-4} ft/year, or 0.4 feet over a 1000-year life of the disposal cell. The disposal cell has adequate topsoil depth (18 inches on the top slope) to account for wind erosion.

D.10 REFERENCES

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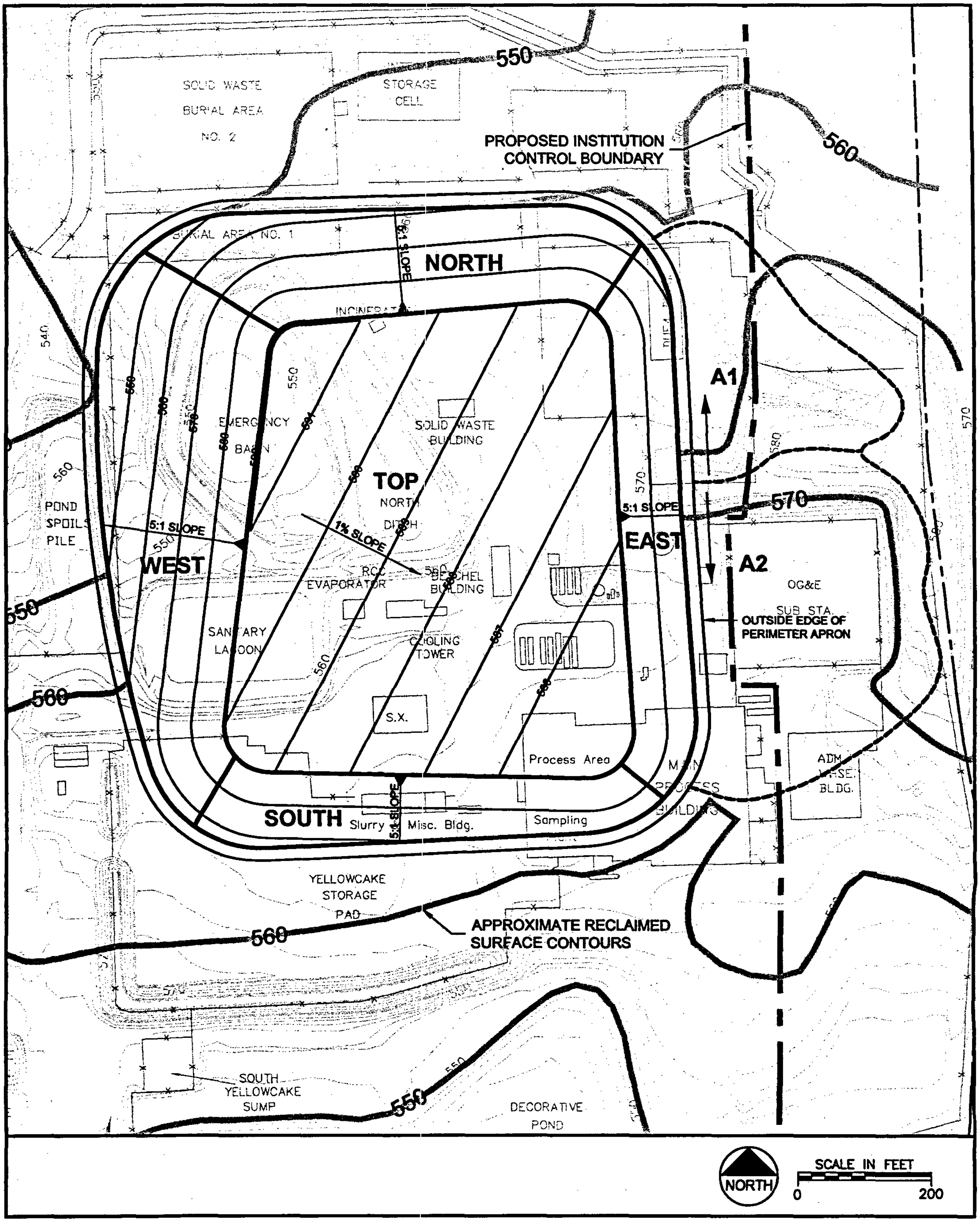

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FIGURE D.1
DRAINAGE AREAS USED IN EROSIONAL STABILITY ANALYSES

Date:	JANUARY 2006
Project:	100734
File:	SITE-12-REV-C.dwg

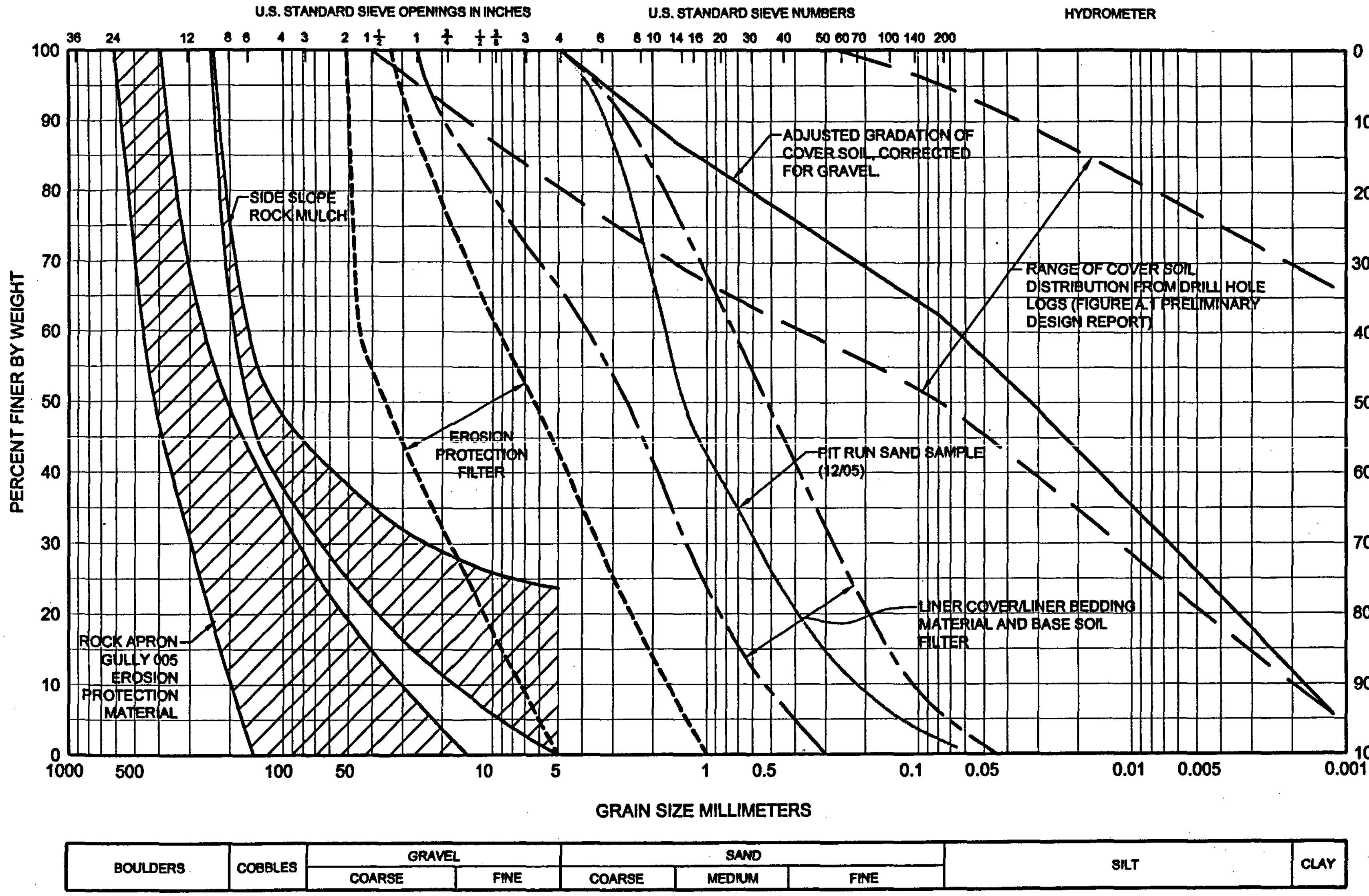

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FIGURE D.2
COVER MATERIAL PARTICLE-SIZE DISTRIBUTION SUMMARY

Date:	JANUARY 2006
Project:	180734
File:	GSD-02.DWG

APPENDIX E

INFILTRATION MODELING

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E.1 INTRODUCTION

This appendix outlines the evaluation of the disposal cell cover system for infiltration of meteoric water and percolation or drainage of meteoric water out the bottom of the cover system. This appendix is an update of infiltration modeling described in Appendix E of the 2002 Preliminary Design Report (Reclamation Plan Appendix C).

The previous infiltration modeling evaluated a cover of uniform stratigraphy, with long-term vegetation consisting of grass, brush, and trees. The modeling described in this appendix evaluated the multilayered cover with long-term vegetation consisting of grass species only.

E.2 INFILTRATION MODEL AND INPUT PARAMETERS

The TerreSIM model is an MFG, Inc. model used to evaluate vegetation system and land use management and its impact on runoff and infiltration. The water balance module has been used to calculate drainage through the disposal cell cover system under various cover material and vegetation scenarios. This module of the TerreSIM model was used to evaluate drainage through the multilayered cover system over the disposal cell. The model description and results are presented in Attachment E.

A 200-year simulation period was used, with perennial grass species established initially (big bluestem, little bluestem, and indiangrass). Available data from Sallisaw Oklahoma was used in the modeling. Actual daily precipitation data from 1949-1993 was used for the data set. The annual precipitation over this period averaged approximately 45 inches. Only the top surface of the cell (at a one percent slope) was evaluated in the model, since the side slopes would have less infiltration.

E.3 DISCUSSION OF RESULTS

The infiltration modeling with the TerreSIM model evaluated drainage out of the bottom of the root zone in the cover system. The clay layer at the base of the cover could not be incorporated into the model, due to the low potential for roots to penetrate the clay layer. Therefore the results described below are for infiltration through the root zone of the cover, and not through the entire cover system.

The infiltration modeling results in Attachment E can be discussed in two time periods: (1) the first 50 years of simulation (as permanent vegetation becomes established), and (2) the remaining 150 years of simulation (after permanent vegetation becomes established). For the years 1 through 50, the average

annual rate of drainage through the root zone of the cover is 6.6 inches per year, or approximately 14.4 percent of average annual precipitation. For the years 51 through 200, the average annual rate of drainage through the root zone of the cover is 3.6 inches per year, or approximately 8.7 percent of average annual precipitation. These values are averages, and the data in Attachment E show a direct relationship between drainage and precipitation, with years of zero drainage through the root zone and years of higher drainage through the root zone. If deeper-rooted species are allowed to become established on the cover, the rates of drainage through the root zone will be less than the values listed above.

During the initial years after disposal cell construction, the synthetic liner at the base of the cover (immediately above the clay layer) will provide a barrier to downward-moving meteoric water and direct this meteoric water laterally through the liner cover material to the perimeter of the cell. The clay layer will provide a similar longer-term barrier. If the saturated hydraulic conductivity of the clay layer is 10^{-7} cm/sec (0.1 feet/year), the rate of flux through the clay layer (under unit gradient conditions) is 0.1 feet/year or 1.2 inches/year.

ATTACHMENT E

TERRESIM MODELING DESCRIPTION

TERRESTRIAL ECOSYSTEM SIMULATION MODEL (TERESIM©) RESULTS FOR THE SEQUOYAH FUELS GORE, OKLAHOMA, ON-SITE DISPOSAL CELL

INTRODUCTION

Sequoyah Fuels Corporation (SFC) is in the process of decommissioning the uranium mill facility in Gore, Oklahoma. One goal in this closure operation is to establish a vegetative community on the disposal cell that 1) will provide for surface stabilization of the site, 2) will minimize water drainage through the profile, and 3) will not compromise the integrity of the disposal cell.

A simplified application of the Terrestrial Ecosystem Simulation Model (TerreSIM©) was used to evaluate the preliminary cover designs for the Sequoyah Fuels Corporation on-site disposal cell. TerreSIM simulated vegetation and water dynamics associated with a soil profile of 1.5 feet of topsoil over 5 feet of subsoil, 1.5 feet of sand, and 2 feet of clay. The application assumed no synthetic liner was present. The TerreSIM application simulated vegetation and water dynamics associated with the proposed cover design through two vegetation scenarios: 1) the proposed design including local grass, shrub, and tree species, and 2) the proposed design with grass species only, assuming annual mowing. The simplified application used a 10,000m^2 area with a 1% slope to simulate a portion of the top area of the disposal cell design. The simulations were conducted for a 200 year period.

TerreSIM is a spatially-explicit, mechanistic, computer model that is used to simulate plant community development (above- and below-ground) over time, the responses of ecological systems to environmental stressors, and the hydrological dynamics related to ecosystem dynamics. It has been applied to revegetation, land-use planning, and ecological responses to environmental stressors by the US Army Corps of Engineers, Natural Resource Conservation Service, National Park Service, U.S. Forest Service, USAF Academy, US Marine Corps, CSIRO-Australia, City of Los Angeles and several mining companies.

OVERVIEW OF THE TERRESIM MODEL

TerreSIM is designed to simultaneously simulate ecosystem dynamics at three different spatial scales: Plots, Communities, and Landscapes (Figure 1). This approach allows adequate representation of ecological processes that operate at different spatial and temporal scales. Because TerreSIM uses mechanistic representations of each process at the most appropriate scale, linkages among different components of the community, ecosystem, and landscape can be projected with reasonable confidence.

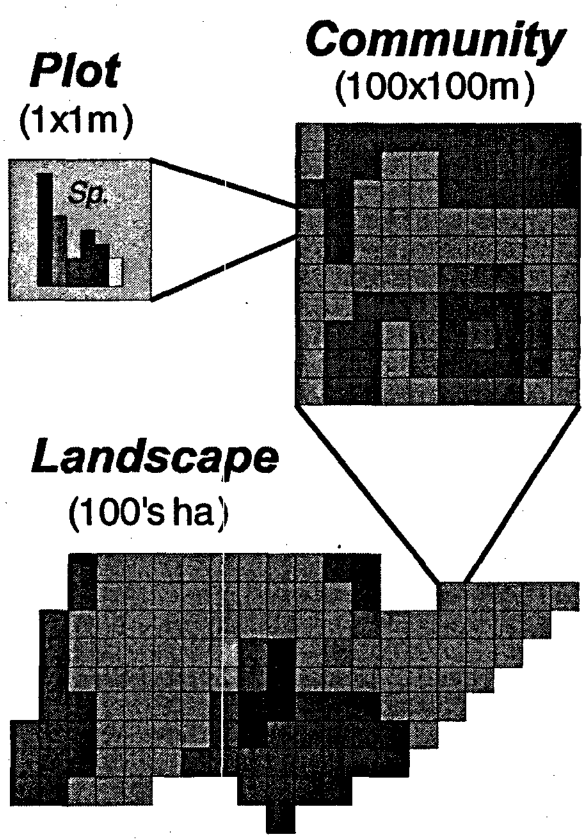

Figure 1. Scaling of the Plot, Community, and Landscape Modules in TerreSIM

The Plot Module in TerreSIM simulates ecological mechanisms and dynamics at the small scale (1-m2 to 400 m2). Most of the processes in TerreSIM related to plants (e.g., growth, water and nutrient uptake, and competition) and soils (e.g., water and nutrient transport through the profile, decomposition) are implemented in this module (Figure 2). This Module is comprised of a number of sub-modules, including Climate, Soil, Hydrologic, Plant, and Animals. Climatic inputs, primarily

precipitation and potential evaporation, are based on historical data, stochastically generated, or some combination of both.

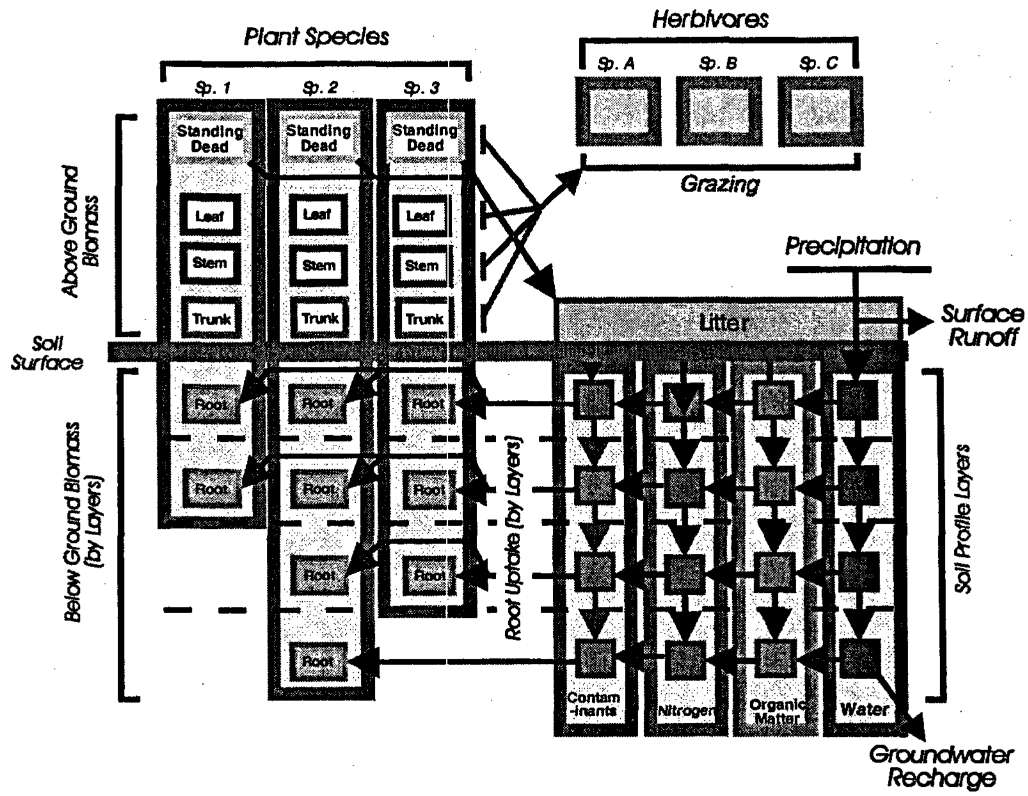

Figure 2. **TerreSIM plot-level structure**

The Soil Module represents the soil profile by partitioning it into up to thirteen different layers (horizons, sub horizons, or artificial layers). This representation incorporates the vertical depth, water content and holding capacity, nitrogen content, organic matter content, microbial activity, decomposition, and contaminant content and activity for each layer. The Hydrologic Module simulates small-scale precipitation dynamics, including interception by above-ground plant biomass, surface runoff, erosion and sediment mobilization, infiltration of water through the profile, mobilization and transport of nitrogen, organic matter, and contaminants, and subsurface export of water out of the profile.

The Plant Module represents the dynamics of above- and belowground components for each major plant species. Plant growth is simulated for each component (roots, trunk, stems, leaves, seeds, and standing dead), relative to season, resource requirements (water, nutrients, sunlight), and stressors

(e.g., herbivory, competition, fire, trampling, chemical contaminants). The Animal Module consists of basic population parameters and diet attributes (preferences, utilization potential, competitive success) for each specified species (e.g., insects, rodent, native ungulates, livestock).

Different plots are represented as cells in the Community Grid (Figure 2). The Community Module focuses on spatial patterns and dynamic from the patch (400-m2) to the community (1-10 hectares) scales. These include spatial heterogeneity in soils, plants, and stressors among plots within the community, stressors such as fire propagation, grazing, and lateral flow of surface and subsurface water and materials, and important spatial patterns such as vegetation cover, habitats, and topography.

In an analogous manner, communities are the basic units in the Landscape Grid (Figure 2). This largest scale Module focuses on ecological processes operating at large spatial scales (1-km2 and larger). These include fire initiation regimes, climatic regimes, watershed-level water movement and transport of materials, and management practices such as prescribed fire, grazing operations, and weed control.

TerreSIM Simulation Outputs

Each simulation run of TerreSIM produces a large volume of data for all state variables (e.g., plant biomasses, soil water and nutrient contents, total surface runoff) and processes (e.g., water and nutrient transport and balances, plant production). These data are stored in a series of large text tables, typically on a monthly basis. Many of these data are also presented in graphical displays at the end of the simulation run.

These extensive output files serve a number of useful functions. These data are required for accurately testing and calibrating the TerreSIM application for particular communities and sites. In addition, these data can be sent in "real time" to other models running simultaneously.

Hydrological Dynamics in TerreSIM

An important component of TerreSIM at all scales is hydrological dynamics. The Plot Module focuses primarily on one-dimensional movement of water up and down in the soil profile. Precipitation events deliver water to each plot, which then percolates down into different layers in the profile. Evaporation removes water from the top horizons, and uptake by plant roots in each horizon is transpired as plants grow. The Community and Landscape Grids allow explicit representation of transport of water among different cells (Figure 3). This allows calculation of surface runoff, subsurface export, and transport of sediment, nutrients, and contaminants across the landscape.

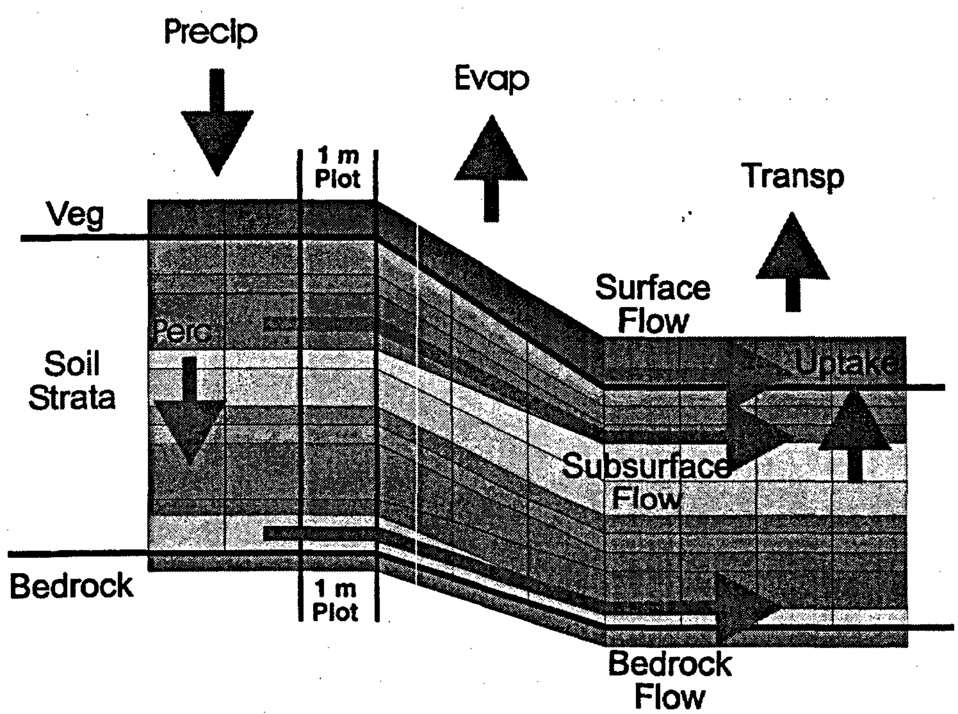

Figure 3. Hydrological dynamics in the TerreSIM Landscape Module

Among the various outputs produced in each TerreSIM simulation run are tables describing water pools and dynamics as well as summary graphical displays of total landscape runoff and export. These outputs allow projection of the effects of different climatic regimes, ecological stressors,

vegetation dynamics, and management practices on surface and subsurface water quantity and quality.

Another hydrological capability of TerreSIM is simulation of water use by layer in the soil profile. This combined with the TerreSIM capability of simulating root dynamics by species, allows for the evaluation of water use dynamics by different types of plants over time (Figure 4). This is especially important in the evaluation of revegetation designs and successional dynamics.

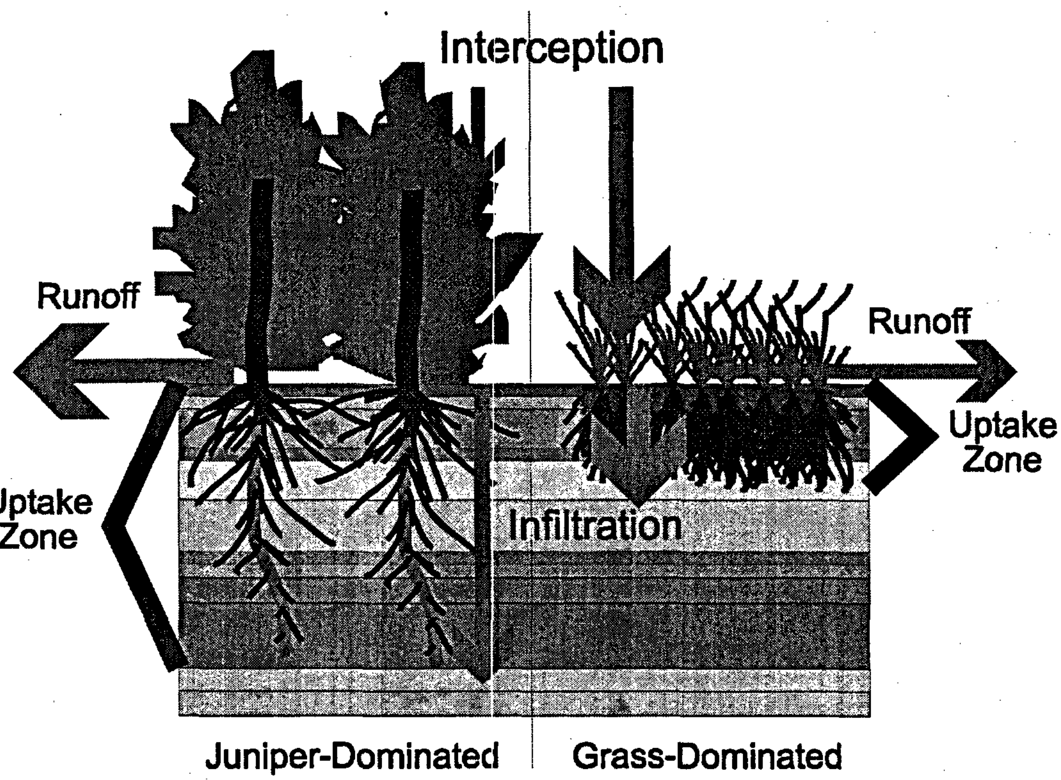

Figure 4. **Hydrological dynamics in grassland and juniper woodlands**

PARAMETERIZATION OF TERRESIM FOR THE DISPOSAL CELL

Application of the TerreSIM model to any management situation requires a formal parameterization process. Because TerreSIM simulates all aspects of ecosystem dynamics, suitable parameters must be implemented for reasonable simulation of each of the wide variety of ecosystem processes in the model. Most of the effort expended in a TerreSIM application involves gathering, converting, and incorporating these data into the model. The actual TerreSIM simulation runs can be conducted in a short period of time, even for a variety of alternative scenarios.

Some of the data required for TerreSIM parameterization are site-specific, i.e., they must be derived for the specific situation and locale. The most obvious local data are climatic, e.g., precipitation and temperature. In addition, descriptions of each soil profile and each plant community type at the site are required for initial conditions. Other data can be obtained from a variety of data sources, including ecological literature. Most of these relate to the ecology of different plant species within the communities at the location.

Climate and Soils Parameterization

A key input into TerreSIM is daily precipitation data. TerreSIM implements a hydrological module which uses daily precipitation as input for simulation of soil infiltration, surface runoff, and percolation through the soil profile. The nearest long-term weather station to the Gore Facility is the Sallisaw weather station, which lies approximately 20 miles to the east. This data set includes 44 years of complete daily precipitation data. TerreSIM simulation runs utilized this data set, recycling the data from year one after 44 years of the model run.

The temperature regime at the site is implemented in the TerreSIM model in a series of matrices which represent monthly timing and variations in a variety of physical and ecological processes. The following processes are representative of these processes: monthly pan evaporation; monthly changes in rate of snow melt; monthly proportion of snow versus rain for precipitation; and months for beginning and end of growing season, seed production, and germination for each plant species. These data were derived from existing climatic data for this locale and from ecological literature.

The cell cover profile was developed by MFG, Inc, as described elsewhere in this document. The simplified community scale TerreSIM application modeled a portion of the top section of the preliminary disposal cell mound design. This modeled area was 10,000 m2 (108,000ft2) with a 1% slope. Infiltration would be the greatest on the flatter slope area, so the simplified model application estimated infiltration for the entire mound conservatively. The local Lonoke Loam soil characteristics were used for the topsoil layers in the model simulations. The subsoil characteristics were derived from test pit data from the borrow areas near the site.

Plant Community Parameterization

The initial plant community in the simplified TerreSIM simulation of ecological and hydrological dynamics on the cover design was a seed bank consisting of three local perennial grasses: big bluestem, little bluestem, and indiangrass, as well as five local tree species: post oak, red oak, hickory, sycamore, and ash. Although it is a minor species in the area, sycamore was included because it is faster growing and has potentially shallower roots than the surrounding oaks and hickories which would be expected to move into the area whether planted or not. Sycamore is a good potential species that could be included in planting of the disposal cell post construction. The species selected are by no means the only species that will be planted or invade the disposal cell, but are dominates in the surrounding area, and therefore most likely to occur at the site naturally. These constitute a very basic plant community which was all that was required for this simplified application.

A variety of parameters are required to simulate dynamics of each plant species. These include morphological data (e.g., aboveground height, root zonation, ratio of root to aboveground biomass), physiological data (e.g., water- and nitrogen-use efficiencies, maximum growth rate, allocation of production to above- and belowground plant parts), and seasonal data (e.g., specific months for spring leaf-out, seed production, seed germination, and winter dormancy). These have been compiled for a wide variety of plant species in the western US and elsewhere, and incorporated into a database for use in TerreSIM applications. Data sets for each plant in the design seed bank were compiled from this database, and then incorporated into this TerreSIM application.

SIMULATION RESULTS

There are four sources for water loss from the revegetated disposal cell: evaporation, transpiration, runoff, and drainage. Evaporation is water loss directly from surfaces to the atmosphere, and TerreSIM separates evaporation by source, i.e., leaf surface of the plant community, soil surface (including the litter layer), and snow pack. Transpiration is evaporative water loss through plants. In most models, evaporation and transpiration are combined into evapotranspiration (ET). However, the dynamics of the two sources can be very different. Therefore, they are modeled separately in TerreSIM. Runoff is overland movement of water from the site. Export is percolation of water through the profile, past the rooting zone (infiltration). It is not direct drainage of the water from the site.

Table 1 summarizes the model output for the hydrological dynamics over the 200-year simulation period for the scenario including grass, shrub and tree species. For the simulated 10,000 m^2 subset of the top area of the disposal cell, total drainage equals 85692.06 m^3 (22,637,442 gal) of water over a 200 year period. The percent of precipitation lost to infiltration over the first 50 years is 15.09%. Drainage ceases by year 45, when the tree component of the vegetation is established successfully. Various sensitivity tests on the TerreSIM runs indicate a slight variation in time to little or no infiltration (up 48 years) and total percent precipitation lost to infiltration annually (up to 40% in some years).

Table 1. TerreSIM simulation results for water dynamics (m^3) on a 10,000 m^2 portion of the top area of the disposal cell design including tree and shrub components

		Evaporation				
Year	Precipitation	Canopy	Soil	Transpiration	Runoff	Export
1	11371.58	526.83	1473.67	3424.81	2.76	3834.12
2	11414.76	560.58	665.09	425.9	66.77	8256.71
3	12453.62	572.6	61.59	629.88	61.03	9344.41
4	8801.1	659.88	54.62	1309.29	6.85	5965.6
5	10248.9	1046.9	66.15	2838.14	31.84	5603.69
6	7762.24	1100.3	55.27	5082.09	7.48	1617.15
7	7683.5	2217.75	89.2	5562.37	0	70.06
8	8135.62	1972.56	92.9	4541.47	6.97	0
9	17363.44	4342.33	91.81	7643.35	52.38	3285.95

10	14711.68	5188.26	112.37	8380.43	51.2	0
11	13032.74	5374.91	106.3	6902.37	2.91	0
12	10398.76	4239.3	108.24	5118	0	0
13	13634.72	5264.27	106.64	6729.84	277.51	0
14	9349.74	4423.78	100.81	4116.02	0	0
15	6670.04	3594	98.48	2657.18	0	0
16	9733.28	4134.19	86.25	4324.5	15.13	0
17	9309.1	4126.46	100.31	4288.64	0	0
18	9636.76	4006.86	84.19	3317.33	0	0
19	9903.46	4949.32	104.6	3514.06	0	0
20	14066.52	5519.05	96.54	4586.02	0	1341.17
21	12448.54	4812.66	96.21	4343.86	188.64	89.61
22	12608.56	5563.67	80.26	4103.12	69.64	2691.02
23	12344.4	5426.93	78.44	3650.86	59.48	856.14
24	8968.74	3981.43	77.55	3230.67	2.28	603.08
25	18435.32	7472.11	94.95	2995.63	98.63	4301.24
26	12796.52	5027.74	89.8	2897.72	79.59	3618.94
27	11468.1	5347.92	75.66	2767.02	27.1	2259.45
28	10038.08	5360.53	86.45	2672.16	12	1425.53
29	9070.34	4221.78	69	2533.76	35.07	1437.44
30	9316.72	3770.85	53.4	2515.69	2.23	1772.52
31	9900.92	4986.76	81.13	2488.02	0	1370.22
32	7706.36	4101.91	71.89	2563.31	0	441.51
33	13703.3	6707.34	82.73	2548.02	163.72	3351.27
34	10063.48	4493.18	69.76	2656.55	0	1425.59
35	14046.2	6448.78	85.86	2645.86	41.82	2893.49
36	12951.46	5838.61	71.57	2765.81	27.12	2191.2
37	12633.96	6026.61	86.02	2761.83	48.46	2778.22
38	14135.1	5355.39	71.72	2921.8	0	2326.12
39	8524.24	4535.37	63.91	2875.72	17.48	1196.17
40	11386.82	5484.14	62.11	3104.1	0	520.82
41	19281.14	8285.83	90.77	3103.21	58.8	3304
42	14051.28	5551.01	82.78	3338.06	75.75	3260.08
43	11551.92	5643.71	79.27	3338.41	0	529.94
44	12600.94	5367.41	83.79	3621.46	0	746.69
45	11371.58	6217.87	67.23	3567.56	0	982.91
46	11414.76	6533.14	68.38	3943.19	1.61	0
47	12453.62	6701.95	73.69	3099.78	0	0
48	8801.1	5559.48	62.08	3000.8	0	0
49	10248.9	6560.39	76.91	3209.99	0	0
50	7762.24	3910.37	52.41	2330.46	0	0
60	9733.28	5930.39	45.39	2612.98	0	0
70	12796.52	7682.52	54.56	3955.4	0	0
80	12951.46	7872.92	44.2	2934.28	0	0
90	11414.76	7940.9	41.85	2280.84	0	0
100	10398.76	7101.07	45.19	2356.79	0	0
110	12608.56	10094.87	49.17	2836.97	0	0
120	7706.36	6089.62	31.87	880.74	0	0

130	14051.28	9886.42	47.88	1934.17	0	0
140	8135.62	5189.22	26.11	1560.48	0	0
150	9636.76	6258.56	31.41	1112.64	0	0
160	10038.08	8593.56	41.58	1405.35	0	0
170	14135.1	8232.45	35.2	1799.99	0	0
180	8801.1	6560.82	31.4	1467.58	0	0
190	9349.74	7175.5	31.33	1498.69	0	0
200	8968.74	6559.34	32.31	1367.77	0	0
Total - 200 years (not all years shown above)						
	2284907.8	1429445.1	12146.8	479352.97	2082.45	85692.06
% of Ppt	100%	62.56%	0.53%	20.98%	0.09%	3.75%
Total - 50 years						
	567766	229115	6040.76	176986.1	1592.25	85692.06
% of Ppt	100%	40.35%	1.06%	31.17%	0.28%	15.09%

Because deep rooted tree species could compromise the integrity of the disposal cell, a second scenario was modeled that excludes trees and shrubs for 200 years through annual mowing. Table 2 summarizes the model output for the hydrological dynamics for this scenario. For the simulated 10,000 m^2 subset of the top area of the disposal cell, total drainage from this scenario equals 257973.4 m^3 (68,149,349 gal) of water over a 200 year period. The percent of precipitation lost to infiltration over the first 50 years is 14.38% and 11.29% over the 200 year model run. Drainage is present in most years of the model run.

Table 2. TerreSIM simulation results for water dynamics (m^3) on a 10,000 m^2 portion of the top area of the disposal cell design assuming no tree and shrub components

		Evaporation				
Year	Precipitation	Canopy	Soil	Transpiration	Runoff	Export
1	11371.58	243.7	2270.83	2029.12	5.74	4706.03
2	11414.76	632.95	217.15	2637.67	68.78	6778.55
3	12453.62	1028.09	75.7	4170.22	38.97	5014.5
4	8801.1	1182.67	83.34	4962.91	3.06	2724.47
5	10248.9	1622.16	105.01	5396.07	23.38	2561.12
6	7762.24	1167.96	77.97	5115.53	6.8	0
7	7683.5	1849.56	100.38	5779.9	0	86.64
8	8135.62	1500.14	94.22	5253.42	10.68	0
9	17363.44	2806.83	88.77	5940.31	77.77	4982.77
10	14711.68	2966.73	110.81	5873.36	83.13	4543.81
11	13032.74	3006.77	96.71	5899.83	79.7	3419.67

12	10398.76	2324.11	92.34	5907.07	58.32	1973.57
13	13634.72	2813.48	93.11	5932.84	471.04	2287.69
14	9349.74	2382.68	91.27	5957.65	11.48	231.15
15	6670.04	1985.54	92.9	5908.08	25.26	0
16	9733.28	2201.07	83.49	6014.35	29.6	0
17	9309.1	2222.01	96.47	6034.23	45.15	0
18	9636.76	2142.15	84.47	5945.64	4.16	0
19	9903.46	2399.76	100.79	5877.55	27.81	0
20	14066.52	2838.46	98.63	6163.13	8.4	1961.17
21	12448.54	2226.94	105.83	6122	264.57	1212.27
22	12608.56	2941.1	82.94	5986.64	158.95	3262.12
23	12344.4	2947.84	99.11	6203.35	159.23	555.17
24	8968.74	2252.38	85.79	6185.79	15.51	0
25	18435.32	3631.18	95.1	6207.19	179.62	4241.35
26	12796.52	2425.09	92.33	6222.68	193.09	2780.06
27	11468.1	2676.96	91.13	6239.38	40.14	1613.54
28	10038.08	2712.5	96.16	6276.99	22.17	399.44
29	9070.34	2187.78	97.1	6269.42	61.2	802.73
30	9316.72	2012.77	77.43	6083.55	26.44	12.33
31	9900.92	2557.9	99.18	6317.1	1.82	0
32	7706.36	2010.18	91.83	5987.43	0	0
33	13703.3	3129	109.02	6356.98	316.82	906.66
34	10063.48	2244.92	97.14	6278.55	5.99	648.79
35	14046.2	2967.9	96.6	6308.35	122.11	1710.17
36	12951.46	2560.95	110.69	6308.41	46.61	1867.98
37	12633.96	2725.86	111.29	6313.25	98.3	2533.97
38	14135.1	2108.69	105.72	6317.39	1.74	2060
39	8524.24	2235.94	102.19	6171.35	27.46	967.77
40	11386.82	2303.35	90.33	6342.48	18.18	301.16
41	19281.14	3063.93	101.15	6326.44	108.93	4903.88
42	14051.28	1911.3	99.42	6333.17	126.59	3475.09
43	11551.92	2226.75	110.56	6335.7	0	1144.66
44	12600.94	2046.85	108.46	6338.74	1.26	898.47
45	11371.58	2699.17	99.87	6341.58	3.59	1563.03
46	11414.76	2732.01	102.77	6344.44	36.03	129.1
47	12453.62	2491.25	102.56	6347.13	23.61	892.82
48	8801.1	2108.94	89.79	6349.73	0	843.89
49	10248.9	2345.85	106.9	6352.2	15.24	644.24
50	7762.24	1510.64	77.1	5448.94	4.57	0
60	9733.28	2215.54	83.26	6185.51	30.76	0
70	12796.52	2442.65	93.06	6308.58	191.14	2677.88
80	12951.46	2561.82	110.66	6344	50.83	1827.34
90	11414.76	2732.84	102.77	6364.14	37.6	104.55
100	10398.76	2417.84	91.49	6315.37	59.68	1490.05
110	12608.56	2969.88	83.62	6236.55	158.79	2982.28
120	7706.36	2010.05	91.9	5944.02	0	0
130	14051.28	1913.45	99.46	6358.48	131.55	3427.82
140	8135.62	1656.5	87.56	5080.13	4.8	0

150	9636.76	2157.35	84.31	5554.22	0	0
160	10038.08	2718.53	96.58	6318.89	22.15	348.5
170	14135.1	2110.38	105.72	6351.4	20.2	2002.92
180	8801.1	2109.82	89.75	6369.84	0	834.05
190	9349.74	2443.73	90.99	6326.07	12.75	0
200	8968.74	2268.26	86.08	6302.63	25.47	0
Total - 200 years (not all years shown above)						
	2284907.8	486074	21478.09	1226478	13996.91	257973.4
% of Ppt	100%	21.27%	0.939%	53.67%	0.613%	11.29%
Total - 50 years						
	567766	113312.7	7089.85	293815.2	3159	81641.83
% of Ppt	100%	19.95%	1.25%	51.75%	0.57%	14.38%

CONCLUSIONS

The model output indicate significant drainage in most years if woody species are not present. The impact that trees have on the water balance of the site is through more use of water throughout the profile, as well as increased precipitation interception and canopy evaporation. The TerreSIM output demonstrates significant water loss form the canopy evaporation in the first scenario. The second (no tree) scenario is less favorable because water infiltration is present over the 200 year model run, and as a large portion of annual precipitation (11.29%). However, if annual mowing is not included as part of the long-term maintenance of the facility, oaks and other deep rooted tree species are expected to establish and eventually dominate the site as part of the natural ecological succession of the site. These species have to ability to physically compromise the integrity of disposal cell over time, through deep root proliferation. Therefore, sycamore is a recommended species to be included in planting of the disposal cell post construction, if long term maintenance is not provided for. Sycamore is faster growing and has potentially shallower roots than the oaks and hickories, and therefore would not compromise the integrity of the disposal cell. In addition, sycamore can prevent the invasion and dominance of the site by oaks and other deep rooted species for several hundred years through competition.

APPENDIX F

SEISMIC AND STATIC STABILITY

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Attachment F.1 Slope/W Input and Output
Attachment F.2 Infinite Slope Analyses

F.1 INTRODUCTION

This appendix presents the methods, input and results of the slope stability analyses for the disposal cell and surrounding natural slopes at the Sequoyah Fuels Corporation (SFC) Facility near Gore, Oklahoma. These analyses are an update of stability analyses in the Preliminary Design Report (Reclamation Plan Appendix C). The slope stability analyses were conducted according to applicable stability criteria under both static and seismic conditions, including geotechnical stability criteria in NRC (2000). Liquefaction analyses were conducted according to procedures outlined in Youd et al., (2001).

Slope stability analyses were performed using limit equilibrium methods with the aid of the computer program SLOPE/W (GEO-SLOPE, 1999). The SLOPE/W program calculates factors of safety by a variety of limit equilibrium methods. Spencer's method was used for these analyses because it considers both force equilibrium and moment equilibrium in the factor of safety calculation.

F.2 CRITICAL CONDITIONS AND GEOMETRY

Slope stability analyses are typically conducted under scenarios that represent the critical conditions for construction and operation. For the disposal cell, these conditions include: (1) the period during cell construction, and (2) the long-term period after cell construction.

Construction period. Key factors during construction are development of excess porewater pressures in foundation, berm or cover materials due to equipment or fill placement, or displacement of low-strength fill materials (such as sludges) in response to covering fill placement. The foundation materials (unsaturated soils and underlying sedimentary rock) are not susceptible to development of excess porewater pressures. Disposed materials will be placed and compacted in a manner to minimize void spaces and future settlement. Due to these construction methods and surrounding perimeter soils within the cell, conditions during cell construction were not analyzed for slope stability.

Long-term period. The long-term period after cell construction was analyzed along a critical section of the disposal cell slope. Long-term, steady-state material properties and porewater pressure conditions were used to represent this area.

The critical cross-section location used in the analysis is shown on Figure F.1, and the geometry of the section is shown on Figures F.2. This critical cross-section was selected because it represents the longest slope of the disposal cell. In addition, the analysis of this section was compared to the results of an

infinite slope scenario (slope length much longer than thickness of critical layer). Analyzing the infinite slope scenario minimizes any stabilization effects of a passive resistive wedge at the base of the slope.

Analysis conditions. The cell profile for the cross-section was based on a reclamation cover thickness of 10 feet, underlain by a textured synthetic liner, contaminated site soils and foundation soils. The foundation soil layer was assumed to be 10 feet thick, based on site boring logs (discussed in Appendix A). The thickness of the contaminated site soils was determined based on the topography shown on Figure F.1.

Slope stability analyses were performed by calculating factors of safety along circular failure surfaces as well as block and fully specified wedge failure surfaces. Circular failure surface analysis was conducted by targeting deeper, full slope failures. Small, shallow surface failures were not considered. Wedge failure surfaces were specified to occur along the synthetic liner. In both cases, a number of failure surfaces were analyzed to find the lowest factor of safety.

Most analyses were run assuming the soils are not saturated. Some analyses were performed assuming two feet of water on top of the synthetic liner. This represents an unlikely scenario, since the sands above the liner likely will drain any precipitation off the liner. However, the analyses are presented to check the sensitivity of the cover stability to pore water pressures.

F.3 MATERIAL PROPERTIES

Materials properties used in SLOPE/W for cover soil, contaminated site soils and foundation materials were based on typical values for the materials present at the site (discussed in Appendix A). Material properties are discussed below and summarized in Table F.1.

Cover material. A multi-layered cover system is proposed. This cover system will consist of (from bottom to top): (1) a two-foot compacted clay layer, (2) a textured synthetic liner, (3) an 18-inch layer of sand, (4) a five-foot subsoil zone, and (5) an 18-inch topsoil layer. On side slopes, the topsoil layer will be reduced to 9 inches thick, and overlain with 9 inches of rock mulch. Potential construction materials for disposal cell cover system include soils and weathered sedimentary rock from on-site sources, and rock from off-site sources. The cover is modeled as being the predominant subsoil zone, underlain by the synthetic liner. From geotechnical testing of a sample of the material for the subsoil zone, (documented in ESCI, 1998), the silty clay portion is a low-plasticity clay with a plasticity index of 17. The dry unit weight is approximately 110 pcf (Appendix A). Based on the general relationship between plasticity

index and shear strength in Holtz and Kovacs (1981), the effective angle of internal friction (for a material with a plasticity index of 17) is 32 degrees. In the stability analyses, the cover materials were conservatively represented by a dry unit weight of 110 pcf, an effective angle of internal friction of 30 degrees, and no cohesion.

Synthetic Liner and Compacted Clay Liner Interface. The critical surface is the interface between the textured geomembrane and compacted clay liner. The texturing on the geomembrane, under light to moderate loadings, will act to force a failure into the compacted clay. An average plasticity index value for the borrow material used to construct the clay liner is 17. Based on the Holtz and Kovacs (1981) relationship, this correlates with an internal friction angle of the clay of 32 degrees. An effective angle of internal friction of 28 degrees was used to conservatively represent the soil/synthetic liner interface. The synthetic liner/clay interface was represented in the analyses as a one-foot thick layer with a dry unit weight of 60 pcf, typical of synthetic liner material.

Foundation materials. Foundation materials in the site area are primarily terrace deposits consisting of silts, sandy silts, silty clays, sandy gravelly clays, silty sandy clays and clays which overlie shale and sandstone units. A dry unit weight of 110 pcf was used for these materials, due to the higher density and gravel content of these materials relative to the potential cover materials. An angle of internal friction of 30 degrees with no cohesion was used to represent the shear strength of these materials.

Contaminated soils. Contaminated site soils are expected to consist of a mixture of soils, construction debris (such as concrete and structural materials and sediments). This material will be placed with a specified compactive effort to minimize voids, thus a dry unit weight of 120 pcf was used to account for the fill materials and compaction. Shear strength was represented by an effective friction angle of 32 degrees with no cohesion.

Table F.1 Material Parameters Used in Stability Analyses

Material Type	Dry Unit Weight, γ (pcf)	Angle of Internal Friction, ϕ (degrees)	Cohesion, c (psf)
Cover Soil	110	30	0
Synthetic Liner	60	28	0
Contaminated Site Soils	120	32	0
Foundation Materials	110	30	0
Alluvial Soils on Natural Slopes	110	25	0

F.4 SEISMIC ANALYSIS AND SEISMICITY

Stability analyses under seismic conditions were conducted as pseudo-static analyses, with a design seismic coefficient applied to each cross-section. The design seismic coefficient is 67 percent of the peak horizontal acceleration (U.S. Department of Energy, 1989).

Analysis approach. If the materials in a structure are saturated and of low density or susceptible to significant loss of shear strength, an evaluation of the potential for liquefaction of these materials is conducted. The structure is then analyzed for slope stability based on a liquefied or reduced shear strength condition. If the materials in the structure are not susceptible to liquefaction or loss of shear strength, an analysis of the structure from seismic-induced accelerations is conducted. This consists of a stability analysis under an equivalent constant acceleration (described in Seed, 1979) or an evaluation of seismic-induced deformations (described in Makdisi and Seed, 1978). The equivalent, constant acceleration used in these analyses is the seismic coefficient, which is a fraction of the maximum seismically-induced acceleration anticipated at the site during the design period.

Seismicity. The site seismicity was reviewed in terms of: (1) general regional data, and (2) site specific data, as discussed below.

Based on general seismicity information, the site is within a region of low seismicity. This region is classified as a Zone 1 area in U.S. Army Corps of Engineers (1982), with a recommended seismic coefficient of 0.025 g (where g is the acceleration of gravity). The region is classified as a Zone 1 area in IBCO (1991), with a recommended seismic coefficient of 0.075 g. In addition, the United States Geological Society (USGS) National Seismic Hazard Mapping Project estimates a peak horizontal acceleration of 0.09 g to have a 2% exceedance in 50 years (2,475-year return period).

Site area seismicity was reviewed from local publications, National Earthquake Information Center (NEIC) earthquake database search, and local geomorphic structure information. Annual seismology data in Oklahoma is compiled by the Oklahoma Geological Survey (Lawson and Luza, 1983, and Luza and Lawson, 1993). This data shows activity of low magnitude, with epicenters primarily in the central and south-central portion of the state. The potential for seismic accelerations at the site was evaluated by considering 1) historical earthquake events, 2) capable faults in the area, and 3) probabilistic analysis of earthquake events not associated with known faults.

A review of recorded or documented seismic activity within a 300-mile radius of the site was conducted from data compiled by the National Earthquake Information Center (NEIC) of the U.S. Geological Survey. The data was compiled from prior to 1811 through April 2003. The results were compared with data published by the Oklahoma Geological Survey from 1900 to 1998 compiled in Lawson and others (1979), Luza and Lawson (1993), and subsequent annual Oklahoma Earthquake Catalog publications. The events that produced the greatest vibratory ground motions at the site, using attenuation relationships developed by Atkinson and Boore (1995), are summarized in Table F.2.

Table F.2 Summary of Seismic Events Producing Accelerations

Rank	Date	Richter Magnitude	Distance from Site		Peak Ground Acceleration (g)	Location
			(mi)	(km)		
1	Jun 20, 1926	4.2	12	19	0.061	Sequoyah County, OK
2	Oct 22, 1882	5.5	116	186	0.013	South-central OK
3	Apr 27, 1961	4.1	43	69	0.013	South-eastern OK
4	May 2, 1969	4.6	71	114	0.012	Central OK
5	Oct 8, 1915	3.4	22	36	0.011	Central-eastern OK
6	Mar 31, 1975	2.9	14	22	0.010	Central-eastern OK
7	Jan 11, 1961	3.8	48	77	0.008	South-eastern OK
8	Dec 16, 1811	7.2	263	424	0.008	New Madrid MO, a.m.
9	Oct 30, 1956	4.0	63	101	0.007	North-eastern OK
10	Dec 16, 1811	7.0	263	424	0.007	New Madrid MO, p.m.
11	Jun 1, 1939	4.3	82	132	0.007	Central OK
12	Jun 2, 1977	4.3	83	133	0.007	Central-western AR
13	Sep 6, 1997	4.5	96	155	0.007	South-eastern OK

Capable faults. Based on geologic investigations, only two documented faults of Quaternary age, the Meers fault and the Humboldt fault zone, are located within 200 miles of the site. The Meers fault, also referred to as the Thomas fault and the Meers Valley fault, is located in southwestern Oklahoma in the Frontal Wichita fault system that is the boundary between the Anadarko basin and the Wichita Mountains. It is the only significant fault within a 200-mile radius of the site with positive documentation of Quaternary tectonic movement. The fault is approximately 54 km (34 miles) long, with the closest section of the fault approximately 306 km (190 miles) from the site. Based on the length of fault, the maximum credible earthquake (MCE) associated with the Meers fault is approximately Richter magnitude 7.2.

The Humboldt fault zone is a north-northeasterly trending complex set of faults that bound the eastern margin of the Nemaha uplift in Nebraska, Kansas, and Oklahoma. The fault zone and the adjacent uplift are known based on drill-hole data from the region. Because the faults are only known from subsurface data, details of the fault slip and fault patterns are limited. Although convincing surficial evidence of

large, prehistoric earthquakes is absent in the area, a regional seismograph network indicates that the structures are currently tectonically active. Based on the length of the fault segments in the Humboldt fault zone, Steepes and others (1990) suggest that infrequent magnitude 6 or greater earthquakes could occur. The nearest part of the fault zone to the site is close to Oklahoma City, approximately 140 miles from the site.

Site investigations performed in 1998 concluded that there are no active faults within 5 miles of the site (Van Arsdale, 1998). In addition, other geologic investigations (Shannon and Wilson, 1975) conducted for the Black Fox Nuclear Power Plant concluded that faults within the tectonic provinces surrounding the site have no evidence of having been active since before Cretaceous time. Although there is no evidence of active faults within 200 miles of the site, specific documentation of every fault meeting the length requirements of 10 CFR 100 Appendix A was not found. Instead, faults that (if considered active) have the capability of producing peak ground accelerations at the site of greater than 0.27 g were considered further. Of these 23 faults, positive documentation was found (Van Arsdale, 1998, Shannon and Wilson, 1975) to show that these faults are not considered capable faults per the criteria set forth in 10 CFR 100.

Random Earthquake Analysis. Two evaluations of the random earthquake event were used to determine the design event for earthquakes not associated with identifiable faults, as is the case for most U.S. earthquakes east of the Rocky Mountains. In both approaches, tectonic provinces are established to group regions with similar seismological characteristics. It is assumed that the spatial distribution of earthquakes is uniform across the province. Within the province, historical data of earthquake events are evaluated and magnitude-frequency plots are generated. The first evaluation of the random earthquake used a semi-probabilistic method. Various areas surrounding the site were modeled as generating a 10,000-year event. The event was applied at the mean distance of the area from the site, and attenuated to the site using Atkinson and Boore (1995) relationships. The peak acceleration associated with the 10,000-year event was estimated to be 0.27 g.

In addition, another analysis using the U.S. Bureau of Reclamation (USBR) program *mrs* (LaForge, 2005) was conducted. The USBR approach is a probabilistic approach that incorporates the probability of seismic magnitude, location of event, and attenuation characteristics. Results from this analysis are considered more rigorous for two reasons. First, it estimates the 10,000-year acceleration at the site, while the semi-probabilistic model estimates the 10,000-year earthquake, and then attenuates the ground motion to the site. Second, the mrs program is able to incorporate variability in the attenuation relationships and the magnitude-frequency relationships. The semi-probabilistic model uses the mean

values for these parameters. The results from the *mrs* analysis estimate that the mean peak acceleration associated with a 10,000-year event is 0.16 g.

Seismic coefficient. For materials that do not liquefy or lose shear strength with seismic shaking, seismic slope stability is analyzed by a pseudo-static approach. This consists of the application of an equivalent horizontal acceleration or seismic coefficient to the structure being analyzed (described in Seed, 1979). The seismic coefficient represents an inertial force due to strong ground motions during the design earthquake, and is represented as a fraction of the maximum expected seismic acceleration at the site (typically at the base of the structure). The coefficient for calculating seismic coefficient is typically 0.5 to 0.7 of the maximum expected acceleration. The 0.5 value typically represents operational conditions (a relatively short period of time), and the 0.7 value represents post-reclamation conditions (a relatively long period of time). This strategy has been adopted in review of uranium tailings facility design and documented in DOE (1989). The following table summarizes the peak horizontal accelerations and associated seismic coefficients resulting from the various seismic sources considered.

Table F.3 Summary of Seismic Events Producing Accelerations at Site

Seismic Source	Peak Horizontal Acceleration	Seismic Coefficient (g)
Historical earthquake causing largest accelerations at site (June 20, 1926 Sequoyah County Earthquake, magnitude 4.2)	0.061	0.04
Maximum credible earthquake associated with known active Meers fault	0.019	0.01
Maximum credible earthquake associated with known active Humboldt zone	0.017	0.01
Maximum credible earthquake associated with all other faults meeting length requirements of 10 CFR 100, Appendix A that are lacking positive documentation to demonstrate they are not active faults	0.27	0.18
Maximum credible earthquake associated with active faults per Black Fox report	0.00	0.00
10,000-year random earthquake event using semi-probabilistic approach	0.27	0.18
10,000-year random earthquake event using *mrs* probabilistic approach	0.16	0.11

From the data summarized above, the peak anticipated horizontal acceleration at the site is conservatively estimated to be 0.27 g, with a corresponding seismic coefficient of 0.18 g. The results of the pseudo-static analyses are summarized below.

F.5 STABILITY OF NATURAL SLOPES

The stability of natural slopes downslope of the disposal cell was analyzed to evaluate the impact of the disposal cell on these slopes.

The natural slopes in the area are less than 10 percent and covered by a thin veneer of terrace materials. As shown in Figures 7-2 through 7-8 of the Hydrogeological and Geochemical Site Characterization Report (SMI, 2001), the slopes have less than 10 feet of alluvial soils. Because of this relatively thin layer of alluvial soils, the construction of the disposal cell has only a small impact on the stability of the native slopes. Borrow material investigation reports on the south borrow area include HC (1980), PSI (1990) and GGH (1997). This borrow material is typical of the clay soils found in the area. Laboratory testing data indicate the plasticity index varies from approximately 10 to 30 percent. Correlations between plasticity index and shear strength of normally consolidated clays indicates the average shear strength is between 28 and 32 degrees, and plus or minus one standard deviation shear strengths are between 25 and 38 degrees (Bowles, 1988, and Lambe and Whitman, 1969). Stability analyses of the natural slopes have been evaluated by looking at a Section CS-1 cut through the west slope of the disposal cell. This section goes through both the longest slope of the disposal cell cover and the head of Stream 005. Although in the previous analyses, the foundation materials were modeled with an angle of internal friction of 30 degrees, for the specific analysis of the stability of the natural slopes, the alluvium was conservatively modeled as having shear strength of 25 degrees.

F.6 LIQUEFACTION ANALYSIS

The potential for liquefaction of the foundation underlying the disposal cell was evaluated using procedures as outlined in Youd et al. (2001). Vertical profiles were evaluated for sections containing both the maximum and minimum height of disposed material, and variable subgrade materials.

Current conditions under the disposal cell footprint consist of approximately 10 feet of alluvial soils overlying bedrock. It is likely much of the alluvial soils will be removed during soil clean up. Excavated areas will be brought to subgrade elevations by compacting granular material. Therefore, the subgrade is assumed to consist of either ten feet of alluvium, or ten feet of compacted granular material. The

reclamation plan stipulates the bottom of the clay liner be a minimum of 2 feet above the maximum observed groundwater table. Therefore, the groundwater table is conservatively assumed to occur eight feet above the base of bedrock.

Profile 1 represents the maximum height in the disposal cell. From the top of cover down, the layers are as follows: 10 feet of compacted cover, 25 feet of disposed material, 3 feet of compacted clay liner, 2 feet of unsaturated native alluvium, and 8 feet of saturated native alluvium.

Profile 2 represents a minimum height of in the disposal cell along the side slope of the disposal cell where the disposed material pinches out. From the top of cover down, the layers are as follows: 10 feet of compacted cover, 3 feet of compacted clay liner, 2 feet of unsaturated native alluvium, and 8 feet of saturated native alluvium.

Profiles 3 and 4 are the same as Profiles 1 and 2, respectively, with the exception that it is assumed all native alluvium has been replaced with relatively clean, compacted granular material.

Material properties in Table F.4 are assumed typical values. Alluvium soils from geotechnical investigations (HC 1980, PSI 1990, and GGH 1997) are described as being low-plasticity clayey soils with a minimum of 25 percent fines and plasticity indexes between approximately 10 and 30 percent.

Table F.4 Material Properties and Thicknesses

Material	Bulk Density	Profile 1	Profile 2	Profile 3	Profile 4
Cover	110	10 feet	10 feet	10 feet	10 feet
Disposed Material	120	25 feet	0 feet	25 feet	0 feet
Clay Liner	115	3 feet	3 feet	3 feet	3 feet
Alluvium	105	10 feet	10 feet	0 feet	0 feet
Granular Backfill	112	0 feet	0 feet	10 feet	10 feet

The factor of safety against liquefaction is given by the following equation

$$FS = \frac{CRR_{7.5}}{CSR} MSF$$

Where:

CRR = Cyclic Resistance Ratio,
CSR= Cyclic Stress Ratio, and
MSF = Magnitude Scaling Factor.

CRR values can be correlated to various field parameters of the foundation materials, including standard penetration tests, cone penetration, and shear-wave velocities. No data has been collected regarding the density of the alluvial soils, therefore a very conservative SPT corrected blow counts of approximately 3 is assumed. This corresponds to a CRR of 0.1. The compacted granular material is assumed to be medium to dense, with a SPT corrected blow count of greater than 15, corresponding to a CRR of 0.17.

CSR is calculated by the following equation:

$$CSR = 0.65 * \frac{a_{max}}{g} * \frac{\sigma_{vo}}{\sigma'_{vo}} * r_d$$

Where:

a_{max}/g = ratio of the peak horizontal acceleration to the acceleration of gravity,
σ_{vo} and σ'_{vo} = total and effective vertical overburden stresses, respectively, and
r_d = stress reduction coefficient.

MSF is a scaling factor to account for scaled effects of earthquakes of magnitudes different than 7.5 and can be estimated by the following equation:

$$MSF = \frac{10^{2.24}}{M_w^{2.56}}.$$

The design earthquake is for a magnitude 4.4 event occurring 5.7 km from the site.

Table F.5 lists the various parameters calculated for the different profiles.

Table F.5 Parameters Used to Evaluate Liquefaction Potential

Parameter	Profile 1	Profile 2	Profile 3	Profile 4
a_{max}/g	0.27	0.27	0.27	0.27
σ_{vo} (pcf)	5495	2195	5565	2565
σ'_{vo} (pcf)	4996	1996	5066	2066
r_d	0.90	0.95	0.90	0.95
CSR	0.174	0.183	0.174	0.207
$CRR_{7.5}$	0.1	0.1	0.17	0.17
MSF	3.91	3.91	3.91	3.91
FS	2.25	2.14	3.82	3.21

Even using very conservative numbers, the potential for liquefaction of the foundation materials underlying the disposal cell is minimal.

F.7 DISCUSSION OF ANALYSIS RESULTS

The results of stability analyses for the critical cross-section and the infinite slope analyses are presented in Table F.6. These values represent the lowest calculated factor of safety from a number of individual failure surfaces. All calculated factors of safety were significantly above the NRC recommended values of 1.5 for static and 1.1 for pseudo-static analysis. In addition, potential for liquefaction of the foundation material is minimal. SLOPE/W input and output for each scenario are presented in Attachment F.1.

Table F.6 Stability Analysis Result Summary

Condition	Circular Failure Surface	Block Specified Wedge Failure Surface	Infinite Slope Block Failure Surface	Minimum Factor of Safety Criteria
Static	2.98	2.97	2.66	1.5
Pseudo-static	1.51	1.46	1.35	1.1
Static with two feet of water above synthetic liner	---	2.59	---	1.5
Pseudo-static with two feet of water above synthetic liner	---	1.30	---	1.1
Natural Slopes, Static	2.48			1.5
Natural Slopes, Pseudostatic	1.33			1.1

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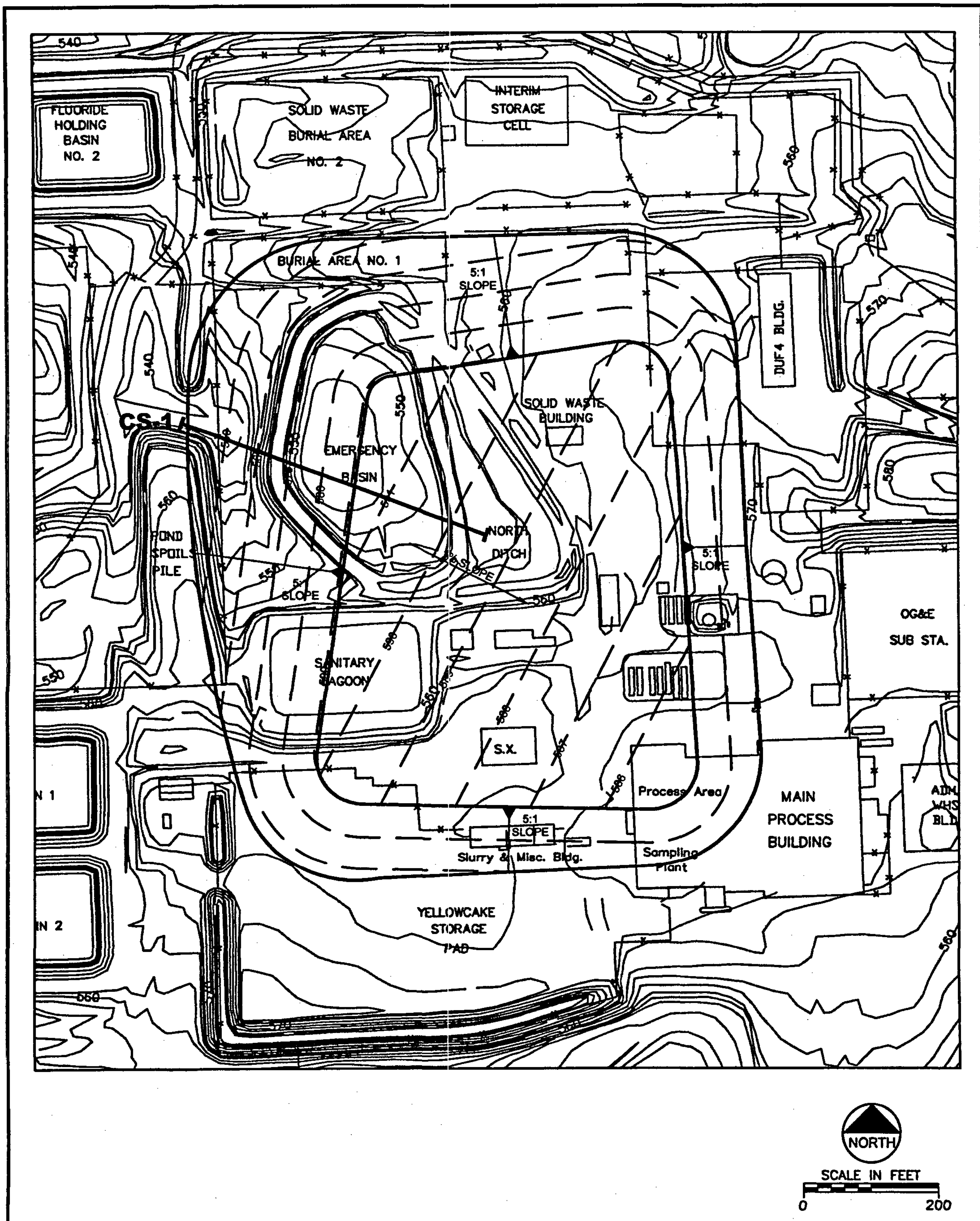
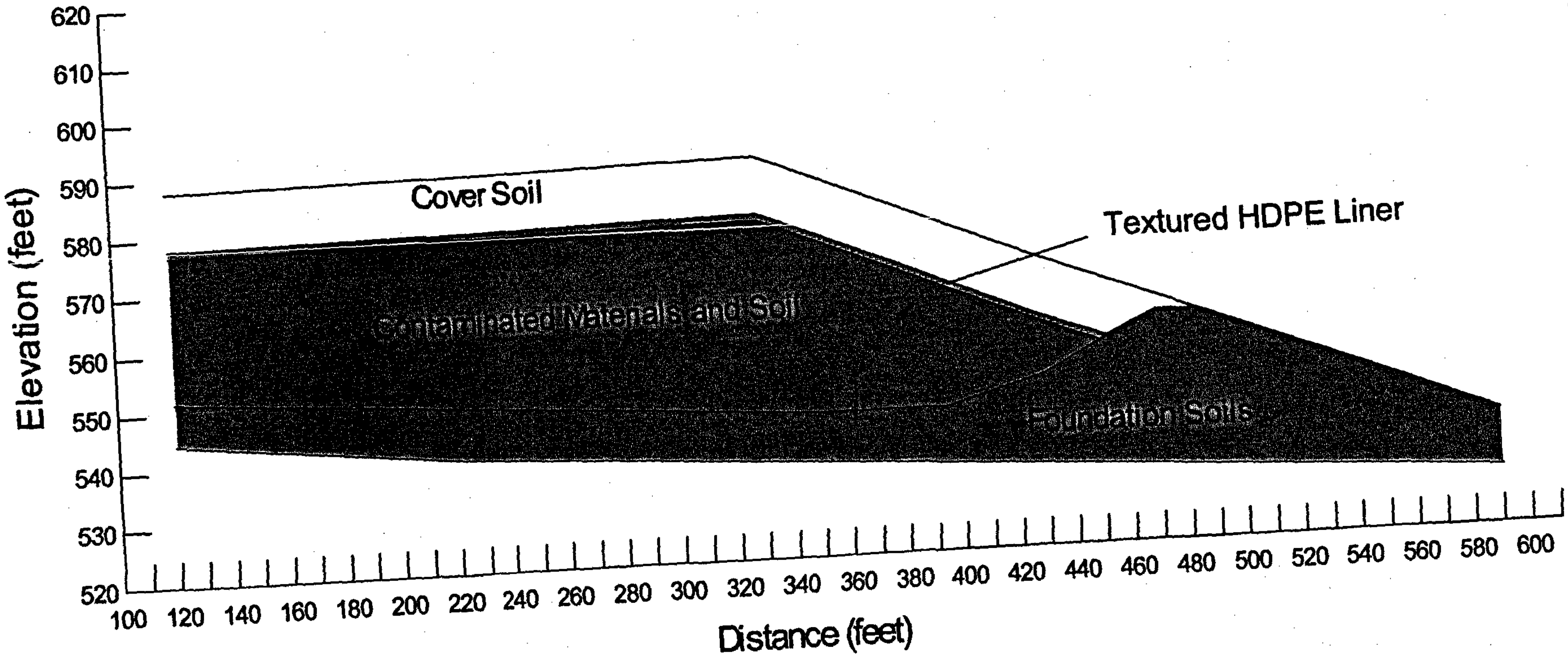


MFG, Inc. *consulting scientists and engineers*	FIGURE F.1 CRITICAL CROSS-SECTION LOCATION	Date: APRIL 2005
		Project: 100734
		File: XSEC-LOC-1.DWG



MFG, Inc.
consulting scientists and engineers

FIGURE F.2
Critical Cross-Section 1 (CS-1) Geometry

Date:	April 2005
Project:	P:\100734 SFC\
File:	DispCD\stability\FIG-F2.doc

ATTACHMENT F.1

SLOPE/W INPUT AND OUTPUT

Description: Sequoyah Fuels
Comments: Disposal Cell - Critical Section 1
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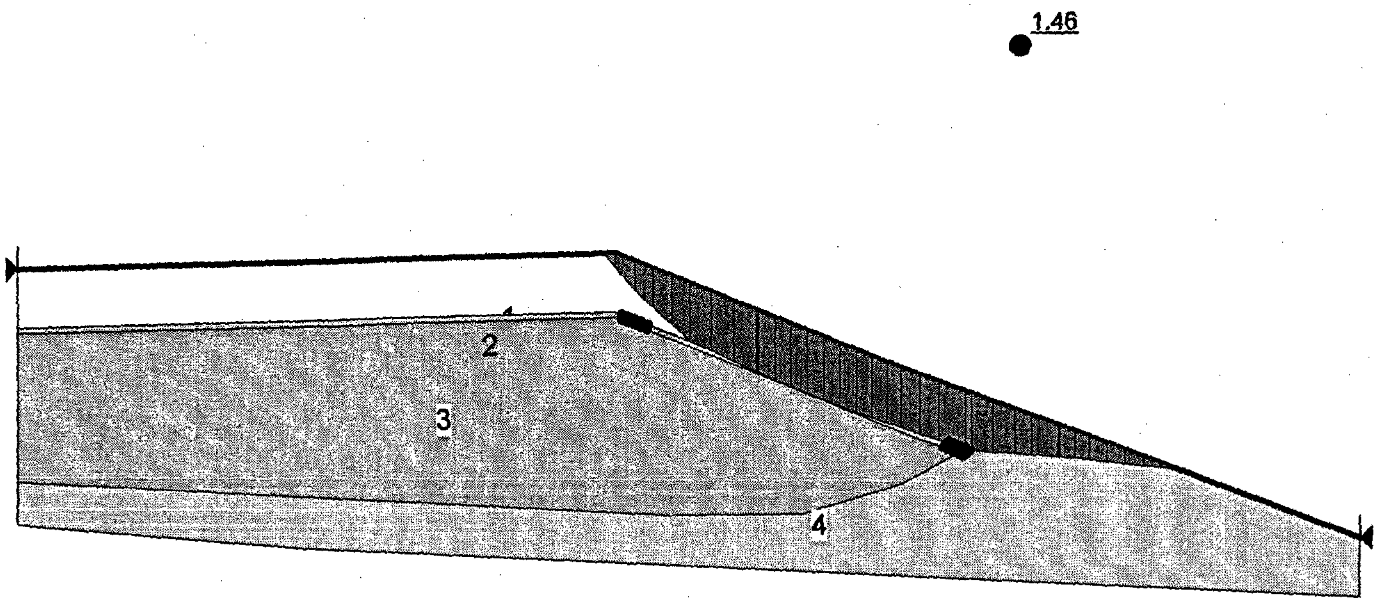
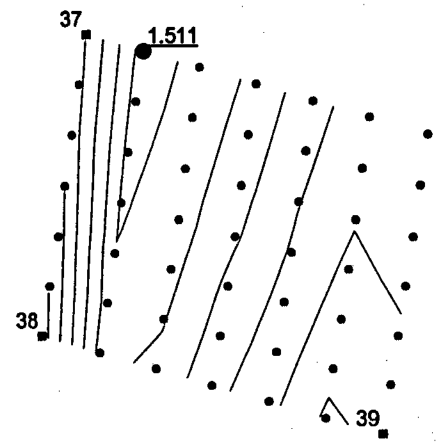
Last Saved Date: 4/25/2005
Analysis Method: Spencer
Slip Surface Option: Block
Seismic Coefficient: horz: 0.18, vert: 0





Description: Sequoyah Fuels
Comments: Disposal Cell - Critical Section 1
File Name: Seq1circularseismic0.18textured.gsz
Last Saved Date: 4/25/2005
Analysis Method: Spencer
Slip Surface Option: GridAndRadius
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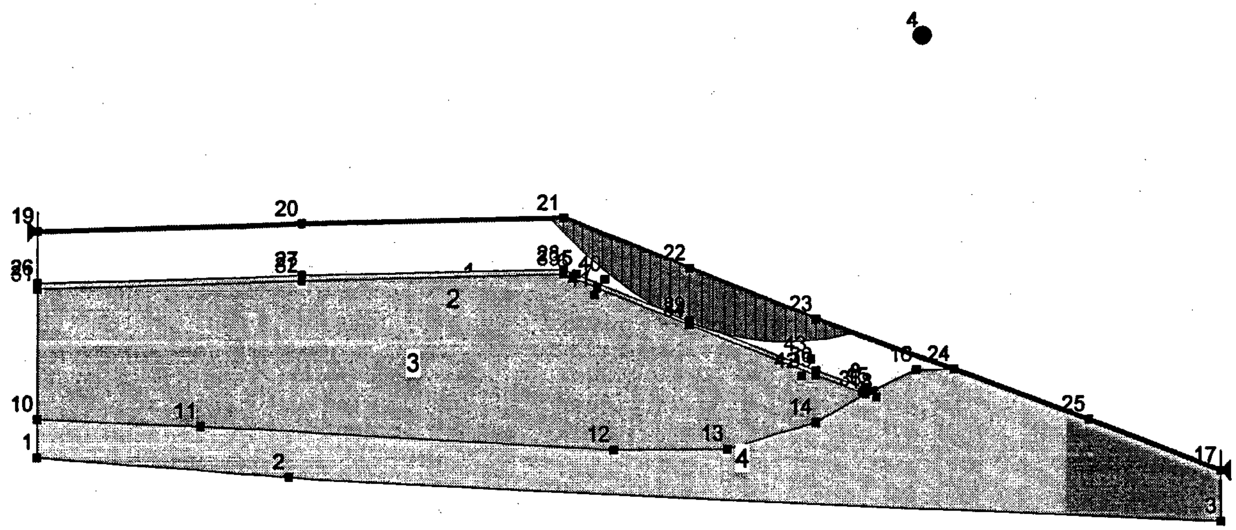

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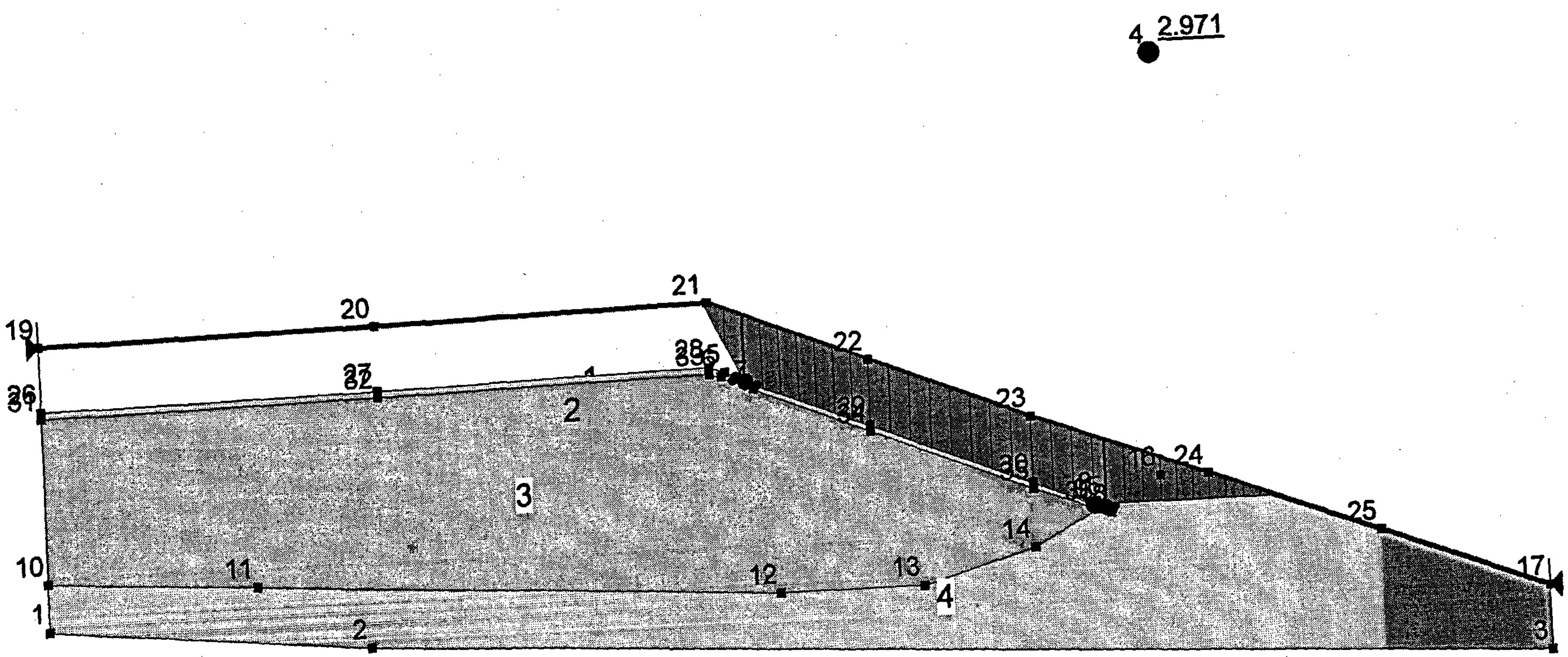

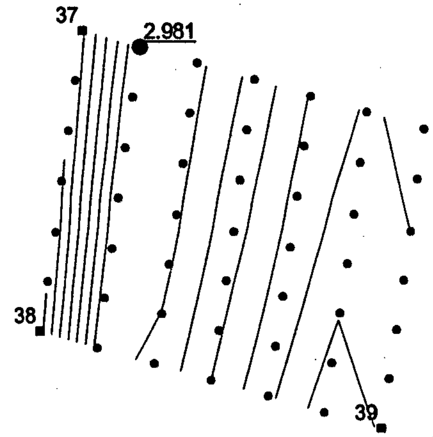

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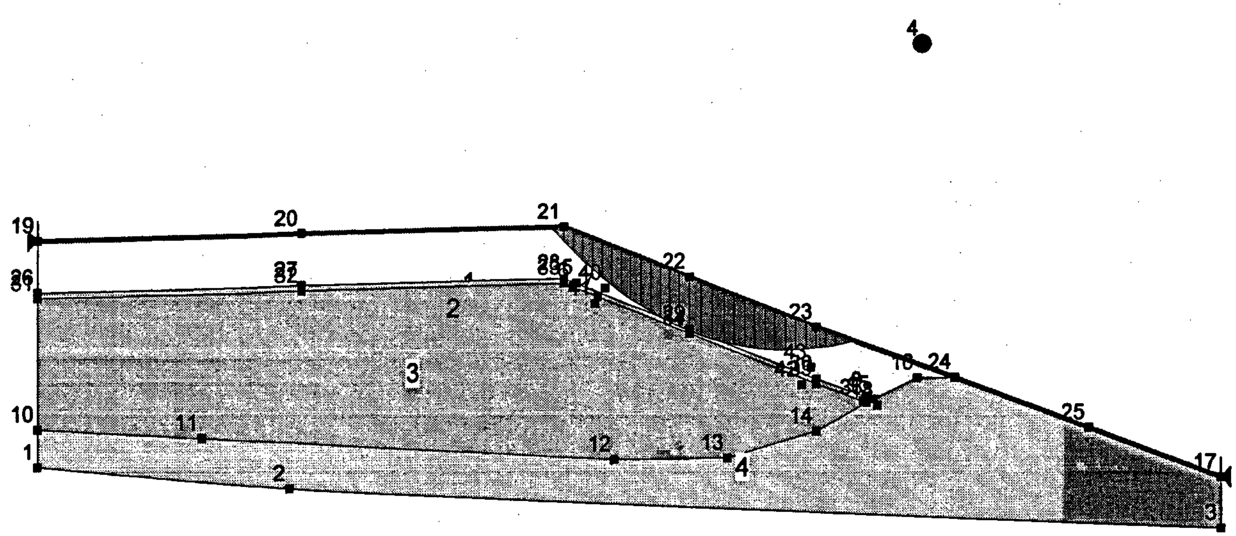

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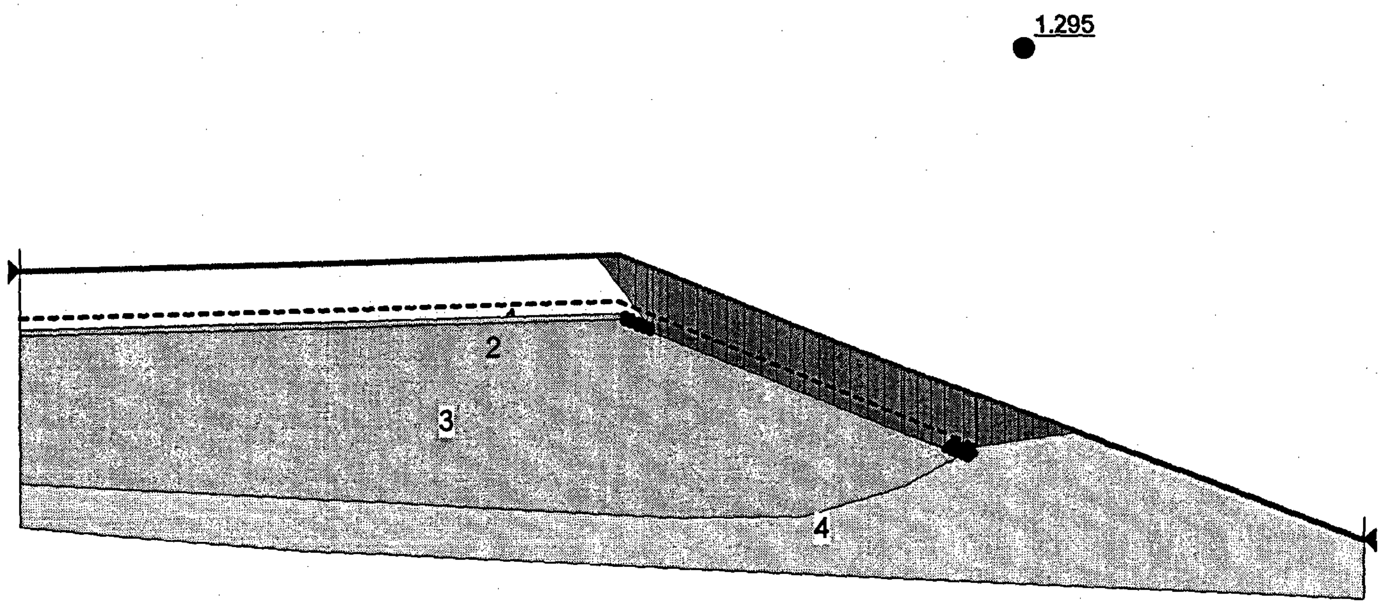

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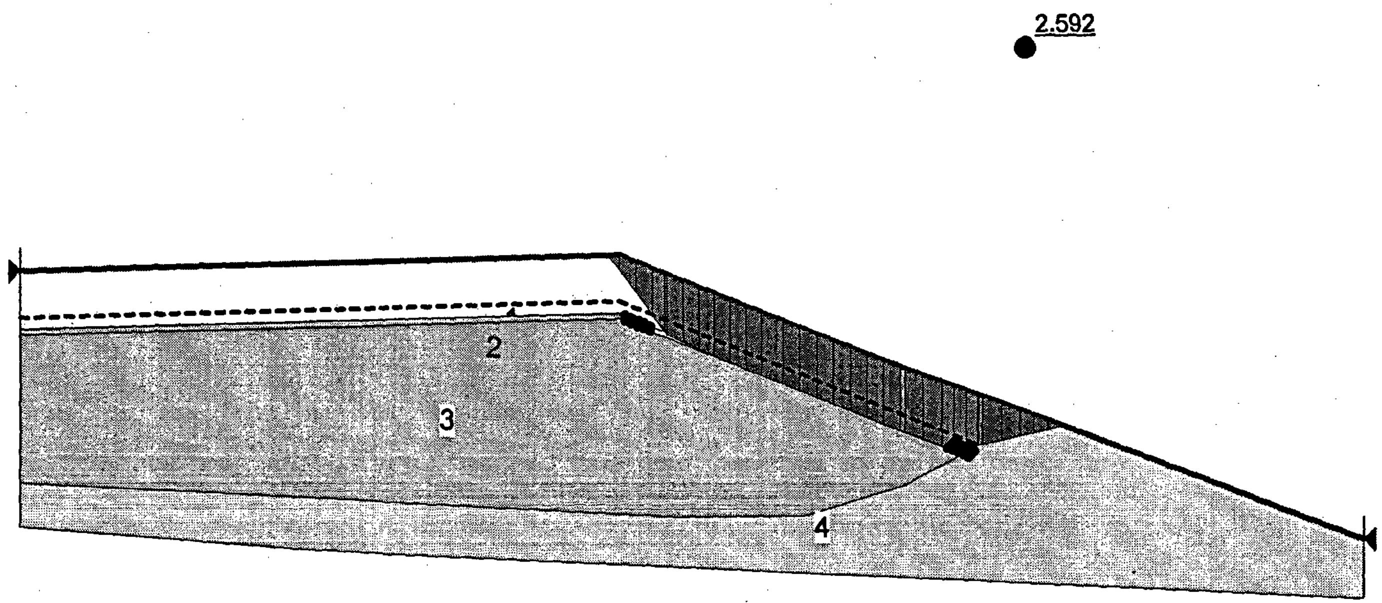

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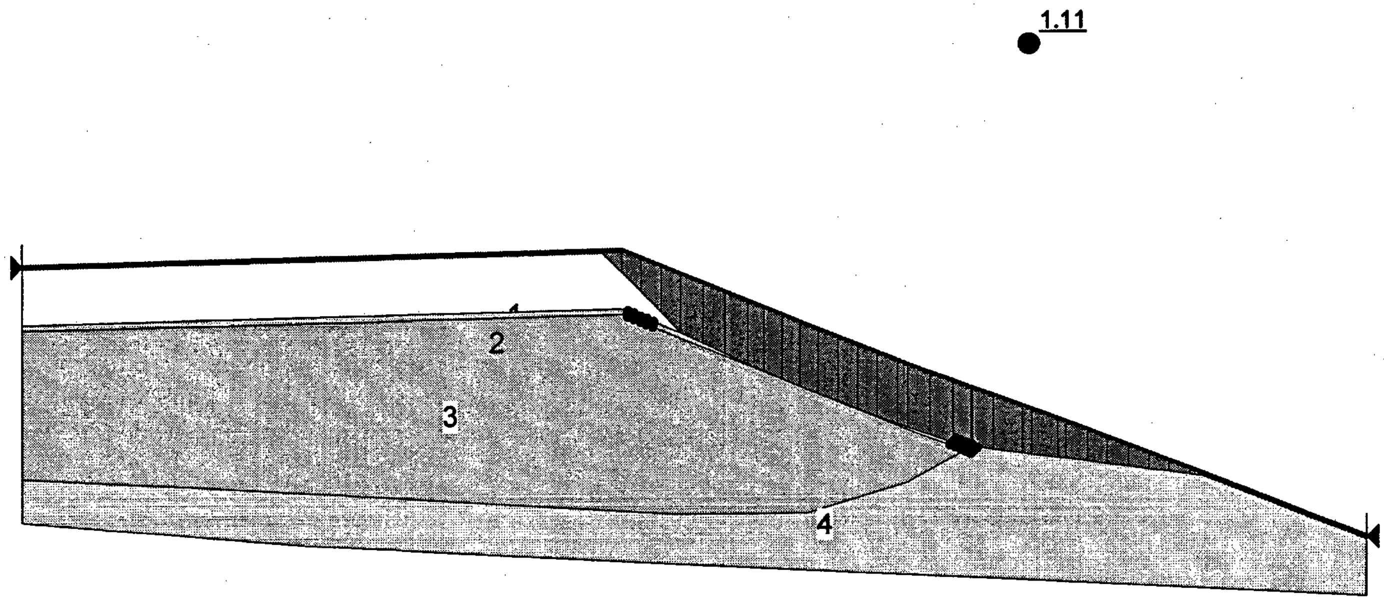

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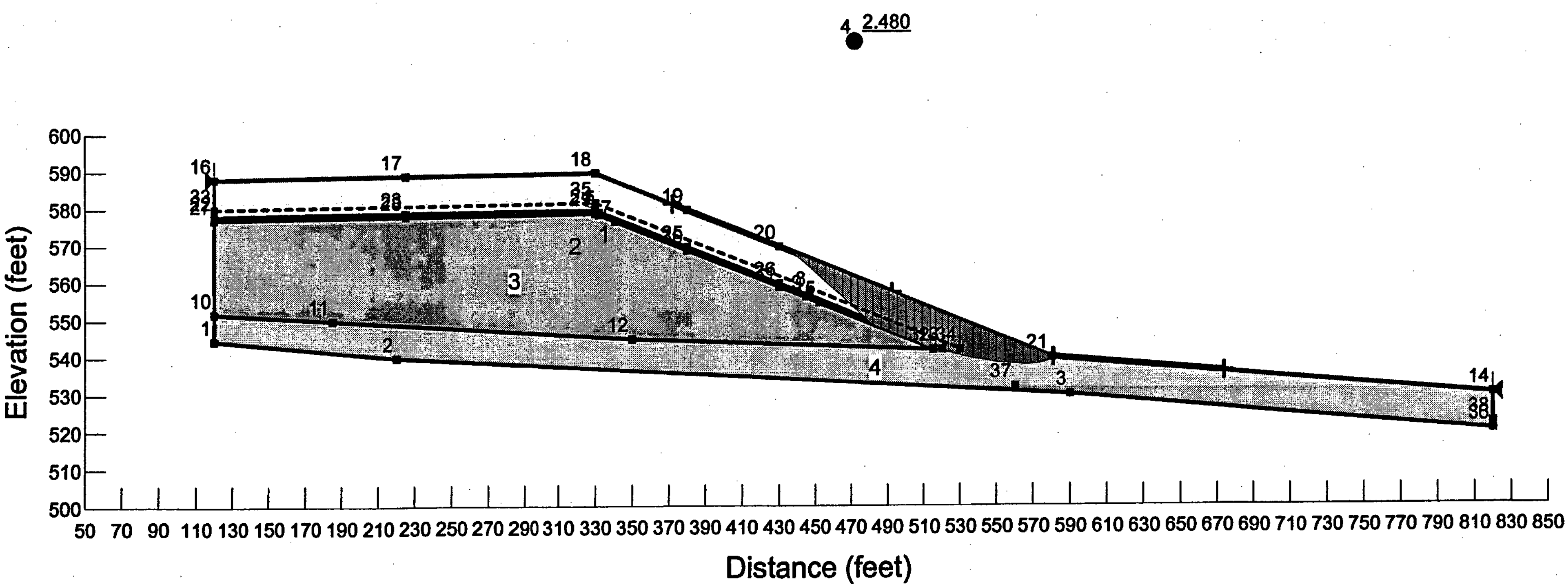

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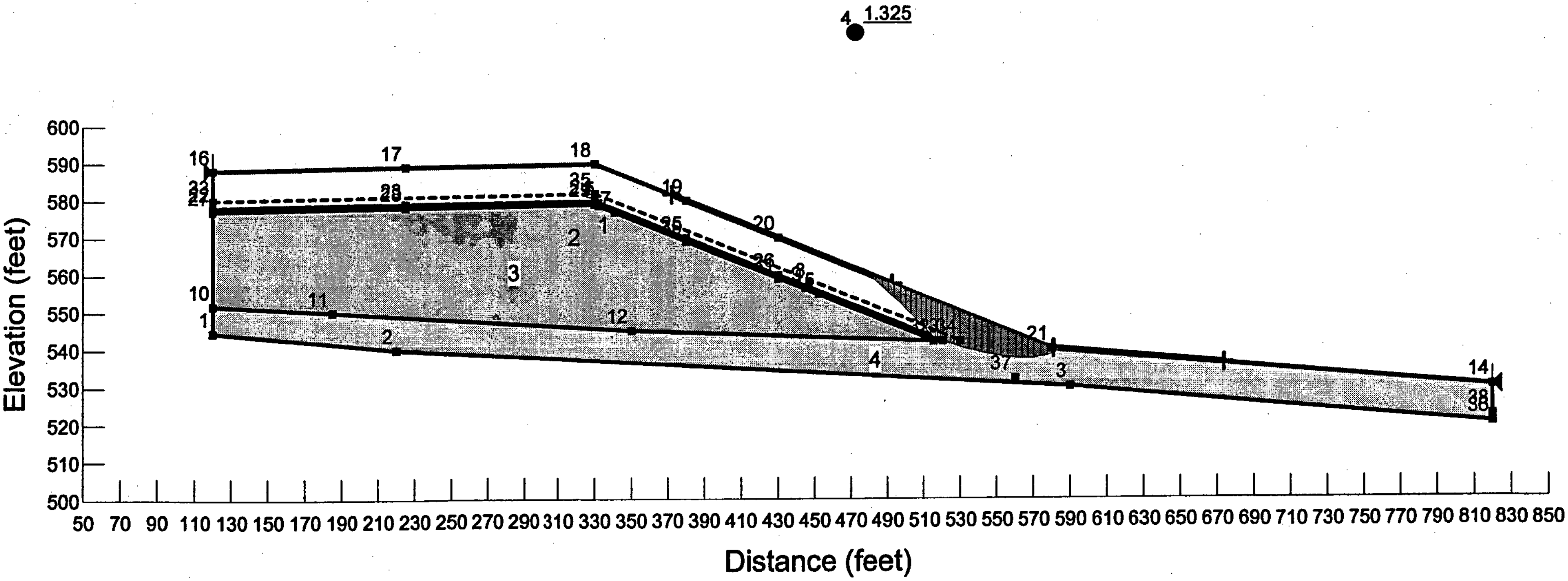
Seismic Coefficient: horz: 0.18, vert: 0



ATTACHMENT F.2

INFINITE SLOPE ANALYSES

Client: Sequoyah Fuels	Job No.: 100734	Page: 1 of 2
Project: Disposal Cell	Date: 4/25/05	Date Checked: 4/25/05
Detail: Slope Stability, Seismic Analyses for Infinite Slope	Computed by: RTS	Checked by: CLS

Problem: Calculate the Factor of Safety of the cover system assuming infinite slope failure. Also calculate the maximum acceleration (assuming no liner/cover interface strength loss with shaking) allowable to maintain a minimum factor of safety of 1.1. Analyze slope perpendicular to cover at 5H:1V. Critical surface is interface between textured geomembrane and compacted clay liner. Average properties of borrow material for clay liner are CL material with LL = 36, PL = 19 and PI = 17. Assume that under moderate loading conditions (8 feet of cover soil), textured membrane will force failure into clay. Therefore, use typical friction angle of CL material as liner/cover interface strength of 28°.

Solution: Use the following equation

$$FS = \frac{\tan(\phi)}{\tan[\beta + \arctan(k_h)]}$$

where FS= Factor of Safety
ϕ= friction angle of textured liner/compacted clay interface= 28°
β= slope angle of cover=arctan (1/5)
k_h=horizontal seismic coefficient (g)

For static conditions, k_h=0.0 g:

$$FS = \frac{\tan(28)}{\tan\left[\arctan(\frac{1}{5}) + \arctan(0.0)\right]} = 2.66$$

For k_h=0.11g (70 percent of peak horizontal acceleration from LaForge, 2005):

$$FS = \frac{\tan(28)}{\tan\left[\arctan(\frac{1}{5}) + \arctan(0.11)\right]} = 1.68$$

For k_h=0.18g (70 percent of peak horizontal acceleration = 0.27 g):

$$FS = \frac{\tan(28)}{\tan\left[\arctan(\frac{1}{5}) + \arctan(0.18)\right]} = 1.35$$

Client: Sequoyah Fuels	Job No.: 100734	Page: 2 of 2
Project: Disposal Cell	Date: 3/9/05	Date Checked: 3/9/05
Detail: Slope Stability, Seismic Analyses for Infinite Slope	Computed by: RTS	Checked by: CLS

Calculate maximum acceleration to maintain minimum FS of 1.1 assuming 100% liner/cover interface strength:

$$1.1 = \frac{\tan(28)}{\tan\left[\arctan(\frac{1}{5}) + \arctan(k_h)\right]}$$

k_h=0.27 g (i.e. peak horizontal acceleration = 0.40 g

Calculate yield acceleration assuming 80% liner/cover interface strength:

$$1.1 = \frac{\tan(23)}{\tan\left[\arctan(\frac{1}{5}) + \arctan(k_h)\right]}$$

k_h=0.20 g (i.e. peak horizontal acceleration = 0.30 g

References:

LaForge, Roland (2005). Probabilistic Hazard Curves for Peak Horizontal Acceleration, Sequoyah Fuels Site, Oklahoma. Submitted to MFG, Inc. April.

APPENDIX G

SETTLEMENT

TABLE OF CONTENTS

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Table G.3 Differential Settlement Estimates
Table G.4 Comparison of Calculated and Allowable Tensile Strains in Cover Soils

G.1 INTRODUCTION

This appendix outlines the evaluation of the disposal cell settlement and its effect on cover system performance. This appendix is an update of a response to the NRC prepared in October 2004, reflecting current plans for disposal cell construction and disposed material placement.

G.2 MATERIAL PLACEMENT AND COMPACTION

The plans for disposed material placement and compaction have been revised for phased construction, and are outlined in the updated Technical Specifications (Reclamation Plan Attachment A). The material placement strategy is to minimize void spaces around the incompressible materials in the cell (using soils) and to minimize void spaces within the compressible materials in the cell.

Structural materials will be placed in the disposal cell using methods depending on material size and compressibility. Structural materials will be broken or cut to manageable size using typical equipment for demotion work (hydraulic excavators with specialized attachments for shearing and grasping). These materials will be hauled with trucks to the disposal cell for placement.

Compressible material (such as thin-walled piping and tanks) will be flattened or crushed at the disposal cell with hydraulic excavator attachments or with a dozer. Non-compressible material (such as steel beams or concrete) will be laid out in the disposal cell a manner that minimizes void spaces. Both compressible and non-compressible material will be laid flat or placed in a manner to facilitate covering with soil.

Contaminated soils (material type D) will be spread in over a layer of structural material to fill in voids around the structural material. Contaminated soils will be placed in lifts (two feet maximum thickness) sufficient to cover the structural material but thin enough to allow compaction of the soil and underlying material. Each lift of soil will be compacted with at least six passes with vibratory tamping-foot compaction equipment.

Material type D consists of soils and weathered sedimentary rock from contaminated soil cleanup that is placed with and on top of structural materials (material type C). The soils will be used to minimize void spaces around the structural material and provide bedding for subsequent lift of structural material. Checking soil compaction with standard field density testing methods (such as with a nuclear density gauge) is not recommended because of interference with structural debris.

As a result, a method specification for compaction of this material is outlined in the Technical Specifications (Reclamation Plan Attachment A). The method would be a minimum of six passes over a two-foot maximum thickness lift of soil with a vibratory tamping-foot compactor. The number of passes would be confirmed on a field test section of soils to establish a correlation between the compaction method and 95 percent of the maximum dry density for the material, as determined by the Standard Proctor test.

Based on a conservatively high total settlement of 5 to 10 percent of waste material height, and differential settlement occurring over a distance of 35 feet (representing the internal berm slopes in the disposal cell), differential settlement values were calculated (as outlined in Appendix G of the Disposal Cell Construction Plan, Reclamation Plan Attachment E). These values were converted to estimated tensile strain values, and were compared with allowable tensile strain values developed for covers over uranium mill tailings. The estimated tensile strain values were less than allowable values, indicating that the estimated differential settlement would not adversely affect cover performance.

The differential settlement at the base of the disposal cell cover is likely to be the greatest where vertical profiles of placed material have the largest difference in compressibility. Therefore, the differential settlement analyses (discussed above) were made by calculating the settlement for vertical profiles estimated to represent the least and the most compressible profiles. The closest lateral distance these profiles would occur is represented by the lateral distance of the internal berm slopes (35 feet). NRC stated that 35 feet could underestimate the strain across a stiff inclusion from a beam in material type C, or the concrete slab in the foundation. Stiff inclusions such as beams within a compacted soil matrix are not likely to have significant effects on the top surface of the disposal cell. If such materials were close to the surface, such stiff inclusions could impact settlement at the surface such that cracking may be of concern. The concrete slab will be covered by a minimum of ten feet of material prior to placement of the cover, as will be non-compressible structural materials. Therefore, the effects of any locally high strains across stiff inclusions will be reduced by the overlying compacted materials.

G.3 DISPOSAL CELL SETTLEMENT

The anticipated settlement of materials in the disposal cell is outlined below based on analysis of both total and differential settlement. Since the amount of differential settlement, rather than total settlement, is a critical factor when evaluating the potential for disruption and cracking of the cover system, settlement estimates were made for areas of maximum anticipated differential settlement. Differential settlement can result from both varying thicknesses of compressible materials, with greater thicknesses

resulting in greater settlement, and varying material properties. As a result, the area of maximum differential settlement for each cell is expected to occur at the location of maximum cell material thickness along the interior berms (where material properties are likely to vary most significantly).

Settlement experience. Related experience with settlement of disposed materials and cover performance is in three general areas: (1) uranium tailings impoundment reclamation, (2) uranium mill demolition and disposal, and (3) municipal landfill performance. Experience at uranium tailings impoundments has shown typical values of 10 percent of tailings thickness. Limited experience with disposed uranium mill debris (with proper compaction) has shown little settlement.

For this evaluation, several publications were cited estimating the typical amount of settlement at municipal landfills. Values ranged from 5 to 25 percent of the waste thickness. Because the disposal cell will not include biodegradable materials, the amount of settlement in the disposal cell was estimated to be 5 to 10 percent of waste material height (consistent with the amount of short-term landfill settlement). Because the disposal cell will not have biodegradable materials (like a landfill) or low-density materials (like slurried mill tailings), the settlement would be from compression of void spaces around structural debris.

Municipal landfill data. Compressibility properties for the materials placed in the disposal cell were estimated based upon a review of published performance summaries for municipal solid waste landfills. In their review of final covers for solid waste landfills, Koerner and Daniel (1997) estimated the typical amount of surface settlement at landfills to be approximately 10 percent of the total height. The City of New York has found that surface settlements at their Fresh Kill landfill ranged from 10 to 15 percent of the waste height, with half of the settlement occurring in the first 5 to 10 years and the remainder occurring within the next 20 years (City of New York, 2004). The United States Environmental Protection Agency indicates landfill settlement can range from 5 to 25 percent of the original waste thickness (EPA, 2004). Vaidya (2002) found that settlements at municipal landfills could be as high as 25 percent of the waste thickness, and that biological decomposition of organics wastes can account for 18 to 24 percent of this settlement. Municipal solid waste landfills contain varying amounts of biodegradable organic waste. The work by Vaidya indicates the decomposition of these wastes is a major component of settlement, and that absent these wastes, settlements would range from 1 to 7 percent of the total waste height.

Disposal cell evaluation. The material placed in the SFC disposal cell will consist of inorganic, non-biodegradable demolition debris and soils from cleanup of the surrounding area. Therefore, decomposition of biodegradable material is not expected to be a factor contributing to settlement of the disposal cell. Consequently, the settlement of the SFC disposal cell is expected to be at the low end of the range cited for typical municipal solid waste landfills. For the purposes of this settlement estimate, the compressibility of the materials to be placed in the disposal cell are assumed to vary from 5 to 10 percent, based upon material type, as indicated in Table G.1.

Table G.1 Material Compressibility

Material	Estimated Compressibility (% of total layer height)
Type A	10
Type B	7.5
Type C	7.5
Type D	5

Total disposal cell settlement was estimated using the compressibility parameters listed above, and the estimated fraction of each material type within the vertical profile at critical locations within the cell. The amount of each material type within the profile were estimated for the three phases of the disposal cell construction based upon volume estimates presented in Appendix A of this report. These volumes were used to estimate the average thickness of each material type, which were used in conjunction with the compressibility parameters listed in Table G.1 to estimate the settlement. The results of the total settlement calculations are presented in Table G.2.

Table G.2 Total Settlement Estimates

Phase	Maximum Height at Internal Cell Boundary (ft)	Cover Height (ft)	Material Type Height (ft)				Total Settlement (ft)
			A	B	C	D	
I	30	10	0.3	2.3	1.6	15.8	1.61
II	45	10	4.4	1.7	3.6	25.3	2.60
III	30	10	0.0	0.5	4.6	14.8	1.63

Analyses of differential settlement were made for each cell at the area of greatest material thickness along the internal berms, where material variations and differential settlements are likely to be greatest. Differential settlement analyses were made by calculating the settlement for a vertical profile consisting entirely of low-compressibility, compacted soil waste (Type D) located immediately beyond (outside) the toe of the internal cells. This vertical profile represents the least compressible profile and results in the minimum settlement, and maximum differential settlement when located near a compressible zone for a given profile height. The low-compressibility layer was assumed to occur at the toe of the internal cell slopes, adjacent to the areas of maximum settlement in the mixed-material profiles shown in Table G.2.

The areas of maximum and minimum settlement were assumed to be separated by the internal slopes of the waste cells at a minimum distance of approximately 35 feet. The cover settlement above the internal slopes was assumed to vary in an approximately linear manner between the areas of maximum and minimum settlement. The estimated maximum settlement in the mixed waste profile (from Table G.2), minimum settlement, and resulting differential settlement are summarized in Table G.3 for the three phases of disposal cell development.

Table G.3 Differential Settlement Estimates

Phase	Maximum Total Settlement (ft)	Minimum Total Settlement (ft)	Differential Settlement (ft)
I	1.61	1.50	0.11
II	2.6	2.25	0.35
III	1.63	1.50	0.13

G.4 COVER CRACKING POTENTIAL

As discussed above, the total settlement of the disposal cell does not influence the performance of the cover system and barrier layers. Rather, it is differential settlement that may lead to disruption of the cover system, and specifically differential settlement over a short horizontal distance. Two criteria were used to evaluate the potential effects of differential settlements on cover performance. The first criterion, proposed by Koerner and Daniel (1992) and cited by the EPA (2004), states that the center of a 20-foot diameter, circular area can settle 0.5 to 1.5 feet before cover cracking of a composite clay cover could be expected. In other words, 0.5 to 1.5 feet of differential settlement over a 10-foot horizontal distance can be accommodated by a clay cover without cracking. Comparing this criterion with the differential settlement estimates in Table G.3 indicates the anticipated level of differential settlement at the disposal cell would not be expected to cause cracking of the cover system.

The second procedure used for evaluating the potential for cover cracking was that proposed by Morrison-Knudsen Environmental Corporation for evaluation of the potential for cover cracking at the Naturita-UMTRA site (M-K/UMTRA, 1993). This procedure compares allowable tensile strains for the cover soils with tensile strains resulting from calculated differential settlement of the underlying materials to estimate the potential for crack development. The allowable tensile strains within the cover are based upon the plasticity index of the cover soils. The allowable tensile strain for the disposal cell cover was estimated assuming a minimum plasticity index of 5 for the non-granular cover layers (cracking is not a concern for granular soil layers). This allowable tensile strain was compared with that resulting from the calculated differential settlements listed in Table G.3, assuming these settlements occurred over a

minimum horizontal distance of 35 feet (as described in the previous section). The calculated and allowable tensile strains resulting from this procedure are presented in Table G.4. These results show that in all cases, the calculated tensile strains are less than the allowable tensile strains and indicate cracking due to differential settlement is not likely.

Table G4 Comparison of Calculated and Allowable Tensile Strains in Cover Soils

Phase	Differential Settlement Over 35 ft Min. Horizontal Distance (ft)	Calculated Horizontal Tensile Strain (%)	Allowable Horizontal Tensile Strain (%)
I	0.11	0.018	0.065
II	0.35	0.057	0.065
III	0.13	0.021	0.065

It should be noted that M-K/UMTRA criterion described above does not take into account the effect of overburden in a relatively thick cover. The overlying cover soils will result in the lower portion of the cover remaining in compression even under some elongation due to differential settlement. The M-K/UMTRA procedure implicitly assumes no overburden stress on the cover. As a result the cover cracking analyses (based upon the M-K/UMTRA procedure) are expected to provide conservative estimates of cover cracking potential, with the disposal cell cover being able to withstand larger differential movements without experiencing settlement-related cracking. Therefore, disruption of the disposal cell cover due to settlement cracking is not likely under the planned method of cell operation.

G.5 REFERENCES

City of New York, 2004. Fresh Kill Landfill Post-Closure Public Information Website: www.NYC.gov/html/dcp/html/fkl/ada/about/1_2_1/html

Environmental Protection Agency (EPA), 2004. EPA Technical Guidance Resource Website: http://www.epa.gov/superfund/resources/presump/caps.htm

Koerner and Daniel, 1992. Better Cover-Ups. *Civil Engineering*, May:55-57.

Koerner and Daniel, 1997. "Final Covers for Solids Waste Landfills and Abandoned Dumps." ASCE Press, Reston VA.

Morrison Knudsen Environmental Corporation (M-K/UMTRA) 1993. UMTRA-Naturita, Embankment Design, Settlement Analysis and Cracking Potential Evaluation. Calc. No. 17-740-02-01, May

ENCLOSURE 6

Reclamation Plan

Appendix G, Radium Benchmark Dose Calculations and Sensitivity Analysis

Update Instructions:

1. **Remove entire section from RP Appendix G tab**
2. **Insert entire section enclosed here**

APPENDIX G

Radium Benchmark Dose Calculations and Sensitivity Analyses

Appendix G

RADIUM BENCHMARK DOSE CALCULATIONS and SENSITIVITY ANALYSES

DEVELOPMENT OF DERIVED CONCENTRATION GUIDELINE LEVELS (DCGLs)
Resident Farmer Scenario

DETERMINATION OF ANNUAL DOSE
Drainage 005 Scenario

DETERMINATION OF ANNUAL DOSE
Industrial Worker Scenario

ATTACHMENTS

Attachment 1
Selection of Thickness of Contaminated Zone and Thickness of Uncontaminated Unsaturated Zone for Development of DCGLs

Attachment 2
Justification of Resident Farmer Scenario for Development of DCGLs

Attachment 3
Justification of Parameter Values for Development of DCGLs

Attachment 4
ALARA Evaluation of DCGLs

Attachment 5
SENSITIVITY ANALYSES
Resident Farmer Scenario
Drainage 005 Scenario
Industrial Worker Scenario

DEVELOPMENT OF DERIVED CONCENTRATION GUIDELINE LEVELS

Introduction

Radioactive materials have been processed, used, and/or stored at SFC since 1970. The soils on site are contaminated with radioactive material. The technical criteria for cleanup of contaminated soil are provided in 10 CFR 40[1]. The technical criteria may be summarized as: 1) the concentration of radium in soil does not exceed the background concentration by more than 5 pCi/g; and 2) concentrations of radionuclides other than radium in soil must not result in a total effective dose equivalent (TEDE) exceeding the dose from cleanup of radium contaminated soil to the aforementioned criteria (radium benchmark dose). The TEDE is applied against an average member of a group of individuals reasonably expected to receive the greatest exposure to residual radioactivity for any applicable set of circumstances.

Exposure pathway modeling was used to calculate the radium benchmark dose and radionuclide concentrations that could result in a TEDE equal to the radium benchmark dose. Exposure pathway modeling is an analysis of various exposure pathways of a given exposure scenario used to convert dose into concentration of radioactive material in the source media. Concentrations were developed independently for the radionuclides other than radium present as contaminants in soil at SFC. These concentrations are referred to herein as derived concentration guideline levels (DCGLs).

The exposure pathway modeling completed here to develop the DCGLs was a deterministic analysis of the peak annual dose to the average member of the critical group for a resident farmer exposure scenario. The DCGLs accounted for site-specific information regarding the source term; critical group, scenario, and pathways identification and selection; the conceptual model; and calculations and input parameters. The units of the DCGLs, µg/g or pCi/g, are the same as for the measurements that will be used to demonstrate compliance with the technical criteria. This allows direct comparison between the DCGLs and results of verification surveys. SFC will show final compliance with the technical criteria by use of radionuclide-specific DCGLs and will ensure that the sum of fractions is met for all radionuclides.

Scope of DCGLs

The DCGLs were developed in particular for the case of license termination. The DCGLs were developed without consideration of any institutional controls and such that there is reasonable assurance that the TEDE from residual radioactivity distinguishable from background to the average member of the critical group is as low as is reasonably achievable.

The development of the DCGLs was completed solely with respect to dose received due to pathways related to residual radioactive material in surface soil. There were several

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[1] 10 CFR 40, Appendix A, Criterion 6, item (6).

pathways not included in the development of the DCGLs. Some pathways were not included because they are not applicable; e.g. drinking water. Other pathways were not included because they cannot be considered directly by the conceptual model applied to develop the DCGLs; e.g. exposure rate from the disposal cell. These and other pathway exceptions are discussed in a following section of this appendix.

If an exposure pathway is later determined applicable, such as drinking water, it may be added into the conceptual model and the DCGLs redeveloped. Exposure rate from the disposal cell will be addressed by design; i.e. exposure rate from the disposal cell will be reduced to background levels by the placement of material in the cell and design of the cell cover. In the case of a pathway not considered directly by the conceptual model is discovered significant, the corresponding dose will be independently determined and the DCGLs would be debited accordingly.

Figure G-1 is a depiction of the areas to which the DCGLs are applicable.

Source Term

Configuration

The radionuclides that have the potential to contribute the dose against which the dose limit criteria are compared are identified as the constituents of concern (CoC). The CoCs are specifically evaluated for the development of site-specific DCGLs. The CoCs were chosen based on historical information and findings of site investigations[2]. The CoCs were determined to be natural uranium and associated transformation products, thorium-230, and radium-226.

The source term is assumed to be uncovered contaminated soil of cylindrical shape. The contaminated soil is modeled as a 0.3-meter thick zone of unconsolidated soil. The contaminated soil is known underlain by one uncontaminated unsaturated soil zone; this zone is modeled as a 1.4-meter thick zone of unconsolidated soil. The next zone is an uncontaminated saturated zone; this zone is modeled as shale and is independent of thickness. The final zone is an aquitard and is not included in the model; this zone is sandstone. Attachment 1 describes the selection of thicknesses for the contaminated zone and the uncontaminated unsaturated zone.

Figure G-2 depicts the soil zones.

The use of nonspecific unconsolidated, shale, and sandstone zones is intentional. The areas at the site that would be available for a farmer to establish residence vary with respect to the particular shale unit that underlies the unconsolidated surface soil. However, shale units 1, 2,

[2] Sequoyah Fuels Corporation, Reclamation Plan Sequoyah Facility, January 2003, Appendix D, Site Characterization Report, Section 4.2.2. "Summary of Radiological and Chemical Materials Utilization".

3, and 4 have essentially equivalent physical characteristics. This condition is also true with respect to the sandstone zone beneath the nearest-surface shale zone. Then a single physical description can be used to represent any viable location upon which a farmer might establish residence.

Residual Radioactivity

The CoCs are assumed homogenously distributed within the contaminated soil at concentrations equivalent to the DCGLs.

Chemical Form

In an effort to quantify the mobility of uranium in soil at the site, a distribution coefficient was determined for each of unconsolidated soils, and shale units 1 through 4. These site-specific values were used for development of the DCGLs.

A site-specific distribution coefficient was not determined for thorium or radium.

Critical Group, Scenario, and Pathways Identification and Selection

Scenario Identification

The exposure scenario applied here may be described as representing a resident farmer. The resident farmer scenario accounts for exposure involving residual radioactivity that is initially in the surface soil. A farmer moves onto the site and grows some of his diet and uses surface water from the site. The scenario assumes no disturbance of the disposal cell (this qualification is discussed later). The scenario is based on assumptions that tend to a realistic estimate of potential dose. Attachment 2 provides a justification for use of the resident farmer scenario.

Critical Group Determination

The average member of the critical group is the resident farmer. This individual is assumed to be an adult with common habits and characteristics. This individual is reasonably expected to receive the greatest exposure to residual radioactivity for the applicable exposure scenario.

Exposure Pathways

The starting point for exposure of the critical group to the CoCs is the contaminated soil zone. The CoCs are assumed released from the soil by erosion, plant uptake, direct ingestion, infiltration, and leaching. The CoCs may also be transported to or by groundwater to eventually be released from soil. The scenario also considers exposure to direct gamma radiation emitted by the CoCs.

The primary exposure pathways include:

- External exposure from soil;
- Inhalation of suspended soil;
- Ingestion of soil;
- Ingestion of plant products grown in contaminated soil and using potentially contaminated surface water to supply irrigation;
- Ingestion of animal products grown onsite using feed and surface water from potentially contaminated sources; and

The exposure pathways selected for evaluation are listed in Table G-1. Five exposure pathways not included in the dose assessment are milk, aquatic foods, groundwater usage, intrusion of the disposal cell, and radon; each is discussed below.

Milk

If dairy cows were to graze in the contaminated area, the milk would probably be sent for processing (thus diluted), and not be consumed directly by the residents. [3]

Aquatic Foods

A pond in the contaminated area providing a significant quantity of fish for the resident's diet is not likely.[3]

Groundwater Usage

Groundwater usage includes use of groundwater for irrigation, livestock water supply, and drinking water. Groundwater usage was not considered a pathway applicable to the exposure scenario. There are no existing active water wells near or downgradient from the facility that could be impacted by migrating groundwater. The few active water wells near the plant are either upgradient of the facility or so far removed that future impact due to migration of CoCs is not possible.[4]

A technical evaluation of the Terrace/Shale Unit 1, Shale Unit 2, and Shale Unit 3 revealed they have essentially no ability to yield sufficient quantities of water to satisfy the EPA criteria for consideration as a potential drinking water source.[5]

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[3] NUREG-1620, Appendix H, H2.1.3(2)(a)

[4] Letter to Charlotte Abrams, U.S. NRC, from John Ellis, Sequoyah Fuels Corporation, "Response to Request for Additional Information Concerning Environmental Renewal of Decommissioning", No. 14, April 30, 2001.

[5] Sequoyah Fuels Corporation, Reclamation Plan Sequoyah Facility, January 2003, Appendix B, Hydrogeological and Chemical Site Characterization Report, Appendix K, Sufficient Yield Memo.

Though Shale Unit 4 may have a very limited potential to yield groundwater slightly greater than the EPA criteria, the background water quality of this formation is of such poor quality that it would not reasonably be used for any domestic purpose. The same reasoning eliminates use of groundwater for irrigation and livestock water. This condition has resulted in the local practice of surface water serving as the supply for irrigation and livestock water.

Limited yield of groundwater wells is typical throughout this part of Oklahoma and has resulted in the construction of extensive potable water distribution systems that rely on surface water as their source(s). Also, adjacent to the site is the Illinois River, which is of much higher quality and yield, and more easily accessed than local groundwater. Considering the abundant and more easily accessed alternate water supplies available, drilling through the hard sandstone units is highly improbable.

Localized areas at the Facility producing higher yields of water, have been affected by recharge from existing surface impoundments or man-made subsurface reservoirs such as utility trenches and foundation backfill areas. Once these features are removed during decommissioning, the yield from the higher output wells is expected to decline significantly. In addition, the highest yields occur in the Terrace (surface) unit. It is unlikely that a well would be constructed in this unit due to potential contamination from septic systems or other near surface features.

The Alluvial Groundwater System has been found to have a high water yield. This groundwater system is primarily supplied by in-flow from the R.S. Kerr Reservoir. This water is therefore of relatively low quality (elevated dissolved solids and salinity), is not currently used for drinking water, nor could it be in the future without expensive treatment.

In the context of the previous description, there exists a reasonable assurance that there is no direct groundwater usage pathway, especially drinking water, resulting in exposure to CoCs at the Facility.

Cell Intrusion

Development of the DCGLs did not consider failure of the cell's engineered cover system. Inadvertent intrusion into the cell by construction of a basement is very unlikely since basements are not a common feature of homes in northeast Oklahoma. The cover system is designed such that erosion by surface water, resulting in exposure of a resident to the cell contents either directly or from redistribution by surface water, will not be a threat.[6]

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[6] NUREG-1727, Appendix C, Section 4.4.3

Deliberate intrusion into the cell was not considered during development of the DCGLs. Such an event implies that the intruder knows of the potential hazards but deliberately chooses to ignore them. Deliberate intrusion into the cell cannot reasonably be protected against and so is not considered further.[7]

Radon

The radon pathway was not considered because it is specifically excluded from the scope of the technical criteria.[8]

Conceptual Model

The conceptual model used to evaluate the previously described exposure scenario and pathways was the RESRAD[9] computer code version 6.21. RESRAD was developed, in part, to calculate site-specific concentrations for RESidual RADioactive material in soil corresponding to a radiation dose limit to a chronically exposed on-site resident. The RESRAD code considers multiple environmental transport and exposure pathways. A description of the code models, as applied here, is provided below.[10]

RESRAD models external exposure from volume sources when the individual is outside, using volume dose rate factors from Federal Guidance Report No. 12. Correction factors are used to account for soil density, areal extent of contamination, and thickness of contamination. When the individual is indoors, exposure from external radiation is modeled in a similar manner except that additional attenuation is included to account for the building. Exposure through ingestion of contaminated animal and plant products is modeled simply through the use of transfer factors.

The generic source-term conceptual model in RESRAD assumes a time-varying release rate of radionuclides into the water and air pathways. Radionuclides in the contaminant zone are assumed uniformly distributed. No transport is assumed to occur within the source zone, but account is made for radioactive transformation. The radioactive material is not assumed contained. The subject scenario does not include a cover of clean soil over the contaminated area. Release of radionuclides by water is assumed to be a function of a constant infiltration rate, time-varying contaminant zone thickness, constant moisture content, and equilibrium adsorption. The contaminant zone is assumed to decrease over time from a constant erosion rate. Particulates are assumed instantaneously and uniformly released into the air as a function of the concentration of particulates in the air, based on a constant mass loading rate.

The RESRAD conceptual groundwater model includes two horizontal homogenous strata for the unsaturated zone. Transport in the unsaturated zone is assumed to result from steady-

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[7] NUREG-0945, page 4-13

[8] 10 CFR 40, Appendix A, Criterion 6 (6)

state, constant vertical flow, with equilibrium adsorption, and decay, but no dispersion. RESRAD, for the subject case, models radionuclides in the saturated zone by a nondispersion approach. In the nondispersion approach, transport in the saturated zone is assumed to occur in a single homogenous stratum, under steady-state, unidirectional flow, with constant velocity, equilibrium adsorption, and radioactive transformation. The nondispersion model is the RESRAD default based on the size of the contaminated area.

The generic conceptual model of the surface water pathway in RESRAD assumes that radionuclides are uniformly distributed in a finite volume of water within a watershed. Radionuclides are assumed to enter the watershed at the same time and concentration as in the groundwater. Accordingly, no additional attenuation is considered as radionuclides are transported to the watershed. Radionuclides are assumed diluted as a function of the size of the contaminated area in relation to the size of the watershed. The model assumes that all radionuclides reaching the surface water are derived from the groundwater pathway. Thus transport of radionuclides overland from runoff is not considered. As well, additional dilution from overland runoff is not considered.

The generic conceptual model of the air pathway in RESRAD uses a constant mass loading factor and area factor to model radionuclide transport. The area factor, which is used to estimate the amount of dilution, relates the concentration of radionuclides from a finite area source to the concentration of radionuclides from an infinite area source. It is calculated as a function of particle diameter, wind speed, and the side length of a square area source. The model assumes a fixed particle density, constant annual rainfall rate, and constant atmospheric stability. No radioactive decay is considered.

Calculations and Input Parameters

Inputs are provided for parameters of the source term configuration and exposure pathways described previously. Site-specific values were used for parameters when available. Otherwise the parameter value was assigned a default value or a value based on professional judgment.

For the source term, the inputs include site-specific values or estimates of contaminated area, thickness, density, porosity, hydraulic conductivity, hydraulic gradient, and distribution coefficient.

Particulars of the input parameters include: the resident farmer spends 25% of the time indoors on site, 50% of the time outdoors on site, and 25% of the time away from the site. Food production is assumed to occur in the contaminated area: 20% of the resident's vegetable, grain, and fruit diet assumed produced from the garden; 20% of the resident's

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[9] Yu, C., et. al., *User's Manual for RESRAD Version 6*, ANL/EAD-4, Argonne National Laboratory, July 2001.

[10] NUREG-1727, Appendix C, Section 5.3.2.1.2

meat diet is assumed produced on site. Dust levels represent tilling, planting, harvesting, and other activities that may increase suspension of soil particles in air.

Vegetables, fruits, and grains are irrigated from overhead with water drawn from a pond at the site boundary, immediately downgradient of the contaminated area. The same water is also used for watering livestock on site. The resident's drinking water is assumed from an uncontaminated municipal potable water system or uncontaminated surface water.

The walls, foundation, and floor of the resident's house reduce external exposure by 21%. Indoor dust level in air is assumed to be 56% of the outdoor dust level.

The parameters, associated inputs, and rationale for value, are included in Table G-2.

Attachment 3 provides specific description of the rationale for the value of each parameter.

Compliance with Regulatory Criteria

The exposure scenario and associated inputs and model described above were applied to a soil concentration of 5 pCi/g Ra-226 with 5 pCi/g Pb-210.[11] The resulting dose, i.e. the radium benchmark dose, to the resident farmer was 57 millirem per year (mrem/y). The radionuclide concentrations in soil for U-natural and Th-230 that result in 57 mrem/y for the same exposure scenario are 570 pCi/g and 66 pCi/g, respectively. The DCGLs are listed in Table G-3.

In areas where thorium and radium are not present, the uranium DCGL will be used. In areas where thorium and radium are present, the DCGLs will be considered in combination to ensure that the applicable dose limit is met; i.e. the sum of ratios of radionuclide concentration to respective DCGL will not exceed one.

An evaluation of the "as low as reasonably achievable" (ALARA) principle is provided as Attachment 4.

Sensitivity Analysis

The results of the sensitivity analysis of the resident farmer scenario are presented in Attachment 5 and summarized here. The summary is confined to those parameters of the radium benchmark dose analysis for which a reasonable change in input caused the dose to be less than the benchmark dose of 57 mrem/y by more than 25%; i.e. the dose was less than 43 mrem/y.

The annual dose for radium-226 was found to be significantly sensitive to two parameters: thickness of contaminated zone and depth of roots. The model input for thickness of

[11] NUREG-1620, Appendix H, Section H2.1.3, (2), (b)

contaminated zone is derived from site characterization data. The value for depth of roots is justified based on the type of crops likely grown on site. No adjustment to the scenario is warranted with respect to these parameters.

DETERMINATION OF ANNUAL DOSE - Drainage 005 Scenario

Introduction

Drainage 005 (the storm water drainage below outfall 005) is contaminated with natural uranium, thorium 230, and radium 226. The concentrations of these radionuclides in the drainage exceed the DCGLs. The contamination is described in the Site Characterization Report.[12]

The Reclamation Plan does not include remediation of Drainage 005. A dose assessment, described below, has been completed demonstrating that the contribution to total annual dose is insignificant. The dose assessment is centered on the resident farmer scenario used to establish the DCGLs.

Source Term

Configuration

The CoCs applicable to Drainage 005 are the same as evaluated for the development of the site-specific DCGLs: natural uranium and associated transformation products, thorium 230, and radium 226.

The source term is assumed to be uncovered contaminated soil of rectangular shape; i.e. length and width of drainage. Specifically, the contaminated zone is modeled as 403 meters long and 1 meter wide. The thickness of the contaminated zone, based on informal empirical information, is modeled as 0.1 meter. Figure G-3 depicts the soil zones.

Residual Radioactivity

The CoCs are assumed homogenously distributed within the contaminated soil at average concentrations derived from the Site Characterization Report. Only the surface sediments are assumed contaminated.

Chemical Form

The discussion of chemical form provided for the development of the site-specific DCGLs is applicable to this scenario.

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[12] Sequoyah Fuels Corporation, Reclamation Plan Sequoyah Facility, January 2003, Appendix D, Site Characterization Report, Table 7, "Unit 34".

Critical Group, Scenario, and Pathways Identification and Selection

Scenario Identification

The exposure scenario assumed here is based on the resident farmer scenario used to derive the site-specific DCGLs. However, it accounts only for the resident farmer's interaction with Drainage 005. The scenario is based on prudently conservative assumptions that tend to overestimate potential dose.

Critical Group Determination

The average member of the critical group is the resident farmer. This individual is assumed to be an adult with common habits and characteristics. This individual is reasonably expected to receive the greatest exposure to residual radioactivity for the applicable exposure scenario.

Exposure Pathways

The Drainage 005 scenario accounts for exposure involving residual radioactivity that is in the surface sediments of the drainage. The resident farmer enters the drainage and performs light-duty activities. The primary exposure pathways include:

- External exposure from soil;
- Inhalation of suspended soil; and
- Ingestion of soil.

The radon pathway is not considered because it is not within the scope of the technical criteria.[13]

The exposure pathways selected are listed in Table G-4.

Conceptual Model

The conceptual model used to evaluate the subject exposure scenario and pathways was the RESRAD[14] computer code version 6.21. RESRAD was developed, in part, to calculate annual dose to a chronically exposed on-site individual for site-specific concentrations of RESidual RADioactive material in soil. The RESRAD code considers multiple environmental transport and exposure pathways.

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[13] 10 CFR 40, Appendix A, Criterion 6 (6).

[14] Yu, C., et. al., *User's Manual for RESRAD Version 6*, ANL/EAD-4, Argonne National Laboratory, July 2001.

Calculations and Input Parameters

Site-specific values were used for parameters when available. Otherwise the parameter value was assigned a default value or a value based on professional judgment.

In particular, the total exposure time is outdoors; the resident farmer is assumed to spend one hour per day each day of the year in the drainage. Other differences from the resident farmer scenario include no irrigation, no runoff, and a shallower depth of soil mixing layer. The other parameters are the same as for the resident farmer scenario.

The parameters (i.e. inputs to the conceptual model) describing the aforementioned source term and exposure pathways are listed in Table G-5. The table also describes each parameter's value and a rationale for the value.

Compliance with Regulatory Criteria

This dose assessment was performed to evaluate the specific contribution of the residual radioactivity in Drainage 005 to the total dose estimated for the resident farmer (i.e. the radium benchmark dose limit of 57 mrem per year). The result of the dose assessment for Drainage 005 to the resident farmer was 0.2 mrem per year. This value is an insignificant contribution to the total dose estimated for the resident farmer scenario; i.e. from application of the site specific DCGLs.

Sensitivity Analysis

A sensitivity analysis was completed of the parameters used in the subject dose assessment. The sensitivity analysis was completed for the three COCs together. The results of the sensitivity analysis are summarized in Attachment 5.

The sensitivity analysis revealed the dose not sensitive to any parameter with respect to the difference between the annual dose (0.2 mrem/y) and the radium benchmark dose (57 mrem/y).

DETERMINATION OF ANNUAL DOSE - Industrial Worker Scenario

Introduction

The decommissioning of the Facility includes provision for long-term control of the site. The control includes periodic groundwater monitoring, inspection, mowing, and general physical maintenance. These tasks will be performed by an individual (i.e. Industrial Worker) employed or contracted by the long-term custodian.

The applicable regulatory dose limit will be assumed that for a member of the general public, currently 100 mrem per year.[15] The dose assessment described in the following sections demonstrates that the annual dose to the industrial worker is substantially below this limit.

Source Term

Configuration

The configuration applicable to the industrial worker scenario is the same as evaluated for development of the site-specific DCGLs.

Residual Radioactivity

The source term is assumed to be uncovered contaminated soil of cylindrical shape. The CoCs are assumed homogenously distributed within the contaminated soil at concentrations equivalent to the DCGLs. As an element of conservatism, and for ease of assessment, the CoCs are assumed to all be present together at the respective DCGL. Figure G-4 depicts the soil zones.

Chemical Form

The chemical form applicable to the industrial worker scenario is the same as evaluated for development of the site-specific DCGLs.

Critical Group, Scenario, and Pathways Identification and Selection

Scenario Identification

The exposure scenario applied here may be described as representing an industrial worker. The industrial worker moves across the site performing the tasks described previously. The scenario is applicable only to the time the worker spends on site. The scenario is based on prudently conservative assumptions that tend to overestimate potential dose.

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[15] 10 CFR 20.1301(a)(1) and (b).

Critical Group Determination

The average member of the critical group is the industrial worker. This individual is assumed to be an adult male with common habits and characteristics. This individual is reasonably expected to receive the greatest exposure to residual radioactivity for the applicable scenario.

Exposure Pathways

The industrial worker scenario accounts for exposure involving residual radioactivity that is in the surface soil. The worker enters the area and performs light-duty activities. The primary exposure pathways include:

- External exposure from soil;
- Inhalation of suspended soil; and
- Ingestion of suspended soil.

The radon pathway is not considered because it is not within the scope of the technical criteria.[16]

The exposure pathways selected are listed in Table G-6.

Conceptual Model

The conceptual model used to evaluate the subject exposure scenario and pathways was the RESRAD[17] computer code version 6.21. RESRAD was developed, in part, to calculate annual dose to a chronically exposed on-site individual for site-specific concentrations of RESidual RADioactive material in soil. The RESRAD code considers multiple environmental transport and exposure pathways.

Calculations and Input Parameters

Site-specific values were used for parameters when available. Otherwise the parameter value was assigned a default value or a value based on professional judgment.

In particular, the contaminated zone physical and hydrological parameters are the same as for determination of the site-specific DCGLs. The inhalation rate and mass loading for inhalation are also the same as for the resident farmer. The total exposure time is 130 hours per year outdoors (32 hours well sampling and 96 hours mowing).

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[16] 10 CFR 40 Appendix A, Criterion 6 (6).

[17] Yu, C., et. al., *User's Manual for RESRAD Version 6*, ANL/EAD-4, Argonne National Laboratory, July 2001.

The parameters (i.e. inputs to the conceptual model) describing the aforementioned source term and exposure pathways are listed in Table G-7. The table also describes each parameter's value and a rationale for the value.

Compliance with Regulatory Criteria

This dose assessment was performed to evaluate compliance with the dose limit for individual members of the public of 100 mrem in a year. The result of the dose assessment was about 2 mrem per year to the industrial worker. This value is far below the applicable regulatory dose limit.

Sensitivity Analysis

A sensitivity analysis was completed of the parameters used in the subject dose assessment. The sensitivity analysis was completed for the three CoCs together. The results of the sensitivity analysis are summarized in Attachment 5.

The sensitivity analysis revealed the dose not sensitive to any parameter with respect to the difference between the annual dose (2 mrem/y) and the annual dose limit (100 mrem/y).

TABLE G-1: RESIDENT FARMER SCENARIO EXPOSURE PATHWAY SELECTIONS

PATHWAY[1]	USER SELECTION
External Gamma	Active
Inhalation (w/o radon)	Active
Plant Ingestion	Active
Meat Ingestion	Active
Milk Ingestion	Suppressed
Aquatic Foods	Suppressed
Drinking Water	Suppressed
Soil Ingestion	Active
Radon	Suppressed

[1] These pathways match those available from the conceptual model used in the dose assessment; i.e. RESRAD version 6.21.

TABLE G-2: RESIDENT FARMER SCENARIO MODEL SFC SELECTED VALUES		
Parameter	**SFC Input**	**Background Information**
Source		
Nuclide concentration for U-238 (pCi/g)		To be determined for the "Basic radiation dose limit (mrem/yr)"; i.e. the Ra-226 benchmark dose.
Transport Distribution coefficients for U-238		
Contaminated zone (cm**3/g)	572	Site-specific estimate: see Attachment 3.
Unsaturated zone 1 (cm**3/g)	572	Site-specific estimate: see Attachment 3.
Saturated zone (cm**3/g)	17.1	Site-specific estimate: see Attachment 3.
Time since material placement (yr)	0	RESRAD default
Groundwater concentration (pCi/L)	-	Not available; reflects availability of distribution coeff.[1]
Solubility Limit (mol/L)	0	RESRAD default
Leach Rate (/yr)	0	RESRAD default
Nuclide concentration for U-235 (pCi/g)		To be determined for the "Basic radiation dose limit (mrem/yr)"; i.e. the Ra-226 benchmark dose.
Transport Distribution coefficients for U-235		
Contaminated zone (cm**3/g)	572	Site-specific estimate: see Attachment 3.
Unsaturated zone 1 (cm**3/g)	572	Site-specific estimate: see Attachment 3.
Saturated zone (cm**3/g)	17.1	Site-specific estimate: see Attachment 3.
Time since material placement (yr)	0	RESRAD default
Groundwater concentration (pCi/L)	-	Not available; reflects availability of distribution coeff.[1]
Solubility Limit (mol/L)	0	RESRAD default
Leach Rate (/yr)	0	RESRAD default
Nuclide concentration for Pa-231 (pCi/g)		To be determined for the "Basic radiation dose limit (mrem/yr)"; i.e. the Ra-226 benchmark dose.
Transport Distribution coefficients for daughter Pa-231		
Contaminated zone (cm**3/g)	380	Assigned by RESRAD guidance.[2]
Unsaturated zone 1 (cm**3/g)	380	Assigned by RESRAD guidance.[2]
Saturated zone (cm**3/g)	380	Assigned by RESRAD guidance.[2]
Time since material placement (yr)	0	RESRAD default
Groundwater concentration (pCi/L)	-	Not available; reflects availability of distribution coeff.[1]
Solubility Limit (mol/L)	0	RESRAD default
Leach Rate (/yr)	0	RESRAD default

TABLE G-2: RESIDENT FARMER SCENARIO MODEL SFC SELECTED VALUES

Parameter	SFC Input	Background Information
(continued 2 of 7)		
Nuclide concentration for Ac-227 (pCi/g)		To be determined for the "Basic radiation dose limit (mrem/yr)"; i.e. the Ra-226 benchmark dose.
Transport Distribution coefficients for daughter Ac-227		
Contaminated zone (cm**3/g)	825	Assigned by RESRAD guidance.[2]
Unsaturated zone 1 (cm**3/g)	825	Assigned by RESRAD guidance.[2]
Saturated zone (cm**3/g)	825	Assigned by RESRAD guidance.[2]
Time since material placement (yr)	0	RESRAD default
Groundwater concentration (pCi/L)	-	Not available; reflects availability of distribution coeff.[1]
Solubility Limit (mol/L)	0	RESRAD default
Leach Rate (/yr)	0	RESRAD default
Nuclide concentration for U-234 (pCi/g)		To be determined for the "Basic radiation dose limit (mrem/yr)"; i.e. the Ra-226 benchmark dose.
Transport Distribution coefficients for U-234		
Contaminated zone (cm**3/g)	572	Site-specific estimate: see Attachment 3.
Unsaturated zone 1 (cm**3/g)	572	Site-specific estimate: see Attachment 3.
Saturated zone (cm**3/g)	17.1	Site-specific estimate: see Attachment 3.
Time since material placement (yr)	0	RESRAD default
Groundwater concentration (pCi/L)	-	Not available; reflects availability of distribution coeff.[1]
Solubility Limit (mol/L)	0	RESRAD default
Leach Rate (/yr)	0	RESRAD default
Nuclide concentration for Th-230 (pCi/g)		To be determined for the "Basic radiation dose limit (mrem/yr)"; i.e. the Ra-226 benchmark dose.
Transport Distribution coefficients for Th-230		
Contaminated zone (cm**3/g)	5884	Assigned by RESRAD guidance.[2]
Unsaturated zone 1 (cm**3/g)	5884	Assigned by RESRAD guidance.[2]
Saturated zone (cm**3/g)	5884	Assigned by RESRAD guidance.[2]
Time since material placement (yr)	0	RESRAD default
Groundwater concentration (pCi/L)	-	Not available; reflects availability of distribution coeff.[1]
Solubility Limit (mol/L)	0	RESRAD default
Leach Rate (/yr)	0	RESRAD default

TABLE G-2: RESIDENT FARMER SCENARIO MODEL SFC SELECTED VALUES		
Parameter	**SFC Input**	**Background Information**
(continued 3 of 7)		
Nuclide concentration for Ra-226 (pCi/g)	5	10 CFR 40, Appendix A, Criterion 6 (6)
Transport Distribution coefficients for Ra-226		
Contaminated zone (cm**3/g)	3533	Assigned by RESRAD guidance.[2]
Unsaturated zone 1 (cm**3/g)	3533	Assigned by RESRAD guidance.[2]
Saturated zone (cm**3/g)	3533	Assigned by RESRAD guidance.[2]
Time since material placement (yr)	0	RESRAD default
Groundwater concentration (pCi/L)	-	Not available; reflects availability of distribution coeff.[1]
Solubility Limit (mol/L)	0	RESRAD default
Leach Rate (/yr)	0	RESRAD default
Nuclide concentration for Pb-210 (pCi/g)	5	NUREG-1620, Appendix H, Section H2.1.3, (2), (b)
Transport Distribution coefficients for Pb-210		
Contaminated zone (cm**3/g)	2392	Assigned by RESRAD guidance.[2]
Unsaturated zone 1 (cm**3/g)	2392	Assigned by RESRAD guidance.[2]
Saturated zone (cm**3/g)	2392	Assigned by RESRAD guidance.[2]
Time since material placement (yr)	0	RESRAD default
Groundwater concentration (pCi/L)	-	Not available; reflects availability of distribution coeff.[1]
Solubility Limit (mol/L)	0	RESRAD default
Leach Rate (/yr)	0	RESRAD default
Calculation Parameters		
Basic radiation dose limit (mrem/yr)	25	RESRAD default
Times for Calculations (years)	1	RESRAD default
Times for Calculations (years)	3	RESRAD default
Times for Calculations (years)	10	RESRAD default
Times for Calculations (years)	30	RESRAD default
Times for Calculations (years)	100	RESRAD default
Times for Calculations (years)	300	RESRAD default
Times for Calculations (years)	1000	RESRAD default
Contaminated Zone Parameters		
Area of contaminated zone (m**2)	263120	Site-specific estimate: see Attachment 3.
Thickness of contaminated zone (m)	0.3	Site-specific estimate: unconsolidated soils over shale; see Attachment 1.
Length parallel to aquifer flow (m)	662	Diameter of circle of 85 acre area

TABLE G-2: RESIDENT FARMER SCENARIO MODEL SFC SELECTED VALUES		
Parameter	**SFC Input**	**Background Information**
(continued 4 of 7)		
Cover and Contaminated Zone Hydrological Data		
Cover depth (m)	0	Planned actual conditions
Density of cover material (g/cm**3)	-	Not available; reflects absence of cover.[1]
Cover erosion rate (m/yr)	-	Not available; reflects absence of cover.[1]
Density of contaminated zone (g/cm**3)	1.76	Site-specific estimate: see Attachment 3.
Contaminated zone erosion rate (m/yr)	0.0006	Recommendation from RESRAD guidance.[2]
Contaminated zone total porosity	0.30	Estimate from RESRAD guidance.[3]
Contaminated zone field capacity	0.2	RESRAD default
Contaminated zone hydraulic conductivity (m/yr)	8.9	Site-specific estimate: see Attachment 3.
Contaminated zone b parameter	3	Recommendation from RESRAD guidance.[3]
Humidity in air (g/cm**3)	-	Not available due suppressed radon pathway.[1,4]
Evapotranspiration coefficient	0.5	Suggestion from RESRAD guidance.[2]
Wind Speed (m/sec)	4	Site-specific estimate: see Attachment 3
Precipitation (m/yr)	1.1	Site-specific estimate: see Attachment 3
Irrigation (m/yr)	0.6	Estimate from RESRAD guidance.[3]
Irrigation mode	overhead	Site specific observation (local practice).
Runoff coefficient	0.4	Estimate from RESRAD guidance.[2]
Watershed area for nearby stream or pond (m**2)	575000	Site-specific estimate: see Attachment 3
Accuracy for water/soil computations	1.00E-03	RESRAD default
Saturated Zone Hydrological Data		
Density of saturated zone (g/cm**3)	2.69	Site-specific estimate: see Attachment 3.
Saturated zone total porosity	0.4	Estimate from RESRAD guidance.[3]
Saturated zone effective porosity	0.1	Site-specific estimate: see Attachment 3.
Saturated zone field capacity	0.2	RESRAD default
Saturated zone hydraulic conductivity (m/yr)	89	Site-specific estimate: see Attachment 3.
Saturated zone hydraulic gradient	0.04	Site-specific estimate: see Attachment 3.
Saturated zone b parameter	-	Not available; reflects *water table drop rate* equal zero[1]
Water table drop rate (m/yr)	0	Assume unconfined groundwater system
Well pump intake depth (m below water table)	0.00001	Lowest value allowed by RESRAD[1]; reflects absence of a well
Model for Water Transport Parameters		
Nondispersion (ND) or Mass-Balance (MB)	ND	RESRAD default based on size of contaminated area.[1]
Well pumping rate (m**3/yr)	0	Reflects absence of a well (no groundwater usage).

(continued 5 of 7)		
Uncontaminated Unsaturated Zone Parameters		
Unsaturated Zones	1	Site-specific estimate: see Attachment 1.
Unsaturated Zone 1, Thickness (m)	1.4	Site-specific estimate: see Attachment 1.
Unsaturated Zone 1, Density (g/cm**3)	1.76	Site-specific estimate: see Attachment 3.
Unsaturated Zone 1, Total Porosity	0.3	Estimate from RESRAD guidance[3].
Unsaturated Zone 1, Effective Porosity	0.25	Site-specific estimate: see Attachment 3.
Unsaturated Zone 1, Field Capacity	0.2	RESRAD default
Unsaturated Zone 1, Hydraulic Conductivity (m/yr)	8.9	Site-specific estimate: see Attachment 3.
Unsaturated Zone 1, b Parameter	3	Recommendation from RESRAD guidance.[3]
Occupancy, Inhalation, and External Gamma Data		
Inhalation rate (m**3/yr)	8400	Recommendation from RESRAD guidance.[2]
Mass loading for inhalation (g/m**3)	2.00E-04	Suggestion from RESRAD guidance.[3]
Exposure duration	1	Reflects applicable regulatory evaluation period.
Indoor dust filtration factor	0.56	Estimate from RESRAD guidance.[2]
External gamma shielding factor	0.21	Suggestion from RESRAD guidance.[2]
Indoor time fraction	0.25	Recommendation from NRC guidance.[4]
Outdoor time fraction	0.50	Recommendation from NRC guidance.[4]
Shape of the contaminated zone	circular	Assumed shape of *area of contaminated zone*.
Ingestion Pathway, Dietary Data		
Fruits, vegetables and grain consumption (kg/yr)	178	Suggestion from RESRAD guidance.[2]
Leafy vegetable consumption (kg/yr)	25	Estimate from RESRAD guidance.[2]
Milk consumption (L/yr)	-	Not available due suppressed milk pathway.[1,4]
Meat and poultry consumption (kg/yr)	63	RESRAD default.
Fish consumption (kg/yr)	-	Not available due suppressed aquatic food pathway.[1,4]
Other seafood consumption	0	Not applicable
Soil ingestion (g/yr)	18.3	Suggestion from RESRAD guidance.[2]
Drinking water intake (L/yr)	-	Not available due suppressed drinking water pathway.[1]
Contaminated fraction Drinking water	-	Not available due suppressed drinking water pathway.[1]
Contaminated fraction Household water	-	Not available due suppressed radon pathway.[1]
Contaminated fraction Livestock water	1	Assume all from onsite pond
Contaminated fraction Irrigation water	1	Assume all from onsite pond
Contaminated fraction Aquatic food	-	Not available due suppressed aquatic food pathway.[1]
Contaminated fraction Plant food	0.2	Recommendation from NRC guidance.[5]
Contaminated fraction Meat	0.2	Recommendation from NRC guidance.[5]
Contaminated fraction Milk	-	Not available due suppressed milk pathway.[1]

(continued 6 of 7)		
Ingestion Pathway, Nondietary Data		
Livestock fodder intake for meat (kg/day)	68	RESRAD default
Livestock fodder intake for milk (kg/day)	-	Not available due suppressed milk pathway.[1]
Livestock water intake for meat (L/day)	50	RESRAD default
Livestock water intake for milk (L/day)	-	Not available due suppressed milk pathway.[1]
Livestock soil intake (kg/day)	0.5	RESRAD default
Mass loading for foliar deposition (g/m**3)	1.00E-04	RESRAD default
Depth of soil mixing layer (m)	0.15	RESRAD default
Depth of roots (m)	0.3	Recommendation from NRC guidance.[4]
Groundwater Fractional Usage Drinking water	-	Not available due suppressed drinking water pathway.[1]
Groundwater fractional Usage Household water	-	Not available due suppressed radon pathway.[1]
Groundwater Fractional Usage Livestock water	0	Reflects the absence of groundwater usage; e.g. *well pumping rate* equal zero.
Groundwater Fractional Usage Irrigation water	0	Reflects the absence of groundwater usage; e.g. *well pumping rate* equal zero.
Plant Factors		
Wet weight crop yield for Non-Leafy (kg/m**2)	0.6	A State-specific value from RESRAD guidance.[2]
Wet weight crop yield for Leafy (kg/m**2)	1.5	RESRAD default
Wet weight crop yield for Fodder (kg/m**2)	1.1	RESRAD default
Length of growing season for Non-Leafy (years)	0.17	RESRAD default
Length of growing season for Leafy (years)	0.25	RESRAD default
Length of growing season for Fodder (years)	0.38	Site-specific estimate: see Attachment 3.

(continued 7 of 7)		
Translocation factor for Non-Leafy	0.1	RESRAD default
Translocation factor for Leafy	1	RESRAD default
Translocation factor for Fodder	1	RESRAD default
Weathering removal constant for vegetation	18	Suggestion from RESRAD guidance.[2]
Wet foliar interception fraction for Non-Leafy	0.25	RESRAD default
Wet foliar interception fraction for leafy	0.67	Suggestion from RESRAD guidance.[2]
Wet foliar interception fraction for fodder	0.25	RESRAD default
Dry foliar interception fraction for Non-Leafy	0.25	RESRAD default
Dry foliar interception fraction for Leafy	0.25	RESRAD default
Dry foliar interception fraction for Fodder	0.25	RESRAD default

[1] Yu, C., et. al. "User's Manual for RESRAD Version 6." Argonne National Laboratory. ANL/EAD-4. July 2001.

[2] U.S. Nuclear Regulatory Commission. Development of Probabilistic RESRAD 6.0 and RESRAD-BUILD 3.0 Computer Codes. Washington, D.C.: U.S. Nuclear Regulatory Commission. NUREG/CR-6697. December 2000.

[3] Yu, C., et.al. "Data Collection Handbook to Support Modeling the Impacts of Radioactive Material in Soil." Argonne, IL: Argonne National Laboratory. ANL/EAIS-8. April 1993.

[4] U.S. Nuclear Regulatory Commission. Standard Review Plan for the Review of a Reclamation Plan for Mill Tailings Sites Under Title II of the Uranium Mill Tailings Radiation Control Act of 1978, Final Report, Revision 1. Washington, D.C.: U.S. Nuclear Regulatory Commission. NUREG-1620. June 2003.

[5] U.S. Nuclear Regulatory Commission, Commission Paper SECY 98 084, "Status of Efforts to Finalize Regulations for Radiological Criteria for License Termination: Uranium Recovery Facilities", April 15, 1998.

TABLE G-3: DERIVED CONCENTRATION GUIDELINE LEVELS (DCGLS)

Condition	U-natural (pCi/g)	Th-230 (pCi/g)	Ra-226 (pCi/g)
DCGL	570 (840 µg/g)	66	5.0

TABLE G-4: DRAINAGE 005 SCENARIO EXPOSURE PATHWAY SELECTIONS

PATHWAY[1]	USER SELECTION
External Gamma	Active
Inhalation (w/o radon)	Active
Plant Ingestion	Suppressed
Meat Ingestion	Suppressed
Milk Ingestion	Suppressed
Aquatic Foods	Suppressed
Drinking Water	Suppressed
Soil Ingestion	Active
Radon	Suppressed

[1] These pathways match those available from the conceptual model used in the dose assessment; i.e. RESRAD version 6.21.

TABLE G-5: DRAINAGE 005 SCENARIO SFC SELECTED VALUES		
Parameter	**SFC Input**	**Background Information**
Source		
Nuclide concentration for U-238 (pCi/g)	45	Average from Table 7 of SCR.[1]
Transport Distribution coefficients for U-238		
Contaminated zone (cm**3/g)	572	Site-specific estimate: see Attachment 3.
Unsaturated zone 1 (cm**3/g)	-	Not applicable
Saturated zone (cm**3/g)	17.1	Site-specific estimate: see Attachment 3.
Time since material placement (yr)	0	RESRAD default
Groundwater concentration (pCi/L)	-	Not available; reflects availability of distribution coeff.[2]
Solubility Limit (mol/L)	0	RESRAD default
Leach Rate (/yr)	0	RESRAD default
Nuclide concentration for U-235 (pCi/g)	2	Average from Table7 of SCR.[1]
Transport Distribution coefficients for U-235		
Contaminated zone (cm**3/g)	572	Site-specific estimate: see Attachment 3.
Unsaturated zone 1 (cm**3/g)	-	Not applicable
Saturated zone (cm**3/g)	17.1	Site-specific estimate: see Attachment 3.
Time since material placement (yr)	0	RESRAD default
Groundwater concentration (pCi/L)	-	Not available; reflects availability of distribution coeff.[2]
Solubility Limit (mol/L)	0	RESRAD default
Leach Rate (/yr)	0	RESRAD default
Nuclide concentration for Pa-231 (pCi/g)		Determined by RESRAD
Transport Distribution coefficients for daughter Pa-231		
Contaminated zone (cm**3/g)	380	Assigned by RESRAD guidance.[3]
Unsaturated zone 1 (cm**3/g)	-	Not applicable
Saturated zone (cm**3/g)	380	Assigned by RESRAD guidance.[3]
Time since material placement (yr)	0	RESRAD default
Groundwater concentration (pCi/L)	-	Not available; reflects availability of distribution coeff.[2]
Solubility Limit (mol/L)	0	RESRAD default
Leach Rate (/yr)	0	RESRAD default

(continued 2 of 7)		
Nuclide concentration for Ac-227 (pCi/g)		Determined by RESRAD
Transport Distribution coefficients for daughter Ac-227		
Contaminated zone (cm**3/g)	825	Assigned by RESRAD guidance.[3]
Unsaturated zone 1 (cm**3/g)	-	Not applicable
Saturated zone (cm**3/g)	825	Assigned by RESRAD guidance.[3]
Time since material placement (yr)	0	RESRAD default
Groundwater concentration (pCi/L)	-	Not available; reflects availability of distribution coeff.[2]
Solubility Limit (mol/L)	0	RESRAD default
Leach Rate (/yr)	0	RESRAD default
Nuclide concentration for U-234 (pCi/g)	47	Average from Table 7 of SCR.[1]
Transport Distribution coefficients for U-234		
Contaminated zone (cm**3/g)	572	Site-specific estimate: see Attachment 3.
Unsaturated zone 1 (cm**3/g)		Not applicable
Saturated zone (cm**3/g)	17.1	Site-specific estimate: see Attachment 3.
Time since material placement (yr)	0	RESRAD default
Groundwater concentration (pCi/L)	-	Not available; reflects availability of distribution coeff.[2]
Solubility Limit (mol/L)	0	RESRAD default
Leach Rate (/yr)	0	RESRAD default
Nuclide concentration for Th-230 (pCi/g)	44	Average from Table 7 of SCR.[1]
Transport Distribution coefficients for Th-230	-	
Contaminated zone (cm**3/g)	5884	Assigned by RESRAD guidance.[3]
Unsaturated zone 1 (cm**3/g)	-	Not applicable
Saturated zone (cm**3/g)	5884	Assigned by RESRAD guidance.[3]
Time since material placement (yr)	0	RESRAD default
Groundwater concentration (pCi/L)	-	Not available; reflects availability of distribution coeff.[2]
Solubility Limit (mol/L)	0	RESRAD default
Leach Rate (/yr)	0	RESRAD default

(continued 3 of 7)		
Nuclide concentration for Ra-226 (pCi/g)	1.4	Average from Table 7 of SCR.[1]
Transport Distribution coefficients for Ra-226		
Contaminated zone (cm**3/g)	3533	Assigned by RESRAD guidance.[3]
Unsaturated zone 1 (cm**3/g)	-	Not applicable
Saturated zone (cm**3/g)	3533	Assigned by RESRAD guidance.[3]
Time since material placement (yr)	0	RESRAD default
Groundwater concentration (pCi/L)	-	Not available; reflects availability of distribution coeff.[2]
Solubility Limit (mol/L)	0	RESRAD default
Leach Rate (/yr)	0	RESRAD default
Nuclide concentration for Pb-210 (pCi/g)		Determined by RESRAD
Transport Distribution coefficients for Pb-210		
Contaminated zone (cm**3/g)	2392	Assigned by RESRAD guidance.[3]
Unsaturated zone 1 (cm**3/g)	-	Not applicable
Saturated zone (cm**3/g)	2392	Assigned by RESRAD guidance.[3]
Time since material placement (yr)	0	RESRAD default
Groundwater concentration (pCi/L)	-	Not available; reflects availability of distribution coeff.[2]
Solubility Limit (mol/L)	0	RESRAD default
Leach Rate (/yr)	0	RESRAD default
Calculation Parameters		
Basic radiation dose limit (mrem/yr)	25	RESRAD default
Times for Calculations (years)	1	RESRAD default
Times for Calculations (years)	3	RESRAD default
Times for Calculations (years)	10	RESRAD default
Times for Calculations (years)	30	RESRAD default
Times for Calculations (years)	100	RESRAD default
Times for Calculations (years)	300	RESRAD default
Times for Calculations (years)	1000	RESRAD default
Contaminated Zone Parameters		
Area of contaminated zone (m**2)	540	L x W x r = 403m x 1m x RESRAD radii factor
Thickness of contaminated zone (m)	0.1	Typical depth of sediment
Length parallel to aquifer flow (m)	-	Not available

(continued 4 of 7)		
Cover and Contaminated Zone Hydrological Data		
Cover depth (m)	0	Planned actual conditions
Density of cover material (g/cm**3)	-	Not available; reflects absence of cover.[2]
Cover erosion rate (m/yr)	-	Not available; reflects absence of cover.[2]
Density of contaminated zone(g/cm**3)	1.76	Site-specific estimate: see Attachment 3.
Contaminated zone erosion rate (m/yr)	0.001	RESRAD default
Contaminated zone total porosity	0.30	Estimate from RESRAD guidance.[4]
Contaminated zone field capacity	0.2	RESRAD default
Contaminated zone hydraulic conductivity (m/yr)	8.9	Site-specific estimate: see Attachment 3.
Contaminated zone b parameter	-	Recommendation from RESRAD guidance.[4]
Humidity in air (g/cm**3)		Not available due suppressed radon pathway.[1, 4]
Evapotranspiration coefficient	0.5	Suggestion from RESRAD guidance.[2]
Wind Speed (m/sec)	4	Site-specific estimate.
Precipitation (m/yr)	1.1	Site-specific estimate.
Irrigation (m/yr)	0	Not applicable
Irrigation mode	-	Not applicable
Runoff coefficient	0	Conservative assumption.
Watershed area for nearby stream or pond (m**2)	-	Not available
Accuracy for water/soil computations	-	Not available
Saturated Zone Hydrological Data		
Density of saturated zone (g/cm**3)	-	Not available due to suppressed pathways.[2]
Saturated zone total porosity	-	Not available due to suppressed pathways.[2]
Saturated zone effective porosity	-	Not available due to suppressed pathways.[2]
Saturated zone hydraulic conductivity (m/yr)	-	Not available due to suppressed pathways.[2]
Saturated zone hydraulic gradient	-	Not available due to suppressed pathways.[2]
Saturated zone b parameter	-	Not available due to suppressed pathways.[2]
Saturated zone field capacity	-	Not available due to suppressed pathways.[2]
Water table drop rate (m/yr)	-	Not available due to suppressed pathways.[2]
Well pump intake depth (m below water table)	-	Not available due to suppressed pathways.[2]
Model for Water Transport Parameters		
Nondispersion (ND) or Mass-Balance (MB)	ND	RESRAD default based on size of contaminated area.[1]
Well pumping rate (m**3/yr)	-	Not available due to suppressed pathways.[2]

(continued 5 of 7)		
Uncontaminated Unsaturated Zone Parameters		
Unsaturated Zones	0	Assume contaminated sediments on saturated shale.
Unsaturated Zone Thickness (m)	-	Not available
Unsaturated Zone Density (g/cm**3)	-	Not available
Unsaturated Zone Total Porosity	-	Not available
Unsaturated Zone Effective Porosity	-	Not available
Unsaturated Zone Field Capacity	-	Not available
Unsaturated Zone Hydraulic Conductivity (m/yr)	-	Not available
Unsaturated Zone b`Parameter	-	Not available
Occupancy, Inhalation, and External Gamma Data		
Inhalation rate (m**3/yr)	8400	Recommendation from RESRAD guidance.[3]
Mass loading for inhalation (g/m**3)	2.00E-04	Suggestion from RESRAD guidance.[4]
Exposure duration	1	Reflects applicable regulatory evaluation period.
Indoor dust filtration factor	0	Not applicable
External gamma shielding factor	0	Not applicable
Indoor time fraction	0	Not applicable
Outdoor time fraction	0.042	1 h/d x 365 d/y x y/8760 h = 0.042
Shape of the contaminated zone	non-circular	Assume straight line 403 m x 1 m
Ingestion Pathway, Dietary Data		
Fruits, vegetables and grain consumption (kg/yr)	-	Not available due to suppressed pathways.[2]
Leafy vegetable consumption (kg/yr)	-	Not available due to suppressed pathways.[2]
Milk consumption (L/yr)	-	Not available due to suppressed pathways.[2]
Meat and poultry consumption (kg/yr)	-	Not available due to suppressed pathways.[2]
Fish consumption (kg/yr)	-	Not available due to suppressed pathways.[2]
Other seafood consumption	-	Not available due to suppressed pathways.[2]
Soil ingestion (g/yr)	18.3	Suggestion from RESRAD guidance.[3]
Drinking water intake (L/yr)	-	Not available due to suppressed pathways.[2]
Contaminated fraction Drinking water	-	Not available due to suppressed pathways.[2]
Contaminated fraction Household water	-	Not available due to suppressed pathways.[2]
Contaminated fraction Livestock water	-	Not available due to suppressed pathways.[2]
Contaminated fraction Irrigation water	-	Not available due to suppressed pathways.[2]
Contaminated fraction Aquatic food	-	Not available due to suppressed pathways.[2]
Contaminated fraction Plant food	-	Not available due to suppressed pathways.[2]
Contaminated fraction Meat	-	Not available due to suppressed pathways.[2]
Contaminated fraction Milk	-	Not available due to suppressed pathways.[2]

(continued 6 of 7)		
Ingestion Pathway, Nondietary Data		
Livestock fodder intake for meat (kg/day)	-	Not available due to suppressed pathways.[2]
Livestock fodder intake for milk (kg/day)	-	Not available due to suppressed pathways.[2]
Livestock water intake for meat (L/day)	-	Not available due to suppressed pathways.[2]
Livestock water intake for milk (L/day)	-	Not available due to suppressed pathways.[2]
Livestock soil intake (kg/day)	-	Not available due to suppressed pathways.[2]
Mass loading for foliar deposition (g/m**3)	-	Not available due to suppressed pathways.[2]
Depth of soil mixing layer (m)	0.1	Informal empirical determination of sediment depth.
Depth of roots (m)	-	Not available due to suppressed pathways.[2]
Groundwater Fractional Usage Drinking water	-	Not available due to suppressed pathways.[2]
Groundwater fractional Usage Household water	-	Not available due to suppressed pathways.[2]
Groundwater Fractional Usage Livestock water	-	Not available due to suppressed pathways.[2]
Groundwater Fractional Usage Irrigation water	-	Not available due to suppressed pathways.[2]
Plant Factors		
Wet weight crop yield for Non-Leafy (kg/m**2)	-	Not available due to suppressed pathways.[2]
Wet weight crop yield for Leafy (kg/m**2)	-	Not available due to suppressed pathways.[2]
Wet weight crop yield for Fodder (kg/m**2)	-	Not available due to suppressed pathways.[2]
Length of growing season for Non-Leafy (years)	-	Not available due to suppressed pathways.[2]
Length of growing season for Leafy (years)	-	Not available due to suppressed pathways.[2]
Length of growing season for Fodder (years)	-	Not available due to suppressed pathways.[2]

(continued 7 of 7)		
Translocation factor for Non-Leafy	-	Not available due to suppressed pathways.[2]
Translocation factor for Leafy	-	Not available due to suppressed pathways.[2]
Translocation factor for Fodder	-	Not available due to suppressed pathways.[2]
Weathering removal constant for vegetation	-	Not available due to suppressed pathways.[2]
Wet foliar interception fraction for Non-Leafy	-	Not available due to suppressed pathways.[2]
Wet foliar interception fraction for leafy	-	Not available due to suppressed pathways.[2]
Wet foliar interception fraction for fodder	-	Not available due to suppressed pathways.[2]
Dry foliar interception fraction for Non-Leafy	-	Not available due to suppressed pathways.[2]
Dry foliar interception fraction for Leafy	-	Not available due to suppressed pathways.[2]
Dry foliar interception fraction for Fodder	-	Not available due to suppressed pathways.[2]

1 Sequoyah Fuels Corporation, Reclamation Plan Sequoyah Facility, January 2003, Appendix D, "Site Characterization Report".

2 Yu, C., et. al. "User's Manual for RESRAD Version 6." Argonne National Laboratory. ANL/EAD-4. July 2001.

3 U.S. Nuclear Regulatory Commission. Development of Probabilistic RESRAD 6.0 and RESRAD-BUILD 3.0 Computer Codes. Washington, D.C.: U.S. Nuclear Regulatory Commission. NUREG/CR-6697. December 2000.

4 Yu, C., et.al. "Data Collection Handbook to Support Modeling the Impacts of Radioactive Material in Soil." Argonne, IL: Argonne National Laboratory. ANL/EAIS-8. April 1993.

TABLE G-6: INDUSTRIAL WORKER SCENARIO EXPOSURE PATHWAY SELECTIONS

PATHWAY[1]	USER SELECTION
External Gamma	Active
Inhalation (w/o radon)	Active
Plant Ingestion	Suppressed
Meat Ingestion	Suppressed
Milk Ingestion	Suppressed
Aquatic Foods	Suppressed
Drinking Water	Suppressed
Soil Ingestion	Active
Radon	Suppressed

[1] These pathways match those available from the conceptual model used in the dose assessment; i.e. RESRAD version 6.21.

Table G-7: Industrial Worker Scenario SFC Selected Values		
Parameter	**SFC Input**	**Background Information**
Source		
Nuclide concentration for U-238 (pCi/g)	279	DCGL for U-natural times 0.489.
Transport Distribution coefficients for U-238		
Contaminated zone (cm**3/g)	572	Site-specific estimate: see Attachment 3.
Unsaturated zone 1 (cm**3/g)	572	Site-specific estimate: see Attachment 3.
Saturated zone (cm**3/g)	17.1	Site-specific estimate: see Attachment 3.
Time since material placement (yr)	0	RESRAD default
Groundwater concentration (pCi/L)	-	Not available; reflects availability of distribution coeff.[1]
Solubility Limit (mol/L)	0	RESRAD default
Leach Rate (/yr)	0	RESRAD default
Nuclide concentration for U-235 (pCi/g)	12.5	DCGL for U-natural times 0.022.
Transport Distribution coefficients for U-235		
Contaminated zone (cm**3/g)	572	Site-specific estimate: see Attachment 3.
Unsaturated zone 1 (cm**3/g)	572	Site-specific estimate: see Attachment 3.
Saturated zone (cm**3/g)	17.1	Site-specific estimate: see Attachment 3.
Time since material placement (yr)	0	RESRAD default
Groundwater concentration (pCi/L)	-	Not available; reflects availability of distribution coeff.[1]
Solubility Limit (mol/L)	0	RESRAD default
Leach Rate (/yr)	0	RESRAD default
Nuclide concentration for Pa-231 (pCi/g)		Determined by RESRAD
Transport Distribution coefficients for daughter Pa-231		
Contaminated zone (cm**3/g)	380	Assigned by RESRAD guidance.[2]
Unsaturated zone 1 (cm**3/g)	380	Assigned by RESRAD guidance.[2]
Saturated zone (cm**3/g)	380	Assigned by RESRAD guidance.[2]
Time since material placement (yr)	0	RESRAD default
Groundwater concentration (pCi/L)	-	Not available; reflects availability of distribution coeff.[1]
Solubility Limit (mol/L)	0	RESRAD default
Leach Rate (/yr)	0	RESRAD default

(continued 2 of 7)		
Nuclide concentration for Ac-227 (pCi/g)		Determined by RESRAD
Transport Distribution coefficients for daughter Ac-227		
Contaminated zone (cm**3/g)	825	Assigned by RESRAD guidance.[2]
Unsaturated zone 1 (cm**3/g)	825	Assigned by RESRAD guidance.[2]
Saturated zone (cm**3/g)	825	Assigned by RESRAD guidance.[2]
Time since material placement (yr)	0	RESRAD default
Groundwater concentration (pCi/L)	-	Not available; reflects availability of distribution coeff.[1]
Solubility Limit (mol/L)	0	RESRAD default
Leach Rate (/yr)	0	RESRAD default
Nuclide concentration for U-234 (pCi/g)	279	DCGL for U-natural times 0.489.
Transport Distribution coefficients for U-234		
Contaminated zone (cm**3/g)	572	Site-specific estimate: see Attachment 3.
Unsaturated zone 1 (cm**3/g)	572	Site-specific estimate: see Attachment 3.
Saturated zone (cm**3/g)	17.1	Site-specific estimate: see Attachment 3.
Time since material placement (yr)	0	RESRAD default
Groundwater concentration (pCi/L)	-	Not available; reflects availability of distribution coeff.[1]
Solubility Limit (mol/L)	0	RESRAD default
Leach Rate (/yr)	0	RESRAD default
Nuclide concentration for Th-230 (pCi/g)	66	DCGL
Transport Distribution coefficients for Th-230		
Contaminated zone (cm**3/g)	5884	Assigned by RESRAD guidance.[2]
Unsaturated zone 1 (cm**3/g)	5884	Assigned by RESRAD guidance.[2]
Saturated zone (cm**3/g)	5884	Assigned by RESRAD guidance.[2]
Time since material placement (yr)	0	RESRAD default
Groundwater concentration (pCi/L)	-	Not available; reflects availability of distribution coeff.[1]
Solubility Limit (mol/L)	0	RESRAD default
Leach Rate (/yr)	0	RESRAD default

(continued 3 of 7)		
Nuclide concentration for Ra-226 (pCi/g)	5	DCGL
Transport Distribution coefficients for Ra-226		
Contaminated zone (cm**3/g)	3533	Assigned by RESRAD guidance.[2]
Unsaturated zone 1 (cm**3/g)	3533	Assigned by RESRAD guidance.[2]
Saturated zone (cm**3/g)	3533	Assigned by RESRAD guidance.[2]
Time since material placement (yr)	0	RESRAD default
Groundwater concentration (pCi/L)	-	Not available; reflects availability of distribution coeff.[1]
Solubility Limit (mol/L)	0	RESRAD default
Leach Rate (/yr)	0	RESRAD default
Nuclide concentration for Pb-210 (pCi/g)	5	DCGL
Transport Distribution coefficients for Pb-210		
Contaminated zone (cm**3/g)	2392	Assigned by RESRAD guidance.[2]
Unsaturated zone 1 (cm**3/g)	2392	Assigned by RESRAD guidance.[2]
Saturated zone (cm**3/g)	2392	Assigned by RESRAD guidance.[2]
Time since material placement (yr)	0	RESRAD default
Groundwater concentration (pCi/L)	-	Not available; reflects availability of distribution coeff.[1]
Solubility Limit (mol/L)	0	RESRAD default
Leach Rate (/yr)	0	RESRAD default
Calculation Parameters		
Basic radiation dose limit (mrem/yr)	100	10 CFR20.1301
Times for Calculations (years)	1	RESRAD default
Times for Calculations (years)	3	RESRAD default
Times for Calculations (years)	10	RESRAD default
Times for Calculations (years)	30	RESRAD default
Times for Calculations (years)	100	RESRAD default
Times for Calculations (years)	300	RESRAD default
Times for Calculations (years)	1000	RESRAD default
Contaminated Zone Parameters		
Area of contaminated zone (m**2)	263120	RESRAD default
Thickness of contaminated zone (m)	0.3	Site-specific estimate: unconsolidated soils over shale
Length parallel to aquifer flow (m)	-	Not available due to suppressed pathways.[1]

(continued 4 of 7)		
Cover and Contaminated Zone Hydrological Data		
Cover depth (m)	0	Planned actual conditions
Density of cover material (g/cm**3)	-	Not available; reflects absence of cover.[1]
Cover erosion rate (m/yr)	-	Not available; reflects absence of cover.[1]
Density of contaminated zone(g/cm**3)	1.76	Site-specific estimate: see Attachment 3.
Contaminated zone erosion rate (m/yr)	0.0006	Recommendation from RESRAD guidance.[2]
Contaminated zone total porosity	0.30	Estimate from RESRAD guidance.[3]
Contaminated zone effective porosity	0.25	Estimate from RESRAD guidance.[3]
Contaminated zone field capacity	0.2	RESRAD default
Contaminated zone hydraulic conductivity (m/yr)	8.9	Site-specific estimate: see Attachment 3.
Contaminated zone b parameter	3	Recommendation from RESRAD guidance.[3]
Humidity in air (g/cm**3)		Not available due suppressed radon pathway.[1,4]
Evapotranspiration coefficient	0.5	Suggestion from RESRAD guidance.[2]
Wind Speed (m/sec)	4	Site-specific measurement (5.7 mph).
Precipitation (m/yr)	1.1	Site-specific measurement (49 inch/y).
Irrigation (m/yr)	0	Not applicable
Irrigation mode	-	Not applicable
Runoff coefficient	0.4	Estimate from RESRAD guidance.[2]
Watershed area for nearby stream or pond (m**2)	-	Not available due to suppressed pathways.[1]
Accuracy for water/soil computations	-	Not available due to suppressed pathways.[1]
Saturated Zone Hydrological Data		
Density of saturated zone (g/cm**3)	-	Not available due to suppressed pathways.[2]
Saturated zone total porosity	-	Not available due to suppressed pathways.[2]
Saturated zone effective porosity	-	Not available due to suppressed pathways.[2]
Saturated zone field capacity	-	Not available due to suppressed pathways.[2]
Saturated zone hydraulic conductivity (m/yr)	-	Not available due to suppressed pathways.[2]
Saturated zone hydraulic gradient	-	Not available due to suppressed pathways.[2]
Saturated zone b parameter	-	Not available due to suppressed pathways.[2]
Water table drop rate (m/yr)	-	Not available due to suppressed pathways.[2]
Well pump intake depth (m below water table)	-	Not available due to suppressed pathways.[2]
Model for Water Transport Parameters		
Nondispersion (ND) or Mass-Balance (MB)	ND	RESRAD default based on size of contaminated area.[1]
Well pumping rate (m**3/yr)	-	Not available due to suppressed pathways.[2]

(continued 5 of 7)		
Uncontaminated Unsaturated Zone Parameters		
Unsaturated Zones	-	Not available due to suppressed pathways.[1]
Unsaturated Zone 1 Thickness (m)	-	Not available due to suppressed pathways.[1]
Unsaturated Zone 1 Density (g/cm**3)	-	Not available due to suppressed pathways.[1]
Unsaturated Zone 1 Total Porosity	-	Not available due to suppressed pathways.[1]
Unsaturated Zone 1 Effective Porosity	-	Not available due to suppressed pathways.[1]
Unsaturated Zone 1 Field Capacity	-	Not available due to suppressed pathways.[1]
Unsaturated Zone 1 Hydraulic Conductivity (m/yr)	-	Not available due to suppressed pathways.[1]
Unsaturated Zone 1 b Parameter	-	Not available due to suppressed pathways.[1]
Occupancy, Inhalation, and External Gamma Data		
Inhalation rate (m**3/yr)	8400	Recommendation from RESRAD guidance.[2]
Mass loading for inhalation (g/m**3)	2.00E-04	Suggestion from RESRAD guidance.[3]
Exposure duration	1	Reflects applicable regulatory evaluation period.
Indoor dust filtration factor	0	Not applicable; all maintenance work outdoors
External gamma shielding factor	0	Not applicable; all maintenance work outdoors
Indoor time fraction	0	Not applicable; all maintenance work outdoors
Outdoor time fraction	0.015	130 hours worked/y x y/8760 hours = 0.015
Shape of the contaminated zone	circular	Assumed shape of *area of contaminated zone*.
Ingestion Pathway, Dietary Data		
Fruits, vegetables and grain consumption (kg/yr)	-	Not available due to suppressed pathways.[1]
Leafy vegetable consumption (kg/yr)	-	Not available due to suppressed pathways.[1]
Milk consumption (L/yr)	-	Not available due to suppressed pathways.[1]
Meat and poultry consumption (kg/yr)	-	Not available due to suppressed pathways.[1]
Fish consumption (kg/yr)	-	Not available due to suppressed pathways.[1]
Other seafood consumption	-	Not available due to suppressed pathways.[1]
Soil ingestion (g/yr)	18.3	Suggestion from RESRAD guidance.[2]
Drinking water intake (L/yr)	-	Not available due to suppressed pathways.[1]
Contaminated fraction Drinking water	-	Not available due to suppressed pathways.[1]
Contaminated fraction Household water	-	Not available due to suppressed pathways.[1]
Contaminated fraction Livestock water	-	Not available due to suppressed pathways.[1]
Contaminated fraction Irrigation water	-	Not available due to suppressed pathways.[1]
Contaminated fraction Aquatic food	-	Not available due to suppressed pathways.[1]
Contaminated fraction Plant food	-	Not available due to suppressed pathways.[1]
Contaminated fraction Meat	-	Not available due to suppressed pathways.[1]
Contaminated fraction Milk	-	Not available due to suppressed pathways.[1]

(continued 6 of 7)		
Ingestion Pathway, Nondietary Data		
Livestock fodder intake for meat (kg/day)	-	Not available due to suppressed pathways.[1]
Livestock fodder intake for milk (kg/day)	-	Not available due to suppressed pathways.[1]
Livestock water intake for meat (L/day)	-	Not available due to suppressed pathways.[1]
Livestock water intake for milk (L/day)	-	Not available due to suppressed pathways.[1]
Livestock soil intake (kg/day)	-	Not available due to suppressed pathways.[1]
Mass loading for foliar deposition (g/m**3)	-	Not available due to suppressed pathways.[1]
Depth of soil mixing layer (m)	0.15	RESRAD default
Depth of roots (m)	-	Not available due to suppressed pathways.[1]
Groundwater Fractional Usage Drinking water	-	Not available due to suppressed pathways.[1]
Groundwater fractional Usage Household water	-	Not available due to suppressed pathways.[1]
Groundwater Fractional Usage Livestock water	-	Not available due to suppressed pathways.[1]
Groundwater Fractional Usage Irrigation water	-	Not available due to suppressed pathways.[1]
Plant Factors	-	Not available due to suppressed pathways.[1]
Wet weight crop yield for Non-Leafy (kg/m**2)	-	Not available due to suppressed pathways.[1]
Wet weight crop yield for Leafy (kg/m**2)	-	Not available due to suppressed pathways.[1]
Wet weight crop yield for Fodder (kg/m**2)	-	Not available due to suppressed pathways.[1]
Length of growing season for Non-Leafy (years)	-	Not available due to suppressed pathways.[1]
Length of growing season for Leafy (years)	-	Not available due to suppressed pathways.[1]
Length of growing season for Fodder (years)	-	Not available due to suppressed pathways.[1]

(continued 7 of 7)		
Translocation factor for Non-Leafy	-	Not available due to suppressed pathways.[1]
Translocation factor for Leafy	-	Not available due to suppressed pathways.[1]
Translocation factor for Fodder	-	Not available due to suppressed pathways.[1]
Weathering removal constant for vegetation	-	Not available due to suppressed pathways.[1]
Wet foliar interception fraction for Non-Leafy	-	Not available due to suppressed pathways.[1]
Wet foliar interception fraction for leafy	-	Not available due to suppressed pathways.[1]
Wet foliar interception fraction for fodder	-	Not available due to suppressed pathways.[1]
Dry foliar interception fraction for Non-Leafy	-	Not available due to suppressed pathways.[1]
Dry foliar interception fraction for Leafy	-	Not available due to suppressed pathways.[1]
Dry foliar interception fraction for Fodder	-	Not available due to suppressed pathways.[1]

[1] Yu, C., et. al. "User's Manual for RESRAD Version 6." Argonne National Laboratory. ANL/EAD-4. July 2001.

[2] U.S. Nuclear Regulatory Commission. Development of Probabilistic RESRAD 6.0 and RESRAD-BUILD 3.0 Computer Codes. Washington, D.C.: U.S. Nuclear Regulatory Commission. NUREG/CR-6697. December 2000.

[3] Yu, C., et.al. "Data Collection Handbook to Support Modeling the Impacts of Radioactive Material in Soil." Argonne, IL: Argonne National Laboratory. ANL/EAIS-8. April 1993.

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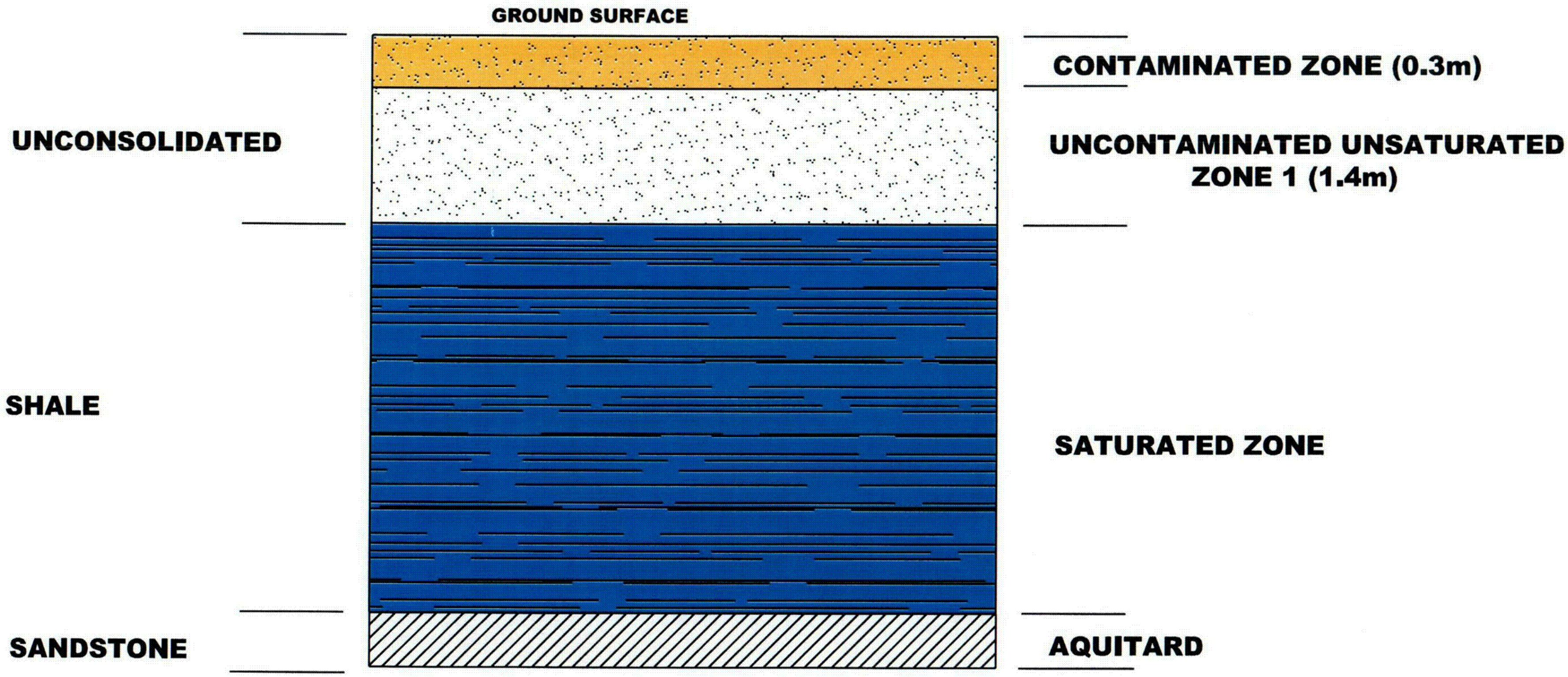
SEQUOYAH FUELS CORPORATION
Reclamation Plan

Title: Depiction of Areas to Which the DCGLs are Applicable	
PREPARED BY: SFC	Filename: SFC0084D
Reviewed by: RM	Figure No. G-1
Date: 01/10/06	



SEQUOYAH FUELS CORPORATION Reclamation Plan	
Title: Depiction of Soil Zones Used for Development of DCGLs from the Resident Farmer Scenario	
PREPARED BY: SFC	Filename: SFC0068B2
Reviewed by: RM	Figure No. G-2
Date: 01/10/06	

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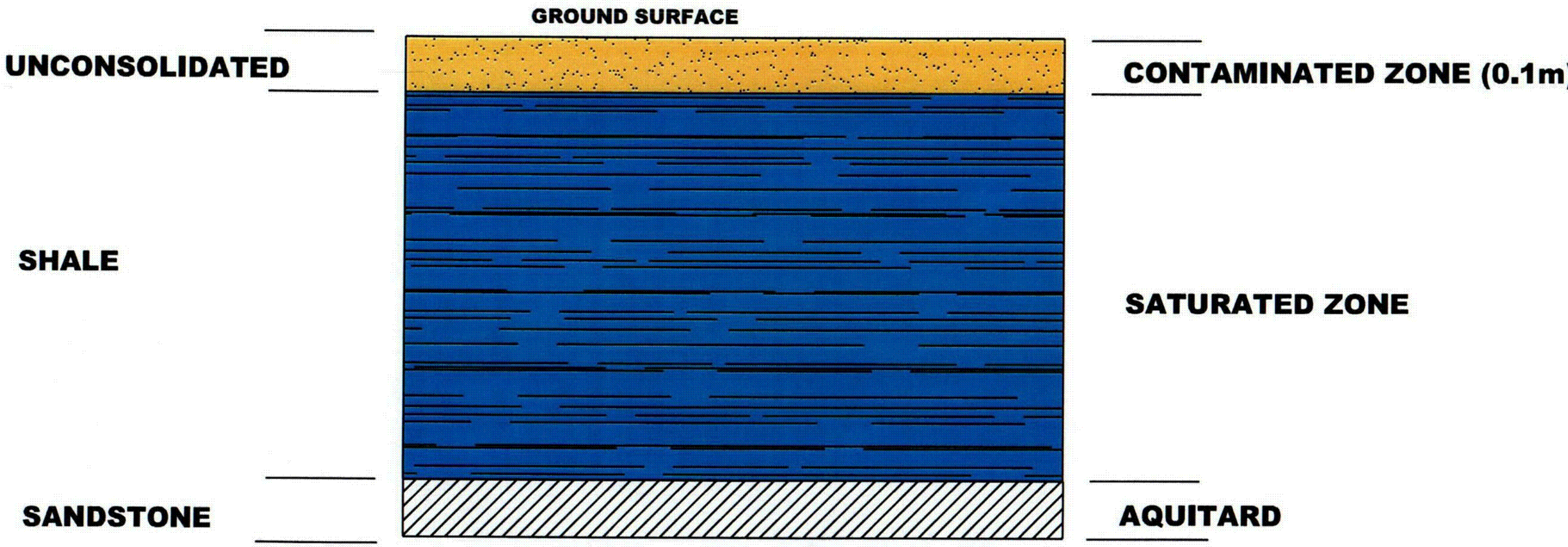

SEQUOYAH FUELS CORPORATION Reclamation Plan	
Title: Depiction of Soil Zones Used for Determination of Annual Dose from the Drainage 005 Senario	
PREPARED BY: SFC	Filename: SFC0068C1
Reviewed by: RM	Figure No. G-3
Date: 01/22/03	

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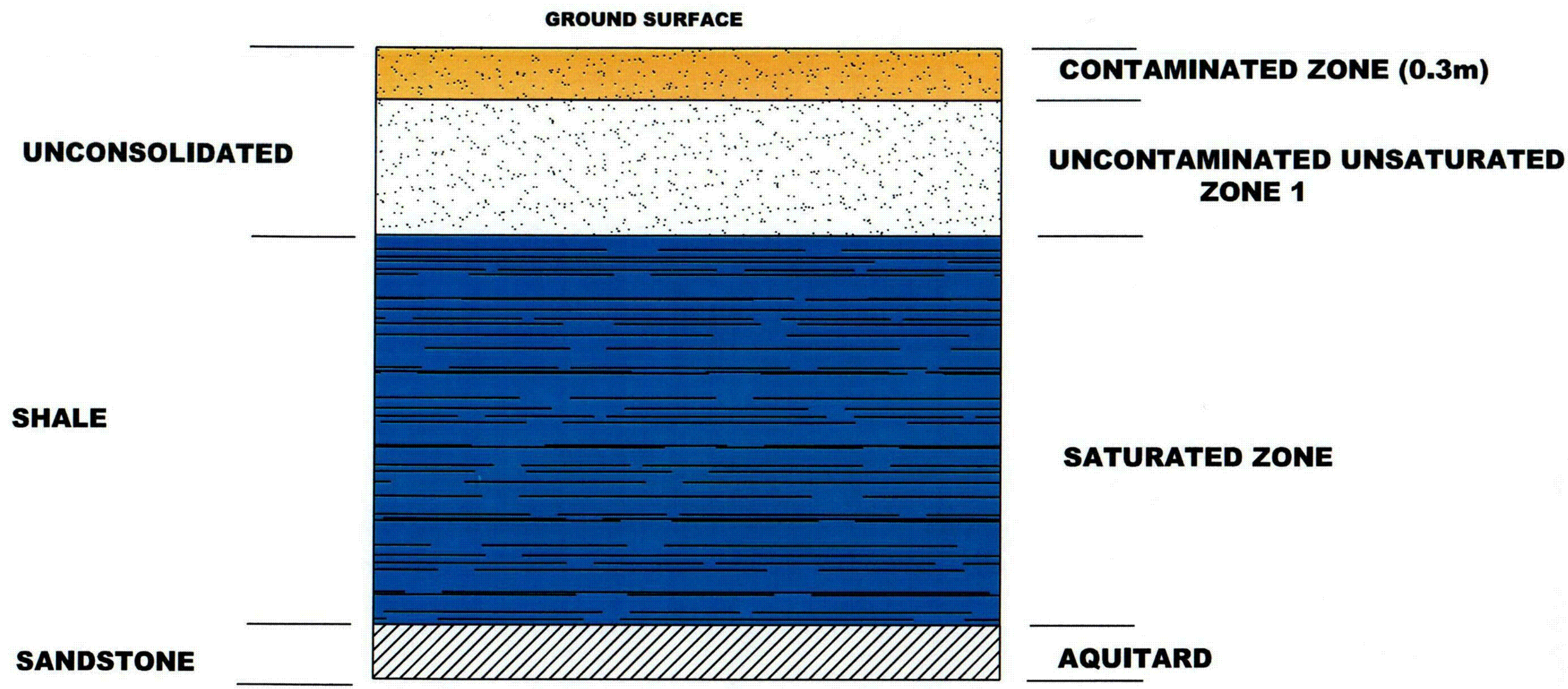

SEQUOYAH FUELS CORPORATION Reclamation Plan	
Title: Depiction of Soil Zones Used for Determination of Annual Dose from the Industrial Worker Senario	
PREPARED BY: SFC	Filename: SFC0068D2
Reviewed by: RM	Figure No. G-4
Date: 01/10/06	

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Attachment 1

Selection of Thickness of Contaminated Zone and Thickness of Uncontaminated Unsaturated Zone for Development of DCGLs

Resident Farmer Scenario

SELECTION OF THICKNESS OF CONTAMINATED ZONE AND THICKNESS OF UNCONTAMINATED UNSATURATED ZONE FOR DEVELOPMENT OF DCGLs

Resident Farmer Scenario

Introduction

Two important parameters used to determine the derived concentration guideline levels (DCGLs) are the *thickness of contaminated zone* and the *uncontaminated unsaturated zone thickness*. The *thickness of contaminated zone* is an important factor in determining the total source term available to the respective model; e.g. the thicker the contaminated zone, potentially more contaminant can be removed by infiltrating water. It is also important with respect to the elapsed time for which the source term is available; e.g. the thicker the contaminated zone, the longer time before it is removed by erosion.

The *uncontaminated unsaturated zone thickness* is important with respect to movement of the contaminant into the saturated zone. The greater the thickness, the longer the travel time from contaminated zone to groundwater.

The following text describes selection of the thickness of each of these zones at Sequoyah Fuels Corporation (SFC) site. The selection uses information from site characterization activities as reported in the Facility Environmental Investigation Findings Report[1], the Final RCRA Facility Investigation Report[2], and the Site Characterization Report[3].

Selection Process

During site characterization efforts, soil samples were collected using two methods – hand auger and borehole. Hand auger samples are collected with hand tools and are generally 0.5 feet and sometimes up to five feet. Borehole samples are collected using drilling equipment and the borings are typically much deeper. Only borehole samples were considered here since they are most likely to extend over a depth range great enough to encompass the entire depth of contamination.

The site characterization included completion of lithological logs for each of the boreholes used in this selection process. These logs allow identification of the thickness

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[1] "Facility Environmental Investigation Findings Report", Volume V, appendices E and F, Sequoyah Fuels Corporation, July 1991.

[2] "Final RCRA Facility Investigation Report", Volume II, Appendix C, Sequoyah Fuels Corporation, October 1996.

[3] "Reclamation Plan Sequoyah Facility", Appendix D, Site Characterization Report, Sequoyah Fuels Corporation, January 2003 .

of the unconsolidated soils (unsaturated zone) above the uppermost shale layer (saturated zone). Thus, the *thickness of contaminated zone* and the *uncontaminated unsaturated zone thickness* might be determined for any particular location where boreholes exist.

Only those boreholes inside the Process Area and outside the footprint of the proposed disposal cell were considered in the selection process. The Process Area includes the vast majority of the contaminated soils. The presence of the proposed disposal cell will necessarily preclude use of the underlying soils as a potential area of human habitation and therefore from contribution to dose within the context of the model used to determine the DCGLs.

The boreholes included in the selection process are listed in Table G-8. Figure G-5 shows the location of each borehole listed in Table G-8. Figure G-5 also depicts the Process Area boundary and the footprint of the proposed disposal cell.

Thickness of Contaminated Zone

Since the predominant contaminant in soil at SFC is uranium, it was chosen as the constituent of concern on which to base the selection of *thickness of contaminated zone*. In order to assess the thickness of contamination relative to uranium, a concentration value was chosen to differentiate between contamination and background. The concentration value chosen was two times the reported laboratory detection limit for total uranium in soil. During the primary period of site characterization activities (1990 and 1991), the reported laboratory detection limit for total uranium in soil was 3.4 pCi/g (5 μg/g). Then contamination was considered present for the purpose of this selection process when the uranium concentration in a soil sample exceeded 7 pCi/g (10 μg/g).

Some boreholes were eliminated from the selection process because of bias by physical features at the Facility. For example, several boreholes were completed near the Combination Stream Drain. Contamination at depth at these locations would be removed when the Combination Stream Drain is excavated during decommissioning. Several locations were eliminated because the area where the samples were collected has been decontaminated; i.e. the soil was removed after the sampling effort. Finally, in a few locations the borehole did not extend through the contamination. The boreholes eliminated from the selection process are identified in Table G-8 by absence of a value in the column describing thickness of contaminated zone.

At locations where contamination is present and the complete extent sampled, the *thickness of contaminated zone* was determined as the difference between the bottom of the lower most contaminated sample and the top of the uppermost contaminated sample.

Uncontaminated Unsaturated Zone Thickness

The *uncontaminated unsaturated zone thickness* was selected from a two-step process. First, the thickness of the unsaturated zone was determined for each borehole used in selection of the *thickness of contaminated zone*. This determination was made directly

from review of the lithological log for the respective borehole. Second, the *uncontaminated unsaturated zone thickness* was calculated as the difference between the thickness of the unsaturated zone and the *thickness of contaminated zone*.

Some boreholes were eliminated from the selection process because no lithological logs were available for the respective location. Other boreholes were eliminated because no unconsolidated material exists between the surface (e.g. pavement) and the uppermost shale layer. Still other boreholes were eliminated from the selection process because the borehole did not completely extend through the unconsolidated soils thereby not allowing determination of the thickness. The boreholes eliminated from the selection process are identified in Table G-8 by absence of a value in the column describing thickness of the unsaturated zone.

At locations where the lithological log indicated auger refusal, the depth of auger refusal was considered to indicate the depth of bedrock. The bedrock was assumed to be the uppermost shale layer.

Results

Thickness of Contaminated Zone

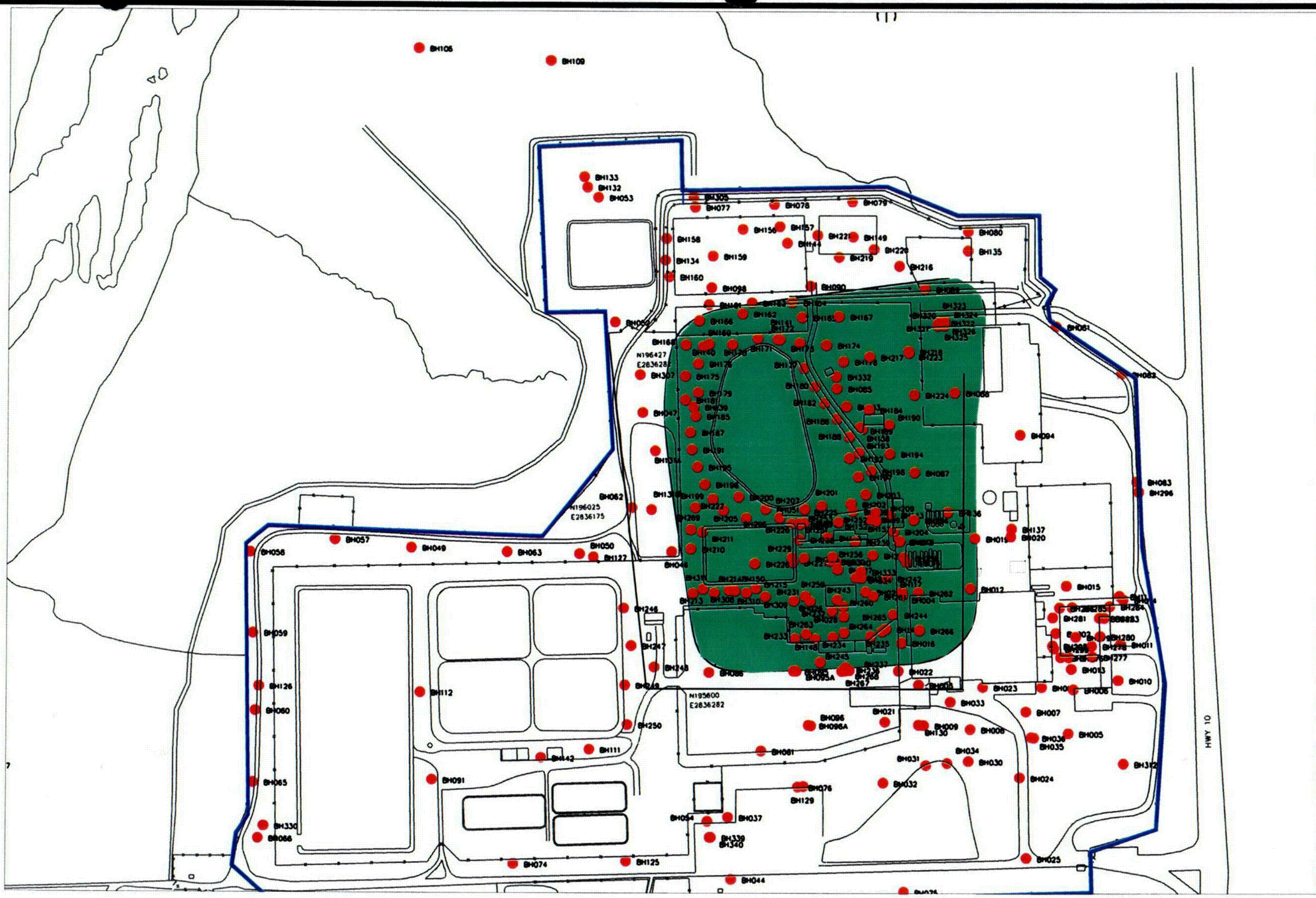
Table G-8 reflects that 135 boreholes were considered for development of the *thickness of contaminated zone*. A *thickness of contaminated zone* was determined, as described previously, for 91 of these boreholes. The average *thickness of contaminated zone* for these 91 boreholes is one foot (0.3 meter).

Uncontaminated Unsaturated Zone Thickness

Table G-8 reflects that 135 boreholes were considered for development of the *uncontaminated unsaturated zone thickness*. An *uncontaminated unsaturated zone thickness* was determined, as described previously, for 83 of these boreholes. The average *uncontaminated unsaturated zone thickness* for these 83 boreholes is 4.6 feet (1.4 meter).

Table G-8 Selection of Thickness of Contaminated and Uncontaminated Unsaturated Zone for Development of DCGLs

Location[1]	Thickness of Unsaturated Zone (feet)	Thickness of Contaminated Zone (feet)	Difference (Uncontaminated Unsaturated Zone Thickness) (feet)
BH001	7.6	1	6.6
BH002	-	-	-
BH003	16.4	6	10.4
BH005	5.8	0	5.8
BH006	7.6	7	0.6
BH007	1.5	0	1.5
BH008	-	-	-
BH009	-	-	-
BH010	6	0	6
BH011	7	0	7
BH013	8.5	1	7.5
BH014	8	1	7
BH015	5	1	4
BH020	-	1	-
BH021	14.5	3	11.5
BH022	16.4	0	16.4
BH023	6	1	5
BH024	5	1	4
BH025	5	1	4
BH030	5	0.5	4.5
BH031	7	0.5	6.5
BH032	9	0.5	8.5
BH033	12.7	0.5	12.2
BH034	7.5	0.5	7
BH035	5.9	0	5.9
BH036	4	0.5	3.5
BH037	-	-	-
BH038	-	-	-
BH039	-	-	-
BH040	-	-	-
BH041	-	-	-
BH044	-	-	-
BH047	8.4	0	8.4
BH049	4.5	0	4.5
BH050	7.1	2	5.1
BH052	6.5	1	5.5
BH053	9.5	1	8.5
BH054	-	-	-
BH057	3.7	0	3.7
BH058	9.8	0	9.8
BH059	3.4	0	3.4
BH060	3.5	0	3.5
BH061	-	-	-
BH062	8.9	1	7.9
BH063	7	2	5
BH065	11.4	0	11.4
BH066	12.7	0	12.7
BH067	3.5	0	3.5
BH068	5	0	5
BH069	0.5	0	0.5
BH074	6.5	0	6.5
BH075	3	1	2
BH076	4	0	4
BH077	9	0	9
BH078	7.6	0	7.6
BH079	8.5	2	6.5
BH080	4.7	1	3.7
BH081	9	0	9
BH082	11.4	1	10.4
BH083	15.7	0	15.7
BH086	9.8	4.5	5.3
BH090	-	-	-
BH091	7	2	5
BH094	8.7	0	8.7
BH096	6.8	0	6.8
BH098	8	2	6
BH111	1.5	1	0.5
BH112	9	0	9
BH116	3.7	2	1.7
BH124	-	-	-
BH125	4.7	2	2.7
BH126	3.9	0.5	3.4
BH127	2.8	2	0.8
BH128	0.9	0	0.9
BH129	2.7	2	0.7
BH130	-	-	-
BH133	-	-	-
BH134	4.7	0	4.7
BH135	3.9	2	1.9
BH137	2.3	2	0.3
BH142	5	0	5
BH144	7.8	1	6.8
BH156	-	-	-
BH157 (SC-7)	5	2	3
BH158 (SC-15)	5	1.5	3.5
BH159	-	-	-
BH160 (SC-43)	5	0	5
BH161 (SC-73)	5	2	3
BH163	-	-	-
BH170 (SC-102)	4.5	3	1.5
BH176 (SC-115)	5	3	2
BH216 (SC-55)	5	0	5
BH219 (SC-38)	5	0	5
BH220 (SC-40)	5	0	5
BH221 (SC-23)	5	3	2
BH246	-	-	-
BH247 (SC-11)	-	1	-
BH248	-	0	-
BH249	-	-	-
BH250	-	-	-
BH275	-	-	-
BH276	-	-	-
BH278	-	-	-
BH279	-	-	-
BH280	-	-	-
BH281	-	-	-
BH282	-	-	-
BH283	-	-	-
BH284	-	-	-
BH285	-	-	-
BH286	-	-	-
BH296	-	0	-
BH297	-	-	-
BH298	-	-	-
BH299	-	-	-
BH305	-	2	-
BH307	-	-	-
BH312	-	-	-



Location of Proposed Cell

Protected Area Boundary
(Area of Contaminated Zone)

SEQUOYAH FUELS CORPORATION Decommissioning Plan	
Title: Locations Used for Selection of Thickness of Contaminated Zone and Thickness of Uncontaminated Unsaturated Zone	
PREPARED BY: SFC	Filename: NRC0068E2
Reviewed by: CH	Figure No. G-5
Date: 01/10/06	

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Attachment 2

Justification of Resident Farmer Scenario for Development of DCGLs

JUSTIFICATION OF RESIDENT FARMER SCENARIO FOR DEVELOPMENT OF DCGLs

Introduction

The resident farmer was identified as a likely scenario for the SFC site for the Decommissioning Plan (DP) submitted in 1999.[1] The NRC staff evaluated the dose modeling completed by SFC as part of the Environmental Impact Statement development and accepted the resident farmer scenario as the likely critical group. In developing the Reclamation Plan (RP), SFC updated and revised the DP to accommodate public input and extensive review previously completed by the NRC and its contractors.[2] The dose modeling for the DP was reviewed against NRC guidance on Radium Benchmark Dose determinations to identify any necessary changes.[3] Additional relevant NRC guidance, SECY-98-084, evaluated two possible scenarios for use in calculating the Radium Benchmark Dose for mill sites.[4] One of the two scenarios was the resident farmer living on a Nebraska site which is conceptually similar to the SFC site. As such, SFC did not see the need to change the scenario used in the DP to determine the Radium Benchmark Dose.

Description

Land use in this area of Oklahoma includes resident farmers as evidenced by the 2002 Census of Agriculture. The profile for Sequoyah County, Oklahoma reports:

- Number of farms is 1259
    - 679 include farming as the primary occupation of the principal operator
- Average size of farm is 177 acres
- Land in farms by type of land
    - 46% cropland
    - 35% pastureland
    - 15% woodland
    - 4% other uses

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[1] Sequoyah Fuels Corporation, Decommissioning Plan, March 26, 1999.

[2] Sequoyah Fuels Corporation, Reclamation Plan Sequoyah Facility, January 2003.

[3] U.S. Nuclear Regulatory Commission. Standard Review Plan for the Review of a Reclamation Plan for Mill Tailings Sites Under Title II of the Uranium Mill Tailings Radiation Control Act of 1978 (Revision 1). Washington, D.C.: U.S. Nuclear Regulatory Commission. NUREG-1620. June 2003.

[4] U.S. Nuclear Regulatory Commission, Commission Paper SECY 98 084, "Status of Efforts to Finalize Regulations for Radiological Criteria for License Termination: Uranium Recovery Facilities", April 15, 1998.

Tabulation of Selected Items for the Zip Code of SFC in the same census reveals the following:

- 101 family operated farms
  - 87 include the principal operator living on the farm (51 include farming as the primary occupation of the principal operator)
  - 75 include beef cow inventory
  - None include milk cow inventory
  - 69 are of size between 50 and 1000 acres (26 are less than 50 acres)

The NRC questioned the likelihood of several food sources and irrigation on a hypothetical farm placed at the site. Edible fish do exist in the adjacent surface water and is readily confirmed by observation or interview of local residents. SFC stocked the onsite pond with game fish which are routinely caught by local anglers. The river system is frequently used by anglers and contains the native fishes for the area. The fraction of fish produced from the adjacent surface waters cannot be objectively defended.

The Census citation above indicates that milk is probably not produced on the average farm in this area. No information was found describing the fraction of other foods produced and consumed on the farm.

The likelihood of irrigation from the adjacent pond versus the adjacent river is not known. However, for a family garden, irrigation from the pond would be substantially easier and less costly than from the river due primarily to proximity and elevation difference.

Application

SFC modified the radium benchmark dose model presented in the Reclamation Plan[3] by changing input parameters to evaluate the concern for conservatism expressed by the NRC. The inputs were changed to reflect the evaluation provided in SECY-98-084[4] (Attachment 4, Section 4 and Table 2) for the Nebraska site as a family farm. These changes are consistent with the U.S. Census data described above, and knowledge of local habit. Specifically,

- The aquatic foods pathway was turned off,
- The milk ingestion pathway was turned off, and
- The contaminated fractions of plant food and meat were reduced from 50% to 20%.

Attachment 3

Justification of Parameter Values for Development of DCGLs

Resident Farmer Scenario

JUSTIFICATION OF PARAMETER VALUES FOR DEVELOPMENT OF DCGLS

Resident Farmer Scenario

Introduction

The following text provides the justification for the value chosen for each RESRAD parameter that required an input for development of the derived concentration guideline levels under the resident farmer scenario. The order and identification of headings, subheadings, and parameter names are aligned with the input screens of the RESRAD code.

Source

Transport Distribution Coefficients (cm^3/g)

The distribution coefficient describes the portioning of elements or compounds (radioactive material) in a soil column between the solid (soil) and liquid (groundwater). It is a key parameter influencing the migration of radioactive material from the surface soil to groundwater. Distribution coefficients for a given radioactive material (e.g. uranium) can vary over several orders of magnitude depending on soil type, pH, oxidation/reduction potential, and presence of other ions. Distribution coefficient is not a function of isotope (i.e. mass or specific activity) therefore a distribution coefficient was determined only with respect to the element.

Uranium

SFC sampled the soils at the Facility to determine site-specific values of the distribution coefficient. Samples were collected for each of the soil and shale zones at the Facility. A distribution coefficient was not determined for any sandstone zone since the sandstone effectively acts as an aquitard.

The values for distribution coefficient of uranium used in the dose assessment are the lowest site-specific values available and are provided in the following table[1].

Geologic Zone	Uranium distribution coefficient, cm^3/g
Unconsolidated soils	572
Unit 1 shale	17.1
Unit 2 shale	220
Unit 3 shale	40.6
Unit 4 shale	80.2

[1] Sequoyah Fuels Corporation, Reclamation Plan Sequoyah Facility, January 2003, Appendix B, Hydrogeological and Chemical Site Characterization Report (tables 5.2 and 5.5).

The value used in the dose assessment for the distribution coefficient of uranium is 572 cm^3/g for the contaminated zone and for the uncontaminated unsaturated zone.

The value used in the dose assessment for the distribution coefficient of uranium is 17.1 cm^3/g for saturated zone. This application is conservative since it is the lowest of the distribution coefficients of the shale zones.

Protactinium

A site-specific distribution coefficient was not determined for protactinium. The value used in the dose assessment is a mean value assigned as an input for RESRAD[2].

The value used in the dose assessment for the distribution coefficient of protactinium is 380 cm^3/g for all soil zones.

Actinium

A site-specific distribution coefficient was not determined for actinium. The value used in the dose assessment is a mean value assigned as an input for RESRAD[2].

The value used in the dose assessment for the distribution coefficient of actinium is 825 cm^3/g for all soil zones.

Thorium

A site-specific distribution coefficient was not determined for thorium. The value used in the dose assessment model is a mean value assigned as an input for RESRAD[2].

The value used in the dose assessment for the distribution coefficient of thorium is 5884 cm^3/g for all soil zones.

Radium

A site-specific distribution coefficient was not determined for radium. The value used in the dose assessment is a mean value assigned as an input for RESRAD[2].

The value used in the dose assessment for the distribution coefficient of radium is 3533 cm^3/g for all soil zones.

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[2] U.S. Nuclear Regulatory Commission. Development of Probabilistic RESRAD 6.0 and RESRAD-BUILD 3.0 Computer Codes. Washington, D.C.: U.S. Nuclear Regulatory Commission. NUREG/CR-6697. December 2000. (Attachment C, Table 3.9-1)

Lead

A site-specific distribution coefficient was not determined for lead. The value used in the dose assessment is a mean value assigned as an input for RESRAD[2].

The value used in the dose assessment for the distribution coefficient of lead is 2392 cm^3/g for all soil zones.

Time since material placement (y)

This parameter describes the duration between the placement of radioactive material in soil (contamination) and the performance of a radiological survey. It is assumed that all radioactive material in soil at the Facility is "placed" there at the same time; i.e. at the end of decommissioning and as a single source. Also, this value is not applicable when transport distribution coefficients are available[3] as they are in this case. This parameter is independent of the source of contamination in soil and therefore is determined without regard for chemical element or soil zone.

The value used in the dose assessment for elapsed time since placement of contamination is the RESRAD default of zero years for all soil zones.

Groundwater concentration (pCi/L)

This parameter is a measure of the concentration of the principal radionuclide in a well located at the downgradient edge of the contaminated zone. Input values are required only if the value of the parameter *time since material placement* is greater than zero. In such a case, this input is used to calculate transport distribution coefficients. This parameter is not available in this case since transport distribution coefficients are provided and time since material placement is zero.

The groundwater concentration of radionuclides is not used in the dose assessment.

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[3] Yu, C., et.al. "Data Collection Handbook to Support Modeling the Impacts of Radioactive Material in Soil." Argonne, IL: Argonne National Laboratory. ANL/EAIS-8. April 1993. (Section 49.1)

Solubility Limit (mol/L)

The solubility equilibrium concentration is the reference saturated solubility of the radionuclide in soil. A non-zero input prompts calculation of a modified distribution coefficient based on the input. This parameter is not applicable in the case that a transport distribution coefficient is input to the model[4].

The value used in the dose assessment for solubility limit is the RESRAD default of zero mol/L for all soil zones.

Leach Rate (/y)

The leach rate is the fraction of the available radionuclide leached out from the contaminated zone per unit of time. No site-specific information is available for this parameter. In this case, an input value of zero invokes the calculation of the value for this parameter and uses the calculated value with the transport distribution coefficient provided previously.

The input for the dose assessment for leach rate is the RESRAD default of zero /y for all soil zones.

Calculation Parameters

Basic radiation dose limit (mrem/y)

The basic radiation dose limit is the effective dose equivalent from external radiation plus the committed effective dose equivalent from internal radiation. The radiation dose limit is used to derive the cleanup criteria (i.e. the derived concentration guideline levels, DCGLs). The applicable value is the Radium Benchmark Dose derived for the site

The basic radiation dose limit is not meaningful for Ra-226 since its concentration limit is used for the derived dose limit; hence the RESRAD default value of 25 mrem/y is used in the Ra-226 dose assessment.

The value used in the derivation of site specific clenup criteria for natural uranium and Th-230 is the Radium Benchmark Dose

Times for calculations (years)

These are the times in years following the radiological survey for which tabular values for single-radionuclide soil guidelines will be obtained.

The values used in the dose assessment for calculation times are the RESRAD defaults.

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[4] Yu, C., et.al. "Data Collection Handbook to Support Modeling the Impacts of Radioactive Material in Soil." Argonne, IL: Argonne National Laboratory. ANL/EAIS-8. April 1993. (Section 32.3)

Contaminated Zone Parameters

Area of contaminated zone (m^2)

This is the size of the contaminated area at the site. It reflects the size of the area that contains the locations with radionuclide concentrations in soil clearly above background. The area is defined as the difference between the area of the current protected area (Process Area) (about 85 acres) and the area of the footprint of the proposed disposal cell (about 20 acres). The footprint of the disposal cell was subtracted to reflect the condition that the disposal cell, in the context of use of the RESRAD code, will not contribute to the source term in the soil; i.e. this area will not be subject to rainfall, wind erosion, plant uptake, etc. since the area is covered by the disposal cell. As well, the footprint of the cell will not be available for habitation.

The value used in the dose assessment for the area of the contaminated zone is 263,120 m^2 (65 acres).

Thickness of contaminated zone

This value is the distance between the uppermost and lowermost soil samples in the *area of contaminated zone* that have radionuclide concentrations clearly above background. The thickness was selected with respect to concentrations of total uranium in soil greater than an approximate background concentration. The value selected for this parameter represents an average thickness of the contaminated soil layer that currently exists in the *area of contaminated zone*. The selection of the subject thickness is described in Attachment 1.

The value used in the dose assessment for the thickness of the contaminated zone is 0.3 meters (1 foot) for the unconsolidated surface soils.

Length parallel to aquifer flow (m)

This parameter describes the maximum horizontal distance measured in the contaminated zone, from its upgradient edge to the downgradient edge, along the direction of the groundwater flow in the underlying water bearing formation.

The length chosen here is equal to the diameter of a circle of 85 acres. The 85 acre area is the size of the current protected area (Process Area). It is intended to represent the total surface area that bounds the *area of contaminated zone*. It is intended to represent the condition that there will be a large area of contaminated surface soil upgradient of the modeled area and therefore may lead to insignificant dilution from uncontaminated groundwater flowing into the contaminated zone.

The value used in the dose assessment for the length of the contaminated zone parallel to the aquifer flow is 662 m.

Cover and Contaminated Zone Hydrological Data

Cover depth (m)

This parameter describes the distance from ground surface to the top of the contaminated soil. In some areas at the Facility, the contaminated soil will not be covered with clean soil after remediation; i.e. no cover.

The value used in the dose assessment for the depth of cover is zero m.

Density of cover material (g/cm^3)

This value describes the dry (bulk) density of the cover material. This parameter is not applicable since *cover depth* is zero meters.

The density of the cover material is not used in the dose assessment.

Cover erosion rate (m/y)

This value represents the average depth of soil that is removed from the ground surface per year due to weather conditions (e.g. running water, wind). This parameter is not applicable since *cover depth* is zero meters.

The erosion rate of the cover is not used in the dose assessment.

Density of contaminated zone (g/cm^3)

This value describes the dry (bulk) density of the contaminated soils. The value for this parameter is site-specific for the unconsolidated surface soils[5].

The value used in the dose assessment for density of the contaminated zone is 1.76 g/cm^3.

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[5] Sequoyah Fuels Corporation, Reclamation Plan Sequoyah Facility, January 2003, Appendix B, Hydrogeological and Chemical Site Characterization Report (Section 8.5.2).

Contaminated zone erosion rate (m/y)

This value represents the average depth of soil that is removed from the ground surface per year due to weather conditions (e.g. running water, wind). The value for this parameter is chosen in accordance with guidance recommending an erosion rate for farm/garden scenario in which dose contribution from the food ingestion pathway is expected to be significant[6].

The value used in the dose assessment for erosion rate of the contaminated zone is 0.0006 m/y.

Contaminated zone total porosity (dimensionless)

This value represents the ratio of the pore volume to the total volume for the contaminated soils. The value for this parameter is an estimate for the unconsolidated surface soils. The estimate was drawn from values representing the high end for unconsolidated deposits of gravel and the low end for unconsolidated deposits of clay.[7] It is an intermediate value for unconsolidated deposits of sand or silt.

The value used in the dose assessment for total porosity of the contaminated zone is 0.3.

Contaminated zone field capacity (dimensionless)

Field capacity is the volumetric moisture content of the soil at which (free) gravity drainage ceases. This is the amount of moisture that will be retained in a column of soil against the force of gravity. The field capacity is used as the lower bound of the moisture content in the soil layer.

The value used in the dose assessment for field capacity of the contaminated zone is the RESRAD default of 0.2.

Contaminated zone hydraulic conductivity (m/y)

This parameter measures a soil's ability to transmit water when subjected to a *hydraulic gradient*. The value used in the dose assessment represents the vertical component of the

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[6] U.S. Nuclear Regulatory Commission. Development of Probabilistic RESRAD 6.0 and RESRAD-BUILD 3.0 Computer Codes. Washington, D.C.: U.S. Nuclear Regulatory Commission. NUREG/CR-6697. December 2000. (Attachment C, Section 3.8)

[7] Yu, C., et.al. "Data Collection Handbook to Support Modeling the Impacts of Radioactive Material in Soil." Argonne, IL: Argonne National Laboratory. ANL/EAIS-8. April 1993. (Table 3.1)

[9] Yu, C., et.al. "Data Collection Handbook to Support Modeling the Impacts of Radioactive Material in Soil." Argonne, IL: Argonne National Laboratory. ANL/EAIS-8. April 1993. (Section 5.3)

hydraulic conductivity.[9] The value for this parameter is site-specific for the unconsolidated surface soils.[10]

The value used in the dose assessment for hydraulic conductivity of the contaminated zone is 8.9 m/y.

Contaminated zone b parameter (dimensionless)

The soil-specific b parameter is an empirical parameter used to evaluate the saturation ratio of the soil. The value used in the dose assessment is the mean value recommended for generic soil type as an input for RESRAD.[11]

The value used in the dose assessment for the contaminated zone b parameter is 3.

Humidity in air (g/cm^3)

This parameter is used only for the computation of tritium concentration in air.[12] Since tritium is not a constituent of concern at SFC, this parameter is not applicable to the dose assessment.

The humidity in air is not used in the dose assessment.

Evapotranspiration Coefficient (dimensionless)

This parameter is the ratio of the total volume of water leaving the ground as a result of evapotranspiration to the total volume of water available within the root zone of the soil. The value for this parameter is suggested by RESRAD guidance for the case of a small family farm that is not well managed.[13]

The value used in the dose assessment for evapotranspiration coefficient is 0.5.

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[10] Sequoyah Fuels Corporation, Reclamation Plan Sequoyah Facility, January 2003, Appendix B, Hydrogeological and Chemical Site Characterization Report (Table 4.9 and Section 8.4.3).

[11] U.S. Nuclear Regulatory Commission. Development of Probabilistic RESRAD 6.0 and RESRAD-BUILD 3.0 Computer Codes. Washington, D.C.: U.S. Nuclear Regulatory Commission. NUREG/CR-6697. December 2000. (Attachment C, Section 3.5)

[12] Yu, C., et. al. "User's Manual for RESRAD Version 6." Argonne National Laboratory. ANL/EAD-4. July 2001. (Section 4.4.6)

[13] U.S. Nuclear Regulatory Commission. Development of Probabilistic RESRAD 6.0 and RESRAD-BUILD 3.0 Computer Codes. Washington, D.C.: U.S. Nuclear Regulatory Commission. NUREG/CR-6697. December 2000. (Attachment C, Section 4.3)

Wind speed (m/s)

This value is the average wind speed for a one-year period. The value used here is an average monthly value of a multiyear period for Muskogee, Oklahoma; this is the closest location to the Facility at which such measurements are recorded[14].

The value used in the dose assessment for wind speed is 4 meters per second.

Precipitation (m/y)

This value is the average rainfall for a one-year period. The value used here is an annual average of the period 1961 –1990 for Sallisaw, Oklahoma; this is the closest location to the Facility at which such measurements are recorded[15].

The value used in the dose assessment for precipitation is 1.1 meters per year.

Irrigation (m/y)

This parameter describes the average volume of water applied to the soil, per unit of surface area, per year. The value used in the dose assessment is an average of 0.2 for humid regions and 1 for arid regions.[16]

The value used in the dose assessment for irrigation is 0.6 meters per year.

Irrigation mode (overhead or ditch)

This parameter indicates the predominant method of irrigation. The method of irrigation used in the dose assessment was chosen based on observation of local irrigation practices.

Overhead irrigation is the irrigation mode used in the dose assessment.

Runoff coefficient (dimensionless)

This parameter represents the fraction of precipitation, in excess of the deep percolation and evapotranspiration, that becomes surface flow and ends up in surface water bodies. An estimate of the runoff coefficient for the Facility was made in accordance with the guidance from

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[14] National Oceanic and Atmospheric Administration, Preliminary Local Climatological Data (Form F-6), Davis Field, Muskogee, Oklahoma, 1999 through 2001.

[15] National Weather Service, Tulsa, Oklahoma, Station Sallisaw, Oklahoma, Climatology.

[16] Yu, C., et.al. "Data Collection Handbook to Support Modeling the Impacts of Radioactive Material in Soil." Argonne, IL: Argonne National Laboratory. ANL/EAIS-8. April 1993. (Section 11.3)

applicable literature.[17] The runoff coefficient was derived from the partial coefficients from the same guidance for "Rolling land ...", "Intermediate combinations of clay and loam", and "Woodlands".

The value used in the dose assessment for runoff coefficient is 0.4.

Watershed area for nearby stream or pond (m^2)

The watershed area parameter represents the area of the region draining into the nearby stream or pond located at the Facility. The most likely location of a pond at the Facility, with respect to the presumed resident farmer scenario, is south of the Protected Area and north of the fertilizer basins. This location is also downgradient with respect to groundwater flow at the Facility. The watershed area for this location is estimated from the anticipated post-decommissioning Facility topography. The watershed area for this location is shown on Figure G-6. The watershed area is estimated to be 142 acres.

The value used in the dose assessment for the watershed area is 575000 m^2.

Accuracy for water/soil computations

The RESRAD default is used for this dose assessment.

Saturated Zone Hydrological Data

Density of saturated zone (g/m^3)

This value describes the dry (bulk) density of the saturated zone. The value for this parameter is site-specific for the shale zones at the Facility[18].

The value used in the dose assessment for density of the saturated zone is 2.69 g/cm^3.

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[17] U.S. Nuclear Regulatory Commission. Development of Probabilistic RESRAD 6.0 and RESRAD-BUILD 3.0 Computer Codes. Washington, D.C.: U.S. Nuclear Regulatory Commission. NUREG/CR-6697. December 2000. (Attachment C, Table 4.2-1, footnote a)

[18] Sequoyah Fuels Corporation, Reclamation Plan Sequoyah Facility, January 2003, Appendix B, Hydrogeological and Chemical Site Characterization Report (Section 8.5.2).

Saturated zone total porosity (dimensionless)

This value represents the ratio of the pore volume to the total volume for the saturated zone. The value for this parameter is an estimate for the shale zones at the Facility. The estimate was taken from RESRAD guidance.[19]

The value used in the dose assessment for total porosity of the saturated zone is 0.4.

Saturated zone effective porosity (dimensionless)

This value represents the ratio of the part of the pore volume where water can circulate to the total volume for the saturated soils. The value for this parameter is site-specific for the shale zones.[20]

The value used in the dose assessment for effective porosity of the saturated zone is 0.1.

Saturated zone field capacity (dimensionless)

Field capacity is the volumetric moisture content of the soil at which (free) gravity drainage ceases. This is the amount of moisture that will be retained in a column of soil against the force of gravity. The field capacity is used as the lower bound of the moisture content in the soil layer.

The value used in the dose assessment for field capacity of the saturated zone is the RESRAD default of 0.2.

Saturated zone hydraulic conductivity (m/y)

This parameter measures a formation's ability to transmit water when subjected to a *hydraulic gradient*. The value used in the dose assessment represents the horizontal component of the hydraulic conductivity.[21] The value for this parameter is site-specific for the shale zones.[22]

The value used in the dose assessment for hydraulic conductivity of the saturated zone is 89 m/y.

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[19] Yu, C., et.al. "Data Collection Handbook to Support Modeling the Impacts of Radioactive Material in Soil." Argonne, IL: Argonne National Laboratory. ANL/EAIS-8. April 1993. (Table 3.1)

[20] Sequoyah Fuels Corporation, Reclamation Plan Sequoyah Facility, January 2003, Appendix B, Hydrogeological and Chemical Site Characterization Report (Section 8.5.2).

[21] Yu, C., et.al. "Data Collection Handbook to Support Modeling the Impacts of Radioactive Material in Soil." Argonne, IL: Argonne National Laboratory. ANL/EAIS-8. April 1993. (Section 5.3)

[22] Sequoyah Fuels Corporation, Reclamation Plan Sequoyah Facility, January 2003, Appendix B, Hydrogeological and Chemical Site Characterization Report (Table 4.9).

Saturated zone hydraulic gradient (dimensionless)

The hydraulic gradient is the change in hydraulic head per unit of distance of the groundwater flow in a given direction. The value for this parameter is site-specific for the shale zones.[23]

The value used in the dose assessment for hydraulic gradient of the saturated zone is 0.04.

Saturated zone b parameter (dimensionless)

The formation-specific b parameter is an empirical parameter used to evaluate the saturation ratio of the formation. Input for the parameter is only required if the *water table drop rate* is greater than zero.[24] The water table drop rate is defined as zero in this dose assessment therefore the saturated zone b parameter is not used.

The saturated zone b parameter is not used in the dose assessment.

Water table drop rate (m/y)

The water table drop rate describes the fluctuation in the level of the water table due to temporal variations processes in the hydrologic cycle as well as extra use of water from the system. The value of this parameter is estimated from the conditions of an unconfined groundwater system and assumed lack of groundwater use (i.e. no withdrawal).

The value used in the dose assessment for water table drop rate is zero.

Well pump intake depth (m below water table)

This parameter represents the screened depth of a well within the saturated zone. The value for this parameter is determined by the assumption that groundwater is not used (i.e. no withdrawal).

The value used in the dose assessment for well pump intake depth is 0.00001 m corresponding to the lowest value allowed by the RESRAD code.[25]

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[23] Sequoyah Fuels Corporation, Reclamation Plan Sequoyah Facility, January 2003, Appendix B, Hydrogeological and Chemical Site Characterization Report (Section 7.2).

[24] Yu, C., et.al. "Data Collection Handbook to Support Modeling the Impacts of Radioactive Material in Soil." Argonne, IL: Argonne National Laboratory. ANL/EAIS-8. April 1993. (Section 13.3)

[25] Yu, C., et. al. "User's Manual for RESRAD Version 6." Argonne National Laboratory. ANL/EAD-4. July 2001.

Model for Water Transport Parameters (nondispersion or mass-balance)

This parameter selects which of the two models will be used for water/soil concentration ratio calculations. The RESRAD default, based on the size of the contaminated area, is the nondispersion model.[26]

The model for water transport used in the dose assessment is the nondispersion model.

Well pumping rate (m^3/y)

The well pumping rate is the total volume of water obtained annually from the well for use by humans and livestock and for agricultural and other purposes. The value for this parameter is determined by the assumption that groundwater is not used; i.e. *groundwater fractional usage* is zero: no withdrawal).

The value used in the dose assessment for well pumping rate is zero.

Uncontaminated Unsaturated Zone Parameters

Unsaturated zones

The uncontaminated and unsaturated zone is the portion of the uncontaminated zone that lies below the bottom of the contaminated zone and above the groundwater table. The dose assessment here assumes one unsaturated zone: the unconsolidated soil (the same unconsolidated soils of *contaminated zone*) above the shale (*saturated zone*).

Unsaturated Zone 1, Thickness (m)

This parameter describes the thickness of the uncontaminated unsaturated unconsolidated soil below the *contaminated zone* and above the *saturated zone*. The value is an average thickness of unconsolidated soil in the *area of contaminated zone* minus the *thickness of contaminated zone*. The selection of the subject thickness is described in Attachment 1.

The value used in the dose assessment for thickness of unsaturated zone 1 is 1.4 meter (4.6 feet).

Unsaturated Zone 1, Density (g/m^3)

This value describes the dry (bulk) density of unsaturated zone 1. The value for this parameter is equivalent to that of the contaminated zone.

The value used in the dose assessment for density of unsaturated zone 1 is 1.76 g/cm^3.

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[26] Yu, C., et. al. "User's Manual for RESRAD Version 6." Argonne National Laboratory. ANL/EAD-4. July 2001. (sections 2.2.4.2 and E.3.1)

Unsaturated Zone 1, Total Porosity (dimensionless)

This value represents the ratio of the pore volume to the total volume for the unsaturated zone 1. The value for this parameter is equivalent to that of the contaminated zone.

The value used in the dose assessment for total porosity of the unsaturated zone 1 is 0.3.

Unsaturated Zone 1, Effective Porosity (dimensionless)

This value represents the ratio of the part of the pore volume where water can circulate to the total volume for the unsaturated zone 1 soils. An estimate was derived representing an average of mean values for sand, gravel, silt, and clay[27].

The value used in the dose assessment for effective porosity of the unsaturated zone 1 is 0.25.

Unsaturated Zone 1, field capacity (dimensionless)

Field capacity is the volumetric moisture content of the soil at which (free) gravity drainage ceases. This is the amount of moisture that will be retained in a column of soil against the force of gravity. The field capacity is used as the lower bound of the moisture content in the soil layer.

The value used in the dose assessment for field capacity of the unsaturated zone 1 is the RESRAD default of 0.2.

Unsaturated Zone 1, Hydraulic Conductivity (m/y)

This parameter measures a formation's ability to transmit water when subjected to a *hydraulic gradient*. The value used in the dose assessment represents the vertical component of the hydraulic conductivity.[28] The value for this parameter is site-specific for the unconsolidated surface soils.[29]

The value used in the dose assessment for hydraulic conductivity of the unsaturated zone 1 is 8.9 m/y.[30]

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[27] Yu, C., et.al. "Data Collection Handbook to Support Modeling the Impacts of Radioactive Material in Soil." Argonne, IL: Argonne National Laboratory. ANL/EAIS-8. April 1993. (Table 3.2)

[28] Yu, C., et.al. "Data Collection Handbook to Support Modeling the Impacts of Radioactive Material in Soil." Argonne, IL: Argonne National Laboratory. ANL/EAIS-8. April 1993. (Section 5.3)

[29] U.S. Nuclear Regulatory Commission. Development of Probabilistic RESRAD 6.0 and RESRAD-BUILD 3.0 Computer Codes. Washington, D.C.: U.S. Nuclear Regulatory Commission. NUREG/CR-6697. December 2000. (Attachment C, Section 3.5)

[30] Sequoyah Fuels Corporation, Reclamation Plan Sequoyah Facility, January 2003, Appendix B, Hydrogeological and Chemical Site Characterization Report (Table 4.9 and Section 8.4.3).

Unsaturated Zone 1, b parameter (dimensionless)

The formation-specific b parameter is an empirical parameter used to evaluate the saturation ratio of the formation. The value used in the dose assessment is the mean value recommended for generic soil type as an input for RESRAD.[31]

The value used in the dose assessment for the unsaturated zone 1 b parameter is 3.

Occupancy, Inhalation, and External Gamma Data

Inhalation rate (m^3/y)

The inhalation rate used in the dose assessment represents the annual average breathing rate of the average member of the resident farmer.[32] The activities accounted for include indoor, outdoor, and gardening.

The value used in the dose assessment for inhalation rate is 8400 m^3/y.

Mass loading for inhalation (g/m^3)

This parameter represents the concentration of soil particles in air. The value used here accounts for short periods of high mass loading and sustained periods of normal farmyard activities for which the dust level may be somewhat higher than ambient.[33]

The value used in the dose assessment for mass loading for inhalation is 0.0002 g/m^3.

Exposure duration (y)

The exposure duration is the span of time, in years, during which an individual is expected to spend time on site. This parameter is evaluated as one since the results of the dose assessment are expressed per unit time (e.g. dose per year).

The value used in the dose assessment for exposure duration is one year.

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[31] Yu, C., et.al. "Data Collection Handbook to Support Modeling the Impacts of Radioactive Material in Soil." Argonne, IL: Argonne National Laboratory. ANL/EAIS-8. April 1993. (Section 13.3)

[32] U.S. Nuclear Regulatory Commission. Development of Probabilistic RESRAD 6.0 and RESRAD-BUILD 3.0 Computer Codes. Washington, D.C.: U.S. Nuclear Regulatory Commission. NUREG/CR-6697. December 2000. (Attachment C, Table 5.1-3)

[33] Yu, C., et.al. "Data Collection Handbook to Support Modeling the Impacts of Radioactive Material in Soil." Argonne, IL: Argonne National Laboratory. ANL/EAIS-8. April 1993. (Section 35.2)

Indoor dust filtration factor (dimensionless)

This parameter is also termed the shielding factor for inhalation pathway. This factor is the ratio of airborne dust concentration indoors on site to the concentration outdoors on site. It is based on the fact that a building provides shielding against entry of wind-blown dust particles. The value chosen is an estimate derived from an average of mean values from RESRAD guidance.[34]

The value used in the dose assessment for indoor dust filtration factor is 0.56.

External gamma shielding factor (dimensionless)

This factor is the ratio of the external gamma radiation level indoors on site to the radiation level outdoors on site. It is based on the fact that a building provides shielding against penetration of gamma radiation. The value used here represents a frame house constructed with a slab[35]; i.e. a reasonably conservative guess (vs brick on slab) of type of home construction on site based on current construction practices.

The value used in the dose assessment for external gamma shielding factor is 0.21.

Indoor time fraction (dimensionless)

The fraction of time indoors on site is the average fraction of time in a year during which an individual stays inside a house on site. The value used here is from NRC guidance. [36]

The value used in the dose assessment for indoor time fraction is 0.25.

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[34] U.S. Nuclear Regulatory Commission. Development of Probabilistic RESRAD 6.0 and RESRAD-BUILD 3.0 Computer Codes. Washington, D.C.: U.S. Nuclear Regulatory Commission. NUREG/CR-6697. December 2000. (Attachment C, Table 7.1-2)

[35] U.S. Nuclear Regulatory Commission. Development of Probabilistic RESRAD 6.0 and RESRAD-BUILD 3.0 Computer Codes. Washington, D.C.: U.S. Nuclear Regulatory Commission. NUREG/CR-6697. December 2000. (Attachment C, Table 7.10-1)

[36] U.S. Nuclear Regulatory Commission. Standard Review Plan for the Review of a Reclamation Plan for Mill Tailings Sites Under Title II of the Uranium Mill Tailings Radiation Control Act of 1978, Final Report, Revision 1. Washington, D.C.: U.S. Nuclear Regulatory Commission. NUREG-1620. June 2003. (Section H2.1.3(2)(i))

Outdoor time fraction (dimensionless)

The fraction of time outdoors on site is the average fraction of time in a year during which an individual stays outside on site. The value used here is from NRC guidance.[37]

The value used in the dose assessment for outdoor time fraction is 0.5.

Shape of the contaminated zone

The shape factor is used to correct for a noncircular-shaped contaminated area on the basis of an ideally circular zone. The shape of the contaminated area is assumed to be circular.

The choice of circular is made in the dose assessment for the shape of the contaminated zone.

Ingestion Pathway, Dietary Data

Fruits, Vegetables (nonleafy) and grain consumption (kg/y)

This parameter describes the total quantity of these food items (contaminated and noncontaminated) consumed per year per individual. It is a composite value obtained by summing individual consumption rates for each of the food items.[38]

The value used in the dose assessment for fruit, vegetables (nonleafy) and grain consumption is 178 kg/y.

Leafy vegetable consumption (kg/y)

This parameter describes the total quantity of this food item (contaminated and noncontaminated) consumed per year per individual. The value for this parameter was estimated to be 0.33 of a total vegetable consumption rate.[39]

The value used in the dose assessment for leafy vegetable consumption is 25 kg/y.

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[37] U.S. Nuclear Regulatory Commission. Standard Review Plan for the Review of a Reclamation Plan for Mill Tailings Sites Under Title II of the Uranium Mill Tailings Radiation Control Act of 1978, Final Report, Revision 1. Washington, D.C.: U.S. Nuclear Regulatory Commission. NUREG-1620. June 2003. (Section H2.1.3(2)(i))

[38] U.S. Nuclear Regulatory Commission. Development of Probabilistic RESRAD 6.0 and RESRAD-BUILD 3.0 Computer Codes. Washington, D.C.: U.S. Nuclear Regulatory Commission. NUREG/CR-6697. December 2000. (Attachment C, Table 5.4-2)

[39] U.S. Nuclear Regulatory Commission. Development of Probabilistic RESRAD 6.0 and RESRAD-BUILD 3.0 Computer Codes. Washington, D.C.: U.S. Nuclear Regulatory Commission. NUREG/CR-6697. December 2000. (Attachment C, Section 5.4 and Table 5.4-2)

Milk consumption (L/y)

The milk consumption rate is the amount of fluid milk (beverage) consumed per year. The milk pathway is not active therefore this parameter is not available.[40]

The milk consumption is not used in the dose assessment.

Meat and poultry consumption (kg/y)

This parameter describes the annual consumption of homegrown beef, poultry, and eggs. Site specific information is not available for this parameter, therefore the RESRAD default was chosen as the input.

The value used in the dose assessment for meat and poultry consumption is 63 kg/y.

Fish Consumption (kg/y)

This parameter describes the amount of fresh fish consumed per year. The aquatic foods pathway is not active therefore this parameter is not available.[42]

The fish consumption is not used in the dose assessment.

Other seafood consumption

This parameter describes the annual average rate for consumption of nonfish seafood. This parameter is not applicable to the dose assessment scenario.

The value used in the dose assessment for other seafood consumption is zero kg/y.

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[40] U.S. Nuclear Regulatory Commission. Standard Review Plan for the Review of a Reclamation Plan for Mill Tailings Sites Under Title II of the Uranium Mill Tailings Radiation Control Act of 1978, Final Report, Revision 1. Washington, D.C.: U.S. Nuclear Regulatory Commission. NUREG-1620. June 2003. (Section H2.1.3(2)(a))

[42] U.S. Nuclear Regulatory Commission. Standard Review Plan for the Review of a Reclamation Plan for Mill Tailings Sites Under Title II of the Uranium Mill Tailings Radiation Control Act of 1978, Final Report, Revision 1. Washington, D.C.: U.S. Nuclear Regulatory Commission. NUREG-1620. June 2003. (Section H2.1.3(2)(a))

Soil ingestion (g/y)

This parameter describes the accidental ingestion rate of soil from outdoor activities. The chosen value represents a most likely value for the outdoor lifestyle of the resident farmer scenario.[43]

The value used in the dose assessment for soil ingestion is 18.3 g/y.

Drinking water intake (L/y)

The drinking water intake rate is the average amount of water consumed by an adult per year. The drinking water pathway is not active therefore this parameter is not available.

The drinking water intake is not used in the dose assessment.

Contaminated fraction drinking water (dimensionless)

This parameter specifies the fraction of *drinking water intake* that is drawn from [groundwater] sources on site and is assumed contaminated. The balance of drinking water is assumed to be from off site sources and uncontaminated. The drinking water pathway is not active therefore this parameter is not available.

The contaminated fraction drinking water is not used in the dose assessment.

Contaminated fraction household water (dimensionless)

This parameter allows specification of the contaminated fraction of household water for use in calculating radon exposure. The radon is not active therefore this parameter is not available.

The contaminated fraction household water is not used in the dose assessment.

Contaminated fraction livestock water (dimensionless)

This parameter specifies the fraction of livestock drinking water that is drawn from sources on site and is assumed contaminated. The value chosen for this parameter reflects the worst-case assumption that all livestock water is drawn from contaminated on site sources.

The value used in the dose assessment for contaminated fraction livestock water is one.

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[43] U.S. Nuclear Regulatory Commission. Development of Probabilistic RESRAD 6.0 and RESRAD-BUILD 3.0 Computer Codes. Washington, D.C.: U.S. Nuclear Regulatory Commission. NUREG/CR-6697. December 2000. (Attachment C, Section 5.6)

Contaminated fraction irrigation water (dimensionless)

This parameter specifies the fraction of *irrigation* water that is drawn from sources on site and is assumed contaminated. The value chosen for this parameter reflects the worst-case assumption that all *irrigation* water is drawn from contaminated on site sources.

The value used in the dose assessment for contaminated fraction irrigation water is one.

Contaminated fraction aquatic food (dimensionless)

This parameter specifies the fraction of *fish consumption* that is from sources on site and is assumed contaminated. The aquatic food pathway is not active therefore this parameter is not available.

The contaminated fraction aquatic food is not used in the dose assessment.

Contaminated fraction plant food (dimensionless)

This parameter allows specification of the fraction of contaminated intake for the *fruits, vegetables and grain consumption*, and *leafy vegetable consumption* pathways. The balance is from off site sources assumed to be uncontaminated.[44]

The value used in the dose assessment for contaminated fraction plant food is 0.2.

Contaminated fraction meat (dimensionless)

This parameter allows specification of the fraction of contaminated intake for the *meat and poultry consumption* pathway. The balance is from off site sources assumed to be uncontaminated.[45]

The value used in the dose assessment for contaminated fraction meat is 0.2.

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[44] U.S. Nuclear Regulatory Commission, Commission Paper SECY 98 084, "Status of Efforts to Finalize Regulations for Radiological Criteria for License Termination: Uranium Recovery Facilities", April 15, 1998. (Attachment 3, Table 2)

[45] U.S. Nuclear Regulatory Commission, Commission Paper SECY 98 084, "Status of Efforts to Finalize Regulations for Radiological Criteria for License Termination: Uranium Recovery Facilities", April 15, 1998. (Attachment 3, Table 2)

Contaminated fraction milk (dimensionless)

This parameter allows specification of the fraction of contaminated intake for the *milk consumption* pathway. The milk pathway is not active therefore this parameter is not available.

The contaminated fraction milk is not used in the dose assessment.

Ingestion Pathway, Nondietary Data

Livestock fodder intake for meat (kg/d)

This is the daily intake of fodder for livestock kept for *meat and poultry consumption*. The RESRAD default is considered adequately representative of a resident farmer scenario with respect to the absence of site-specific information.

The value used in the dose assessment for livestock fodder intake for meat is 68 kg/d.

Livestock fodder intake for milk (kg/d)

This is the daily intake of fodder for livestock kept for *milk consumption*. This parameter is not available, reflecting the absence of the milk pathway on site (see also *contaminated fraction milk*).

The livestock fodder intake for milk is not used in the dose assessment.

Livestock water intake for meat (L/d)

This is the daily intake of water for livestock kept for *meat and poultry consumption*. The RESRAD default is considered adequately representative of a resident farmer scenario with respect to the absence of site-specific information.

The value used in the dose assessment for livestock water intake for meat is 50 L/d.

Livestock water intake for milk (kg/d)

This is the daily intake of water for livestock kept for *milk consumption*. This parameter is not available, reflecting the absence of the milk pathway on site (see also *contaminated fraction milk*).

The livestock water intake for milk is not used in the dose assessment.

Livestock soil intake (kg/d)

This is the daily intake of soil for livestock kept for *meat and poultry consumption* or *milk consumption.* The RESRAD default is considered adequately representative of a resident farmer scenario with respect to the absence of site-specific information.

The value used in the dose assessment for livestock soil intake is 0.5 kg/d.

Mass loading for foliar deposition (g/m^3)

This is the air/soil concentration ratio, specified as the average mass loading of airborne contaminated soil particles in a garden during the growing season. The RESRAD default is considered adequately representative of a resident farmer scenario with respect to the absence of site-specific information.

The value used in the dose assessment for mass loading for foliar deposition is $0.0001 g/m^3$.

Depth of soil mixing layer (m)

The depth of soil mixing layer is used in calculating the depth factor for the dust inhalation and soil ingestion pathways and for foliar deposition for the ingestion pathway. The depth factor is the fraction of resuspendable soil particles at the ground surface that are contaminated. The RESRAD default is considered to represent the most likely value for the resident farmer scenario.[46]

The value used in the dose assessment for mass loading for depth of soil mixing layer is 0.15 m.

Depth of roots (m)

This parameter represents the average root depth of various plants grown in the contaminated zone.[47]

The value used in the dose assessment for depth of roots is 0.3 m.

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[46] U.S. Nuclear Regulatory Commission. Development of Probabilistic RESRAD 6.0 and RESRAD-BUILD 3.0 Computer Codes. Washington, D.C.: U.S. Nuclear Regulatory Commission. NUREG/CR-6697. December 2000. (Attachment C, Section 3.12)

[47] U.S. Nuclear Regulatory Commission. Standard Review Plan for the Review of a Reclamation Plan for Mill Tailings Sites Under Title II of the Uranium Mill Tailings Radiation Control Act of 1978, Final Report, Revision 1. Washington, D.C.: U.S. Nuclear Regulatory Commission. NUREG-1620. June 2003. (Section H2.1.3(2)(j))

Groundwater fractional usage drinking water (dimensionless)

This parameter allows distinction between the groundwater and surface water scenarios with respect to *drinking water*. This parameter is not available, reflecting the absence of the drinking water pathway on site (see also *contaminated fraction drinking water*).

The groundwater fractional usage drinking water is not used in the dose assessment.

Groundwater fractional usage household water (dimensionless)

This parameter allows distinction between the groundwater and surface water scenarios with respect to *household water*. This parameter is not available, reflecting the absence of the radon pathway on site (see also *contaminated fraction household water*).

The contaminated fraction household water is not used in the dose assessment.

Groundwater fractional usage livestock water (dimensionless)

This parameter allows distinction between the groundwater and surface water scenarios with respect to *livestock water*. The value of the parameter is chosen to reflect the most-likely case, based on observation of local practice, that all *livestock water* will come from surface water (see also *contaminated fraction livestock water* and *well pumping rate*).

The value used in the dose assessment for groundwater fractional usage livestock water is zero.

Groundwater fractional usage irrigation water (dimensionless)

This parameter allows distinction between the groundwater and surface water scenarios with respect to *irrigation*. The value of the parameter is chosen to reflect the most-likely case, based on observation of local practice, that all *irrigation* water will come from surface water (see also *contaminated fraction irrigation water* and *well pumping rate*).

The value used in the dose assessment for groundwater fractional usage irrigation water is zero.

Plant Factors

Wet weight crop yield for non-leafy (kg/m^2)

This is the mass (wet weight) of the edible portion of non-leafy vegetable plant food produced from a unit land area. A State-specific value was chosen for this parameter.[48]

The value used in the dose assessment for wet weight crop yield for non-leafy vegetables is 0.6 kg/m^2.

Wet weight crop yield for leafy (kg/m^2)

This is the mass (wet weight) of the edible portion of leafy vegetable plant food produced from a unit land area. The RESRAD default is considered adequately representative respect to the absence of site-specific information.

The value used in the dose assessment for wet weight crop yield for leafy vegetables is 1.5 kg/m^2.

Wet weight crop yield for fodder (kg/m^2)

This is the mass (wet weight) of the edible portion of livestock plant food produced from a unit land area. The RESRAD default is considered adequately representative respect to the absence of site-specific information.

The value used in the dose assessment for wet weight crop yield for fodder is 1.1 kg/m^2.

Length of growing season for non-leafy (y)

This is the exposure time of the non-leafy plant food to contamination during the growing season. The contaminants can get to the edible portion of the plant food through foliar deposition, root uptake and water irrigation. The RESRAD default is considered adequately representative respect to the absence of site-specific information.

The value used in the dose assessment for length of growing season of non-leafy vegetables is 0.17 year.

Length of growing season for leafy (y)

This is the exposure time of the leafy plant food to contamination during the growing season. The contaminants can get to the edible portion of the plant food through foliar deposition, root

[48] U.S. Nuclear Regulatory Commission. Development of Probabilistic RESRAD 6.0 and RESRAD-BUILD 3.0 Computer Codes. Washington, D.C.: U.S. Nuclear Regulatory Commission. NUREG/CR-6697. December 2000. (Attachment C, Section 6.5)

uptake and water irrigation. The RESRAD default is considered adequately representative respect to the absence of site-specific information.

The value used in the dose assessment for length of growing season of leafy vegetables is 0.25 year.

Length of growing season for fodder (y)

This is the exposure time of the livestock plant food to contamination during the growing season. The contaminants can get to the edible portion of the plant food through foliar deposition, root uptake and water irrigation.[49]

The value used in the dose assessment for length of growing season of fodder is 0.38 year.

Translocation factor for non-leafy (dimensionless)

This is the contaminant non-leafy foliage-to-food transfer coefficient. A fraction of the contaminant that retains on the foliage of the plant food will be absorbed and transferred to the edible portion of the plant food. The RESRAD default is considered adequately representative respect to the absence of site-specific information.

The value used in the dose assessment for translocation factor for non-leafy is 0.1.

Translocation factor for leafy (dimensionless)

This is the contaminant leafy foliage-to-food transfer coefficient. A fraction of the contaminant that retains on the foliage of the plant food will be absorbed and transferred to the edible portion of the plant food. The RESRAD default is considered adequately representative respect to the absence of site-specific information.

The value used in the dose assessment for translocation factor for leafy is 1.

Translocation factor for fodder (dimensionless)

This is the contaminant fodder foliage-to-food transfer coefficient. A fraction of the contaminant that retains on the foliage of fodder will be absorbed and transferred to the edible portion of the plant food. The RESRAD default is considered adequately representative respect to the absence of site-specific information.

The value used in the dose assessment for translocation factor for fodder is 1.

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[49] Letter from Billy B. Tucker, Extension Agronomist, Emeritus, Oklahoma State University, to Scott C. Munson, Sequoyah Fuels Corporation, August 14, 2004.

Weathering removal constant for vegetation (dimensionless)

The weathering process removes contaminants from foliage of the plant food. This process is characterized by a removal constant that accounts for reduction of the amount of contaminants on foliage during the exposure period. A most-likely value is chosen from RESRAD guidance for this parameter.[50]

The value used in the dose assessment for weathering removal constant for vegetation is 18.

Wet foliar interception fraction for non-leafy (dimensionless)

This is the fraction of contaminant deposited by irrigation water that retains on the foliage of non-leafy plant food. The RESRAD default is considered adequately representative respect to the absence of site-specific information.

The value used in the dose assessment for wet interception fraction for non-leafy is 0.25.

Wet foliar interception fraction for leafy (dimensionless)

This is the fraction of contaminant deposited by irrigation water that retains on the foliage of leafy plant food. A most-likely value is chosen from RESRAD guidance for this parameter.[51]

The value used in the dose assessment for wet interception fraction for leafy is 0.67.

Wet foliar interception fraction for fodder (dimensionless)

This is the fraction of contaminant deposited by irrigation water that retains on the foliage of fodder. The RESRAD default is considered adequately representative respect to the absence of site-specific information.

The value used in the dose assessment for wet interception fraction for fodder is 0.25.

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[50] U.S. Nuclear Regulatory Commission. Development of Probabilistic RESRAD 6.0 and RESRAD-BUILD 3.0 Computer Codes. Washington, D.C.: U.S. Nuclear Regulatory Commission. NUREG/CR-6697. December 2000. (Attachment C, Section 6.6)

[51] U.S. Nuclear Regulatory Commission. Development of Probabilistic RESRAD 6.0 and RESRAD-BUILD 3.0 Computer Codes. Washington, D.C.: U.S. Nuclear Regulatory Commission. NUREG/CR-6697. December 2000. (Attachment C, Section 6.7)

Dry foliar interception fraction for non-leafy (dimensionless)

This is the fraction of contaminant deposited by airborne particulate that retains on the foliage of non-leafy plant food. The RESRAD default is considered adequately representative respect to the absence of site-specific information.

The value used in the dose assessment for dry interception fraction for non-leafy is 0.25.

Dry foliar interception fraction for leafy (dimensionless)

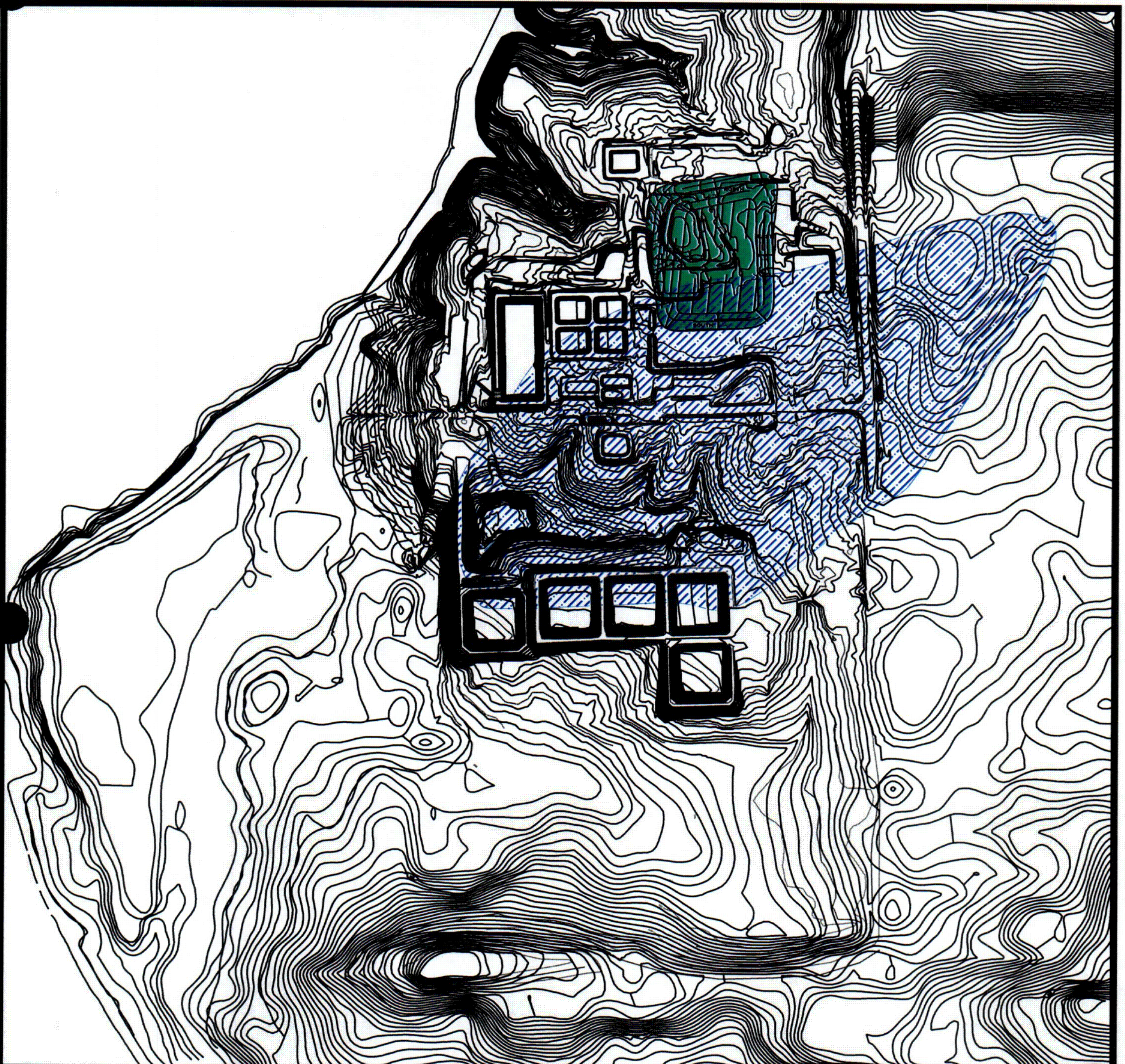
This is the fraction of contaminant deposited by airborne particulate that retains on the foliage of leafy plant food. The RESRAD default is considered adequately representative respect to the absence of site-specific information.

The value used in the dose assessment for dry interception fraction for leafy is 0.25.

Dry foliar interception fraction for fodder (dimensionless)

This is the fraction of contaminant deposited by airborne particulate that retains on the foliage of fodder. The RESRAD default is considered adequately representative respect to the absence of site-specific information.

The value used in the dose assessment for dry interception fraction for fodder is 0.25.



Cell Footprint

Watershed Area

Sequoyah Fuels Corporation
Reclamation Plan

Title: **Watershed Area for Nearby Stream or Pond**	
Prepared By: **SFC**	File Name: **NRC00029B**
Reviewed By: **RHM**	
Date: **01/10/06**	**Figure No. G-6**

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Attachment 4

ALARA Evaluation of DCGLs

ALARA EVALUATION OF DCGLs

SFC used the radium benchmark dose approach to derive concentration guideline levels (DCGLs) for remediation of contaminated soil. SFC subsequently selected cleanup levels (CL) for natural uranium and Th-230 well below the DCGLs. In effect, the dose from uranium if left at the CL is only 20% of the radium benchmark dose, and the dose from Th-230 would be 25% of the radium benchmark dose at the outset and limited to the benchmark dose value at its peak. In addition, the cleanup levels for all three radionuclides will be applied with no background subtracted further driving down the concentrations in soil at the Facility after cleanup. (See the Reclamation Plan at Section 3.2.2).

NRC procedures for review of decommissioning land areas provide an approach for evaluating soil cleanup against the ALARA principle (NUREG-1620 Section 5.2.2 (3)). The approach recognizes that compliance with the ALARA requirement at the end of decommissioning can be demonstrated by satisfying the predetermined concentration guidelines. If the licensee's final survey results meet the self-imposed concentration limits, the licensee has met the ALARA requirement (NUREG-1727 Section 7, ALARA Analysis, Evaluation Findings, Evaluation Criteria). The approach provides a calculation to determine whether it is feasible to further reduce the levels of residual radioactivity to levels below those necessary to meet the benchmark dose limit (NUREG-1727 Appendix D). That calculation with inputs taken from the SFC reclamation plan is provided as Figure 1 of this attachment. As shown by that calculation, any reduction below the CL cannot be justified on the ALARA principle.

Finally, SFC has made contact with the Department of Energy (DOE) regarding transfer of the site. The DOE has indicated a willingness to take title to the Sequoyah Facility.[1]

Thus, remediating to the cleanup levels proposed without subtracting natural background certainly satisfies the ALARA requirement. Institutional control of the site will further reduce any potential doses that might result from unauthorized activities on the site after reclamation.

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[1] Letter from Jessie Hill Roberson, Assistant Secretary for Environmental Management, department of Energy, to Mr. John H. Ellis, President, Sequoyah Fuels Corporation, dated June 5, 2003.

Figure 1

ALARA Calculation for Soil Cleanup Levels

$$\frac{Conc}{CL} = \frac{Cost_T}{\$2000 \times P_D \times 0.01 \times F \times A} \times \frac{r+\lambda}{1-e^{-(r+\lambda)N}}$$

Inputs and Assumptions:

$Cost_T$ = Total cost of remedial action: $1,429,787.

- $Cost_R$ – $1,418,000 (Rec Plan, Table 7-1, Item 7.
- $Cost_{WD}$ – The cost of waste disposal (placement of soil in onsite disposal cell) is included in the cost of remediation, $Cost_R$.
- $Cost_{Acc}$ – $11,787; remediation as described for $Cost_R$, 4.2 x 10^{-8} accident/h, and $3,000,000 per fatality (NUREG-1727, Table D.2).
- $Cost_{TF}$ – There will be no increase in the chance for traffic fatalities due to the fact that there will be no offsite shipments of waste material.
- $Cost_{WDose}$ – The cost of worker dose is not included.
- $Cost_{PDose}$ – There will be no change in public dose for this alternative since there is no offsite shipment of radioactive materials.
- $Cost_{Other}$ – No other cost impacts are anticipated for this alternative.

$2000 = Value in dollars of a person-rem.

P_D = Population density for the critical group scenario in people/m^2; 0.0004 person/m^2. (NUREG-1727, Table D.2)

f = Annual dose to an average member of the critical group from residual radioactivity at the cleanup level (rem); i.e. fraction of the benchmark dose attributed to cleanup level = $\frac{CL(pCi/g)}{DCGL(pCi/g)} \times 0.057$ *rem/y*.

F = Fraction of the residual radioactivity removed by the remediation action. All residual activity is assumed remediated to the DCGL.

A = Area being evaluated in square meters (m^2); the area of the benchmark dose calculation. (Rec Plan, Appendix G)

r = Monetary discount rate in units of yr^{-1}; 0.03/y. (NUREG-1727, Table D.2)

λ = Radiological decay constant for the radionuclide in units of yr^{-1}; input of zero since this parameter is overwhelmed by the monetary discount rate for each radionuclide of concern.

N = Number of years over which the collective dose will be calculated; the design period of 1000 years. (NUREG-1727, Table D.2)

Conc = The average concentration of residual radioactivity in the area that will be considered ALARA.

CL = The Cleanup Level for contaminated soil (Reclamation Plan, Table 3-1).

$$\frac{Conc}{CL} = \frac{\$1{,}429{,}787}{\$2000 \times (4 \times 10^{-4}) \times f \times 1 \times 263{,}120} \times \frac{0.03+0}{1-e^{-(0.03+0)1000}}$$

A ratio of one or greater indicates that the ALARA condition has been satisfied. (The ratios for U_{nat}, Th-230, and Ra-226 are 20, 17, and 3.6 respectively.)

Attachment 5

SENSITIVITY ANALYSES

RESIDENT FARMER SCENARIO
Evaluation of DCGLs

DRAINAGE 005 SCENARIO
Evaluation of annual dose

INDUSTRIAL WORKER SCENARIO
Evaluation of annual dose

SENSITIVITY ANALYSES

Introduction

To ensure that the results of the DCGL development and the dose assessments described in Appendix G reasonably estimate potential dose, the analyses used likely scenarios and conceptual model. As well, realistic estimates of values were used for key parameters. Sensitivity analyses were subsequently completed for which the primary objective was to identify input parameters that were major contributors to variation in the calculated doses.

The sensitivity analyses were of a deterministic technique; i.e. the change in the output result of peak dose was determined with respect to a change in the independent input parameters. The sensitivity analyses were performed after completing the RESRAD calculations used to determine the DCGLs. The sensitivity analyses were performed by taking each parameter and repeating the RESRAD calculation with the parameter under test set at two previously chosen extremes. Only one parameter is varied at a time. The results of the sensitivity analyses for the three dose assessment scenarios described in Appendix G are discussed in the following sections. The input parameters analyzed, the two extremes analyzed for the respective parameter, and the effect on the peak dose are described in tables 1 through 9 for the three dose assessment scenarios described in Appendix G.

Resident Farmer Scenario

The sensitivity analysis of the resident farmer scenario was completed independently for each of the three radionuclides U-natural, Th-230, and Ra-226.

The RESRAD parameters available for input to evaluate the resident farmer scenario are listed in Table 1. The parameters evaluated in the sensitivity analysis are marked accordingly in Table 1.

Table 1

PARAMETERS OF RESIDENT FARMER SCENARIO AVAILABLE FOR SENSITIVITY ANALYSIS

PARAMETER CATEGORY	PARAMETER DESCRIPTION	SENSITIVITY ANALYSIS PERFORMED
Soil Concentrations	Transport Distribution coefficient: contaminated zone	
	Transport Distribution coefficient: unsaturated zone	
	Transport Distribution coefficient: saturated zone	
	Transport Solubility Limit	
	Transport Leach Rate	
Contaminated Zone	Area of contaminated zone	
	Thickness of contaminated zone	√
	Length parallel to aquifer flow	√
Cover and Contaminated Zone Hydrological Data	Cover depth	
	Density of contaminated zone	√
	Contaminated zone erosion rate	√
	Contaminated zone total porosity	√
	Contaminated zone field capacity	√
	Contaminated zone hydraulic conductivity	√
	Contaminated zone b parameter	√
	Evapotranspiration coefficient	√
	Wind speed	√
	Precipitation	√
	Irrigation	√
	Runoff coefficient	√
	Watershed area for nearby stream or pond	
	Accuracy for soil/water computations	
Saturated Zone Hydrological Data	Density of saturated zone	√
	Saturated zone total porosity	√
	Saturated zone effective porosity	√
	Saturated zone field capacity	√
	Saturated zone hydraulic conductivity	√
	Saturated zone hydraulic gradient	√
	Water table drop rate	
	Well pump intake depth	√
	Well pumping rate	√

Table 1 (continued)

PARAMETERS OF RESIDENT FARMER SCENARIO AVAILABLE FOR SENSITIVITY ANALYSIS

PARAMETER CATEGORY	PARAMETER DESCRIPTION	SENSITIVITY ANALYSIS PERFORMED
Uncontaminated Unsaturated Zone Parameters	Unsaturated Zone Thickness	
	Unsaturated Zone Density	
	Unsaturated Zone Total Porosity	
	Unsaturated Zone Effective Porosity	
	Unsaturated Zone Field Capacity	
	Unsaturated Zone Hydraulic Conductivity	
	Unsaturated Zone b Parameter	
Occupancy, Inhalation, And External Gamma Data	Inhalation rate	√
	Mass loading for inhalation	√
	Exposure duration	
	Indoor dust filtration factor	√
	External gamma shielding factor	√
	Indoor time fraction	√
	Outdoor time fraction	√
Ingestion Pathway, Dietary Data	Fruit, vegetable, and grain consumption	√
	Leafy vegetable consumption	√
	Meat and poultry consumption	√
	Soil ingestion	√
	Contaminated fraction Livestock water	
	Contaminated fraction Irrigation water	
	Contaminated fraction Plant food	√
	Contaminated fraction Meat	√
Ingestion Pathway, Nondietary Data	Livestock fodder intake for meat	√
	Livestock water intake for meat	√
	Livestock intake of soil	√

Table 1 (continued)

PARAMETERS OF RESIDENT FARMER SCENARIO AVAILABLE FOR SENSITIVITY ANALYSIS

PARAMETER CATEGORY	PARAMETER DESCRIPTION	SENSITIVITY ANALYSIS PERFORMED
Ingestion Pathway, Nondietary Data (cont.)	Mass loading for foliar deposition	√
	Depth of soil mixing layer	√
	Depth of roots	√
	Groundwater Fractional Usage Livestock Water	
	Groundwater Fractional Usage Irrigation Water	
Storage Times Before Use Data	Fruits, non-leafy vegetables, and grain	
	Leafy vegetables	
	Milk	
	Meat	
	Fish	
	Crustacea and mollusks	
	Well water	
	Surface water	
	Livestock fodder	
Carbon-14 Data	{ Not applicable. }	

Several parameters, although available to the RESRAD sensitivity analysis, were not evaluated. Each such parameter and the reason it was not evaluated is included in Table 2.

Table 2

Parameters of Resident Farmer Scenario Available for Sensitivity Analysis but not Evaluated

Transport Distribution Coefficient:	The scenario included the condition of assuming the lowest distribution coefficient determined for the area of contaminated zone applied to the entire area of contaminated zone.
Transport Solubility Limit:	This parameter was not used by RESRAD since a distribution coefficient was provided.
Transport Leach Rate:	This parameter was not used by RESRAD since a distribution coefficient was provided.
Area of contaminated zone:	The scenario used an actual value for this parameter.
Cover depth:	The dose assessment included the actual condition that no cover will be applied.
Watershed area ...	The dose assessment included the actual value for this parameter.
Accuracy ... computations:	A sufficient value for accuracy was chosen.
Water table drop rate:	The dose assessment included the assumption that the groundwater system is unconfined.
Unsaturated zone parameters:	These parameters affect only the time until exposure and not the degree of exposure under the given exposure scenario.
Exposure duration:	This parameter is not applicable since the model result is evaluated as peak dose and not total dose or risk.
Contaminated fraction Livestock water:	The model input for this parameter is 1, which is the likely condition.

Table 2 (continued)

Parameters of Resident Farmer Scenario Available for Sensitivity Analysis but not Evaluated

Contaminated fraction Irrigation water:	The model input for this parameter is 1 which is the maximum or conservative assumption.
Groundwater fractional Usage Livestock Water:	Changing the value of this parameter from zero would contradict the condition that groundwater is not an exposure pathway as a volumetric source of water.
Groundwater fractional Usage Irrigation Water:	Changing the value of this parameter from zero would contradict the condition that groundwater is not an exposure pathway as a volumetric source of water.
Storage Times Before Use:	These parameters are not applicable since the radionuclides of interest do not appreciably transform during the modeled time period.
Carbon-14:	Carbon-14 is not a radionuclide of interest in the subject dose assessment.

Several parameters were not available to the sensitivity analysis provided by the RESRAD software: they were either turned off by the software based on the active exposure pathways (e.g. "Density of cover material"; there is no cover in the model), or the software did not allow a sensitivity analysis of the parameter (e.g. "Plant Factors Wet weight crop yield"). The parameters not available to the RESRAD sensitivity analysis are listed in Table 3.

Table 3

Parameters of Resident Farmer Scenario not available for Sensitivity Analysis

PARAMETER CATEGORY	PARAMETER DESCRIPTION
Soil Concentrations	Transport Time since material placement
	Transport Groundwater concentration
Calculation Parameters	Basic Radiation Dose Limit
	Times for Calculation
Cover and Contaminated Zone Hydrological Data	Density of cover material
	Cover erosion rate
	Humidity in air
	Irrigation mode
Saturated Zone Hydrological Data	Saturated zone b parameter
	Model for Water Transport Parameters
Occupancy, Inhalation, And External Gamma Data	Shape of the contaminated zone
Ingestion Pathway, Dietary Data	Milk consumption
	Fish consumption
	Other sea food consumption
	Drinking water intake
	Contaminated fraction Drinking water
	Contaminated fraction Household water
	Contaminated fraction Aquatic Food
	Contaminated fraction Milk
Ingestion Pathway, Nondietary Data	Livestock fodder intake for milk
	Livestock water intake for milk
	Groundwater Fractional Usage Drinking water
	Groundwater Fractional Usage Household water
	Plant Factors Wet weight crop yield
	Plant Factors Length of growing season
	Plant Factors Translocation factor
	Plant Factors Weathering removal constant
	Plant Factors Wet foliar interception fraction
	Plant Factors Dry foliar interception fraction
Radon	{ All }

The results of the sensitivity analysis completed for each of the three radionuclides of interest are summarized in tables 4, 5, and 6. The basis for the range over which the sensitivity analyses were completed is described in Table 7.

Table 4
Summary of Sensitivity Analysis for Resident Farmer Scenario
U-natural = DCGL (570 pCi/g)

DOSE ASSESSMENT PARAMETER	VALUE OF PARAMETER LOW	MODEL	HIGH
Transport Distribution coefficient of contaminated zone, cm^3/g (uranium)		572	---
Maximum Dose, mrem/y	---	57	---
Area of contaminated zone, m^2	---	263120	---
Maximum Dose, mrem/y	---	57	---
Thickness of contaminated zone, m	0.15	0.3	0.6
Maximum Dose, mrem/y	47	57	57
Length parallel to aquifer flow, m	441	662	993
Maximum Dose, mrem/y	57	57	57
Density of contaminated zone, g/cm^3	1.17	1.76	2.64
Maximum Dose, mrem/y	57	57	57
Contaminated zone erosion rate, m/y	0.00006	0.0006	0.006
Maximum Dose, mrem/y	57	57	57
Contaminated zone total porosity, dimensionless	0.09	0.30	1
Maximum Dose, mrem/y	57	57	57
Contaminated zone field capacity, dimensionless	0.04	0.20	1
Maximum Dose, mrem/y	57	57	57
Contaminated zone hydraulic conductivity, m/y	4.45	8.9	17.8
Maximum Dose, mrem/y	57	57	57
Contaminated zone b parameter, dimensionless	0.6	3	15
Maximum Dose, mrem/y	57	57	57
Evapotranspiration coefficient, dimensionless	0.33	0.5	0.75
Maximum Dose, mrem/y	57	57	57
Wind Speed, m/s	2.67	4	6
Maximum Dose, mrem/y	64	57	54
Precipitation, m/y	0.73	1.1	1.65
Maximum Dose, mrem/y	57	57	57
Irrigation, m/y	0.3	0.6	1.2
Maximum Dose, mrem/y	57	57	57
Runoff coefficient, dimensionless	0.2	0.4	0.8
Maximum Dose, mrem/y	57	57	57

Table 4 (continued)
Summary of Sensitivity Analysis for Resident Farmer Scenario
U-natural = DCGL (570 pCi/g)

DOSE ASSESSMENT PARAMETER	VALUE OF PARAMETER LOW	MODEL	HIGH
Watershed area for nearby stream or pond, m^2	---	575000	---
Maximum Dose, mrem/y	---	57	---
Density of saturated zone, g/m^3	1.79	2.69	4.04
Maximum Dose, mrem/y	57	57	57
Saturated zone total porosity, dimensionless	0.16	0.4	1
Maximum Dose, mrem/y	57	57	57
Saturated zone effective porosity, dimensionless	0.01	0.10	1
Maximum Dose, mrem/y	57	57	57
Saturated zone field capacity, dimensionless	0.04	0.20	1
Maximum Dose, mrem/y	57	57	57
Saturated zone hydraulic conductivity, m/y	44.5	89	178
Maximum Dose, mrem/y	57	57	57
Saturated zone hydraulic gradient, dimensionless	0.04	0.08	0.16
Maximum Dose, mrem/y	57	57	57
Unsaturated zone 1 thickness, m	---	1.4	---
Maximum Dose, mrem/y	---	57	---
Inhalation rate, m^3/y	5383	8400	13104
Maximum Dose, mrem/y	53	57	62
Mass loading for inhalation, g/m^3	0.00004	0.0002	0.001
Maximum Dose, mrem/y	49	57	96
Indoor dust filtration factor, dimensionless	0.33	0.56	1
Maximum Dose, mrem/y	56	57	58
External gamma shielding factor, dimensionless	0.05	0.21	0.81
Maximum Dose, mrem/y	55	57	64
Indoor time fraction, dimensionless	0.17	0.25	0.38
Maximum Dose, mrem/y	55	57	60
Outdoor time fraction, dimensionless	0.33	0.5	0.75
Maximum Dose, mrem/y	45	57	75

Table 4 (continued)
Summary of Sensitivity Analysis for Resident Farmer Scenario
U-natural = DCGL (570 pCi/g)

DOSE ASSESSMENT PARAMETER	VALUE OF PARAMETER LOW	MODEL	HIGH
Fruit, vegetable, and grain consumption, kg/y	148	178	214
Maximum Dose, mrem/y	55	57	59
Leafy vegetable consumption, kg/y	12.5	25	50
Maximum Dose, mrem/y	56	57	59
Meat and poultry consumption, kg/y	31.5	63	126
Maximum Dose, mrem/y	57	57	57
Soil ingestion, g/y	9.15	18.3	36.6
Maximum Dose, mrem/y	56	57	59
Contaminated fraction Plant food	0.1	0.2	0.4
Maximum Dose, mrem/y	49	57	73
Contaminated fraction Meat	0.1	0.2	0.4
Maximum Dose, mrem/y	57	57	57
Livestock fodder intake for meat, kg/d	34	68	136
Maximum Dose, mrem/y	57	57	57
Livestock water intake for meat, L/d	25	50	57
Maximum Dose, mrem/y	57	57	57
Livestock intake of soil, kg/d	0.25	0.5	1
Maximum Dose, mrem/y	57	57	57
Mass loading for foliar deposition, g/m^3	0.00001	0.0001	0.001
Maximum Dose, mrem/y	57	57	57
Depth of soil mixing layer, m	0.04	0.15	0.6
Maximum Dose, mrem/y	57	57	47
Depth of roots, m	---	0.3	3.9
Maximum Dose, mrem/y	---	57	45

Table 5
Summary of Sensitivity Analysis for Resident Farmer Scenario
Th-230 = DCGL (66 pCi/g)

DOSE ASSESSMENT PARAMETER	VALUE OF PARAMETER LOW	MODEL	HIGH
Transport Distribution coefficient of all zones, cm^3/g	---	5884	---
Maximum Dose, mrem/y	---	57	---
Area of contaminated zone, m^2	---	263120	---
Maximum Dose, mrem/y	---	57	---
Thickness of contaminated zone, m	0.15	0.3	0.6
Maximum Dose, mrem/y	20	57	146
Length parallel to aquifer flow, m	441	662	993
Maximum Dose, mrem/y	57	57	57
Density of contaminated zone, g/cm^3	1.17	1.76	2.64
Maximum Dose, mrem/y	49	57	63
Contaminated zone erosion rate, m/y	0.00006	0.0006	0.006
Maximum Dose, mrem/y	185	57	9
Contaminated zone total porosity, dimensionless	0.09	0.30	1
Maximum Dose, mrem/y	57	57	57
Contaminated zone field capacity, dimensionless	0.04	0.20	1
Maximum Dose, mrem/y	57	57	57
Contaminated zone hydraulic conductivity, m/y	4.45	8.9	17.8
Maximum Dose, mrem/y	57	57	57
Contaminated zone b parameter, dimensionless	0.6	3	15
Maximum Dose, mrem/y	57	57	57
Evapotranspiration coefficient, dimensionless	0.33	0.5	.75
Maximum Dose, mrem/y	55	57	54
Wind Speed, m/s	2.67	4	6
Maximum Dose, mrem/y	58	57	55
Precipitation, m/y	0.73	1.1	1.65
Maximum Dose, mrem/y	58	57	56
Irrigation, m/y	0.3	0.6	1.2
Maximum Dose, mrem/y	58	57	55
Runoff coefficient, dimensionless	0.2	0.4	0.8
Maximum Dose, mrem/y	56	57	58

Table 5 (continued)
Summary of Sensitivity Analysis for Resident Farmer Scenario
Th-230 = DCGL (66 pCi/g)

DOSE ASSESSMENT PARAMETER	VALUE OF PARAMETER LOW	MODEL	HIGH
Watershed area for nearby stream or pond, m^2	---	575000	---
Maximum Dose, mrem/y	---	57	---
Density of saturated zone, g/m^3	1.79	2.69	4.04
Maximum Dose, mrem/y	57	57	57
Saturated zone total porosity, dimensionless	0.16	0.4	1
Maximum Dose, mrem/y	57	57	57
Saturated zone effective porosity, dimensionless	0.01	0.10	1
Maximum Dose, mrem/y	57	57	57
Saturated zone field capacity, dimensionless	0.04	0.20	1
Maximum Dose, mrem/y	57	57	57
Saturated zone hydraulic conductivity, m/y	44.5	89	178
Maximum Dose, mrem/y	57	57	57
Saturated zone hydraulic gradient, dimensionless	0.04	0.08	0.16
Maximum Dose, mrem/y	57	57	57
Unsaturated zone 1 thickness, m	---	1.4	---
Maximum Dose, mrem/y	---	57	---
Inhalation rate, m^3/y	5383	8400	13104
Maximum Dose, mrem/y	56	57	58
Mass loading for inhalation, g/m^3	0.00004	0.0002	0.001
Maximum Dose, mrem/y	54	57	60
Indoor dust filtration factor, dimensionless	0.33	0.56	1
Maximum Dose, mrem/y	57	57	57
External gamma shielding factor, dimensionless	0.05	0.21	0.81
Maximum Dose, mrem/y	54	57	67
Indoor time fraction, dimensionless	0.17	0.25	0.38
Maximum Dose, mrem/y	55	57	59
Outdoor time fraction, dimensionless	0.33	0.5	0.75
Maximum Dose, mrem/y	45	57	76

Table 5 (continued)
Summary of Sensitivity Analysis for Resident Farmer Scenario
Th-230 = DCGL (66 pCi/g)

DOSE ASSESSMENT PARAMETER	VALUE OF PARAMETER LOW	MODEL	HIGH
Fruit, vegetable, and grain consumption, kg/y	148	178	214
Maximum Dose, mrem/y	55	57	59
Leafy vegetable consumption, kg/y	12.5	25	50
Maximum Dose, mrem/y	56	57	59
Meat and poultry consumption, kg/y	31.5	63	126
Maximum Dose, mrem/y	56	57	59
Soil ingestion, g/y	9.15	18.3	36.6
Maximum Dose, mrem/y	56	57	58
Contamination fraction Plant food	0.1	0.2	0.4
Maximum Dose, mrem/y	50	57	72
Contamination fraction Meat	0.1	0.2	0.4
Maximum Dose, mrem/y	57	57	57
Livestock fodder intake for meat, kg/d	34	68	136
Maximum Dose, mrem/y	57	57	57
Livestock water intake for meat, L/d	25	50	57
Maximum Dose, mrem/y	57	57	57
Livestock intake of soil, kg/d	0.25	0.5	1
Maximum Dose, mrem/y	57	57	57
Mass loading for foliar deposition, g/m^3	0.00001	0.0001	0.001
Maximum Dose, mrem/y	57	57	57
Depth of soil mixing layer, m	0.04	0.15	0.6
Maximum Dose, mrem/y	58	57	54
Depth of roots, m	---	0.3	3.9
Maximum Dose, mrem/y	---	57	43

Table 6
Summary of Sensitivity Analysis for Resident Farmer Scenario
Ra-226 = DCGL (5.0 pCi/g)

DOSE ASSESSMENT PARAMETER	VALUE OF PARAMETER LOW	MODEL	HIGH
Transport Distribution coefficient of all zones, cm^3/g	353.3	3553	35330
Maximum Dose, mrem/y	57	57	57
Area of contaminated zone, m^2	---	263120	---
Maximum Dose, mrem/y	---	57	---
Thickness of contaminated zone, m	0.15	0.3	0.6
Maximum Dose, mrem/y	41	57	57
Length parallel to aquifer flow, m	441	662	993
Maximum Dose, mrem/y	57	57	57
Density of contaminated zone, g/cm^3	1.17	1.76	2.64
Maximum Dose, mrem/y	56	57	57
Contaminated zone erosion rate, m/y	0.00006	0.0006	0.006
Maximum Dose, mrem/y	57	57	57
Contaminated zone total porosity, dimensionless	0.09	0.30	1
Maximum Dose, mrem/y	57	57	57
Contaminated zone field capacity, dimensionless	0.04	0.20	1
Maximum Dose, mrem/y	57	57	57
Contaminated zone hydraulic conductivity, m/y	4.45	8.9	17.8
Maximum Dose, mrem/y	57	57	57
Contaminated zone b parameter, dimensionless	0.6	3	15
Maximum Dose, mrem/y	57	57	57
Evapotranspiration coefficient, dimensionless	0.33	0.5	.75
Maximum Dose, mrem/y	57	57	57
Wind Speed, m/s	2.67	4	6
Maximum Dose, mrem/y	57	57	57
Precipitation, m/y	0.73	1.1	1.65
Maximum Dose, mrem/y	57	57	57
Irrigation, m/y	0.3	0.6	1.2
Maximum Dose, mrem/y	57	57	57
Runoff coefficient, dimensionless	0.2	0.4	0.8
Maximum Dose, mrem/y	57	57	57

Table 6 (continued)
Summary of Sensitivity Analysis for Resident Farmer Scenario
Ra-226 = DCGL (5.0 pCi/g)

DOSE ASSESSMENT PARAMETER	VALUE OF PARAMETER LOW	MODEL	HIGH
Watershed area for nearby stream or pond, m^2	---	575000	---
Maximum Dose, mrem/y	---	57	---
Density of saturated zone, g/m^3	1.79	2.69	4.04
Maximum Dose, mrem/y	57	57	57
Saturated zone total porosity, dimensionless	0.16	0.4	1
Maximum Dose, mrem/y	57	57	57
Saturated zone effective porosity, dimensionless	0.01	0.10	1
Maximum Dose, mrem/y	57	57	57
Saturated zone field capacity, dimensionless	0.04	0.20	1
Maximum Dose, mrem/y	57	57	57
Saturated zone hydraulic conductivity, m/y	44.5	89	178
Maximum Dose, mrem/y	57	57	57
Saturated zone hydraulic gradient, dimensionless	0.04	0.08	0.16
Maximum Dose, mrem/y	57	57	57
Unsaturated zone 1 thickness, m	---	1.4	---
Maximum Dose, mrem/y	---	57	---
Inhalation rate, m^3/y	5383	8400	13104
Maximum Dose, mrem/y	57	57	57
Mass loading for inhalation, g/m^3	0.00004	0.0002	0.001
Maximum Dose, mrem/y	57	57	57
Indoor dust filtration factor, dimensionless	0.33	0.56	1
Maximum Dose, mrem/y	57	57	57
External gamma shielding factor, dimensionless	0.05	0.21	0.81
Maximum Dose, mrem/y	55	57	66
Indoor time fraction, dimensionless	0.17	0.25	0.38
Maximum Dose, mrem/y	56	57	59
Outdoor time fraction, dimensionless	0.33	0.5	0.75
Maximum Dose, mrem/y	48	57	71

Table 6 (continued)
Summary of Sensitivity Analysis for Resident Farmer Scenario
Ra-226 = DCGL (5.0 pCi/g)

DOSE ASSESSMENT PARAMETER	VALUE OF PARAMETER LOW	MODEL	HIGH
Fruit, vegetable, and grain consumption, kg/y	148	178	214
Maximum Dose, mrem/y	53	57	62
Leafy vegetable consumption, kg/y	12.5	25	50
Maximum Dose, mrem/y	56	57	60
Meat and poultry consumption, kg/y	31.5	63	126
Maximum Dose, mrem/y	57	57	58
Soil ingestion, g/y	9.15	18.3	36.6
Maximum Dose, mrem/y	57	57	58
Contaminated fraction Plant food	0.1	0.2	0.4
Maximum Dose, mrem/y	44	57	83
Contaminated fraction Meat	0.1	0.2	0.4
Maximum Dose, mrem/y	57	57	58
Livestock fodder intake for meat, kg/d	34	68	136
Maximum Dose, mrem/y	57	57	57
Livestock water intake for meat, L/d	25	50	54
Maximum Dose, mrem/y	57	57	57
Livestock intake of soil, kg/d	0.25	0.5	1
Maximum Dose, mrem/y	57	57	105
Mass loading for foliar deposition, g/m^3	0.00001	0.0001	0.001
Maximum Dose, mrem/y	57	57	57
Depth of soil mixing layer, m	0.04	0.15	0.6
Maximum Dose, mrem/y	57	57	57
Depth of roots, m	---	0.3	3.9
Maximum Dose, mrem/y	---	57	33

Table 7
Value and Basis of Multiplier for Sensitivity Analysis Range

DOSE ASSESSMENT PARAMETER	VALUE OF PARAMETER MODEL	MULTIPLIER
Transport Distribution coefficient of all zones, cm^3/g (uranium)	500 / 33.575	N/A
Basis for value of multiplier	This is the low end of a site-specific range	
Area of contaminated zone, m^2	263120	N/A
Basis for value of multiplier	This is the 65 acre contaminated area.	
Thickness of contaminated zone, m	0.3	2
Basis for value of multiplier	A lower bound of model.	
Length parallel to aquifer flow, m	662	1.5
Basis for value of multiplier	An upper bound based on size of the site.	
Density of contaminated zone, g/cm^3	1.76	1.5
Basis for value of multiplier	A maximum expected variation.	
Contaminated zone erosion rate, m/y	0.0006	10
Basis for value of multiplier	Arbitrary as an order of magnitude.	
Contaminated zone total porosity, dimensionless	0.3	3.3
Basis for value of multiplier	A maximum possible variation.	
Contaminated zone field capacity, dimensionless	0.20	5
Basis for value of multiplier	A maximum possible variation.	
Contaminated zone hydraulic conductivity, m/y	8.9	2
Basis for value of multiplier	A maximum expected variation.	
Contaminated zone b parameter, dimensionless	3	5
Basis for value of multiplier	Reflects an upper limit of RESRAD.	
Evapotranspiration coefficient, dimensionless	0.5	1.5
Basis for value of multiplier	A maximum expected variation.[1]	
Wind Speed, m/s	4	1.5
Basis for value of multiplier	A maximum expected variation.	
Precipitation, m/y	1.1	1.5
Basis for value of multiplier	A maximum expected variation.	
Irrigation, m/y	0.6	2
Basis for value of multiplier	An upper bound reflecting arid conditions.[2]	
Runoff coefficient, dimensionless	0.4	2
Basis for value of multiplier	A maximum expected variation.[1]	

Table 7 (continued)
Value and Basis of Multiplier for Sensitivity Analysis Range

DOSE ASSESSMENT PARAMETER	VALUE OF PARAMETER MODEL	MULTIPLIER
Watershed area for nearby stream or pond, m^2	575000	N/A
Basis for value of multiplier	This is the actual size of the watershed.	
Density of saturated zone, g/m^3	2.69	1.5
Basis for value of multiplier	A maximum expected variation.	
Saturated zone total porosity, dimensionless	0.4	2.5
Basis for value of multiplier	A maximum possible variation.	
Saturated zone effective porosity, dimensionless	0.1	10
Basis for value of multiplier	A maximum possible variation.	
Saturated zone field capacity, dimensionless	0.20	5
Basis for value of multiplier	A maximum possible variation.	
Saturated zone hydraulic conductivity, m/y	89	2
Basis for value of multiplier	A maximum expected variation.	
Saturated zone hydraulic gradient, dimensionless	0.08	2
Basis for value of multiplier	A maximum expected variation.	
Unsaturated zone 1 thickness, m	3	2
Basis for value of multiplier	A maximum expected variation.	
Inhalation rate, m^3/y	8400	1.56
Basis for value of multiplier	A maximum expected variation.[1]	
Mass loading for inhalation, g/m^3	0.0002	5
Basis for value of multiplier	A maximum expected variation.[2]	
Indoor dust filtration factor, dimensionless	0.56	1.78
Basis for value of multiplier	A maximum expected variation.[1]	
External gamma shielding factor, dimensionless	0.21	3.86
Basis for value of multiplier	A maximum expected variation.[1]	
Indoor time fraction, dimensionless	0.25	1.5
Basis for value of multiplier	A maximum expected variation.	
Outdoor time fraction, dimensionless	0.50	1.5
Basis for value of multiplier	A maximum expected variation.	

Table 7 (continued)
Value and Basis of Multiplier for Sensitivity Analysis Range

DOSE ASSESSMENT PARAMETER	VALUE OF PARAMETER MODEL	MULTIPLIER
Fruit, vegetable, and grain consumption, kg/y	178	1.2
Basis for value of multiplier	A maximum expected variation.[1]	
Leafy vegetable consumption, kg/y	25	2
Basis for value of multiplier	Arbitrary.	
Meat and poultry consumption, kg/y	63	2
Basis for value of multiplier	Arbitrary.	
Soil ingestion, g/y	18.3	2
Basis for value of multiplier	A maximum expected variation.[1]	
Contaminated fraction Plant food	0.2	2
Basis for value of multiplier	A maximum expected variation.	
Contaminated fraction Meat	0.2	2
Basis for value of multiplier	A maximum expected variation.	
Livestock fodder intake for meat, kg/d	68	2
Basis for value of multiplier	Arbitrary.	
Livestock water intake for meat, L/d	50	2
Basis for value of multiplier	Arbitrary.	
Livestock intake of soil, kg/d	0.5	2
Basis for value of multiplier	Arbitrary.	
Mass loading for foliar deposition, g/m^3	0.0001	10
Basis for value of multiplier	Arbitrary as an order of magnitude.	
Depth of soil mixing layer, m	0.15	4
Basis for value of multiplier	A maximum expected variation.[1]	
Depth of roots, m	0.3	13
Basis for value of multiplier	A maximum expected variation.[1]	

[1] U.S. Nuclear Regulatory Commission. Development of Probabilistic RESRAD 6.0 and RESRAD-BUILD 3.0 Computer Codes. Washington, D.C.: U.S. Nuclear Regulatory Commission. NUREG/CR-6697. December 2000. (Attachment C)

[2] Yu, C., et.al. "Data Collection Handbook to Support Modeling the Impacts of Radioactive Material in Soil." Argonne, IL: Argonne National Laboratory. ANL/EAIS-8. April 1993.

The results of the sensitivity analysis of the resident farmer scenario, as presented in the preceding tables, are discussed in the following paragraph. The discussion is confined to those parameters of the Ra-226 benchmark dose analysis for which a reasonable change in input caused the dose to be less than the benchmark dose (57 mrem/y) by more than 25%; i.e. the dose was less than 43 mrem/y. A sensitivity analysis was not completed for the three radionuclides of interest in combination because this condition is inherently accounted for by application of the unity rule during implementation of the DCGLs.

The annual dose for radium-226 was found to be sensitive to two parameters: thickness of contaminated zone and depth of roots. The model input for thickness of contaminated zone is derived from site characterization data. The value for depth of roots is justified based on the type of crops likely grown on site. No adjustment to the scenario is warranted with respect to these parameters.

Drainage 005 Scenario

The single sensitivity analysis completed for the Drainage 005 scenario included the three radionuclides U-natural, Th-230, and Ra-226 together. The results of the sensitivity analysis are summarized in Table 8. Those parameters for which the sensitivity analysis result is labeled "Not applicable" were not available for evaluation because they were turned off by the software based on the active exposure pathways.

Table 8

Summary of Sensitivity Analysis for Drainage 005 Dose Assessment
Existing average radionuclide concentrations
(U-nat = 94 pCi/g, Th-230 = 44 pCi/g, Ra-226 = 1.4 pCi/g)

DOSE ASSESSMENT PARAMETER	VALUE OF PARAMETER LOW	MODEL	HIGH
Transport Distribution coefficient of all zones, cm^3/g	572, 588, 353	572,5884,3533	572, 58840,35330
Maximum Dose, mrem/y	0.2	0.2	0.2
Area of contaminated zone, m^2	270	540	1080
Maximum Dose, mrem/y	0.2	0.2	0.2
Thickness of contaminated zone, m	0.01	0.1	1
Maximum Dose, mrem/y	0	0.2	0.3
Length parallel to aquifer flow, m	Not applicable		
Maximum Dose, mrem/y			
Density of contaminated zone, g/cm^3	1.17	1.76	2.64
Maximum Dose, mrem/y	0.2	0.2	0.2
Contaminated zone erosion rate, m/y	0.00006	0.0006	0.006
Maximum Dose, mrem/y	0.1	0.2	0.2
Contaminated zone total porosity, dimensionless	0.09	0.2	1
Maximum Dose, mrem/y	0.2	0.2	0.2
Contaminated zone field capacity, dimensionless	0.04	0.20	1
Maximum Dose, mrem/y	0.2	0.2	0.2
Contaminated zone hydraulic conductivity, m/y	4.45	8.9	17.8
Maximum Dose, mrem/y	0.2	0.2	0.2
Contaminated zone b parameter, dimensionless	0.2	3	30
Maximum Dose, mrem/y	0.2	0.2	0.2
Evapotranspiration coefficient, dimensionless	0.23	0.5	0.75
Maximum Dose, mrem/y	0.2	0.2	0.2
Wind Speed, m/s	1.67	4	6
Maximum Dose, mrem/y	0.2	0.2	0.3
Precipitation, m/y	0.73	1.1	1.65
Maximum Dose, mrem/y	0.2	0.2	0.2
Irrigation, m/y	-----	0	1
Maximum Dose, mrem/y	-----	0.2	0.2
Runoff coefficient, dimensionless	-----	0	0.9
Maximum Dose, mrem/y	-----	0.2	0.2

Table 8 (continued)
Summary of Sensitivity Analysis for Drainage 005 Dose Assessment
Existing average radionuclide concentrations
(U-nat = 94 pCi/g, Th-230 = 44 pCi/g, Ra-226 = 1.4 pCi/g)

DOSE ASSESSMENT PARAMETER	VALUE OF PARAMETER LOW	MODEL	HIGH
Watershed area for nearby stream or pond, m^2	Not applicable		
Maximum Dose, mrem/y			
Density of saturated zone, g/m^3	1.79	2.69	4.04
Maximum Dose, mrem/y	0.2	0.2	0.2
Saturated zone total porosity, dimensionless	0.16	0.4	1
Maximum Dose, mrem/y	0.2	0.2	0.2
Saturated zone effective porosity, dimensionless	0.01	0.10	1
Maximum Dose, mrem/y	0.2	0.2	0.2
Saturated zone hydraulic conductivity, m/y	44.5	89	178
Maximum Dose, mrem/y	0.2	0.2	0.2
Saturated zone hydraulic gradient, dimensionless	0.04	0.08	0.16
Maximum Dose, mrem/y	0.2	0.2	0.2
Unsaturated Zone 1 Thickness, m	Not applicable		
Maximum Dose, mrem/y			
Inhalation rate, m^3/y	5383	8400	13104
Maximum Dose, mrem/y	0.1	0.2	0.2
Mass loading for inhalation, g/m^3	0.00004	0.0002	0.001
Maximum Dose, mrem/y	0.1	0.2	0.7
Indoor dust filtration factor, dimensionless	Not applicable		
Maximum Dose, mrem/y			
External gamma shielding factor, dimensionless	Not applicable		
Maximum Dose, mrem/y			
Indoor time fraction, dimensionless	Not applicable		
Maximum Dose, mrem/y			
Outdoor time fraction, dimensionless	0.01	0.042	0.17
Maximum Dose, mrem/y	0.1	0.2	0.7

Table 8 (continued)
Summary of Sensitivity Analysis for Drainage 005 Dose Assessment
Existing average radionuclide concentrations
(U-nat = 94 pCi/g, Th-230 = 44 pCi/g, Ra-226 = 1.4 pCi/g)

DOSE ASSESSMENT PARAMETER	VALUE OF PARAMETER LOW	MODEL	HIGH
Fruit, vegetable, and grain consumption, kg/y	Not applicable		
Maximum Dose, mrem/y			
Leafy vegetable consumption, kg/y	Not applicable		
Maximum Dose, mrem/y			
Meat and poultry consumption, kg/y	Not applicable		
Maximum Dose, mrem/y			
Soil ingestion, g/y	9.15	18.3	36.5
Maximum Dose, mrem/y	0.2	0.2	0.2
Contaminated fraction Plant food	Not applicable		
Maximum Dose, mrem/y			
Contaminated fraction Meat	Not applicable		
Maximum Dose, mrem/y			
Livestock fodder intake for meat, kg/d	Not applicable		
Maximum Dose, mrem/y			
Livestock water intake for meat, L/d	Not applicable		
Maximum Dose, mrem/y			
Livestock intake of soil, kg/d	Not applicable		
Maximum Dose, mrem/y			
Mass loading for foliar deposition, g/m^3	Not applicable		
Maximum Dose, mrem/y			
Depth of soil mixing layer, m	0.025	0.1	---
Maximum Dose, mrem/y	0.2	0.2	---
Depth of roots, m	Not applicable		
Maximum Dose, mrem/y			

The following parameters, although available to RESRAD sensitivity analysis for Drainage 005, were not evaluated:

Transport Solubility Limit:	This parameter was not used by RESRAD since a distribution coefficient was provided.
Transport Leach Rate:	This parameter was not used by RESRAD since a distribution coefficient was provided.
Cover depth:	The dose assessment included the conservative assumption that no cover will be applied.
Exposure duration:	This parameter is not applicable since the model result is evaluated as peak dose and not total dose or risk.
Carbon-14:	Carbon-14 is not a radionuclide of interest in the subject dose assessment.

Several parameters were not available to the sensitivity analysis provided by the RESRAD software: they were either turned off by the software based on the active exposure pathways (e.g. "Density of cover material"; there is no cover in the model), or the software did not allow a sensitivity analysis of the parameter (e.g. "Irrigation mode").

The results indicate the annual dose to be particularly insensitive, with respect to the difference between the annual dose and the radium benchmark dose to all parameters.

Industrial Worker Scenario

The single sensitivity analysis completed for the industrial worker scenario included the three radionuclides U-natural, Th-230, and Ra-226 together. The results of the sensitivity analysis are summarized in Table 9. Those parameters for which the sensitivity analysis result is labeled "Not applicable" were not available for evaluation because they were turned off by the software based on the active exposure pathways.

Table 9

Summary of Sensitivity Analysis for Industrial Worker Dose Assessment
U-nat = DCGL, Th-230 = DCGL, Ra-226 = DCGL
(U-nat = 570 pCi/g, Th-230 = 66 pCi/g, Ra-226 = 5.0 pCi/g)

DOSE ASSESSMENT PARAMETER	VALUE OF PARAMETER LOW	MODEL	HIGH
Transport Distribution coefficient of all zones, cm^3/g	572, 584, 353	572,5884,3533	572, 58840,35330
Maximum Dose, mrem/y	2	2	2
Area of contaminated zone, m^2	---	263120	---
Maximum Dose, mrem/y	---	2	---
Thickness of contaminated zone, m	---	2	---
Maximum Dose, mrem/y	---	2	---
Length parallel to aquifer flow, m	Not applicable		
Maximum Dose, mrem/y			
Density of contaminated zone, g/cm^3	1.17	1.76	2.64
Maximum Dose, mrem/y	2	2	2
Contaminated zone erosion rate, m/y	0.00006	0.0006	0.006
Maximum Dose, mrem/y	2	2	2
Contaminated zone total porosity, dimensionless	0.09	0.2	1
Maximum Dose, mrem/y	2	2	2
Contaminated zone field capacity, dimensionless	0.04	0.20	1
Maximum Dose, mrem/y	2	2	2
Contaminated zone hydraulic conductivity, m/y	4.45	8.9	17.8
Maximum Dose, mrem/y	2	2	2
Contaminated zone b parameter, dimensionless	0.6	3	15
Maximum Dose, mrem/y	2	2	2
Evapotranspiration coefficient, dimensionless	0.33	0.5	0.75
Maximum Dose, mrem/y	2	2	2
Wind Speed, m/s	2.67	4	6
Maximum Dose, mrem/y	2	2	2
Precipitation, m/y	0.73	1.1	1.65
Maximum Dose, mrem/y	2	2	2
Irrigation, m/y	---	0	---
Maximum Dose, mrem/y	---	2	---
Runoff coefficient, dimensionless	0.2	0.4	0.8
Maximum Dose, mrem/y	2	2	2

Table 9 (continued)
Summary of Sensitivity Analysis for Industrial Worker Dose Assessment
U-nat = DCGL, Th-230 = DCGL, Ra-226 = DCGL
(U-nat = 570 pCi/g, Th-230 = 66 pCi/g, Ra-226 = 5.0 pCi/g)

DOSE ASSESSMENT PARAMETER	VALUE OF PARAMETER LOW	MODEL	HIGH
Watershed area for nearby stream or pond, m^2	Not applicable		
Maximum Dose, mrem/y			
Density of saturated zone, g/m^3	Not applicable		
Maximum Dose, mrem/y			
Saturated zone total porosity, dimensionless	Not applicable		
Maximum Dose, mrem/y			
Saturated zone effective porosity, dimensionless	Not applicable		
Maximum Dose, mrem/y			
Saturated zone hydraulic conductivity, m/y	Not applicable		
Maximum Dose, mrem/y			
Saturated zone hydraulic gradient, dimensionless	Not applicable		
Maximum Dose, mrem/y			
Unsaturated Zone 1 Thickness, m	Not applicable		
Maximum Dose, mrem/y			
Inhalation rate, m^3/y	5383	8400	13104
Maximum Dose, mrem/y	2	2	2
Mass loading for inhalation, g/m^3	0.00004	0.0002	0.001
Maximum Dose, mrem/y	2	2	3
Indoor dust filtration factor, dimensionless	Not applicable		
Maximum Dose, mrem/y			
External gamma shielding factor, dimensionless	Not applicable		
Maximum Dose, mrem/y			
Indoor time fraction, dimensionless	Not applicable		
Maximum Dose, mrem/y			
Outdoor time fraction, dimensionless	---	0.015	0.06
Maximum Dose, mrem/y	---	2	9

Table 9 (continued)
Summary of Sensitivity Analysis for Industrial Worker Dose Assessment
U-nat = DCGL, Th-230 = DCGL, Ra-226 = DCGL
(U-nat = 570 pCi/g, Th-230 = 66 pCi/g, Ra-226 = 5.0 pCi/g)

DOSE ASSESSMENT PARAMETER	VALUE OF PARAMETER LOW	MODEL	HIGH
Fruit, vegetable, and grain consumption, kg/y	Not applicable		
Maximum Dose, mrem/y			
Leafy vegetable consumption, kg/y	Not applicable		
Maximum Dose, mrem/y			
Meat and poultry consumption, kg/y	Not applicable		
Maximum Dose, mrem/y			
Soil ingestion, g/y	9.15	18.3	36.6
Maximum Dose, mrem/y	2	2	2
Contaminated fraction Plant food	Not applicable		
Maximum Dose, mrem/y			
Contaminated fraction Meat	Not applicable		
Maximum Dose, mrem/y			
Livestock fodder intake for meat, kg/d	Not applicable		
Maximum Dose, mrem/y			
Livestock water intake for meat, L/d	Not applicable		
Maximum Dose, mrem/y			
Livestock intake of soil, kg/d	Not applicable		
Maximum Dose, mrem/y			
Mass loading for foliar deposition, g/m^3	Not applicable		
Maximum Dose, mrem/y			
Depth of soil mixing layer, m	0.04	0.15	0.6
Maximum Dose, mrem/y	2	2	2
Depth of roots, m	Not applicable		
Maximum Dose, mrem/y			

The following parameters, although available to RESRAD sensitivity analysis, were not evaluated:

Transport Solubility Limit:	This parameter was not used by RESRAD since a distribution coefficient was provided.
Transport Leach Rate:	This parameter was not used by RESRAD since a distribution coefficient was provided.
Cover depth:	The dose assessment included the conservative assumption that no cover will be applied.
Exposure duration:	This parameter is not applicable since the model result is evaluated as peak dose and not total dose or risk.
Carbon-14:	Carbon-14 is not a radionuclide of interest in the subject dose assessment.

Several parameters were not available to the sensitivity analysis provided by the RESRAD software: they were either turned off by the software based on the active exposure pathways (e.g. "Density of cover material"; there is no cover in the model), or the software did not allow a sensitivity analysis of the parameter (e.g. "Irrigation mode").

The results indicate the annual dose to be particularly insensitive, with respect to the difference between the annual dose and the annual dose limit, to all parameters.