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APPENDIX 8.0-3
QUALITATIVE PATHWAY ANALYSIS

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QUALITATIVE PATHWAY ANALYSIS

1.0 INTRODUCTION

This appendix describes the qualitative analysis of exposure scenarios and environmental transport pathways. The scenarios defined for the performance assessment are described in Section 8.3 of the application. The scenarios evaluate normal operations, institutional control, post-institutional control, and accidents. Table 8.3-1 in Section 8.3 shows how the transport pathways are combined to support each of the exposure scenarios. This appendix focuses only on the individual environmental pathways, with the objective of selecting the most important pathways for detailed analysis. Based on the qualitative analysis presented here, minor exposure pathways whose impacts are bounded by other pathways are eliminated from further detailed analysis. This approach focuses more scrutiny on the pathways of greater potential importance.

The qualitative analysis describes each pathway and compares the potential human exposures to those from other similar pathways. Many of the exposure pathways will have small or negligible potential for causing doses to individuals. Other pathways will be more significant. The qualitative analysis will narrow the list of pathways that will be evaluated in detail to demonstrate compliance with the performance objectives.

2.0 PATHWAY EVALUATION APPROACH

The performance assessment considers a set of 27 potential exposure pathways. The complete set of environmental pathways is presented in Section 8.3 and is summarized below in Table 8.0-3-1. These pathways include radionuclide exposures through air, soil, groundwater, surface water, plants, animals, and direct external exposure.

Exposures may affect any of five human receptors. The receptors identified for the performance assessment are (1) workers at the Site (during operations and the Institutional Control Period), (2) an individual at the disposal site boundary, (3) the nearest resident to the facility, (4) an on-site inadvertent intruder drilling a water well at the end of the 100-year Institutional Control Period, and (5) an on-site inadvertent intruder resident after the Institutional Control Period.

The time periods considered for the performance assessment include the operational period, the 100-year Institutional Control Period, and the Post-Institutional Control Period. During operations and the Institutional Control Period, the Site will be monitored and maintained. A security fence will prevent unauthorized access to the Site. Maintenance activities during the Institutional Control Period will include removing deep-rooted plant species from the waste disposal area, maintaining site slopes and drainage control features, and preventing burrowing animals from disturbing the Site. After the end of institutional control of the Site, no site maintenance or access control is assumed to occur. The intruder scenarios are assumed to occur following the end of the Institutional Control Period.

The 27 exposure pathways are described below. Following the pathway description, a qualitative analysis is presented that evaluates and compares the pathways. The result is a reduced list of pathways that will be evaluated in detail.

Table 8.0-3-1. Exposure Pathways for Performance Assessment

PATHWAY	Pathway Abbreviation	Receptor Worker, Disposal Site Boundary, Nearest resident, On-site resident	Period of Concern Operations, Institutional control, Post-institutional control
Air Pathway	**Air**		
Airborne dust from open bulk waste cell	A1	W, B, N	O
Airborne dust from loading and transport of bulk waste	A2	W, B, N	O
Airborne gases from waste cell (H-3, C-14, Kr-85, I-129, radon)	A3	W, B, N	O
Evaporating water from disposal unit sumps in bulk waste cell	A4	W, B, N	O
Suspension of post-closure residual soil contamination	A5	W, B, N, O	I, P
Gas emanation through finished cover (H-3, C-14, Kr-85, I-129, radon)	A6	W, B, N, O	I, P
Transport of contamination exhumed by burrowing animals and deep-rooted plants	A7	O	P
Air releases associated with a dropped, breached container	A8	W, B, N	O
Air releases associated with a truck fire	A9	W, B, N	O
Air releases associated with a tornado	A10	W, B, N	O
Soil Pathway	**Soil**		
Worker inadvertent soil ingestion	S1	W	O
Inhalation of off-site resuspended soil contamination (contaminated by dust deposition)	S2	B, N	O
External radiation from off-site soil (contaminated by dust deposition)	S3	B, N	O
Groundwater Pathway	**Groundwater**		
Leaching and groundwater transport to a well screened above the Redbeds	G1	B, O	O,I, P
Leaching and groundwater transport through the 125-foot sand zone to a well screened above the red beds	G2	B, O	O, I, P
Leaching and groundwater transport to a well screened in the 225-foot water-bearing zone	G3	B, O	O, I, P
Leaching and groundwater transport to a well screened in the Trujillo sandstone	G4	B, O	O, I, P
Leaching and groundwater transport to a well screened in the Santa Rosa formation	G5	B, O	O, I, P
Surface Water Pathway	**Surface Water**		
Off-site transport of bulk waste as a result of high precipitation or flood conditions	W1	B, N	O
Surface water transport of ground-deposited dust to a low-lying area	W2	B, N	O
Surface water run-on and contaminant transport	W3	B, N	O
Plant Pathway	**Plant**		
Mesquite logs gathered from the Site, post-closure, used locally for firewood	P1	O	P
Cattle grazing on deep-rooted grass	P2	O	P

Table 8.0-3-1. Exposure Pathways for Performance Assessment

PATHWAY	Pathway Abbreviation	Receptor Worker, Disposal Site Boundary, Nearest resident, On-site resident	Period of Concern Operations, Institutional control, Post-institutional control
Burrowing Animal Pathway	**Burrowing**		
Waste exhumation by burrowing animals	B1	O	P
Direct External Pathway	**Direct**		
Exposure to an off-site person from high activity waste packages during operations	D1	W, B	O
Exposure through finished cover to an on-site maintenance worker after closure	D2	W	I
Exposure to contaminated drill cuttings in the inadvertent intruder well mud pit	D3	W, O	P

3.0 PATHWAY DESCRIPTIONS AND QUALITATIVE ANALYSIS

All of the pathways considered in the performance assessment are described below using the pathway abbreviations defined in Table 8.0-3-1. The descriptions include the source of the radionuclides, the radionuclide release process, the environmental transport mechanism, the location of the exposed individual, and the parameters used to describe or quantify the exposure.

Many of the pathways are not evaluated in detail in the performance assessment. Pathways with insignificant doses are eliminated from further consideration. These pathways are noted in the descriptions that follow. Some pathways have been eliminated from detailed analysis because the radiological exposures are always bounded by the exposures from another more important pathway. The reasons and justification for eliminating pathways are presented below in the individual pathway descriptions.

Pathway A1 – Airborne dust from open bulk waste cell. This pathway was evaluated in the detailed analysis. It applies only to the FWF Non-Canister Disposal Unit (NCDU), since it will receive bulk waste. There will be no contaminated dust suspension in the CWF or the FWF-CDU because all waste in those facilities will be in containers. Waste compaction activities in the FWF-NCDU may expose workers to airborne suspended dust. Airborne dust may also be transported off-site to an individual at the disposal site boundary, approximately 100 m from the waste cell, and to the nearest resident, located 6 km west of the Site in Eunice, New Mexico. Although future residents could be located closer to the Site than 6 km, this analysis considers the current conditions in the site vicinity. Doses are calculated for direct inhalation of dust in the plume. Dust deposition from the plume results in a ground surface concentration of radionuclides. External radiation from radionuclides deposited on the ground surface is evaluated in Pathway S3.

Secondary pathways were not considered because their effects would be small compared to direct inhalation of the airborne dust plume. Secondary pathways would include plant uptake of deposited dust that later enters the human food chain through grazing livestock.

Pathway A2 – Airborne dust from loading and transport of bulk waste. This pathway was eliminated from the detailed analysis. This is similar to Pathway A1 except that the source of dust is a bulk waste loading and transfer area, such as a dump pad. This pathway was eliminated because there is no loading or transfer area for bulk waste. Bulk waste will be unloaded only in the disposal cell. After unloading the waste will be compacted in place.

Pathway A3 – Airborne gases from waste cell (H-3, C-14, Kr-85, I-129, radon). This pathway was evaluated in the detailed analysis. It evaluates the doses from radioactive gases that may emanate from the waste cells during operations. As suggested by NUREG-1573, the gaseous radionuclides included in the analysis were H-3, C-14, Kr-85, I-129, and radon. All of the gases except radon may be generated from the decomposition of waste materials over a long period of time. During operations, waste decomposition will not be a significant gas generating process, so radon is the only gaseous radionuclide considered. Gases from waste decomposition are addressed in Pathway A6. In contrast to decomposition, radioactive decay is the only means of generating radon gas. Radium in the waste will continuously generate radon gas. The radium-226 inventory is used to determine the radon gas generation rates. In the detailed analysis, radon inhalation doses are calculated for workers, an individual at the disposal site boundary, and the nearest resident. The nearest resident is assumed to be located 6 km west of the facility in Eunice, New Mexico. Although future residents could be located closer to the Site than 6 km, this analysis considered the current conditions in the site vicinity. No secondary exposures are postulated for this pathway.

Pathway A4 – Evaporating water from disposal unit sumps in bulk waste cell. This pathway was eliminated from the detailed analysis. The doses are expected to be negligible and are bounded by the doses from Pathway A1. This pathway applies only to the FWF-NCDU, because the Compact Facility is not anticipated to receive bulk waste. Water that collects in the sumps in the FWF-NCDU may potentially be contaminated with radionuclides. As this water evaporates, there is the possibility that radionuclides may become airborne and cause inhalation exposures to workers and off-site individuals. The airborne radionuclide concentrations would be minimal because as water vapor leaves the sumps, the radionuclides (if any) would remain in the liquid water. Only a few radionuclides would possibly be volatile, such as H-3, C-14, Kr-85, and I-129 and these are addressed in Pathway A3.

Pathway A5 – Suspension of post-closure residual soil contamination. This pathway was eliminated from the detailed analysis because its impacts will be controlled by administrative procedures during site closure. The source of contamination for this pathway is the residual radioactivity that may remain in surface soils following closure of the disposal facility. The elimination or prevention of residual contamination is part of the routine operational procedures. During operations and closure, any soil contamination that is detected will be cleaned up to regulatory standards and disposed. The Site will be surveyed for residual contamination during the site closure phase to ensure that appropriate regulatory criteria have been met. This exposure pathway was eliminated due to the absence of radionuclide source term in the surface soil after site closure.

Pathway A6 – Gas emanation through finished cover (H-3, C-14, Kr-85, I-129, radon). This pathway was included in the detailed analysis. Waste degradation over time may generate gaseous forms of H-3 or C-14, such as methane, water vapor, or carbon dioxide. In addition, as suggested by NUREG-1573, Kr-85 and I-129 were also included in the gaseous radionuclide analysis. Radon gas is continually generated from the decay of Ra-226. These gases may diffuse from the waste through the soil layers and eventually be released to the atmosphere. Potential receptors for this pathway are the nearest resident, an on-site maintenance worker during the Institutional Control Period, and an on-site resident intruder during the Post-Institutional Control Period.

Secondary pathways are not considered because their effects are small compared to direct inhalation of the gaseous radionuclides. Secondary pathways include plant uptake of gaseous carbon-14 dioxide, which then enters the human food chain through grazing livestock.

Pathway A7 – Transport of waste exhumed by burrowing animals or deep-rooted plants. This pathway was eliminated from the detailed analysis because of the many design features that preclude plant and burrowing animal intrusion. Among these features are the depth of waste burial (25 to 45 feet of cover over waste), the waste containers, the reinforced concrete canisters, the grout backfill inside the canisters, the concrete layer at the top of the waste, and the geotextiles and rock bio-barrier in the cover system. Following closure of the disposal facility, the Site will be maintained during the post-closure and institutional control periods. Deep-rooted plant species and burrowing animals will be removed from the Site to help maintain the cover integrity. During the Post-Institutional Control Period, site maintenance will no longer be performed, but design features will prevent plant and animal intrusion.

Even with no site maintenance, the waste is unlikely to be disturbed because the top of the waste layer will be 25 to 45 feet below ground. In addition, the engineered cover has a bio-barrier layer of coarse gravel located below the plant root zone. The coarse materials of the bio-barrier layer will prevent intrusion by burrowing animals. The bio-barrier is designed to exclude plant roots by creating a capillary break and maintaining a very low moisture content. The moisture content of the bio-barrier will remain low because it is constructed of coarse materials. (The bio-barrier is discussed in Pathways P1 and P2, below.) Even without the bio-barrier layer, animals are not expected to burrow more than a few feet below the ground. Animals such as mice, tortoises, ants, rabbits, and other rodents would not burrow to depths as great as 25 feet where the waste is buried. Concrete canisters and compacted backfill in the waste cells would also prevent plant and animal intrusion.

Pathway A8 – Air releases associated with a dropped, breached container. This pathway was addressed in detail in the accident analysis. This exposure pathway assumes that a waste container is dropped and damaged during waste disposal operations. Airborne radionuclides are released that may potentially affect the workers, an individual at the disposal site boundary, and the nearest resident. Doses to these three receptors are calculated assuming a worst case scenario in which the damaged waste container released radionuclides with the highest inhalation hazards. Details are presented in the accident analysis in Appendix 8.0-5.

Pathway A9 – Air releases associated with a truck fire. This pathway was addressed in detail in the accident analysis. The exposure pathway assumes that a truck carrying a load of waste containers catches fire and releases radionuclides into the air. Potential receptors for this pathway are the workers, an individual at the disposal site boundary, and the nearest resident. As in Pathway A8, the doses to these three receptors are based on a worst case scenario involving waste with the highest inhalation hazard. Details are presented in the accident analysis in Appendix 8.0-5.

Pathway A10 – Air releases associated with a tornado. This pathway was eliminated from the detailed analysis because the truck fire and container drop pathways bound it. The radiological consequences from a tornado would be less than those evaluated for the truck fire and container drop pathways.

There are two general types of consequences that could result from a tornado. One is a waste container or bulk waste being picked up and dispersed. The other is the release of waste when a flying projectile impacts a waste container.

In the case of bulk waste or a waste container being picked up and broken, the tornado would disperse contamination over a wide area, leading to much lower airborne concentrations than those in the truck fire pathway. Individuals would seek shelter during a tornado and would not be exposed to airborne radionuclides outdoors during the event. Following the tornado, the dispersed contamination would be at low concentrations. Cleanup would proceed using protective respirators. For these reasons, the container breach or bulk waste scattering by the tornado would have lower consequences than the truck fire scenario.

In the case of a projectile hitting a waste container, the released radionuclides would be dispersed by the winds, resulting in lower airborne concentrations than in the container drop pathway. During the tornado, individuals would seek shelter and not be exposed to the airborne radionuclides during the event. After the tornado, waste cleanup would proceed using protective respirators to prevent inhalation exposures. For these reasons, the projectile scenario would have lower consequences than the container drop pathway. The effects of a tornado are discussed in more detail in Appendix 8.0-5, “Accident Analysis.”

Pathway S1 – Worker inadvertent soil ingestion. This pathway was included in the detailed analysis. While containerized waste presents no threat for direct contact, the bulk waste at the FWF-NCDU presents a potential for dermal exposure and ingestion by workers. Inadvertent soil ingestion from workers’ dirty hands was evaluated. However, worker training and administrative procedures will help minimize the possibility of soil ingestion from dirty hands for the following reasons:

- Handling procedures will prevent direct dermal contact with waste
- Workers will be forbidden to eat, drink, or smoke in the waste disposal area
- Workers will be trained about the hazards of radioactive waste

Under normal operating procedures, workers will never come into direct dermal contact with contaminated material.

Pathway S2 – Inhalation of off-site resuspended soil contamination. This pathway was eliminated from the detailed analysis because pathway A1 bounds it. The contamination source for this pathway is dust that has been transported from bulk waste in the FWF-NCDU. The dust is deposited off-site in an uncontrolled area. Subsequent resuspension of the dust exposes off-site individuals to airborne contamination. This pathway is bounded by pathway A1, which addresses inhalation exposures from the primary plume that carries dust from the bulk waste area. Following deposition and resuspension of the contaminants, the airborne concentrations must necessarily be lower than the concentrations in the original plume from which the deposition occurred. The resuspended dust will be a mixture of the deposited contaminants and uncontaminated dust, resulting in lower radionuclide concentrations than the original plume. For these reasons, pathway S2 is bounded by pathway A1.

Pathway S3 – External radiation from off-site soil (contaminated by dust deposition). This pathway was included in the detailed analysis. It evaluates the external radiation dose to an off-site individual from radionuclides deposited on the ground surface in an uncontrolled area. The source of contamination is windblown dust from bulk waste in the FWF-NCDU that is deposited on the ground surface. The inhalation doses related to this pathway were evaluated in pathway A1. As in the atmospheric pathways, contaminated material from bulk waste becomes suspended in the atmosphere and is transported off-site. Dust deposition from the plume contaminates off-site soil.

Pathway G1 – Leaching and groundwater transport through the red beds to a well screened in the OAG formation above the red beds. This pathway was included in the detailed analysis. It evaluates the potential doses from leaching of radionuclides from the disposal units and their transport to groundwater. Leaching of the radionuclides from the buried waste is assumed to occur in the presence of water that may enter the disposal units through the cover system. The contaminated leachate is assumed to migrate horizontally through the red beds to a local depression in the red bed surface south of the disposal units. The leachate travels horizontally through the red beds to a location where the red beds discharge to the overlying alluvial materials of the OAG formation. The leachate flows into a localized region of perched water above the red beds. It is further assumed that an individual screens a well in the zone of perched water and withdraws water for drinking and livestock watering.

Pathway G2 – Leaching and groundwater transport through the 125-foot sandstone to a well screened above the red beds. This pathway was included in the detailed analysis. This pathway considers the potential doses from leaching of radionuclides from the disposal units and their transport to groundwater. Leaching of the radionuclides from the buried waste is assumed to occur in the presence of water that may enter the disposal units through the cover system. The contaminated leachate is assumed to migrate horizontally through the sandstone of the 125-foot zone. The sandstone is assumed to be continuous across the Site. While the 125-foot zone appears to be unsaturated at all locations, it is assumed to provide a pathway with greater hydraulic conductivity than the red bed clay. Leachate is assumed to travel horizontally through the sandstone to a point where it subcrops to the OAG formation and enters a region of perched water on top of the red beds. This pathway is included because it represents a very conservative approach to modeling radionuclide transport away from the disposal units through a shallow zone of higher permeability than the red beds.

Pathway G3 – Leaching and groundwater transport to a well screened in the 225-foot water-bearing zone. This pathway was included in the detailed analysis. It evaluates the potential doses from leaching of radionuclides from the disposal units and their transport to groundwater in the 225-foot sandstone layer. Leaching of the radionuclides from the buried waste is assumed to occur in the presence of water that may enter the disposal units through the cover system. The contaminated leachate is assumed to migrate downward through the red beds to the sandstone layer at a depth of about 225 feet. It is assumed that an individual screens a well in the 225-foot sandstone formation and withdraws water for drinking and livestock watering. This formation was selected as the primary groundwater pathway because it is the shallowest sandstone zone that is both continuous and fully saturated across the Site. It is the same formation in which groundwater monitoring wells will be installed.

Like the previous pathway, the potential exposures assumed in pathway G3 are also unrealistic because it is unlikely that a domestic well would be screened in the 225-foot zone. The hydraulic conductivity of the formation is very low (less than 1.0E-7 cm/s). One estimate of the pore water velocity in the formation is about 0.007 ft/yr. The expected yield from a well in the 225-foot sandstone formation (a few gallons per day) is too low to supply the water needs of a residence, much less crop irrigation. It is more likely that a domestic well would be screened in deeper formations, such as the Trujillo sandstone at 600-foot depth or the Santa Rosa Formation at depths of 1,000 feet or more. However, in order to conservatively estimate the potential groundwater doses, the 225-foot zone was assumed to provide enough water for drinking and livestock watering.

Pathway G4 – Leaching and groundwater transport to a well screened in the Trujillo sandstone at a depth of 600 feet. This pathway was eliminated from the detailed analysis because it is bounded by Pathway G3. Pathway G4 considers the potential doses from leaching of radionuclides from the disposal units and their transport to groundwater at a depth of about 600 feet. Leaching of the radionuclides from the buried waste is assumed to occur in the presence of water that may enter the disposal units through the cover system. The contaminated leachate is assumed to migrate downward through the red beds and sandstone interbeds to a depth of about 600 feet. It is assumed that an individual screens a well in the 600-foot sandstone formation and withdraws water for drinking and livestock watering.

Potential radionuclide concentrations in the Trujillo sandstone will be lower than the concentrations in the overlying 225-foot zone because the additional travel time from the 225-foot zone to the Trujillo sandstone will result in more time for radioactive decay and more dilution as the radionuclides migrate downward. Any potential radionuclide concentrations in the 600-foot zone would be lower than in the 225-foot zone and would occur at a later time. Therefore, Pathway G4 is always bounded by Pathway G3.

Pathway G5 – Leaching and groundwater transport to a well screened in the Santa Rosa formation. This pathway was eliminated from the detailed analysis because it is bounded by Pathway G3. Pathway G5 considers the potential doses from leaching of radionuclides from the disposal units and their transport to groundwater in the Santa Rosa Formation at a depth of approximately 1,100 feet. Leaching of the radionuclides from the buried waste is assumed to occur in the presence of water that may enter the disposal units through the cover system. The contaminated leachate is assumed to migrate downward through the red beds and sandstone interbeds to the Santa Rosa formation at a depth of 1,000 feet or more. It is assumed that an individual screens a well in the Santa Rosa formation at this depth and withdraws water for drinking and livestock watering.

Potential radionuclide concentrations in the Santa Rosa will be lower than the concentrations in the overlying 225-foot zone because the additional travel time from the 225-foot zone to the Santa Rosa will result in more time for radioactive decay and more dilution as the radionuclides migrate downward. Any potential radionuclide concentrations in the Santa Rosa would be lower than in the 225-foot zone and would occur at a much later time. Therefore, Pathway G5 is always bounded by Pathway G3.

Pathway W1 – Off-site transport of bulk waste as a result of high precipitation or flood. This pathway was eliminated from the detailed analysis. The pathway considers the possibility that radionuclides may be transported from the Site by surface water resulting from high precipitation or flood conditions. All waste at the Compact Facility and the FWF-CDU will be in canisters and not subject to transport by surface water. The FWF-NCDU will contain bulk waste material that could be affected by surface water. However, design features of the facility, such as berms and the depth of the excavations, will prevent surface water transport of bulk waste. Bulk waste in the disposal units cannot leave the disposal units because of the depth of the excavations. The only water that enters the disposal units is direct precipitation. Surface water will be prevented from entering the disposal units by flood control berms. For these reasons, off-site transport of bulk waste by surface water is not a viable pathway.

Pathway W2 – Surface water transport of ground-deposited dust to a low-lying area. This pathway was included in the detailed analysis. It evaluates the consequences of ground-deposited dust being transported from the facility by surface water to a low-lying area. This scenario applies only to the operational period when dust may be generated from bulk waste in the FWF-NCDU. The dust is deposited on the ground surface prior to the precipitation or flooding event. The surface water, from precipitation or flooding, transports the contaminants and causes them to become concentrated in a low-lying area where water collects and then evaporates. The contaminated dust may be resuspended in the air. Exposures are assumed to occur through dust inhalation and external exposure to the contaminated ground. Doses were calculated for the individual at the disposal site boundary and the nearest resident.

Additional exposures through plant uptake from soil and ingestion by grazing animals are not considered. The area of potential surface contamination would be relatively small compared to the area over which an animal would graze. In addition, the doses to humans from plants and grazing animals would be small secondary pathways compared to the direct doses from dust inhalation and external exposure from the contaminated soil.

Pathway W3 – Surface water run-on and contaminant transport. This pathway was eliminated from the detailed analysis. Surface water control features, such as berms and grading, will prevent water from running onto the Site in any areas where waste is stored or disposed. The Site will be graded to provide surface water control under extreme conditions of high precipitation and flooding. In addition, any water that falls on contaminated materials by direct precipitation will be prevented from leaving the areas where waste is stored or disposed. The Site is designed to prevent surface water transport of waste materials.

Pathway P1 – Mesquite logs gathered from the Site, post-closure, used locally for firewood. This pathway was eliminated from the detailed analysis. This pathway considers root intrusion into the buried waste by mesquite roots. The mesquite bushes absorb radionuclides through their roots and the radionuclides become incorporated into the wood. The mesquite wood is gathered and used for firewood, which releases the radionuclides into the air and causes inhalation exposures.

It is known that mesquite roots can grow to depths of more than 30 feet. If the roots were to penetrate into buried waste, they could absorb radionuclides. The roots likely follow channels of fine materials where moisture is more likely to be found. The undisturbed natural materials at the Site are inhomogeneous and contain fine particles in some areas that allow moisture to be held and support the presence of roots at depth. In some areas roots have been observed in the red beds.

The bio-barrier layer is designed to prevent root penetration. Unlike the natural materials in the OAG formation, the bio-barrier will contain no fine particles that are capable of holding moisture. The bio-barrier will be constructed of coarse gravel and cobbles. With no fine particles, the moisture content of the bio-barrier will remain very low. The low moisture will prevent root penetration into or through the bio-barrier.

The Compact and Federal facilities will have earthen covers that are 25 to 45 feet thick. The top-most layer of waste will be at least 25 feet below the ground surface. The bio-barrier layer is three feet thick and is overlain by four feet of sand and soil that serves as a moisture retention layer. The cover layers above the bio-barrier are designed to hold precipitation moisture until it evaporates or is transpired back to the atmosphere. The moisture retention soil will keep the bio-barrier dry and prevent root intrusion through the bio-barrier. Therefore, no exposures are expected from mesquite root intrusion into the waste.

Pathway P2 – Cattle grazing on deep-rooted grass. This pathway was eliminated from the detailed analysis. This pathway considers uptake of radionuclides by grass roots that intrude into the buried waste. The grass is consumed by beef cattle and, subsequently, human exposures occur through beef consumption.

It is possible under some conditions for grass roots to go to depths of 30 feet or more. The roots likely follow channels of fine materials where moisture is more likely to be found. The undisturbed natural materials at the Site are inhomogeneous and contain fine particles in some areas that allow moisture to be held and support the presence of roots at depth. In some areas, roots have been observed in the red beds.

The bio-barrier layer is designed to prevent root penetration. Unlike the natural materials in the OAG formation, the bio-barrier will contain no fine particles that are capable of holding moisture. The bio-barrier will be constructed of coarse gravel and cobbles. With no fine particles, the moisture content of the bio-barrier will remain very low. The low moisture will prevent root penetration into or through the bio-barrier.

The Compact and Federal facilities will have earthen covers that are 25 to 45 feet thick. The top-most layer of waste will be at least 25 feet below the ground surface. The bio-barrier layer is three feet thick and is overlain by four feet of sand and soil that serves as a moisture retention layer. The cover layers above the bio-barrier are designed to hold precipitation moisture until it evaporates or is transpired back to the atmosphere. The moisture retention soil will keep the bio-barrier dry and prevent root intrusion through the bio-barrier. Therefore, no exposures are expected from grass root intrusion into the waste.

Pathway B1 – Waste exhumation by burrowing animals. This pathway was eliminated from the detailed analysis. During operations and the Institutional Control Period, animals will be prevented from contacting the waste. After the placement of the final cover, the waste will be under at least 25 feet of earthen materials. The final cover includes a bio-barrier layer of coarse gravel and rock approximately three feet thick. The bio-barrier will prevent burrowing by tortoises, ants, mice, rabbits, and other rodents. In addition to the bio-barrier, the depth of waste burial prevents animal intrusion. No animals at the Site are known to burrow to depths approaching 25 feet.

Pathway D1 – External exposure from high activity waste packages. This pathway was included in the detailed analysis. It evaluates the external dose to a worker and a site boundary individual from a high activity waste package. Some of the waste packages that will be accepted for disposal have high surface exposure rates. External radiation from these packages has the potential to affect persons in uncontrolled areas. Because of the depth of the waste disposal units, a direct line of sight exposure is not possible. Initially, disposal operations will take place at the bottom of the disposal units 70 feet to 100 feet below the natural ground surface. As the waste layers are stacked and built up, the top layer of waste packages will be at least 25 feet below the natural ground surface. Direct radiation exposure to a person at the site boundary or farther away is unlikely. The doses for such an exposure are evaluated in the accident analysis, based on the assumption that a high radiation package is suspended in the air by a crane malfunction.

Pathway D2 – Exposure through finished cover to an on-site maintenance worker after closure. This pathway was eliminated from the detailed analysis. The external radiation exposure from buried waste will be negligible because of the thickness of the cover materials. The cover thickness will be at least 25 feet over all waste in the Compact and Federal facilities. Gamma radiation at an energy of 1 MeV is attenuated by at least a factor of 20 for each foot of cover material. Therefore, a 25-foot layer of earthen cover material reduces radiation from the waste to a negligible level at the ground surface. Radiation from the buried waste would be indistinguishable from natural background radiation.

Pathway D3 – Exposure to inadvertent intruder driller and on-site inadvertent intruder resident from drill cuttings in mud pit. This pathway was included in the detailed analysis. This pathway evaluates the doses associated with drilling a water well through the former disposal units after the end of the Institutional Control Period. An inadvertent intruder who builds a residence and occupies the Site first hires a drilling crew to drill a water well. The well is assumed to be drilled to the 225-foot zone. Doses were calculated for the drilling crew from exposures to radionuclides in the mud pit. Following the drilling, the mud pit is covered with soil, leaving the contaminated drill cuttings in place. The inadvertent intruder resident builds a house and resides on the Site. The radionuclides in the covered mud pit are a source of external radiation to the resident.

This pathway also bounds the doses that would occur if an intruder were to drill an oil well through the waste. An oil well, if drilled, would go to a much greater depth than the 225-foot zone. The greater volume of cuttings from an oil well means there would be more uncontaminated cuttings mixed with the contaminated cuttings from the waste zone. This provides for lower overall radionuclide concentrations in the mud pit and a lower radiation exposure than for shallow drilling to the 225-foot zone.

Pathway D3 addresses only the external component of the intruder resident dose. In addition to the external exposures from the mud pit, the intruder resident is also exposed to decomposition gases and contaminated groundwater used for drinking and stock watering. Pathway A6 discusses the decomposition gases and Pathway G3 evaluates the water-related exposures to the intruder resident.

4.0 PATHWAYS FOR DETAILED QUANTITATIVE ANALYSIS

The result of the qualitative analysis is a set of exposure pathways that will require detailed quantitative analysis. The pathways that remain after the qualitative analysis form the basis for demonstrating compliance with the performance objectives in 30 TAC 336.724-727. The pathways to be analyzed in detail are listed below in Table 8.0-3-2. Appendix 8.0-6 describes and documents the detailed analyses of these pathways.

Table 8.0-3-2. Pathways for Detailed Quantitative Analysis

Pathway Designator	Pathway Descriptor
A1	Windblown dust from open bulk waste cell
A3	Airborne gases from waste cell (H-3, C-14, Kr-85, I-129, radon)
A6	Gas emanation through finished cover (H-3, C-14, Kr-85, I-129, radon)
A8	Air releases associated with a dropped, breached container
A9	Air releases associated with a truck fire
S1	Worker inadvertent soil ingestion
S3	External radiation from off-site soil (contaminated by dust deposition)
G1	Leaching and groundwater transport through red beds to a well screened above the red beds
G2	Leaching and transport through the 125-foot zone to a well screened above the red beds
G3	Leaching and groundwater transport to a well screened in the 225-foot water-bearing zone
W2	Surface water transport of ground-deposited dust to a low-lying area
D1	External exposure from high activity waste package during operations
D3	External exposure to intruder driller and resident from drill cuttings in mud pit

5.0 REFERENCES

NRC 1991, U.S. Nuclear Regulatory Commission, "A Self-Teaching Curriculum for the NRC/SNL Low-Level Waste Performance Assessment Methodology," NUREG/CR-5539, January 1991.

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