SITE-SPECIFIC DERIVED CONCENTRATION GUIDELINE LEVELS FOR SOILS

DEFENSE NATIONAL STOCKPILE CENTER
NEW HAVEN DEPOT

NEW HAVEN, INDIANA

Prepared for:

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ACRONYMS AND ABBREVIATIONS

ALARA	as low as reasonably achievable
bgs	below ground surface
CABRERA	Cabrera Services, Inc.
CFR	Code of Federal Regulations
cm	centimeter
cm^2	square centimeter
DCGL	derived concentration guideline level
DLA	Defense Logistics Agency
DNSC	Defense National Stockpile Center
DNS	Defense National Stockpile
DSR	dose-to-source ratio
^0F	degrees Farenheit
FSS	final status survey
ft	foot or feet
GSA	General Services Administration
HSA	historical site assessment
K_d	element partition coefficient
MARSSIM	Multi-Agency Radiation Survey and Site Investigation Manual
m	meter
m^2	square meter
mph	mile per hour
m/sec	meter per second
m/yr	meter per year
mrem	milli-rem
mrem/yr	millirem per year
NRC	U.S. Nuclear Regulatory Commission
ORPP	Occupational Radiation Protection Program
Pa-231	protactinium-231
Pb-210	lead-210
pCi/g	picocuries per gram
Ra-226	radium-226
Ra-228	radium-228
RCOPC	radiological contaminants of potential concern
RESRAD	RESidual RADioactivity
TEDE	total effective dose equivalent
Th-228	thorium-228
Th-232	thorium-232
U.S.	United States
EPA	U.S. Environmental Protection Agency
U-234	uranium-234
U-235	uranium-235
U-238	uranium-238
USGS	U. S. Geological Survey
yd^3	cubic yards

EXECUTIVE SUMMARY

The Defense National Stockpile Center (DNSC) of the Defense Logistics Agency (DLA) is in the process of closing out its depots across the country and seeking to terminate its US Nuclear Regulatory Commission (NRC) license for those facilities. The New Haven Depot site (referred to as the Depot or Site), located in New Haven, Indiana, formerly stored zirconium ore (baddeleyite), containing natural uranium and thorium, in an outdoor area known as 7A. As a step in the license termination process for this site, derived concentration guideline levels (DCGLs) must be determined to provide clean-up levels that satisfy regulatory requirements.

For this analysis, the NRC regulatory endpoint for the total effective dose equivalent (TEDE) was set to 25 mrem (1000-year peak dose) above background in accordance with Title 10, Code of Federal Regulations, Part 20, paragraph 1402 (10 CFR 20.1402). A thorough environmental assessment was conducted to extract information from project records and prior site environmental studies in order to establish representative exposure pathways from residual radioactivity (as defined by the average member of the critical group). Using careful engineering judgment and assessment of the literature as well as correspondence with on-site operations personnel, the computational model was parameterized with relevant site-specific terms.

The most current deterministic and probabilistic RESRAD (Version 6.3) computer code developed by the Argonne National Laboratory (ANL) was used for soil assessment. Model outputs were evaluated first to ensure that physical conditions and mathematical terms were consistent and second by statistical sensitivity analyses to ensure that important exposure pathways were not overlooked. Parameters that were identified during the engineering assessment or the mathematical model phases were reassessed and analyzed in an iterative fashion to ensure completeness of the reported results.

Using the most realistically conservative model allowed (residential farmer scenario) within the context of the computer models, the DCGLs computed for the Site are:

- 2.5 picocuries per gram (pCi/g) Th-232 and decay products; and
- 2.3 pCi/g U-238/U-235 (as natural uranium) and decay products.

A complete description of the methodology, including an assessment of the input parameters, model inputs, and results is provided in this report. The overall approach to the DCGL determination was to adopt a reasonable, yet conservative approach to the analysis, in accordance with the guidance provided in several NUREG documents.

1.0 INTRODUCTION

This report presents the site-specific derived concentration guideline level (DCGL) for the radionuclide contaminants of potential concern (RCOPC) in soil at the New Haven Depot (hereafter referred to as the Site).

1.1 Purpose

The Defense National Stockpile Center (DNSC) of the Defense Logistics Agency (DLA) is in the process of closing its depots across the country and is seeking to terminate its U.S. Nuclear Regulatory Commission (NRC) license. The NRC license allowed for the storage of naturally-occurring radioactive materials, including thorium and uranium. As a step in the license termination process, the decommissioning process described in *Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM)* (NRC 2000a) was planned to be implemented in order to release the Site under unrestricted land use scenario. As a part of the MARSSIM process, Cabrera Services, Inc. performed a historical site assessment (HSA) to specifically address buildings and areas at New Haven Depot where NRC-licensed radioactive materials were handled or stored (Cabrera 2006). This HSA was performed to determine actions necessary to permit the release of storage depot warehouses and property for unrestricted use at New Haven. The HSA process is followed by other site characterization surveys that lead to the final status survey (FSS). As a part of these surveys, DCGLs for soil must be determined to drive clean-up levels that satisfy regulatory requirements in order to release the Site under unrestricted use.

The purpose of this report is to provide a site-specific DCGL in support of decisions regarding the need for additional remediation at the Site and/or demonstrating that the Site can be released for unrestricted use. Specifically, when the DCGL is applied to the final status survey and the survey data demonstrates that the DCGL has been satisfied, the following requirements of Title 10, Code of Federal Regulations (CFR), Part 20, Paragraph 1402 (10 CFR 20.1402) are achieved (NRC 2006):

> *A site will be considered acceptable for unrestricted use if the residual radioactivity that is distinguishable from background radiation results in a TEDE to an average member of the critical group that does not exceed 25 mrem per year, including that from groundwater sources of drinking water, and that the residual radioactivity has been reduced to levels that are as low as reasonably achievable (ALARA). Determination of the levels which are ALARA must take into account the consideration of any detriments, such as deaths from transportation accidents, expected to potentially result from decontamination and waste disposal.*

1.2 Scope

A site-specific DCGL analysis for the Site is presented, including a review of the site-specific environmental parameters that drive the analysis, the methodology used for calculating the numeric limits, and results of the sensitivity analysis performed to ensure that no single lumped parameter, or multiple parameters, were overlooked in the model equations as it pertains to the environmental transport of residual contaminants and the resulting dose at the receptor. The analysis applies to only soil. The analysis applies to the site radioactive contaminants: natural thorium and natural uranium.

2.0 SITE CHARACTERISTICS AND ENVIRONMENTAL SETTINGS

The following sections of the report summarized a brief physical description and environmental setting of the Site.

2.1 Physical Characteristics and Land Uses

The Site is located in New Haven, Indiana, approximately 2.3 miles east of US Highway 469. New Haven is located in the central part of Allen County, Indiana, directly east of the city of Fort Wayne. The current Depot Site encompasses 268 acres. The Site is bordered to the south by the main line of the Norfolk Southern Railroad and Dawkins Road (State Route 14) and to the north by Edgerton Road and a small industrial park (formerly part of the Depot property). Farmland and an industrial facility border the western portion of the Site, while undeveloped property owned by Jefferson Township borders the east side of the Site. The nearest residential properties are along the south side of Dawkins Road, across from the main entrance to the Site.

A railroad siding off of the Norfolk Southern main line crosses the Site with a series of east-west trending rail spurs, converging at the Sites' southwestern and southeastern corners. Vehicular access to the Site is from Dawkins Road near the southwestern corner of the Site where access is monitored and maintained from a manned Security Post. The Site is completely surrounded by a 6 feet (ft) fence topped with three-strand barbed wire. Other gates exist at the entrance/egress points for the rail spurs; these gates are kept closed and locked except when rail cars are actually arriving or leaving the facility (Parsons 1999). Figure 2-1 depicts the current layout of the site and adjoining properties.

FIGURE 2-1: AERIAL VIEW OF NEW HAVEN DEPOT

There are six storage buildings (Warehouses T-210 through T-215, each 180 ft. x 960 ft.) with wood, concrete, or concrete block structural framing supporting wood roof decks, having an aggregate indoor storage capacity of approximately 1,037,000 sq. ft as shown in Figure 2–1. Each warehouse is divided into four sections. Each section is divided into 79 storage bays (each approximately 25 ft. by 20 ft.). The materials containing licensable quantities of thorium and uranium were packaged (in either wooden boxes or drums) and stacked in various bays throughout the warehouse series, as well as in Buildings 136, 141, 145, and 146. Various other smaller structures are located throughout the depot including two pumping stations, two pump houses, an office building, a guardhouse, and a maintenance building. South of the warehouses, within the central and eastern portions of the depot, are a number of storage areas. Other storage areas are located along the rail spur lines in the western portion of the depot. Additionally, various sections of the warehouses once contained stores of raw asbestos and the interior building surfaces of Sections 1 and 4 of Warehouse 214 have had an encapsulant applied.

Land use at the New Haven Depot is predominantly light industrial. Land use surrounding the area is predominantly agricultural. There are seven farmsteads located to the south of the depot, immediately opposite Dawkins Road (State Route 14). The closest farmstead is approximately 250 ft (76 m) south of the south property fence. A small industrial park is situated immediately adjacent to the north central portion of the depot, and the Superior Alloys factory is located to the west. A park, a model airplane flying field, and an antique railroad club occupy the land immediately to the east of the depot. Ashley Lake, a small recreational lake used for sport fishing, is also located in the area east of the depot (DLA 2000).

2.2 Environmental Setting

2.2.1 Regional Soil and Geology

The Site is located near the western margin of the Maumee Lake Plain unit of the Central Lowland Physiographic Province (Fleming 1994). The Maumee Lake Plain is flat and poorly drained, and was developed in fine grained lacustrine deposits (fines sands, silts, and clay). Surficial soils in the area of the Site belong to the Hoytville-Napanee Association, which are described as deep, somewhat poorly drained to very poorly drained, nearly level, and medium-textured to finely-textured soils on uplands.

The Site is underlain by a sequence of wave scoured, lake bottom till. This till is part of the New Holland Member of the Lagro Formation, and is composed of lacustrine deposits described as massive, firm, pale brown to light gray clayey silt to silty clay, with clay content of up to 60% (Fleming 1994). Local lenses of sand and plastic clay may exist. The Lagro Formation overlies the Trafalgar Formation (Bleuer 1978). The Trafalgar tills are described as dark grey sandy silt, and represents outwash of an earlier ice advance. The Trafalgar overlies the bedrock surface (approximately 70 ft below ground surface at the Site (Fleming 1994).

To the west and directly south of the Site are thin sand and gravel deposits overlying the till that developed along the ancient lake margin. These thin deposits, representing sand dune fields or beach ridge complexes are generally not sources of water supply.

2.2.2 Hydrogeology and Water Supply Wells

Groundwater occurs predominantly in the till/bedrock or the upper bedrock units, and occurs between 50 to 70 ft (15 to 21 m) below ground surface (bgs). The aquifer or aquifers underlying the depot are believed to be under confining conditions, and they likely flow in a northwesterly direction towards the axis of the Maumee River Valley. (DLA 2000). The unconsolidated sediments of the Maumee Lake Plain that underlie the Site are very fine grained with low permeability, and are not suitable for development of sustainable water supply wells.

There are no records of water supply wells at the Site. The City of New Haven's water department purchases their water supply from the City of Fort Wayne. Fort Wayne derives their potable water source solely from the St. Joseph River. No groundwater wells are utilized as a secondary water source. There are a number of bedrock and unconsolidated wells onsite. The wells are used primarily for groundwater sampling. It is likely that there are private water supply wells on farms and nearby industrial properties, however, all local wells are completed in productive bedrock aquifers located hundreds of feet bgs (Bleuer 1978).

2.2.3 Hydrology

Surface water drainage on the Site is directed by a series of open swales, ditches, and underground storm sewers. Most surface water is diverted to the north of the Site via two north-south oriented drainage ditches located in the western and the eastern portions of the Site. One of these ditches is located near Area 7A. These north-south trending ditches connect to an east-west oriented surface water ditch located along the south side of Edgerton Road. Flow in this ditch is from west to east. Stormwater sewers around the facility warehouses converge at a manhole located near the northern Site boundary, adjacent to the industrial park. These discharged to open ditches, up to the Edgerton Road ditch. The Edgerton Road ditch discharges to the Lomont Ditch, which is shown on Figure 2-2, near the eastern edge of the figure. The Lomont Ditch flows into the head of Gar Creek, which discharges to the Maumee River approximately 3 stream miles north of the Site. Other man-made ditches connect to the Lomont Ditch and Gar Creek, downstream from the Site.

Ashley Lake is a small recreational lake located to the northeast of the Site on Township-owned property which had been part of the depot facility at one time. This lake was built after the depot was constructed, apparently resulting from borrow operations conducted in the area. There is no surficial hydrological connection between this small lake and the Lomont Ditch under normal conditions; however, during flood conditions an overland connection may occur.

2.2.4 Climate and Meteorology

The climate of the New Haven area (based on data and climate for Fort Wayne International Airport) is typical of northeastern Indiana and is influenced to some extent by the Great Lakes. Average annual temperature is 50 degrees Fahrenheit (^{0}F). Average maximum summer temperature is 82.6 ^{0}F and average minimum summer temperature is 61.1 ^{0}F. Average maximum winter temperature is 33.3 ^{0}F and average minimum winter temperature is 18.2 ^{0}F. The average annual rainfall, 34.75 inches, is fairly well distributed over the year with somewhat larger monthly amounts in the late spring and early summer. Damaging hailstorms occur about twice a year. Average annual snowfall is 35.3 in (DLA 2000).

Four tornadoes were reported in Allen County in the period of January 1993 to May 2000. Several occurrences of high winds usually associated with thunderstorm activity typically occur every year (DLA 2000). The average annual wind speed is 9.9 mile per hour (mph). The maximum wind speed is 65 mph (DLA 2000).

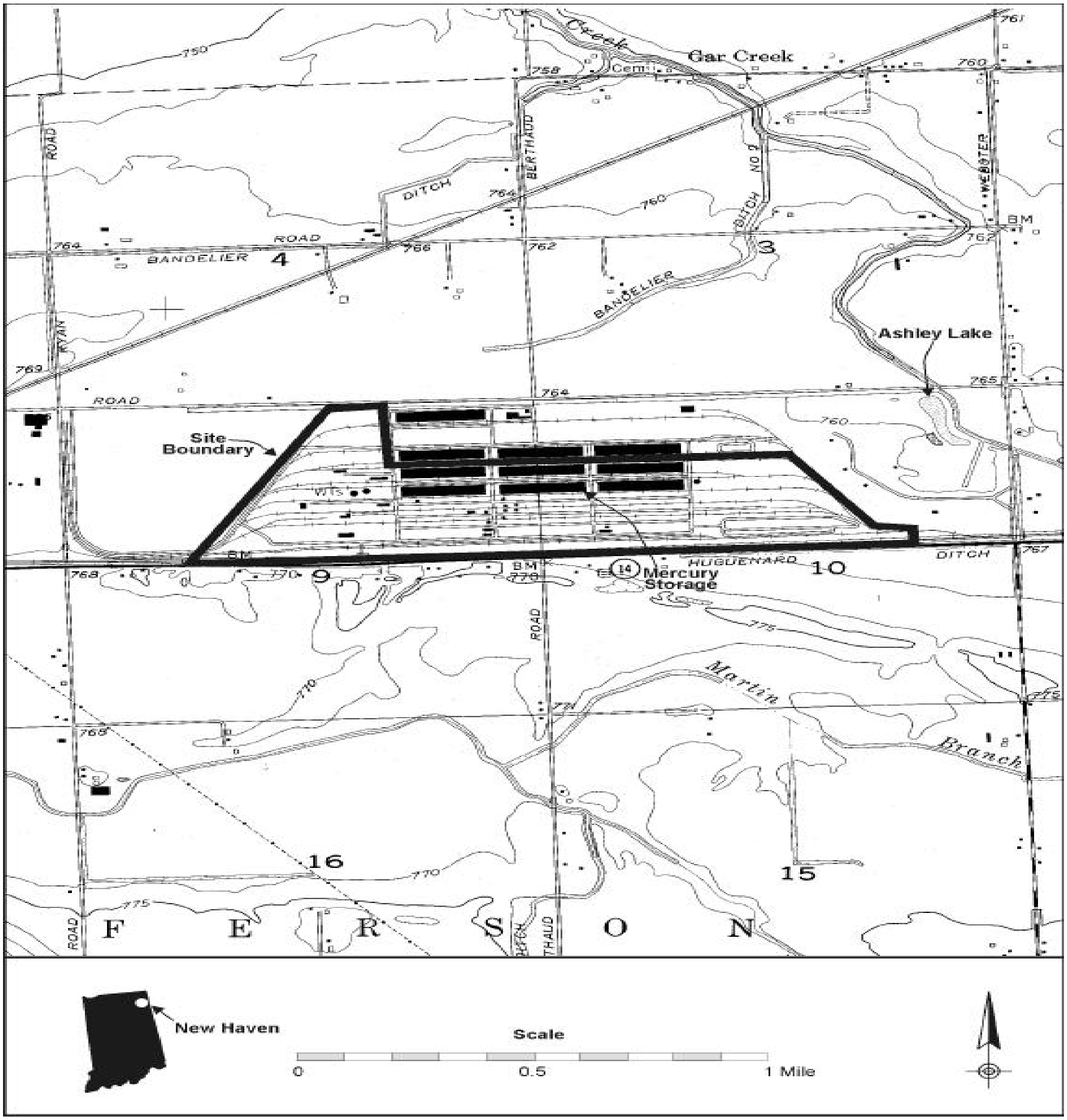

FIGURE 2-2: DETAILED VIEW OF NEW HAVEN DEPOT AND SURROUNDING AREA

3.0 SITE HISTORY AND RADIOLOGICAL CONTAMINATON

3.1 Site History

Historically, the Site's main purpose has been storage of metallurgical ores and materials necessary for manufacturing defense and/or strategic materials. Construction of the New Haven Depot began in April 1942 and was completed in March 1943. The depot was originally assigned to the Ordnance Department and designated the New Haven Ordnance Depot. It was renamed the Casad Ordnance Depot in April 1943. The depot operated during World War II as a Class II Installation. It was deactivated in 1947 and assigned to the Corps of Engineers, which maintained the facility in a stand-by fashion. In April 1948, the facility was re-designated as the Casad Engineer Depot, and operated as an inactive Class II Installation for storing strategic and critical materials for the National Stockpile. In February 1951, the facility was re-designated as an active Class II Installation, and given the added mission of assembling troop supplies. Specifically, engineer sets including equipment for camouflage, carpentry, fire fighting, blacksmithing, pipe fitting, surveying, welding, and field mapping were assembled. The facility was reportedly used as an Army Engineer Training Area until 1955. The Corps of Engineers declared the Site as excess land in 1955. In 1958, control of the Site was given to the GSA. In 1959, 130 acres comprising the original western portion of the Site were sold. In 1972, parcels which comprised the north-central and eastern parts of the original Site property were sold to various local government and private entities. This included property north of the existing warehouses which was developed into a small industrial park, and properties containing Lake Ashley in the northeast portion of the original Site property, as well as the pistol range, fire practice area, and burning area. In the early 1980s, the DNSC under the GSA assumed management responsibility for the Site. In 1988, the stockpile program was transferred from GSA to the DLA, and re-named the Defense National Stockpile (DNS).

3.2 Site Operating History

The Site's main purpose has been storage of metallurgical ores and materials necessary for manufacturing defense and/or strategic materials. Throughout the system of warehouses and outdoor areas at New Haven Depot, the DNSC has stored columbium/tantalum ores and concentrates, tungsten ores and concentrates, zirconium ore (baddeleyite), rare earth sodium sulfate, monazite, tungsten metal scrap, and bastnasite, all containing sufficient amounts of natural uranium and thorium to require licensing under NRC rules. Except for the zirconium ore, the materials containing licensable quantities of thorium and uranium were packaged (in either wooden boxes or drums) and stacked in various bays throughout the warehouse series, as well as in Buildings 136, 141, 145, and 146. The packaged licensed radioactive materials were never removed from their containers, except during some sampling and overpackaging programs. According to the most recent Occupational Radiation Protection Program (ORPP) Annual Survey, all licensed radioactive materials have already been removed from the Site; however, contamination may still remain in certain areas (Skruck 2006). Any other materials remaining in each warehouse were consolidated into Warehouse 214 for ultimate removal.

In October 2000, DNSC sold the zirconium ore stored in piles 111 and 111A at Area 7A. The ore was loaded into rail cars at the location of the piles by a front-end loader. The rail cars were then moved to the rail scale where the amount of ore in the car was adjusted to maintain an acceptable weight. After achieving the optimum weight, the cars were moved to an area where the tops were shrink-wrapped to preclude loss of the ore during transit. The areas affected during this process were the railway and roadways used for the transport of the ore, the rail scale area, and the building used for shrink wrapping the rail cars.

Additionally, various sections of the warehouses once contained stores of raw asbestos and the interior building surfaces of Sections 1 and 4 of Warehouse 214 have had an encapsulant applied.

3.3 Summary of Previous Radiological Investigations

3.3.1 Radiological Scoping Survey

ERS Solutions performed a radiological scoping survey in October 2001 after sale of the zirconium ore in 2000. The results of this survey indicated that significant levels of residual radioactivity remained at former storage piles 111 and 111A in Area 7A. The identified contamination was discovered at the pile footprint and in small, discrete locations around the former stockpiles, indicative of spills during loadout of the ores. The contamination observed did not appear to be homogeneous in nature (Reese 2001).

3.3.2 Spot Remedial and Partial Final Status Survey

ERS Solutions also performed a spot remediation effort and partial FSS in May 2002 in and around areas presumed to be impacted from handling and loading of zirconium ore at the New Haven facility. Remediation efforts focused on removing ore spillage that occurred during loading and shrink-wrapping activities along the Site railbeds, ore handling facilities, and other haul routes on the Site. Area 7A was not included in this scope of work. It was reported that 33 cubic yards (yd^3) was removed by backhoe with survey units (SU) 3A and 4, as defined by ERS. Spot remediation by hand was also performed in other established SUs. All waste materials removed were placed in a defined storage area within Area 7A, with final removal of the debris to be performed at a later date (ERS 2002).

The FSS Report for the above investigation, dated December 2002, was submitted to the US NRC for review. The FSS Report recommended release for unrestricted use of all survey units investigated as part of the ERS FSS, except for the debris storage in Area 7A. The US NRC voided DLA’s application for license amendment in April 2003, pending a request for more information.

3.3.3 Area 7A Remedial Action

In 2004, the Pangea Group completed the removal of 2,503 yd^3 of contaminated soil from Area 7A, the eastern access road, and the railroad truck bed. (Pangea 2005) Pangea was originally scoped to remove 6 in of soil and debris from the surface of all areas deemed to be impacted within these areas. Radiological support surveys performed during the excavation showed that contamination actually was present at depths from 9 in to 3 ft in certain areas. Pangea excavated the contaminated areas down to a satisfactory condition of two-times background, as defined for the project. All wastes were loaded into 39 gondola railcars and shipped to the US Ecology radioactive waste facility in Grandview, Idaho. No FSS activities or license amendment applications to the NRC were performed as part of this remedial action.

3.4 Summary of Potential Contaminated Areas

Eight outdoor storage areas (such as Area 7A, rail way, rail scale area) and ten current or former buildings (Building 136, 141, 145, 146, 210, 211, 212, 213, 214, and 215) have been identified as areas where radioactive materials were stored or handled. Based on the review of records, interview, and results of various investigations, there is a low potential for residual radioactive contamination at any current or former buildings present at the Site. However, the results also showed that there is potential for residual radioactive contamination at Area 7A and weight station area. Hence, this report only determines the soil DCGLs for RCOPC at the Site. No structural or building DCGLs for RCOPCs were developed for the Site.

Area 7A is shown in Figure 3-1.

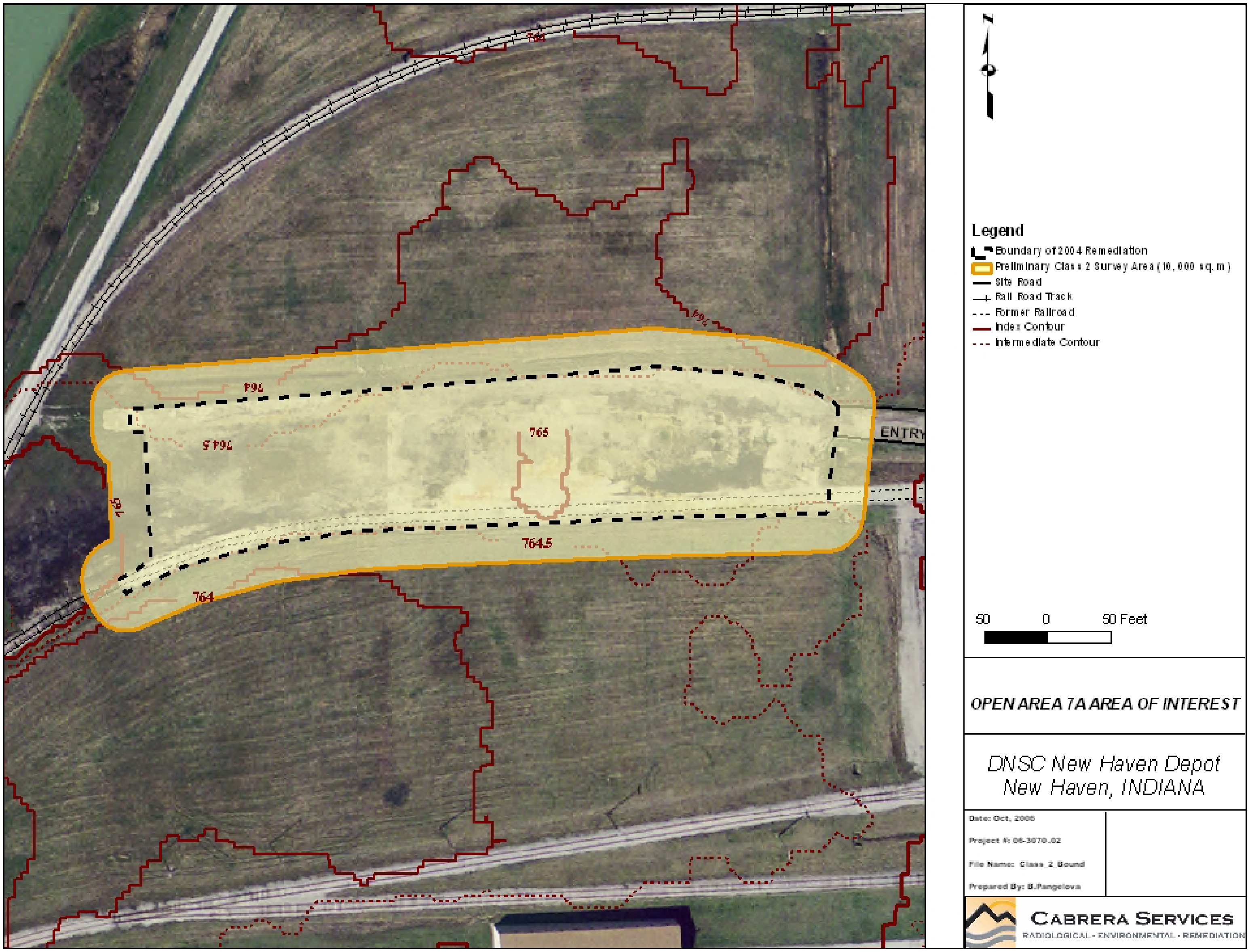

FIGURE 3-1: OPEN AREA 7A - AREA OF INTEREST

3.5 Summary of Radiological Contaminants of Potential Concern

The primary RCOPC at New Haven Depot are those associated with the receipt, storage, and shipment of material containing natural uranium and thorium, both in secular equilibrium with their daughter (or decay) products.

- Natural thorium: Th-232 and its decay products in secular equilibrium. The degree to which the decay products are in equilibrium is just over 99%. RESRAD (Yu 2005) activity concentrations were run with unit activity values representing the equilibrium condition. DCGL values were then calculated per unit activity of the parent radioisotope, Th-232.

- Natural uranium: U-238 and U-235 and associated decay products in secular equilibrium. The weight fraction of U-235 in natural uranium is 0.711 wt%. The associated radioactivity fraction of U-235 to U-238 is 0.047 (Abelquist 1997). RESRAD activity concentrations were run with proportioned unit activity values representing the equilibrium condition of the decay products as well as the 0.047 activity fraction of U-235 to U-238. DCGL values were calculated per unit activity of total uranium.

The thorium-232 and uranium-238/235 decay chains are presented in Figures 3-2, 3-3 and 3-4, respectively.

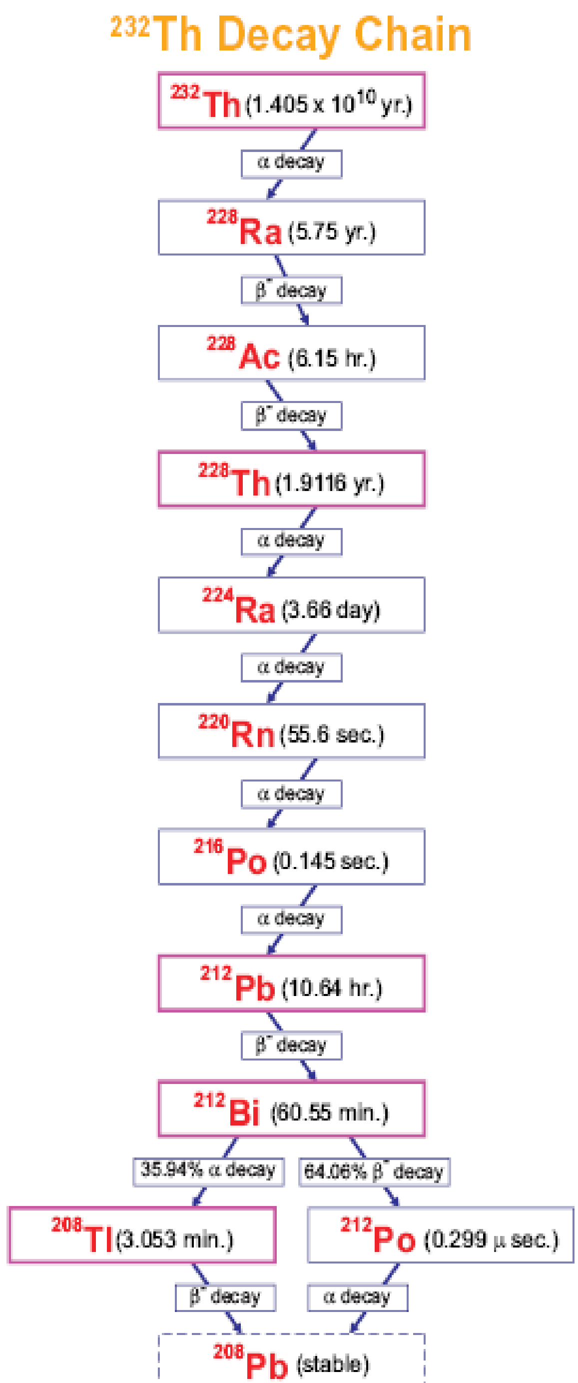

FIGURE 3-2: THORIUM 232 DECAY CHAIN

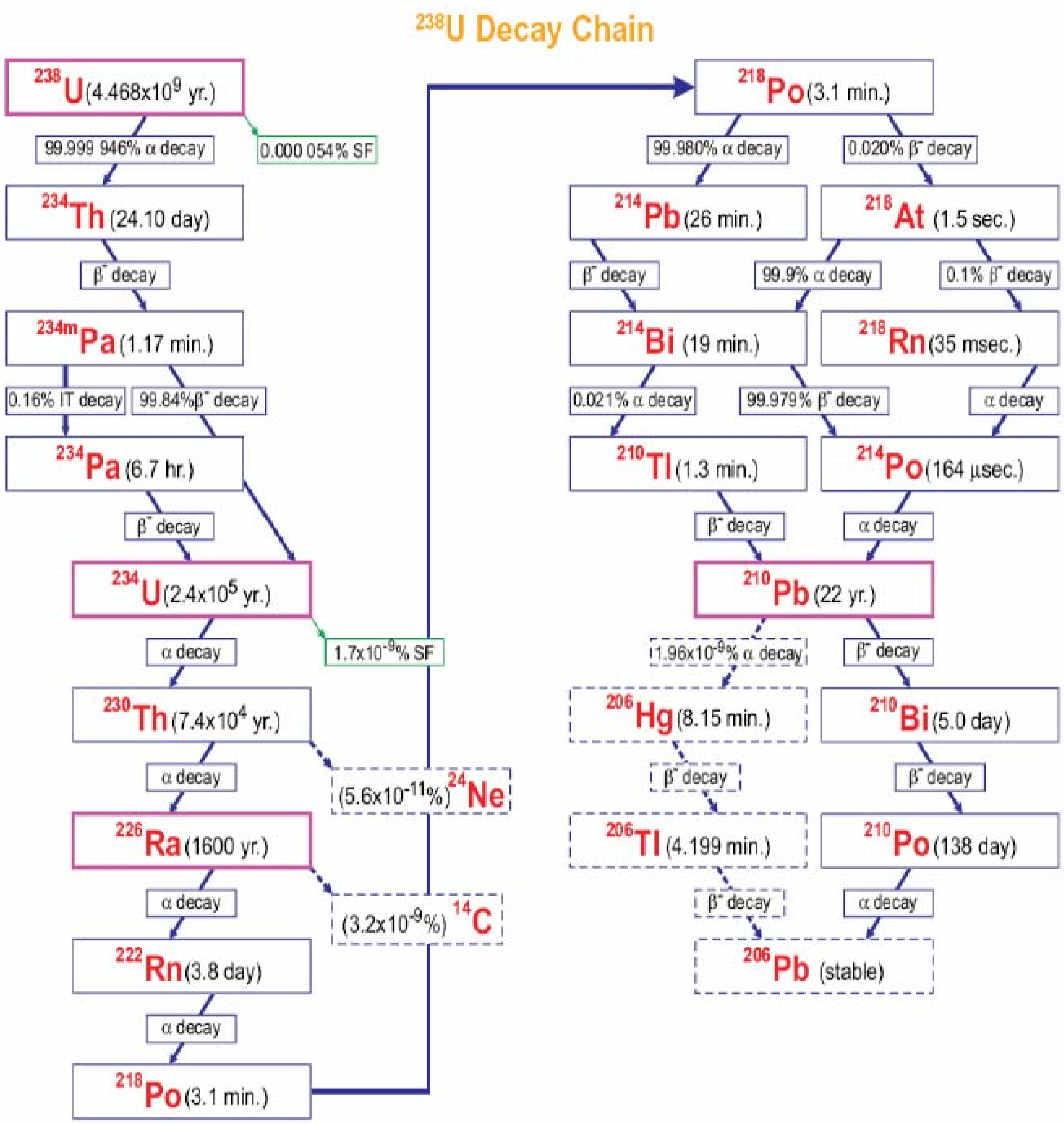

Figure 6 – U-238 Decay Chain (from INL On-line Gamma Spectrum Catalog),
http://www.inl.gov/gammaray/catalogs/catalogs.shtml

FIGURE 3-3: URANIUM-238 DECAY CHAIN

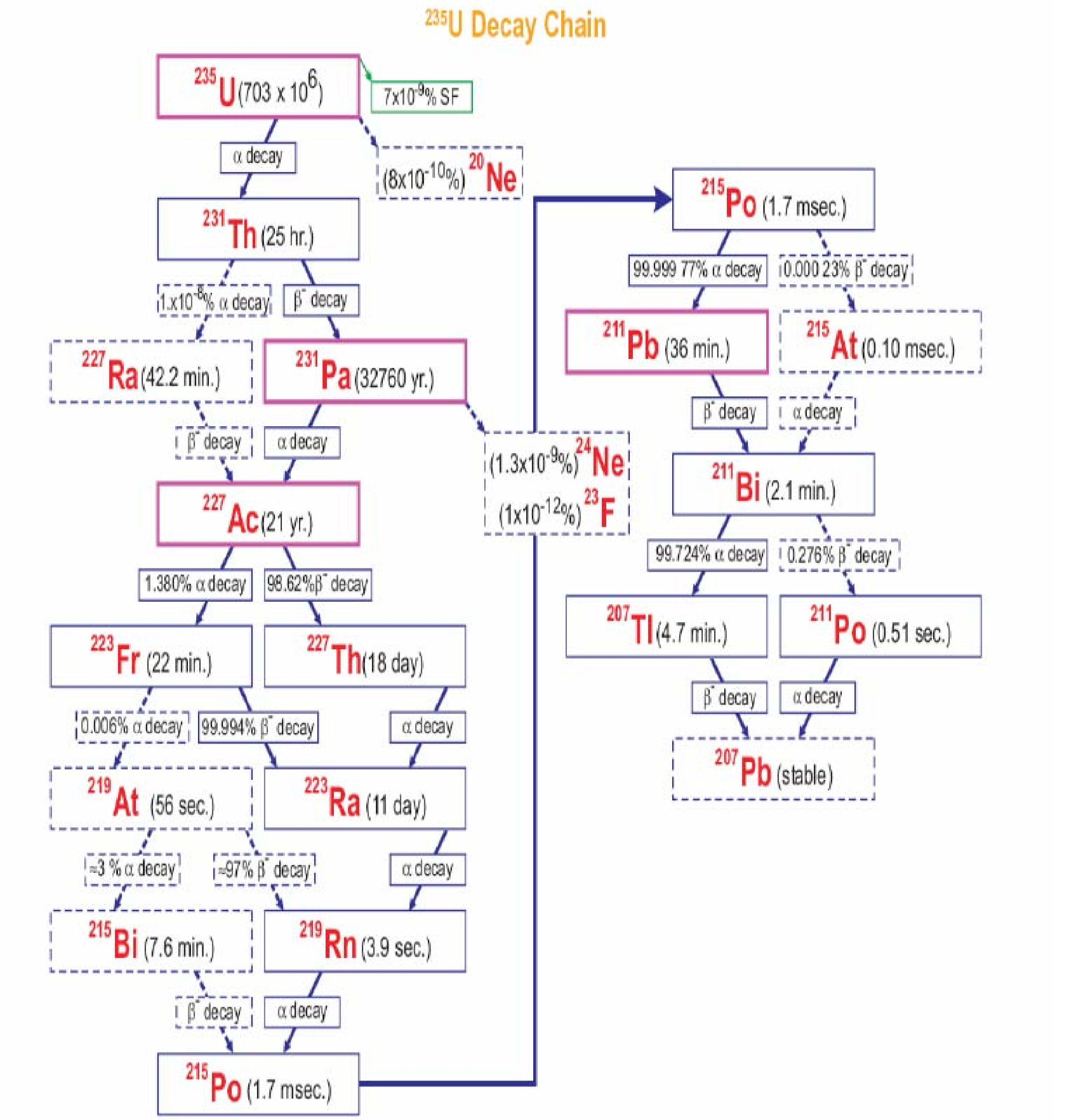

Figure 7 – U-235 Decay Chain (from INL On-line Gamma Spectrum Catalog), http://www.inl.gov/gammaray/catalogs/catalogs.shtml

FIGURE 3-4: URANIUM-235 DECAY CHAIN

3.6 Summary of Potential Contaminated Media

The following environmental media at the Site have been identified as contaminated through sampling or evaluated for potential contamination: surface soil, subsurface soil, surface water, groundwater, and structures.

3.6.1.1 Soil

Surface soil is defined as the top layer (15 centimeters) of soil on the Site. Subsurface soil is any solid materials not considered to be surface soil. Soil contamination has resulted from the release of radioactive material stored in the warehouse, and from loading and unloading operations performed at the Site. Extensive surveys and sampling have been performed at the Site. As a result, several areas have been remediated by removal and disposal of contaminated soil. Since prior remediation in some areas required excavation below the surface soil layer, the thickness of the contaminated soil is assumed to be 0.5 meter (m) for the purpose of site-specific DCGL determination. Although soil contamination in most areas is limited to surface soil, a contaminated soil thickness of 0.5 m results in a conservative approach to DCGL determination.

3.6.1.2 Surface Water and Groundwater

There is no evidence of surface water or groundwater contamination at the Site and is not expected due to a lack of significant source term. Also, because due to very high K_d values for natural thorium and uranium in soil, the contamination of surface water and groundwater is considered an unlikely event.

4.0 DETERMINATION OF DERIVED CONCENTRATION GUIDELINE LEVEL

Methods for determining the DCGL involved a three step process, presented in order in this section:

1. Identifying the regulatory limit for the total effective dose equivalent (TEDE) per year, to which an acceptable level of residual contamination corresponds;
2. Developing a site environmental model (conceptual site model) that accounts for the physical characteristics of the site, identifies exposure pathways from the residual radioactivity, and computes the annual TEDE per unit concentration of natural thorium and natural uranium;
3. Using RESRAD Version 6.3 (Yu 2005) to calculate the TEDE per year per unit concentration or area, respectively, of natural thorium. Computation models must output the TEDE as a function of time, out to 1000 years, to determine allowable soil concentrations to meet the requirements of 10 CFR 20.1402. Microsoft Excel was utilized to generate additional output results based on the dose assessment model results.

4.1 Annual Public Dose Limit

The NRC annual dose limit for a member of the public is 100 mrem TEDE associated with licensed activities and exclusive of background (and other) sources, as specified in 10 CFR 20.1301. As described in Section 1.1 of this report, 10 CFR 20.1402, *Radiological Criteria for Unrestricted Use*, specifies that an average member of the critical population group may not receive a TEDE in excess of 25 mrem, including groundwater sources of drinking water. The RESRAD model utilized this required input parameter (25 mrem) for the applicable dose limit to establish the resulting DCGL for the Site.

4.2 Conceptual Site Model

The conceptual site model has been developed on the basis of Site review, how the Site is currently used and the most probable use of the Site once released, and a complete understanding of the most relevant exposure pathways to occupants/residents on the Site.

Figure 4-1, from the *Users Manual for RESRAD Version 6* (Yu 2001), presents all potential exposure pathways, using a worst case, resident farmer exposure scenario. This is also presented schematically in Figure 4-2.

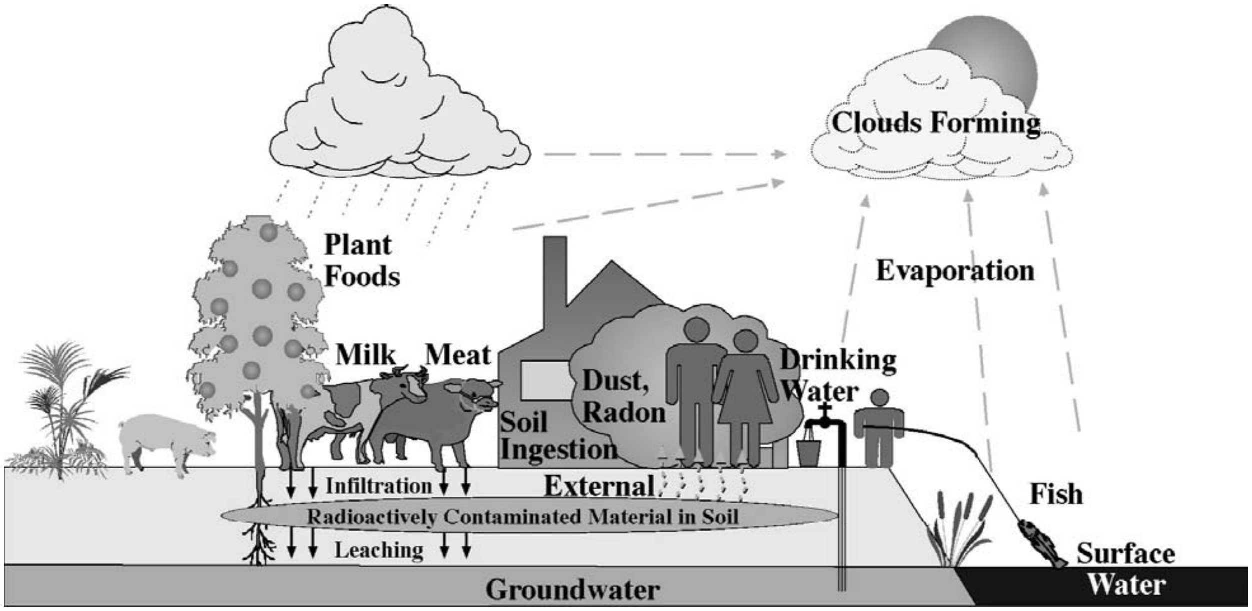

FIGURE 4-1: EXPOSURE PATHWAYS CONSIDERED IN RESRAD

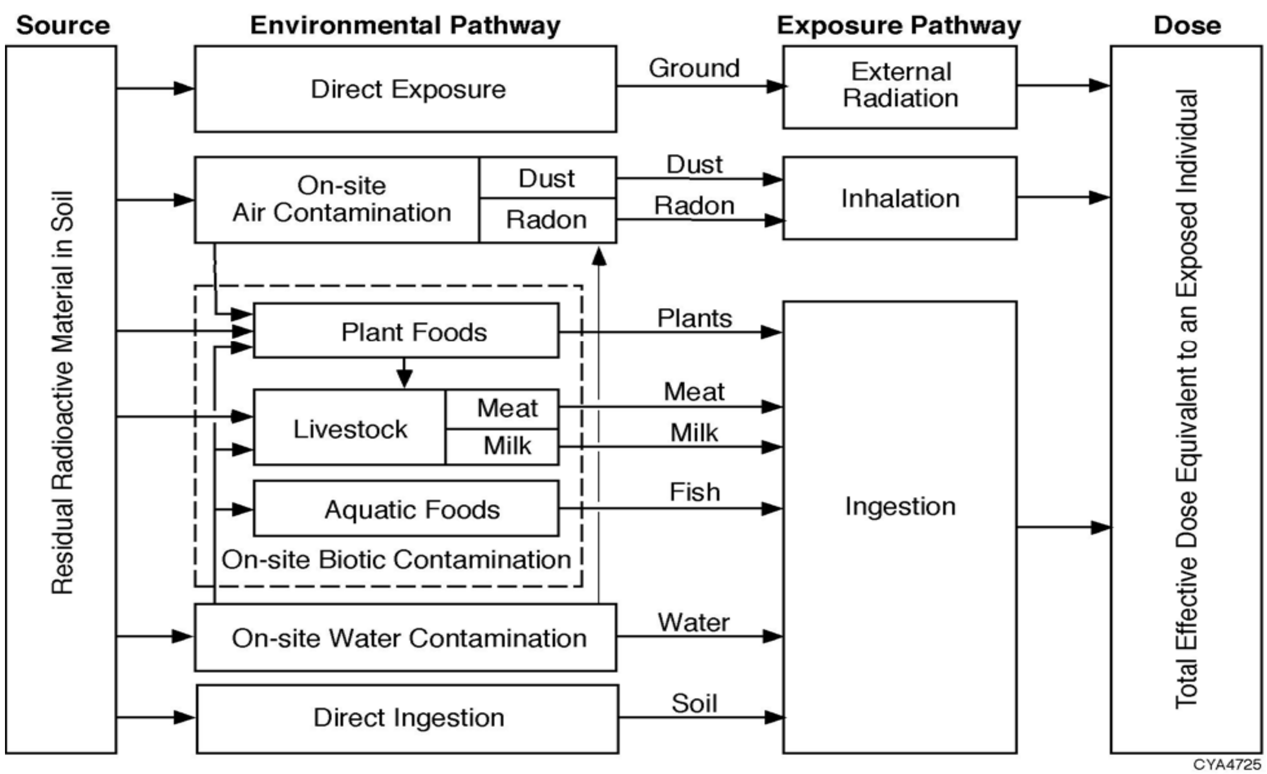

FIGURE 4-2: SCHEMATIC REPRESENTATION OF RESRAD PATHWAYS

As mentioned previously, Figures 4-1 and 4-2 present all potential exposure pathways for a worst case resident farmer scenario. NRC guidance document *Decision Methods for DOE Assessment to Comply with Radiological Criteria for License Termination* (NRC 1998) recommends the use of a residential farmer scenario as the basis for the DCGLs for residual contamination in site-wide soils.

As mentioned in section 2.1.2, the current land use at the Site is predominantly light industrial. The land use for surrounding areas is predominantly agricultural. Although the Site is currently designated for industrial use and will most likely continue to be used for industrial purposes, this area may also be used for expansion of the residential area in the future, making the resident farmer scenario applicable to all areas of the Site. Under the selected scenario, the resident farmer and his family move onto the site after release for unrestricted use, build a house, grow crops, and raise livestock for consumption. The farmer and any associated family members and relatives living permanently on the site in the future form the critical population group. Due to their permanent status, the projected dose to these individuals will be maximized relative to temporary onsite inhabitants such as construction workers, those involved with recreational activities (e.g., baseball games), etc.

Although potable water is supplied to the Site by public water sources, the resident farmer scenario developed for the Site assumes the resident does install a well on the property to provide a source of drinking water. This is believed highly unlikely, but provides a reasonable amount of conservatism in the model. It will be shown that leaving the water pathway “on” in the analysis has no impact on the resulting site-specific DCGL for natural uranium and thorium compared to values generated with the water pathway suppressed.

The radon pathway is suppressed in this assessment due to its inapplicability. In a Federal Register Notice (NRC 1994), issued as a result of comments received from a radon workshop, the NRC noted that “radon would not be evaluated when developing release criteria due to: the ubiquitous nature of radon in the general environment, the large uncertainties in the models used to predict radon concentrations; and the inability to distinguish between naturally occurring radon and that which occurs due to licensed activities.”

Complete exposure pathways applicable to the resident farmer scenario include:

1. Direct radiation from radionuclides in the soil,
2. Inhalation of re-suspended contaminated dust,
3. Ingestion of home grown produce in the contaminated soil,
4. Ingestion of milk from livestock raised in the contaminated area,
5. Ingestion of fish from a nearby pond contaminated by water percolated through the contaminated area,
6. Ingestion of meat from livestock raised in the contaminated area,
7. Ingestion of water from a contaminated well, and
8. Ingestion of contaminated soil.

These exposure pathways are depicted in the adjustment to the schematic representation of RESRAD pathways in Figure 4-3.

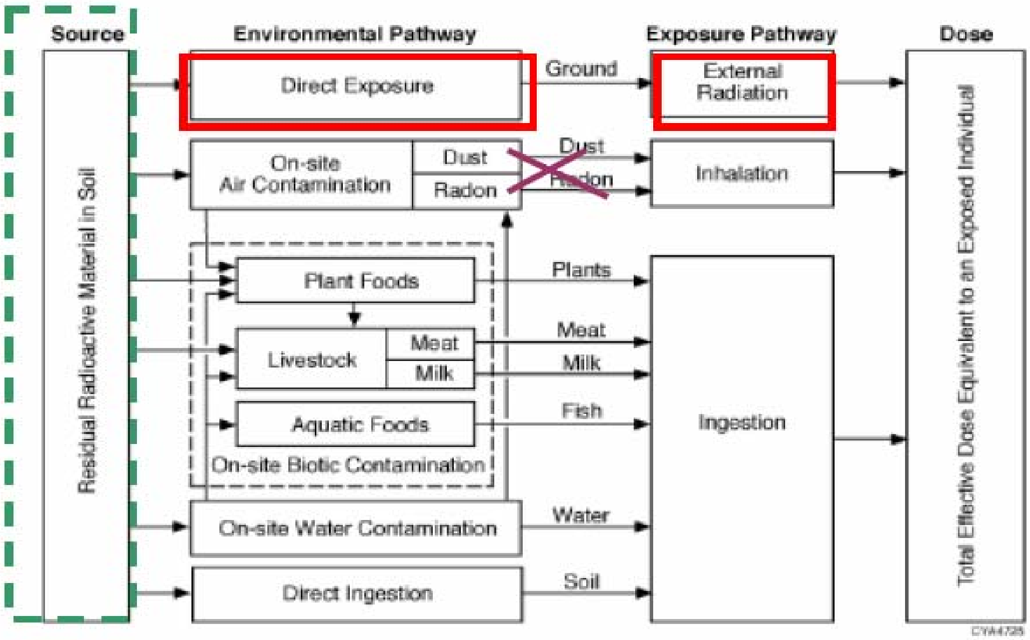

FIGURE 4-3: ADJUSTED SCHEMATIC OF RESRAD PATHWAYS FOR RESIDENT FARMER

4.3 RESRAD Input Parameters

4.3.1 General Basis for the Dose Modeling Assessment

The following general assumptions formed the basis for the dose modeling assessments:

- The resident farmer scenario is applicable to soils at the Site.
- The DCGL for soil was derived based on a review of site surveys, sampling and prior remediation.
- Site-specific values, where available, were used as input to the RESRAD code. In lieu of site-specific values, NRC values, principally from NUREG/CR-5512, Volume 3 (NRC 1999a), NUREG/CR-5512, Volume 4 (NRC 1999b), and NUREG/CR-6697 (NRC, 2000b); EPA *Soil Screening Guidance for Radionuclides: User's Guide* (EPA 2000); RESRAD default values; or information contained in the RESRAD manual (Yu 2001) were used to determine the selected inputs to the code.
- Each parameter and user input selection was evaluated individually and collectively for its appropriateness to the Site. As an example, distribution coefficients for specific elements of interest were ultimately determined based on the soil type comprising the contaminated zone. This was determined to be primarily silty clay (with some areas predominantly clay) (Cabrera 2006). Corresponding values provided in Table 32.1 of the *RESRAD Data Collection Handbook To Support Modeling Impacts of Radioactive Material In Soil* (Yu 1993) were selected for this type of soil matrix. This same matrix and coefficient value was used for the unsaturated and saturated zones.

- The most recent version of RESRAD (Version 6.3) was used for this assessment.

4.3.2 Specific Justification for Parameter Selection

All parameters utilized in the RESRAD evaluations for natural thorium and natural uranium are listed with justifications for their selection in Appendix A. The input/output reports for the RESRAD results are provided in Appendix B.

The following parameters taken from Appendix A were specifically selected for further discussion.

4.3.2.1 Pathway Selection

All pathways, including the irrigation pathway, were utilized, i.e., “active” to add conservatism to the dose assessment. The lone exception consisted of the radon pathway which was suppressed for reasons described previously.

4.3.2.2 Source Term

Th-232, Th-228, and Ra-228 constituted the principal radionuclides for the thorium decay chain. U-238, U-234, Th-230, Ra-226, and Pb-210 comprised the radionuclides from the uranium-238 decay series; U-235 and its decay products (Pa-231 and Ac-227) were added at natural isotopic abundances relative to U-238 (i.e., 0.047 isotopic abundance of U-235 relative to U-238). Secular equilibrium between the parent and decay products was assumed. Uranium is present in trace quantities at the site.

4.3.2.3 Radionuclide Concentration

Unit concentrations of one picocurie per gram (1 pCi/g) for each of the Site RCOPCs were used. This approach provided dose-to-source ratios (DSRs), i.e., dose per unit concentration (mrem/y per pCi/g) which when divided into the primary dose limit resulted in a DCGL for that radionuclide in units of pCi/g.

4.3.2.4 Area of Contamination Zone

The contaminated zone is a belowground region in which radionuclides are present in above background concentrations. The contaminated zone was modeled (with no cover depth) under the assumption that contaminated silty clay soil matrix exists at a depth of 0.5 meter and unlikely beyond a depth of one meter. The primary case assumed a contaminated area of 10,000 square meters. Additional, smaller areas were then evaluated by reducing the contaminated area and length parallel to the aquifer while keeping all other parameters constant (in all cases the length parallel to aquifer was assumed to be equal to the square root of the contaminated area). Due to non-availability of site-specific information, same soil was assumed to be present for the unsaturated and saturated zones.

RESRAD assumes homogeneous (uniformly contaminated) contamination which is largely not the case at the site. No cover depth was also assumed.

Contaminated zone areas were specifically delineated during the characterization survey. Class 1 (MARSSIM) areas comprised areas significantly less than the specified RESRAD default, whereas Class 3 areas consisted of areas significantly greater than the RESRAD default. For purposes of the RESRAD evaluation in this report, the default value of 10,000 square meters (m^2) was used pending subsequent changes to the preliminary DCGLs presented in this report.

4.3.2.5 Thickness of Contaminated Zone

Contamination was assumed to be limited to the top 50 cm of soil for the majority of the site based on an evaluation of the site history and the resultant conceptual site model. Specific contamination depths will be determined during the characterization survey; surface contamination is anticipated at this time to be limited to a maximum depth of less than one meter.

4.3.2.6 Cover Depth

The cover depth corresponds to the distance to the uppermost contaminated soil sample. No cover depth was assumed overlying the contaminated area for conservative dose estimating purposes.

4.3.2.7 Soil Density

From Table 2-1 of ANL Data Collection Handbook, the soil density for silty clay soil, which covers much of the Site, was determined to be 1.2 g/cc.

4.3.2.8 Elemental Distribution (Partition) Coefficients (K_d)

This parameter is one of the most important parameters to understand as it relates to soil migration and retardation. Site-specific values for this parameter were not determined. However, considerable efforts were devoted to the choice of appropriate and reasonable values for these coefficients (in lieu of using the RESRAD default values) for the primary surface soil type (sand) and subsurface (slag) materials present at the site.

The values provided in Table 4-1 were ultimately input into the RESRAD code, using the same values were chosen for all three zones based on the fact that no site-specific soil information are available for unsaturated and saturated zone.

TABLE 4-1: SELECTION OF PARTITION COEFFICIENTS, K_d, BY ELEMENT

Element	Contaminated Zone (clay assumed)	Unsaturated Zone (clay assumed)	Saturated Zone (clay assumed)
U	1,600	1,600	1,600
Th	5,800	5,800	5,800
Ra	9,100	9,100	9,100
Ac	2,400	2,400	2,400
Pa	2,700	2,700	2,700
Pb	550	550	550

4.3.2.9 Contaminated Zone Hydraulic Conductivity

The hydraulic conductivity, in meters per year (m/yr), for the contaminated zone (and unsaturated zone) were assumed to be a factor of 10 less than the saturated zone hydraulic conductivity for silty clay in Table 5.2 of the *RESRAD Data Collection Handbook To Support Modeling Impacts of Radioactive Material In Soil* (Yu 1993) or 3.21 m/yr.

4.3.2.10 Saturated Zone "b" Parameter

The soil specific exponential "b" parameter (unitless) is one of several hydrological parameters used to calculate the radionuclide leaching rate of the contaminated zone. The "b" parameters used in the Site model for the contaminated, unsaturated and saturated zones are 10.4 for silty clay (Yu 1993).

4.3.2.11 Unsaturated Zone Thickness

The unsaturated zone thickness is the thickness of soil between the bottom of the contaminated zone and the water table. The unsaturated zone thickness used for the Site model is 14.5 m. This value is derived by subtracting the contaminated zone thickness (0.5 m for the Site) from the distance below ground surface to the water table, which for the Site is assumed to be 15 m as defined in section 2.2.2.

4.3.2.12 External Gamma Radiation Pathway

The external gamma pathway is the predominant, most significant pathway in the DCGL determination for thorium and uranium. Appendix A cites the input values selected for shielding factors and fraction of time spent indoors/outdoors. These three values vary considerably based on the reference selected. In keeping with the primary parameter selection process cited in this report and without site-specific gamma shielding factors available, NRC values from NUREG/CR-5512, Volume 4, were selected in lieu of the RESRAD default values (NRC 1999b). Regardless of the selected input values and the reference cited which in this case using primarily NUREG values resulted in a "non-conservative" result (a higher DCGL) the external exposure pathway predominates for thorium.

4.3.2.13 Ingestion Pathways:

The plant ingestion pathway is the predominant, most significant pathways in the DCGL determination for thorium and uranium. The significance of the other dietary and non-dietary parameters on the DCGL determination is minimal. Ingestion pathway values used in the evaluation were taken from both NUREG and RESRAD default values.

4.3.2.14 Radon parameters:

As noted previously, this pathway was "suppressed" in the evaluation.

5.0 RESULTS

Previous sections of this report have detailed the approach and methodology for determining the DCGL for natural thorium and uranium. This section utilizes the preceding information to provide the results of the dose assessments for natural thorium in soil at the Site.

5.1 Radiological Parameter Inputs to the RESRAD Code

The following inputs and approach were applied to the RESRAD DCGL determination:

- Principal radionuclides and decay products are in secular equilibrium
  - Natural thorium
  - Natural uranium
- A normalized (unit) concentration of 1 pCi/g per radionuclide was applied
- Doses were calculated (by radionuclide) as a function of time, up to 1000 years.
- The peak dose over the 1000 year time period was determined (per unit activity of the parent radionuclide)
- Resulting DSRs were compared to the NRC regulatory limit, resulting in a DCGL (pCi./g), using the following equation:

DCGL (pCi/g) = 25 mrem / DSR (mrem per pCi/g)

5.2 RESRAD (SOIL) Results

5.2.1 Natural thorium

Because natural thorium (Th-232 and decay products) is the predominant onsite constituent, it was the most significant model investigated for appropriateness against the understanding of environmental transport and resulting exposure at the site. A number of deterministic sensitivity runs as well as probabilistic uncertainty analyses were conducted to assist in the understanding of the overall environmental system and how it relates to the dose.

5.2.1.1 Dose Contribution from All Pathways: Natural Thorium

For the analysis of natural thorium, the maximum (summed) dose of 10 mrem/year is delivered at time (t) = “0” (refer to Figure 5-1). This dose assumes a maximum contaminated area of 10,000 square meters, with a depth of contaminants in soil of 0.5 meter. Numerous additional evaluations were performed with reduced contaminated areas. As expected, the maximum (summed) dose delivered is reduced as the area is reduced. One important aspect of the evaluation is that the maximum delivered dose does not vary considerably when the contaminated area is 1,000 square meters or greater (up to the maximum of 10,000 square meters).

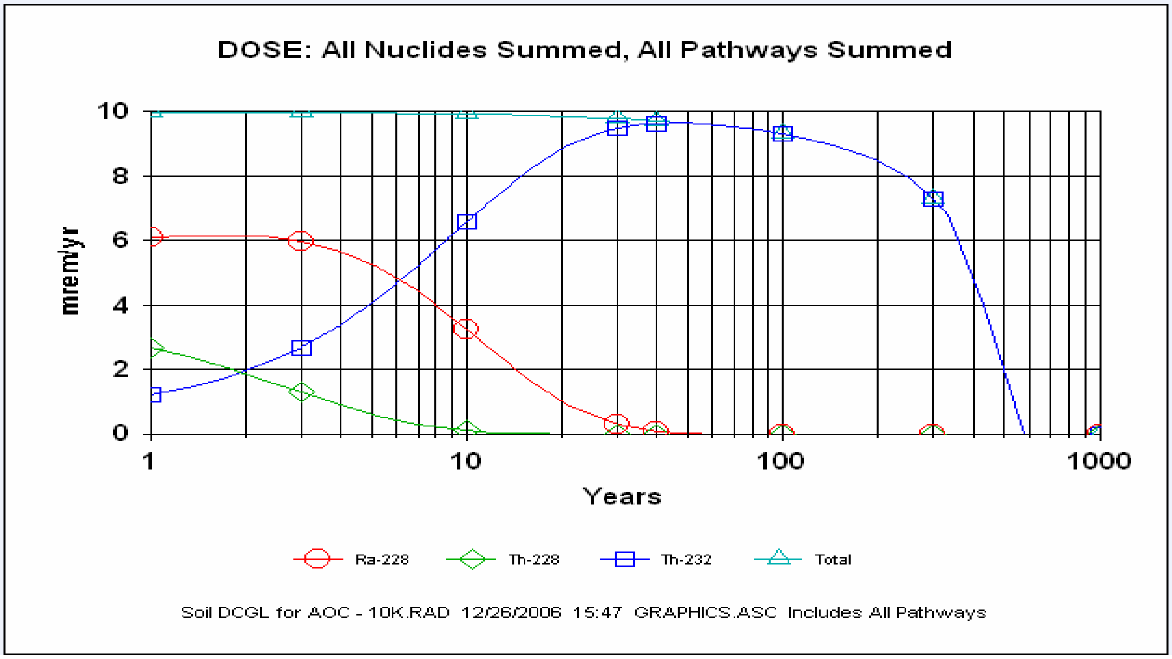

FIGURE 5-1: TOTAL DOSE FOR NATURAL THORIUM, ALL NUCLIDES SUMMED, ALL PATHWAYS SUMMED

5.2.1.2 Significant Pathways: Natural Thorium

The external dose pathway clearly drives the DCGL for this environmental model and therefore has the most significant impact on the potential dose to the critical group. Of the remaining potential resident farmer exposure pathways, plant ingestion is also a significant contributor to dose in the ingestion pathway. Refer to Figure 5-2 for a depiction of the exposure pathways and the contribution to exposure.

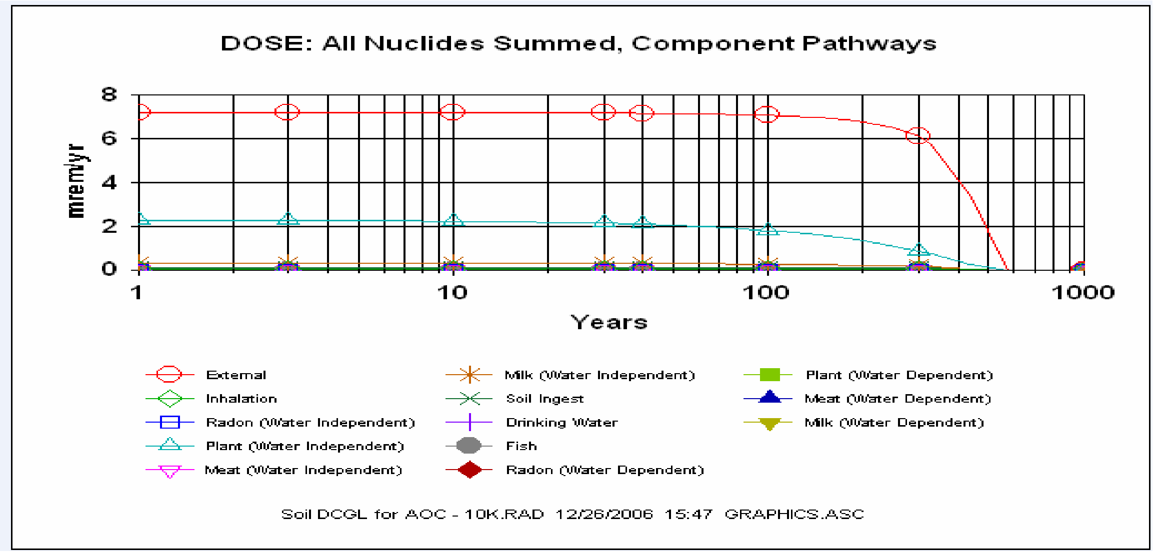

FIGURE 5-2: TOTAL DOSE ALL NUCLIDES (THORIUM CHAIN) SUMMED, COMPONENT PATHWAYS

Sensitivity analyses confirmed the external pathway and plant ingestion pathways were clearly influenced by the selection of the:

- Gamma Shielding Factor
- Fraction spent indoors (on an annual basis)
- Fraction spent outdoors (on an annual basis)
- Fruits, vegetables, and grain consumptions

As a result of the analyses, the following DSR for natural thorium (Th-232 and decay products) in soil was generated:

10 mrem/y per pCi/g at time = 0 years

Dividing the DSR into the annual dose limit resulted in the following preliminary DCGL for natural thorium:

DCGL = 25/10 = 2.5 pCi/g

This DCGL applies to Th-232 and each successive decay product under the assumption that all decay products are in secular equilibrium with the parent and possess half-lives greater than 180 days (the RESRAD recommended half-life cutoff for calculational purposes). Therefore, the 2.5 pCi/g DCGL is applicable to Th-232, Ra-228, and Th-228.

5.2.2 Natural Uranium

The natural uranium analysis utilized the same non-elemental input parameters as were used for the thorium calculations. Elemental parameters were then changed accordingly to represent the proper parameter sets associated with U-238, U-235 and their respective decay products.

5.2.2.1 Dose Contribution from All Pathways: Natural Uranium

For the analysis of natural uranium in Site soil, the maximum (summed) dose of 11.1 mrem is delivered at time (t) = "0" (refer to Figure 5-3). This dose assumes a maximum contaminated area of 10,000 square meters, with a depth of contaminants in soil of 0.5 meter. Numerous additional evaluations were performed with reduced contaminated areas. As expected, the maximum (summed) dose delivered is reduced as the area is reduced. One important aspect of the evaluation is that the maximum delivered dose does not vary considerably when the contaminated area is 1,000 square meters or greater (up to the maximum of 10,000 square meters).

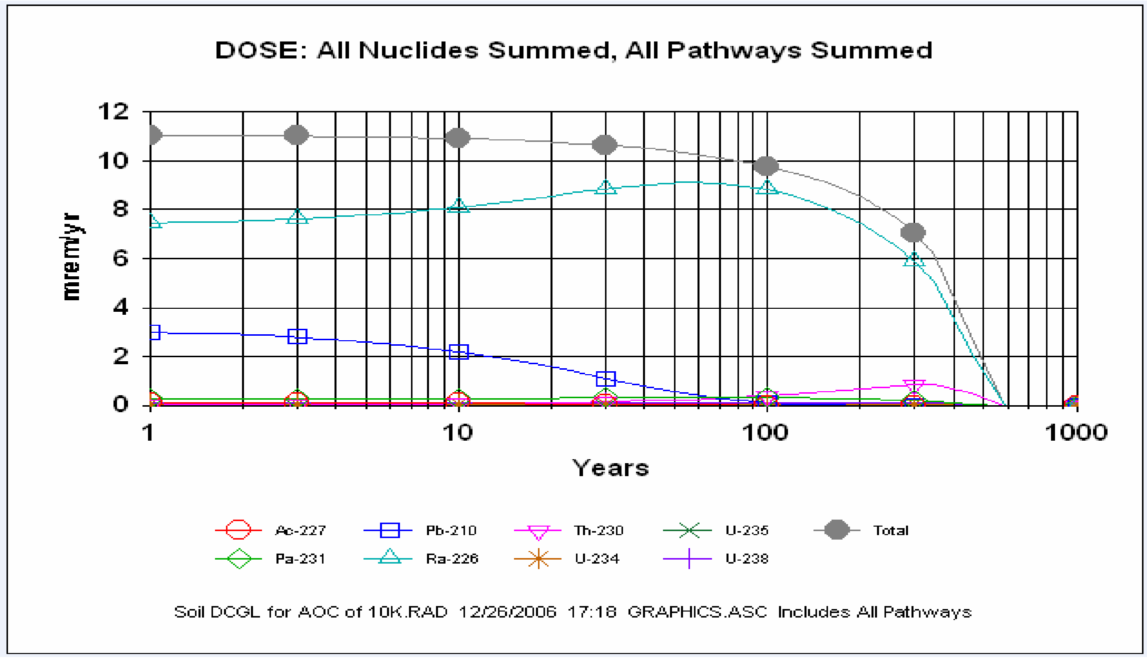

FIGURE 5-3: TOTAL DOSE, ALL NUCLIDES SUMMED, ALL PATHWAYS SUMMED

5.2.2.2 Significant Pathways: Natural Uranium

The external dose and plant ingestion pathways clearly drive the DCGL for this environmental model and therefore have the greatest impact on the potential dose to the critical group. Refer to Figure 5-2 for a depiction of the exposure pathways and the contribution to exposure.

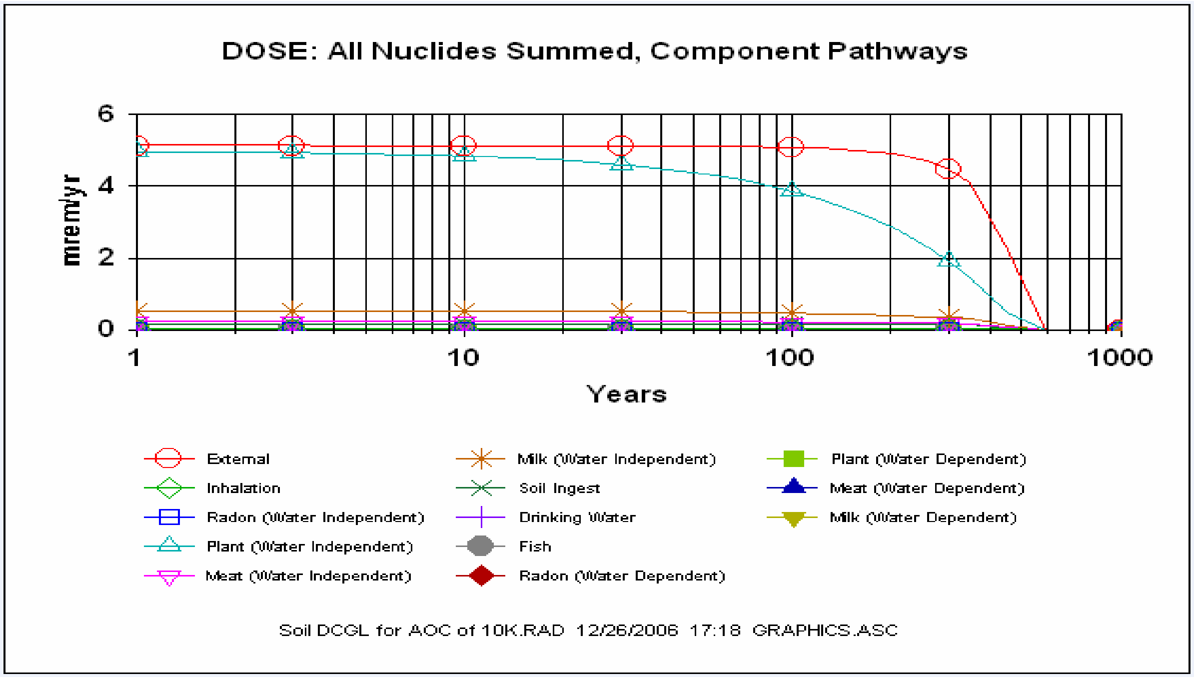

FIGURE 5-4: TOTAL DOSE ALL NUCLIDES SUMMED, COMPONENT PATHWAYS

As a result of the analyses, the following DSR for natural uranium in soil was generated:

11.1 mrem/y per pCi/g at time = 0 years

The corresponding DCGL, based on acceptance of the impact of the drinking water pathway on the results, is:

DCGL = 25/11.1 = 2.3 pCi/g

This DCGL applies equally to U-238 and each successive decay product under the assumption that all decay products are in secular equilibrium with the U-238 parent. Additionally, this DCGL incorporates the contribution from U-235 and its decay products.

5.3 Area Factors

An area factor (A_m) is defined in NUREG-1575, *Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM)* (NRC 2000a), as follows:

> *A factor used to adjust $DCGL_w$ to estimate $DCGL_{EMC}$ and the minimum detectable concentration for scanning surveys in Class 1 survey units---$DCGL_{EMC} = DCGL_w \times A_m$. A_m is the magnitude by which the residual radioactivity in a small area of elevated activity can exceed the DCGLw while maintaining compliance with the release criterion.*

Area factors were generated for both natural thorium and natural uranium in Site soil. To accomplish this, the RESRAD parameter for contaminated area size and length of contaminated area parallel to the aquifer (assumed to be equal to the square root of the contaminated area size) were adjusted while keeping all other parameters constant. The area factors were then computed by taking the ratio of the dose per unit concentration generated by RESRAD for the 10,000 square meter area to that generated for the smaller area. If the DCGL for residual radioactivity distributed over 10,000 square meters is multiplied by the area factor (for the appropriate contaminated area size), the resulting concentration distributed over the smaller area delivers the same calculated dose. Area factors for natural thorium and natural uranium are provided in Table 5-1 and Table 5-2, respectively.

TABLE 5-1: SITE AREA FACTORS FOR NATURAL THORIUM

Nuclide	Area Factor								
	1 m^2	**5 m^2**	**10 m^2**	**50 m^2**	**100 m^2**	**300 m^2**	**1000 m^2**	**3000 m^2**	**10000 m^2**
Th-nat	12.9	4.2	2.8	1.8	1.6	1.4	1.1	1.0	1.0

TABLE 5-2: SITE AREA FACTORS FOR NATURAL URANIUM

Nuclide	Area Factor								
	1 m^2	**5 m^2**	**10 m^2**	**50 m^2**	**100 m^2**	**300 m^2**	**1000 m^2**	**3000 m^2**	**10000 m^2**
U-nat	19.9	6.5	4.3	2.6	2.3	1.8	1.1	1.0	1.0

An example of the use of the area factors is provided below:

> Assume that an area of interest at the Site is identified and the size of the contaminated area is 100 square meters. The adjusted natural thorium site-specific DCGL for this area is:

$$2.5 \text{ pCi/g} \times 1.6 = 4 \text{ pCi/g}$$

6.0 SUMMARY AND CONCLUSIONS

The New Haven Depot site, located in New Haven, Indiana, is being removed from Source Material License STC-133 issued by the U.S. Nuclear Regulatory Commission (NRC). In support of that activity, the development of site-specific DCGLs through conservative dose modeling evaluations was presented in this report. Site-specific DCGLs represent radionuclide-specific concentrations that correspond to the established release criteria and were developed for soil only.

The Site has been used by the Defense National Stockpile Center (DNSC) since 1940's for storage of metallurgical ores and materials necessary for manufacturing defense and/or strategic materials. Numerous radiological surveys and HSA were performed for the site. The results of the survey and HSA indicated that elevated level of contamination remained at former storage piles in Area 7A of the Site. The materials that were received, stored and shipped at the Site include natural uranium and thorium. Both are assumed to be in secular equilibrium with their daughters (or decay) products. Primary uranium radionuclides of interest in this report include U-238, U-235 and their respective decay products, as well as few other radionuclides such as Th-230, Ra-226, and Pb-210. Primary thorium radionuclides of interest in this report were thorium-232 (Th-232) and thorium-228 (Th-228).

Adherence to the NRC's primary dose limit of 25 mrem TEDE (in any one year in excess of natural background) and ALARA philosophy cited in 10 CFR 20.1402 is necessary to satisfy the requirements for unrestricted site use. The 25 mrem limit was accordingly used in the derivation of the DCGLs.

The site-specific DCGLs for thorium and uranium in soil were supported through several means, including review of site records and available references, information gathered during the HSA conducted by Cabrera Services, Inc. in 2006, an extensive environmental engineering analysis of the site, which identified relevant site-specific environmental parameters for the computational model equations, and executing the most current deterministic and probabilistic versions of the RESRAD (Version 6.3) computer model.

Several conservative and reasonable factors were utilized in this dose modeling assessment. These included: 1) Selection of the resident farmer scenario as the conceptual site model and the critical population group. Use of the site for farming purposes in the near future or hundreds of the years in the future may be unlikely due to its location in an industrial area, but remains a credible option; 2) Maintaining all pathways, including the groundwater pathway, as active pathways with the exception of the radon pathway; 3) Taking no credit for the potential of diluting any contaminated soils with a clean soil cover during remedial activities; and 4) Selection of the mass-balance approach for onsite well placement in the contaminated zone. Many other input parameters to the dose modeling code were used with justification for the use of all input parameters provided.

Unit concentrations of one pCi/g for each of the site's radionuclides of concern were used for the RESRAD evaluations. This approach provided DSRs in units of mrem/y per pCi/g, calculated for exposed individuals over a 1000 year time period. The DSRs represented maximum doses a conservative approach since peak doses for specific radionuclides often occur at different times. A DCGL (pCi/g) for each radionuclide of interest was determined by dividing the DSR into the primary dose limit.

The results validated that external dose from gamma radiation and Plant ingestion are the two most predominant contributors to the dose received at this site due to the presence of natural thorium and uranium. All other pathways and radionuclide contributors were of considerably less significance.

As a result of the RESRAD analyses, proposed site-specific soil DCGL's for total natural thorium and total natural uranium are provided in the table below:

TABLE 6-1: SUMMARY OF SOIL DCGLS FOR NATURAL THORIUM AND NATURAL URANIUM

Primary Radionuclide	Soil DCGL (pCi/g) (From RESRAD)
Th-232 (and decay products)	2.5
U-238 (and decay products)	2.3

These DCGLs represent the amount of soil contamination above background that would result in a total effective dose equivalent of 25 mrem to a member of the critical group. The proposed DCGLs are applicable to each of the individual decay products associated with natural thorium and uranium. For example, the DCGL for natural thorium of 2.5 pCi/g applies to not only Th-232, but to Ra-228 and Th-228 in the Th-232 decay chain as well. In like manner, the DCGL of 2.3 pCi/g for natural uranium applies to U-238 and to each of its decay products and incorporates the contribution from U-235 and its decay products based on the associated radioactivity fraction of U-235 to U-238

7.0 REFERENCES

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APPENDIX A

RESRAD INPUT PARAMETERS

APPENDIX B

RESRAD INPUT/OUTPUT FILES FOR NATURAL THORIUM AND NATURAL URANIUM

- **Appendix B-1: RESRAD Input/ Summary Report for Natural Thorium**
- **Appendix B-2: RESRAD Input/ Summary Report for Natural Uranium**